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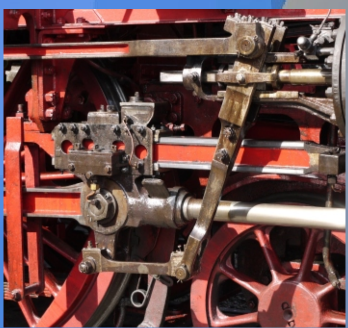

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AGENT-BASED DEVELOPMENT OF CYBER-PHYSICAL SYSTEMS FOR PROCESS CONTROL IN THE CONTEXT OF INDUSTRY 4.0

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Abstract: *In order to achieve its goal in using intelligent adaptive and predictive technical systems with self-X functions and cognitive information processing in continuous interaction with environment, the Industry 4.0 initiative implies integration of Cyber-Physical Systems (CPS), the Internet of Things (IoT) and cloud computing leading to what is called "smart factory". This, in turn, faces the CPS with new challenges in terms of increasing the degree of distribution, autonomy, mobility, communication and security of the systems and their components, as well as expanding their functionality in the direction of data analytics, information and knowledge extraction, and increasing their intelligence. This paper discusses and analyses the CPS in the context of Industry 4.0 and the main trends in the development of process automation and control in order to suggest an appropriate and advanced agent based approach for development of CPS for process control. The proposed approach is based on using the following standards – from one side the IEC61499 Standard for agent specification and from other side the IEC62264 and IEC 61512 Standards for defining the different kind of agents in the control system. The presented approaches are illustrated with a partly presented example of development of Injector control system. Finally some conclusions are made.*

Keywords*:* CYBER-PHYSICAL SYSTEM, INDUSTRY-4.0, AGENTS, PROCESS CONTROL, ONTOLOGY

1. Introduction

The European Commission's strategy for European Reindustrialization aims of increasing the industrial sector's share of gross value added in the European Union to 20% in 2020, based on European strengths in the fields of engineering, automotive, aeronautics, etc. [1]. The Industry 4.0 platform is an initiative of the German Federal Government to support German industry in the transition to digital production with intelligent, digital networks and systems that enable largely self-control and self-management of manufacturing processes [2, 3]. Especially strong is the focus of Industry 4.0 on the functions of future intelligent adaptive and predictive technical systems that need to be self-optimizing, self-configurable and self-diagnosable, enabling cognitive information processing and intelligent networking in continuous interaction with environment. That is why the strategic initiative Industry 4.0 implies integration of Cyber-Physical Systems (CPS), the Internet of Things (IoT) and cloud computing leading to what is called "smart factory".

CPS are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core [4]. They are unique in that the components can be distributed both spatially and temporally, and include complex networks of feedback controllers and real time communication. The effective control, associated with achievement of a high degree of adaptability, autonomy, functionality, reliability, security and usability is the core of cyber-physical systems. The synergy between cyber and physical systems can be both at the nano-level and also at the level of "system of systems". The Strategic Research Co-operation Plan [5] points out that European industry should take advantage of the opportunities resulting from the wider application of the CPS concept as one of the key technological options (capabilities). Still, however the science is owed to CPS, the lack of theoretical foundation and methodologies creates barriers that may hamper the adoption, commercialization, and market success of new CPS applications [6]. The development of CPS is much more than the union of computation and physical systems and in order to apply the principles of CPS to new applications, new methods and tools are needed. Establishing an excellent science foundation and close cooperation between researchers in the field of CPS is a prerequisite for increased competitiveness and a means to address the major challenges.

CPS integrate computing, networking and physical dynamics, as distinguished by a high degree of heterogeneity and parallelism. As a result, the software design techniques are insufficient. New approaches, methods, algorithms and techniques are needed, which will support the process of analysis and design of CPS. The concept of CPS is tightly linked with agent based systems in respect to their basic properties such as: autonomy, sociability, reactivity, proactivity and mobility. Different approaches and methods are used in order to guarantee the useful features of agents in various applications areas of CPS, such as modeling, monitoring, control, diagnostics etc. An important conclusion to be drawn from the analysis of the approach is that the results are more successful when the agent based approach is combined with other approaches, methods and tools.

The main aim of the paper is based on an analysis of CPS in the context of Industry 4.0 and the main challenges in the field of process control and automation to summarize the basic assumptions and capabilities of using an agent based approach for development of CPS for process control. Some results are presented and discussed. The paper is organized in 4 parts. After the introduction, in part 2, a short analysis of the requirements to the CPS in context of Industry 4.0 is proposed. Part 3 discusses the main challenges to process automation and control according to the European Roadmap for process automation [7]. In the next part a short survey of the agent based approaches for control and automation is presented. The last part presents an idea for development of CPS for process control based on agents using IEC-61499, IEC-62264 and IEC 61512 Standards. Finally some conclusions are made.

2. An Analysis of the CPS in the context of Industry 4.0

The advent of control systems in industry started in the era of the first industrial revolution and was characterized by the use of mechanical devices, such as the steam engine governor. The growing number of implemented control systems has led to the emergence and development of the first analysis methods of control theory. The advent of electricity, which is connected to the second industrial revolution led to the replacement of mechanical control devices with electromechanical and their enormous and diverse use in the existing and new emerging industrial branches. With the emergence of the first microprocessors in the seventies began the development and introduction of digital control systems. This has led to the advent of the new levels of control such as DCS, SCADA, MES, the purpose of which is to process and aggregate huge amounts of data from various sensors, releasing the person from multiple control system setup operations, and set him more responsible tasks related to monitoring and optimization of production systems. Unfortunately, however, the theory of computer-based control is underdeveloped. The main task of the theory of cyber-physical systems is to fill this gap.

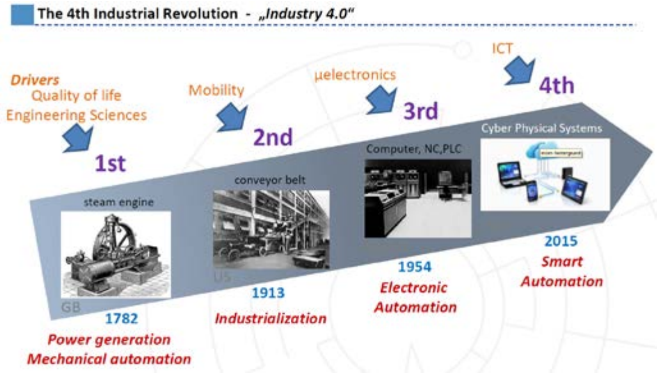

Fig.1: Industrial revolutions and Automation

The fundamental requirements for introducing CPS in industry are specified by [8] as follows:

- *Adaptable to heterogeneous environments:* integration with cutting-edge information systems, smart-devices and the existing environment (from old PLCs to smart object embedded in computing power).
- *Capable of working in distributed networks:* they should gather, transfer and store in a reliable manner all the information provided by smart sensors and actuators through the use of the IoT.
- *Based on a modular open architecture:* the interoperability has to be ensured across different platforms provided by several vendors along the value chain.
- *Incorporate human interfaces (HW & SW based):* integration of user-friendly and reliable service to make decision makers aware about the real time situation of the factory.
- *Fault tolerant:* given by the encapsulation of models to activate prediction control loop and correctness of automation systems.

The design of the CPS requires knowledge on the dynamics of computers, software, networks, and physical processes. The main challenges in the development of cyber-physical systems have different nature and may be grouped in different categories, such as technical, organizational and social. To organizational challenges belong the standardization and issues connected with regulations and legislation. Till now, there is no a reference framework for development of CPS. Different reference models and Standards for interoperability of different systems are needed. The most important social challenges are connected to the Computer – human interactions and interface design. The technical challenges in the design and analysis of CPS stem from the need to build a bridge between sequential semantics and parallel physical world and are connected with the following engineering domains:

- Modeling, development and realization of CPS components and systems;
- Validation, verification and testing of the models at different levels of abstraction;
- Maintenance and evolution of the introduced CPS components and systems.

Industry 4.0's vision requires revision of the approaches for development and use of CPS concerning the following areas:

- In respect to the decentralization in order to integrate the Cyber-Physical Systems (CPS) with cloud computing infrastructures using a high-level architecture for IoT systems, such as this of OpenFog Consortium or FAR-EDGE Reference Architecture [9].
- Empowering decentralization using edge computing that moves some part of computing from the cloud to its edge nodes supporting real-time interactions and scalable analytics;
- Application of new disruptive key enabling technologies in factory automation like DLT (Distributed Ledger Technology) and Smart Contracts (ISO-20022) changing the paradigm of messaging;
- Digital representation of all information and services from and about the physical systems using the concept of Administrative Shell and I4.0 component as a specific case of CPS [10].
- Need for new planning procedures for CPS;
- The Industry 4.0 vision requires smaller, more intelligent and modularized cyber-physical entities that are function-oriented.

3. Main trends in process automation and control

The European roadmap for industrial process automation is developed by the ProcessIT.EU Center of innovation Excellence and formulates the trends, visions and long range goals in industrial process automation, categorizes them into a set of research and development areas and concretises the visions and long range goals into a number of ideal concepts that form the direction of development, proposed in this roadmap [7]. The study also found that automation services predominate over hardware and automation software, which directs attention to the used engineering tools and their efficiency. The roadmap envisions also some technical solutions and methods, summarized in Fig.2, which are of high importance to meet the main challenges of process control and automation. Among these solutions, with particular luminance, three main points stand out:

- The future development of automation and process control systems relies on the use of approaches and methods of cyber-physical systems with a view to achieve collaborative automation and a dynamic virtual twin of the system, available in a real time;
- Secondly, the need for adapting and using the technologies of the Internet of Things to achieve distributed automation and control systems;
- The third major point is the massive need of standards and their use in the development of hardware, software, platforms, network communications and transparency of information.

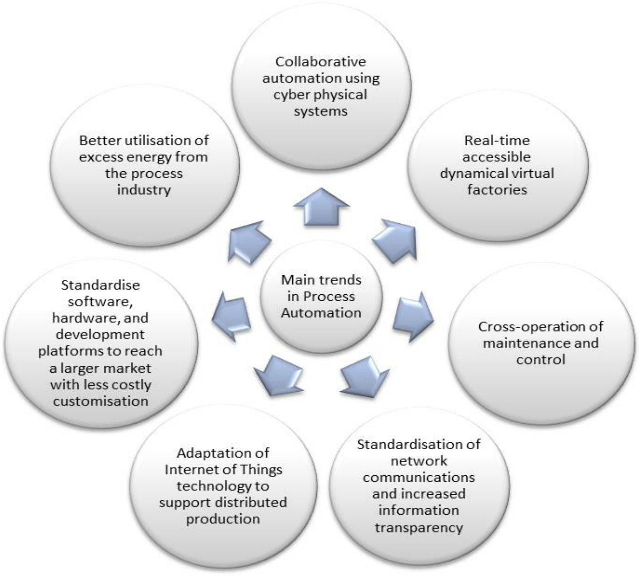

Fig.2: Main trends in Process automation

4. Short overview of agent based development of control systems

Jennings and Wooldridge [11] have defined an agent as “a computer system situated in some environment and capable of autonomous action in this environment, in order to meet its design objectives”. Software agents may be seen as building blocks for virtual environments which augment the reality. They have the following main properties and characteristcs [12]:

- autonomy: agents encapsulate some state (that is not accessible to other agents), and make decisions about what to do, based on this state, without the direct intervention of humans or others;

- socialability (interactivity): agents interact with other agents (and possibly humans) via some kind of agent-communication language, and typically have the ability to engage in social activities (such as cooperative problem solving or negotiation) in order to achieve their goals;
- reactivity: agents are situated in an environment, (which may be the physical world, a user via a graphical user interface, a collection of other agents, the Internet, or perhaps many of these combined), and are able to perceive this environment (through the use of potentially imperfect sensors), and are able to respond in a timely fashion to changes that occur in it;
- pro-activeness: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative;
- mobility: agents can transport themself across different systems architectures and platforms.

CPS may be modeled as Multi Agent Systems (MAS), which may be defined as "a loosely coupled network of problem solvers (agents) that work together to solve problems that are beyond the individual capabilities or knowledge of each problem solver" [13]. The agent community has considerable interest in developing methods and techniques for specifying, modelling, implementing and verifying of MAS for development of CPS in the different applications domains, but so far no standardized methodology has been recognized. Several object-oriented methodologies have been suggested for agent-oriented analysis and design, based on UML. Important drawbacks of using UML to model MAS are the modelling of agent communications as method invocations and the absence of references to the mental state of the agents. To overcome these drawbacks, the UML notations are extended to reflect the characteristic properties of the agents. Successfully extensions of UML are achieved in AUML, GAIA, MESSAGE/UML, AgentUML, Prometheus, etc. Some of them are based on FIPA standard (http://www.fipa.org) suggesting an agent reference model for creation, registration, location, communication, migration and retirement of agents. Recently are also available some specialized tools for lightweight devices, such as DSML4MAS (http://dsml4mas.sourceforge.net/), FIPA-OS, ASEME (for Eclipse), Tropos (http://www.troposproject.org/), INGENIAS (http://sourceforge.net/projects/ingenias/), Jade-Leap, etc. However, there are limitations and drawbacks, associated with the variety of devices and communication protocols, specific for CPS. As well there are some agent-based development environments especially for the CPS domain, as for example: THOMAS, MaRV, ALZ-MAS, CodeBlu, etc.

The actually state of the industrial application of agent technology in CPS is proposed in [14] and the current efforts and challenges for their wider applicability are discussed. The review also shows that the adoption of agent technology in industrial applications is critical in respect to real time constraints and this implies the use of technologies for real-time control as for example the IEC-61499 standard. The agent based technologies are more appropriate for the higher levels in order to provide intelligence and responsiveness.

5. An approach for agent based development of process control system as CPS

As shown in the previous section the concept of CPS is tightly linked with multi-agent systems, however there is not an existing methodology for applying agents to the cyber-physical domain of process control. We suggest using the design principles for development of agent based CPS, defined in [14] and illustrated in Fig.3. They link the high level design abstraction and principles with the final implementation.

There are many different standards associated with the Industry 4.0 vision in order to achieve interoperable and scalable solutions based on the integration of smart agents in industrial CPS environments. This study uses three of them in order to start an approach for development of CPS for process control, connected with improving the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of such systems. For solving real time control tasks, the IEC 61499 standard [15] is adopted, which defines the basic concepts and models for design of distributed process measurement and control systems. It is based on the concept of function block as a main building block of an application and may be used in the design of re-usable intelligent software components. Distributed automation systems could be modeled in cyber-physical way by introducing concurrent model of computations in the IEC-61499 standard. By applying the cyber-physical view with the IEC-61499, control, communication and physical plant in distributed automation systems are covered in one graphical modeling langauge.

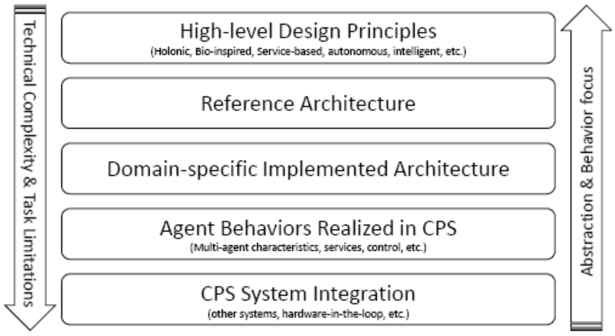

Fig.3: Design principles for agent-based CPS [14]

In cyber-physical systems, there are stronger communications between components and new communication standards and approaches are needed because of the exchange of heterogeneous information. A promising approach in this direction is the use of ontologies, describing the semantics of information and achieving a comprehensible exchange of information. It is extremely important to reuse existing ontologies in automation such as ontology of automation devices, reconfigurable mechatronic systems, diagnostics, and so on. Other important requirements for ontologies used are their modularity, enabling their efficient reuse, refinement and extension; the use of a common standard language for their description, as well as a common automation vocabulary that facilitates the alignment of individual modules to satisfy different requirements.

Both standards IEC-61512 and IEC-62264 are used to create ontology for the automation domain. The IEC-61512 standard [16] provides domain specific models and terminology for design and control of batch production processes and may help to explain the relationships between them. The standard also defined the data models that describe batch control as applied in the process industries, data structures for facilitating communications within and between batch control implementations and language guidelines for representing recipes. The IEC-62264 standard [17] for Enterprise-control system integration defines the terms and models between the enterprise business systems and factory floor control systems. The most important and old parts of the standard include models and terminology, objects and attributes for enterprise-control system and activity models of manufacturing operations management systems. In Fig.4 is shown the "equipment module" of the "manufacturing ontology", structured according to the hierarchical model of the equipment defined by the two standards: IEC-62264 and the IEC-61512.

In Fig.5 an intelligent agent based approach for process control of Injector, based on the IEC-61512 standard is partly illustrated. Common intelligent cyber components have been built and reused for different application. The components are managed in a control recipe that describes their execution schedule. Furthermore, IEC 61499 Standard is adopted as an application framework in which the functional components are implemented as IEC 61499 based function blocks (FB). The operation schedule of the controlled components is then implemented according IEC 61499, based on Scheduler-Selector-Synchronizer (S^3) architecture and a special kind of Petri nets models describing the sequence of control execution may be used in order to verify of algorithm.

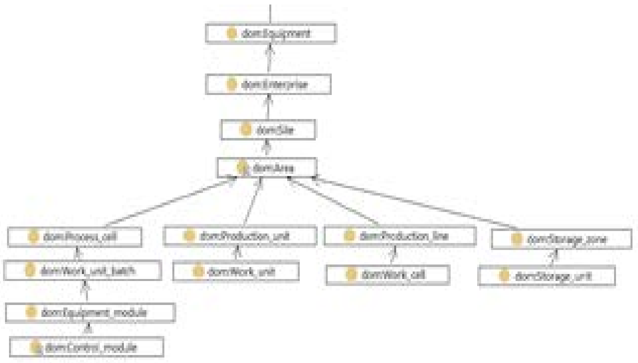

Fig.4: ''Equipment module'' of the "manufacturing ontology"

6. Conclusions

The presented approach is still at an early stage of development. There are a number of extensions to automation ontologies based on other existing standards and developed ontologies. An important step in the right direction is also related to the communication protocols and interfaces used. The discussion around the fusion of MAS and SOA is connected with enhancing some basic features of the CSP, such as adaptability, flexibility, interoperability and modularity. Moreover CPS systems must be improved in respect to service discovery, self-organization, rich knowledge representations and context-awareness.

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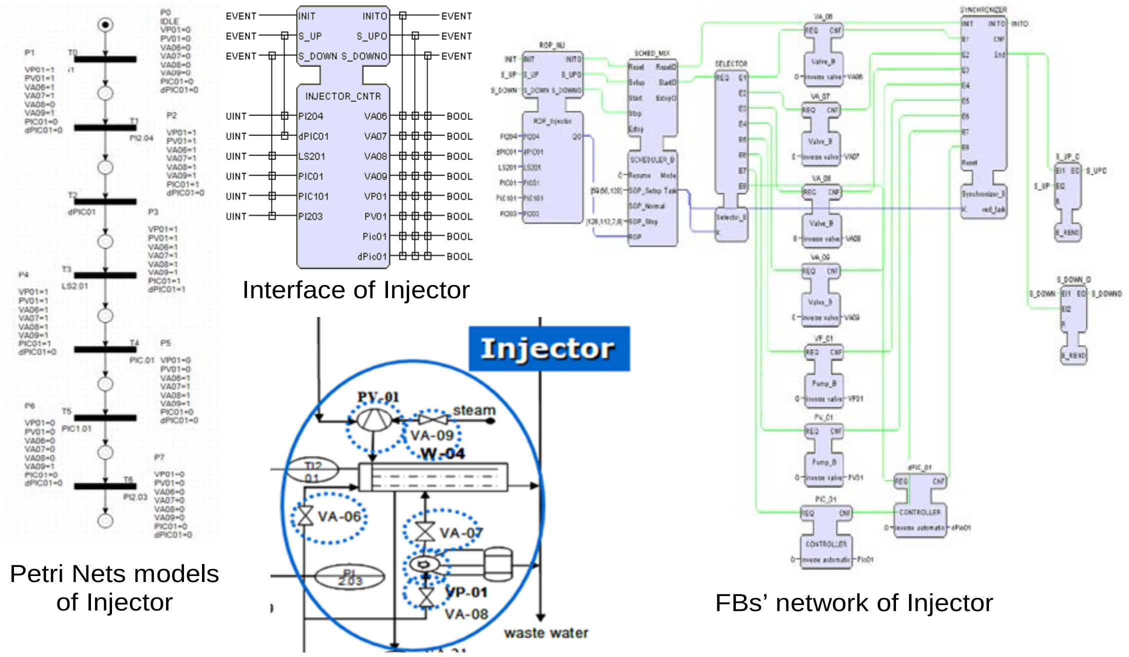

Fig.5: Control components of Injector CPS

PRODUCTION STATE IDENTIFICATION USING RAW ETHERNET DATA OF TOTAL POWER CONSUMPTION IN A CYBER-PHYSICAL FACTORY

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Abstract: *Complex production systems are increasingly using Industrial Ethernet for connecting MES, PLCs, Touch Control, and even sensors and actors within the industrial control network. While today's production is still process driven under MES control, digitalization requires a data driven approach with cyber physical systems acting autonomously in a connected production world. Moving away from a centralized control architecture has the advantage of more flexibility but eliminates the implicit knowledge on global parameters such as the current condition or state of the overall machinery. This paper describes a methodology to retrieve these global parameters independently from any control system and fully transparent to the control network. A data sensor device is introduced that can listen to any Ethernet data traffic. Together with a specialized packet rules engine it is used to extract and combine information out of a raw Ethernet data stream to build up a virtual sensor device. A production state identification sensor is described as an example application of the virtual data sensor device.*

Keywords: CONDITION MONITORING, DATA ANALYSIS, DATA SENSOR, MAINTENANCE, VIRTUAL SENSOR

1. Introduction

Industrial control systems and process control systems are dominating today's factory floors. The centralized information on all production parameters enable supervisory functionality that is used to monitor the machinery condition for example [1]. However, migration to a smart cyber physical factory requires a more distributed control scenario and therefore prevents a centralized condition monitoring.

In this paper, we describe a way to retrieve virtually all relevant information on production parameters even in a smart cyber physical factory environment. As an example, we describe the identification of the working state on a drilling station in a cyber-physical factory (CP-Factory). An approach for transparent condition monitoring (CM) will be introduced. In order to permanently monitor the state of a system it is necessary to measure and analyze one or more physical values in real-time. Often the realization of a forward-looking state-oriented maintenance of an equipment is intended. The challenge in this strategy consists of the search of relevant sensor data, effective signal analysis, pattern recognition and control over the data flow. It was already shown that motor current signatures can be used to detect faults [2]. In this work, the application of a single physical energy data sensor for state identification is considered. The sensor measures the electrical power of all components in a production unit and provides periodically measured data on a digital interface to a cable-connected network (Ethernet). The energy sensor works as a Modbus Slave service and sends measured data upon request over Modbus/TCP protocol. [3] The goal is to reliably identify operational state and state transition from the total power consumption. For that purpose a data sensor (network sniffer) for the recognition of the MODBUS packets, their processing and evaluation of captured energy data was integrated at the network site. The electrical power for nine practice-oriented operational states was measured and saved as reference table values. Hereupon a data model for the state recognition and state transition was developed. It was implemented and validated in a user-friendly rule-based language in the data sensor. This rule-based interpreting language is a formal programming language for rule description and for analysis of the Ethernet data flow. In different tests, it was proven that the identification of an operational state was reliable with an error rate of 0.8 %. A use case of the application is the recognition of irregularities, detection of impermissible states and accordingly the identification of the state transition of a production module at the CP-Factory. The analysis- and evaluating tool consists of the data sensor with implemented rule interpreter. Thereby realizable data capture and evaluation can be implemented in existing networks. Further industrial use cases are discussed in this work.

2. Cyber-physical factory and virtual sensor

Cyber-physical factory (CPF) is a small-scale factory which is used for laboratory experiments and Industry 4.0 production process simulation. It offers a modular construction and modern communication between parts of the factory. The modular structure allows to composite the production process depending on the quickly changing manufacture requirements. Furthermore it allows to replace production units in a minimal time, reducing factory idling and avoid losses. It features radio frequency identification (RFID) for full control of the manufacturing process and to write production data directly onto the production unit, which enables to follow the whole production chain anytime in the future. Module units of the CPF are connected in a chain over industrial Ethernet. A manufacturing execution system (MES) is connected to the internal production network as well. The MES controls the manufacturing process of production units over all production steps. [4]

A power monitoring device SENTRON PAC3200 [5] is built into every production module.

Fig 2.1 Power monitoring device SENTRON PAC3200. [6]

It measures voltage and current, and based on these data it computes other electrical parameters such as total power consumption, active power consumption, etc. All data can be read on the front panel. The device provides all measured and calculated parameters to the Ethernet port over the Modbus/TCP protocol. It works in Modbus-slave mode and receives commands from Programmable Logic Controller (PLC), which has a Modbus-master role. The PLC monitors electrical values and reads them with a period of one second.

The data communication between PLC and Power monitoring device is sniffed using a data sensor device. Sniffing is fully transparent so that the original communication is not changed by any means. In addition to the sniffing capability a data sensor can also process the captured data, extract measurement values, and finally implement a virtual sensor functionality.

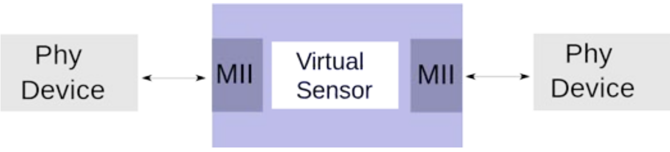

Fig. 2.3 Virtual sensor implemented in a data sensor device.

For implementing the capture unit and the virtual sensor an embedded XMOS parallel processor architecture is used. An embedded rule-based engine is developed on this platform, which makes it possible to define rules for every Ethernet packet of OSI layer 2. Thereby each of the passing Ethernet frames is going to be sequentially processed by the rules engine to filter out important information defined in the rules.

In the current work only the active power for the state monitoring was used, the rules for the Ethernet packets were written to filter out Modbus/TCP packets containing the value of the active power of the production module being monitored. In the next steps the encoded value of a floating point type was extracted from a specific place in an Ethernet frame. This preprocessing stage supplies the data for the further data analysis and for the state monitoring of the manufacturing module.

3. Solution of the examined problem

As a data sensor application example the identification of working states on a drilling machine in a cyber-physical factory was investigated. The working station consists of three actors, the conveyor and two drilling units, which can be moved in an X- and Z-direction. The working station detects a production part using light barrier sensor. The position of the production part is checked and the station can drill up to four holes on it. [4] The objective is the detection of the working states of the actors by measuring and analyzing the active electrical power of the drilling machine.

There are two possibilities to control the actuators, by the Manufacturing Execution System (MES) or manually via a touch panel. All working states are shown in figure 3.1. In state Z2, only the conveyor belt is switched on. During a drilling process, the conveyor belt runs and both drill units are active (state Z9). This corresponds to the production mode (order processing) when the plant is controlled by the MES. The permissible operating state transitions are also shown in green in the figure 3.1.

initial state \ final state		Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
		base load	TB	B1	B2	B12	TB + B1	TB + B2	TB + B12	TB + drilling process
Z1	base load		+TB	+B1	+B2	+B12	+TB +B1	+TB +B2	+TB +B12	
Z2	TB	-TB		-TB +B1	-TB +B2	-TB +B12	+B1	+B2	+B12	+ drilling process
Z3	B1	-B1	-B1 +TB		-B1 +B2	+B2	-B1 +TB +B1	-B1 +TB +B2	+TB +B2	
Z4	B2	-B2	-B2 +TB	-B2 +B1		+B1	-B2 +TB +B1	-B2 +TB +B2	+TB +B1	
Z5	B12	-B12	-B12 +TB	-B2	-B1		-B2 +TB	-B1 +TB	-B12 +TB +B12	
Z6	TB + B1	-B1 -TB	-B1	-B1 -TB +B1	-B1 -TB +B2	+B2 -TB		-B1 +B2	+B2	
Z7	TB + B2	-B2 -TB	-B2	-B2 -TB +B1	-B2 -TB +B2	-TB +B1	-B2 +B1		+B1	
Z8	TB + B12	-B12 -TB	-B12	-TB -B2	-TB -B1	-B12 -TB +B12	-B2	-B1		
Z9	TB + drilling process		- drilling process							

permissible operating state transitions
impermissible operating state transitions
TB = conveyor belt, B1 = drill 1, B2 = drill 2, B12 = drill 1 and 2

Fig. 3.1 State table with permissible and impermissible state transitions.

For example a state transition from state 1 to state 2 is valid. A transition from state 2 to states 3 to 5 (shown in red) would not be permitted. This is caused by the fact that the conveyor belt and the two drilling units may not be simultaneously switched over due to different control mechanisms.

The energy measurement step includes the measuring of the active power of the production module in the nine operating states. For data collection the data sensor (network sniffer) was integrated into the data network running in forward mode. This has the task of detecting and forwarding the Modbus telegrams containing energy data to a desktop computer. In this phase no processing was done within the data sensor. On the desktop computer the energy data could be evaluated in offline mode with the software tool Wireshark.

With the help of Wireshark the collected energy data was exported into a text based network capture data format K12. In this data format every captured network data packet is saved into a single row in form of a time stamp and a sequence of bytes as hexadecimal numerical values represented in text form. In order to make this usable for state detection, data conversion from the hexadecimal to the decimal number system was performed. Finally the recorded data was exported to an Excel spreadsheet.

The data were recorded over a temporal measuring range of 15 to 30 minutes (see figure 3.2).

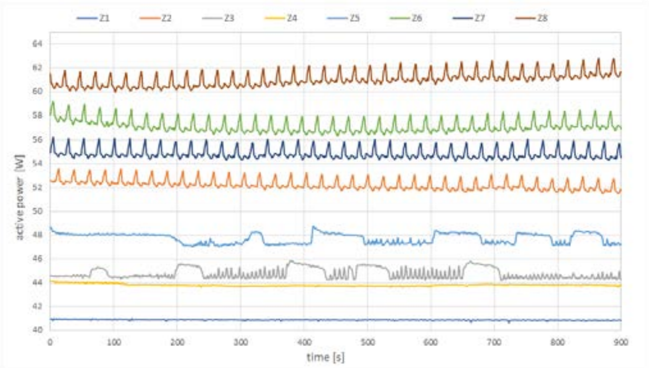

Fig. 3.2 Active power over a temporal measuring range of 15 minutes.

The procedure for measuring the energy values during the state transitions was identical. The active power during operating process and transitions between states were measured and recorded as reference values in tabular form.

A feature-based data model was developed for automatic state detection. For this purpose, the measured average active power values were used as characteristics of the states.

In the case of state transitions the differences between the individual states were calculated and recorded in a matrix.

In order to meet the cybernetic behavior of the plant, the recorded reference values were dynamically adjusted to current consumption in the nine operating states. Thus, possible fluctuations in energy consumption were counteracted. These may be due to load and temperature changes or mechanical wear. In order to enable robust state detection, the reference values have been adapted to the changes via the formation of the moving average.

The reference value of the current state as well as the reference values of the other directly accessible states are continuously adapted to the changes. Another challenge was to recognize the state transitions. For this purpose, the consumption in the operating conditions must be constantly measured and monitored for characteristic changes.

It has been found useful to aggregate the individual active powers readings over a short period of time from a few seconds to a mean value and to use them as a temporarily comparison value. If the difference between the comparison value and the reference value is outside a permissible range, a change of state is assumed. For safety, the status change is checked for validity by comparing it with the valid state changes.

In the second step for online analysis of production states, the above described model was implemented on the data sensor in a proprietary rule-based language with a total of 120 queries and instructions. The following is an explanation of the first two statements (see figure 3.3).

```
// intercept the relevant data packets
1."pass(if:*ETYPE=kIPV4; if:*I4PROTO=kTCP; if:*TCPSPORT=%502;
if:*MODBUSSIZE=%232; cont:%1)\0",
2."pass(set:$break=%1)\0",
```

Fig. 3.3 Example statements of the rule-based language.

The first nested statement checks whether the data packet is relevant to the model-based state detection. All IPv4 packets encapsulating the TCP protocol addressed to the port number 502 and having a length of 232 bytes are relevant. If all conditions are met, the cont:% 1 statement causes the 2nd statement to be skipped. Otherwise, statement 2 is executed, causing the next data packet to be analyzed. With these two commands, a filtering of relevant data packets is implemented. The subsequent instructions for the evaluation of relevant data packets are not explained in detail, as this would be beyond the scope of the present article.

4. Results and discussion

After the transformation of the model into an algorithm, it was implemented into the data sensor using the rule-based language. Following to that an evaluation regarding reliability of the state detection was performed. For this purpose, the data sensor was plugged into the Ethernet connection between the energy data sensor of the drilling station and the local Ethernet switch. The actual power values transmitted by the energy sensor in the data stream are detected by the data sensor and processed to conclude the current operating state of the drilling station.

In order to be able to fully validate the recognition of nine relevant states, all possible state transitions were carried out in a specific cycle during the test runs and production orders were commissioned via the MES. The deduced working states identified by the data sensor were compared with the actual operating states observed. (see figure 4.1 and 4.2).

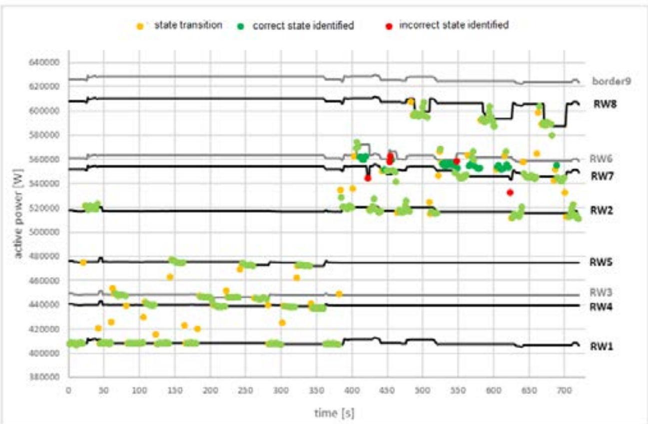

Fig. 4.1 Result of validation (states Z1 to Z8).

During the tests, 842 active power values were evaluated, wherein only 7 of them were identified incorrectly. Thus the error rate is 0.8%. Thereafter the state transition detection was tested. From the totally tested 68 state transitions 65 of them were recognized correctly, and besides none of them was classified as impermissible. The validation result of the commissioned production orders can also be shown: out of 14 orders, 13 were correctly recognized by the data sensor. In 12 of these orders, the data sensor could even distinguish between two different production order types.

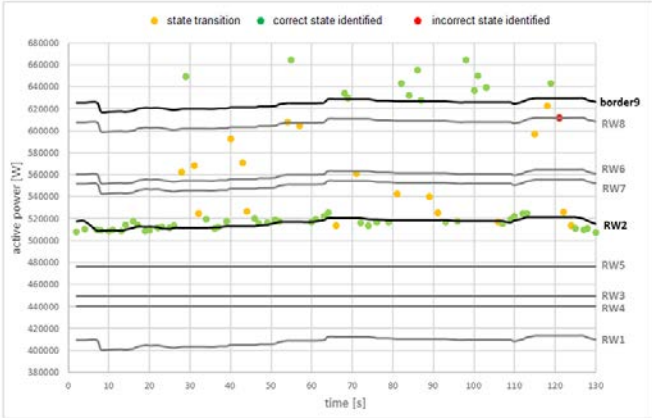

Fig. 4.2 Result of validation (states Z2 and Z9).

The validation result shows that in the case of sufficiently complex production processes, a condition monitoring system with certain level of reliability can be implemented by analyzing the Ethernet data with a single hardware.

5. Conclusion

In this work an algorithm for detection of operation states and state transitions was tested on a production line. Within this project, nine relevant operating states of the drilling station were defined. The total power consumption data of a drilling station in the cyber-physical factory was extensively analyzed and characteristics that represent a correlation between the energy data and the operating states were identified.

The analysis showed that using only the active total power value can be used to identify the operating state of the drilling station. In addition to that, a distinction between different production orders based on current power consumption and a time interval can be drawn. To develop a virtual sensor based on identified features and correlations, a model was derived. The model can recognize operating states and state transitions as well as distinguish between different production order types. In addition, the model includes the detection of impermissible state transitions, in which case an alarm message is issued.

To use the model in a real-time environment, the algorithm was implemented into a data sensors device using a rule-based language. Thus the data sensor represents a virtual sensor which determines the current operating state from the energy data in real-time and outputs it for online monitoring. After successful commissioning, the software was able to validate its reliability. The operating states determined during the tests were compared with the real operating states and an error rate of 0.8% was determined. Therefore, the developed condition monitoring system has a very high reliability. In this application, the virtual sensor was used in transparent mode where no interference with the actual data stream takes place. Due to the permanent monitoring of the production states in real-time, disturbances and irregularities as well as impermissible states or state transitions can be detected. This is important for the development of predictive maintenance applications. The data acquisition and evaluation method describe here can be embedded into any existing data networks.

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APPLICATION OF CAD DESIGN OF TECHNOLOGICAL PROCESSES IN THE FIELD OF MATERIAL SCIENCE

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Abstract. *A review of the existing methods applied to multi-criteria decision aiding has been made as well as the multi-criteria approach to a class of problems in the field of material science has been defined. The multi-criteria decision aiding has been successfully applied to determine appropriate compromise decisions about the examined parameters of a number of technological processes of welding, chemical thermal processing, iron covering, etc. The approach presented determines the values of technological factors satisfying the requirements of users simultaneously to a number of values examined and proposes a solution for the relatively highest thresholds at one and the same time*

KEY WORDS*. SIMULATION, ANN, MODELING, OPTIMIZATION TECHNOLOGICAL PROCESES.*

1. INTRODUCTION

The modern problems of examining the parameters of new and conventional materials and technological processes are multi-criterial and conflict in principle. This nature of the problems is grounded by the fact that, with there examination, it is necessary to provide a certain set of parameters that have to satisfy users' requirements. The solution sought usually consists in determining those combinations of controlling parameters that provide the set of quality parameters specified. The choice of the assessment system of criteria and their rating according to the degree of significance is a problem difficult to formalize. It does not have unambiguous interpretation inevitably causes subjective decisions.

The problem of multi-criteria decision aiding could be most generally defined as a process with:

- a great number of parameters of the solution with a complex interaction among themselves;
- complex cause-and-consequence relations of the solution parameters and the attributes or aims;
- a set of alternatives, which could be reduced to a limited number and in this case the form of cause-and-consequence has to be used.

Due to that reason, looking for an appropriate model to solve a certain multi-criteria problem, one should define first the type of the situation, which is most suitable for solving the problem. An important element of the information base is the component implementing the method of planning the experiment. The main instrument and means of the modern scientific technologies is modeling as by it one can formulate the multi-criteria problem. The models of the complex objects and phenomena are often integrated including contents-describing and formal mathematical parts.

Hence, the study mainly emphasizes on different indices of quality providing including the following groups of criteria: strength (with static and dynamic loading), stiffness (E-module) and toughness (of the material/article), wear-out resistance and hardness, high temperature resistance, appropriate primary cost, compatibility with environment and the possibility of recycling.

2. ANALYSIS OF EXISTING METHODS

An approach to solving the problem (1) is to find the complete set of effective points on the basis of which the decision maker /DM/ chooses one solution. Such algorithms of linear continuous multi-criteria problems have been developed [1], [2]. They have a complex structure and operate slowly. On the other hand, the number of the effective points could be very big and thus make difficult the choice of a decision by the DM.

Another possible approach is to interact directly with the user and his/her preferences to obtain different compromise decisions. In that case, the DM should have a possibility to assess and compare the different solutions obtained. Independently of the method used to find out an effective point, this point has to reflect the DM's preferences to a certain extent. That is why in the multi-criteria decision aiding (MCDA) generally there are two stages: the stage of a dialog with the DM and the stage of computing the effective point. They are interactive procedures [3], which comprise great part of the well-known methods of solving a MCDA problem.

The criteria thus formulated are directly connected with high serviceability (functionality) and quality (constructional and operational properties) as well as economic efficiency.

The optimal matching of all these trends defines the efficiency of materials, i.e. their capability to meet the challenges of engineering in the best way on each stage of its development. Thus a set of problems of multi-criteria compromise decision-making could be formulated also by multi-criteria compromise optimization of one and the same class for which to is necessary to build an appropriate modern instrument in the process of study.

According to the information available about the DM's preferences, the methods of solving MCDA problems can be divided into three main groups:

1. when the DM is able to give a complete information about his/her preference;
2. when there is not such information available;
3. when this information is given by the DM in the process of solving the problem.

The criteria thus formulated are directly connected with high serviceability (functionality) and quality (constructional and operational properties) as well as economic efficiency.

The optimal combining of all these trends defines the efficiency of materials. The optimal matching of all these trends defines the efficiency of materials, i.e. their capability to meet the challenges of engineering in the best way on each stage of its development. Thus a set of problems of multi-criteria compromise decision-making could be formulated also by multi-criteria compromise optimization of one and the same class for which to is necessary to build an appropriate modern instrument in the process of study.

With the problems in the field of material science, the DM does not have information about his/her preference and for that reason the methods developed within the first group cannot be used.

The second group of methods is characterized by generating the whole set of effective solutions. The set of effective solutions is presented partially or entirely by the DM. Such methods are: the method of weight coefficients or *P* problem [4],[5],[6], the method of limitations [7],[8]; the method of weighed Chebishev's standard [9]. These methods are able to generate the whole set of effective solutions of the MCDA. However, their disadvantage lies in the big calculation resources necessary for generating and the impossibility or difficulty of the DM to choose a solution from that set. However, they serve as a base of the interactive methods.

The third group of methods does not require knowledge on the function of preference by the DM. They are the base of the interactive man-computer procedures. The DM interacts with the computer (the algorithm set) on the purpose of clearing and giving additional information about the way of reaching a compromise decision.

The methods consist of three basic steps:

1. Giving the DM's requirements;
2. Finding a compromise solution;
3. Checking if the solution found satisfies the DM.

These methods have been developed most intensively for the past few year and are the base of further studies on the problem of MCDA.

The method of limiting planes [10] is very useful for the peculiarities of the problems in the field of material science. This method can be examined as a variation of the method of the admissible destinations. The methods of this class are unique with the approach, which they use to find the best compromise decision. They reduce the area of criteria iteration reflecting the planes and thus eliminating the stage of looking for a destination. Here precise information about trade-off coefficients is required.

3. APPROACH TO SOLVING MULTI-CRITERIA PROBLEMS IN THE FIELD OF MATERIAL SCIENCE.

The multi-criteria approach [10] proposed is characterized with the peculiarity of defining only one effective point of the whole set, which, according to its nature, turns to be fully sufficient for the different processes examined. That solution is characterized with the peculiarity of the problem class being solved and the solutions are with the highest thresholds of the quality indices examined. Their determination is usually assisted by the nature of the multi-criteria problem defined by the regression models of particular parameters of quality. In the field of material science, the latter require relatively one and the same preferences to all criteria as a whole. The solution presented meets the requirements mentioned and corresponds to the maximal effective point. It is determined after the discretization of the variables with certain exactness and building a transformation containing the lowest value of the criteria examined.

Applying this computation technology, technological solutions important for a number of technologies have been obtained and proved in practice [11]-[14].

The approach has been developed in the form of suitable software [10] that automates the calculations and determines the solutions necessary in a extremely easy way.

Before being visualized, the criteria have been put on a normally distributed scale by finding the discrete extremes and excluding the areas where the function has infinite or indefinite values. The movable limits move along this scale filtrating the visualized multi-dimensional spaces and giving a possibility to focus exactly on the decisions, which the researcher is interested in. The multiple criteria approach is used to visualize the numerical transformation of criteria and this visualization is called a filter. Experiments have been made with geometric mean, arithmetic mean, max and min filters and all decisions found out by these filters are non-dominated. The approach visualizes the symbolic data, transforming it into geometric information that helps to form a real picture of the data. The movable limits are a tool, which is used to focus on some details of the picture, thus finding the decisions looked for. The approach helps the decision-maker to get access to the limits as much as possible from the point of view of criteria. This information aids the participation of the decision-maker's intuition towards the problem and helps him/her to identify and fulfill the aim intentionally

In previous studies, team members conducted research that is summarized in Fig. 1 - Fig.4.

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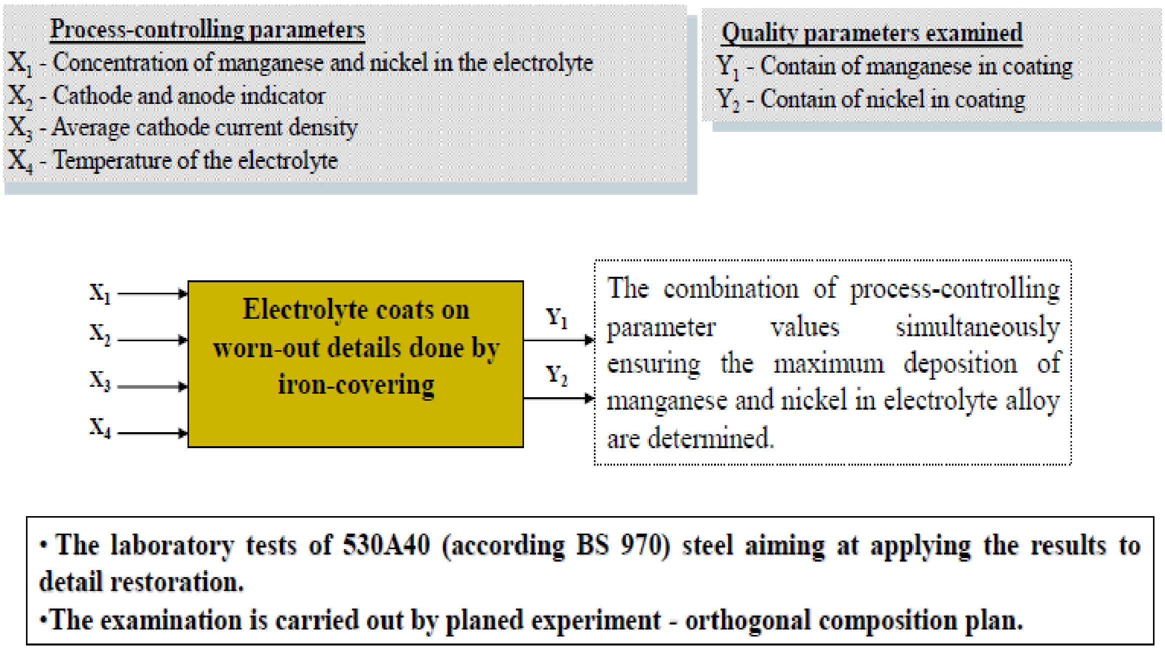

Fig 1. *Electrolyte coats on worn-out details done by iron-covering [12]*

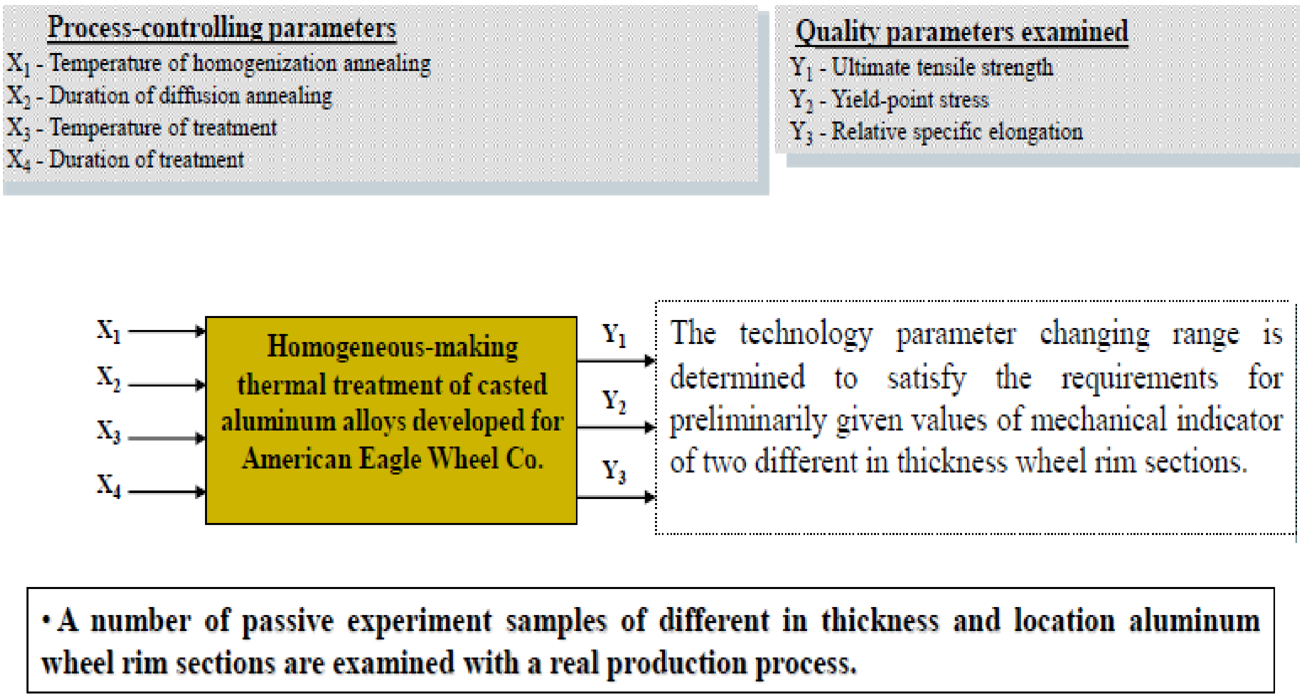

Fig. 2. *Homogeneous-making thermal treatment of casted aluminum alloys developed for American Eagle Wheel Co. /Ordered Company Survey/*

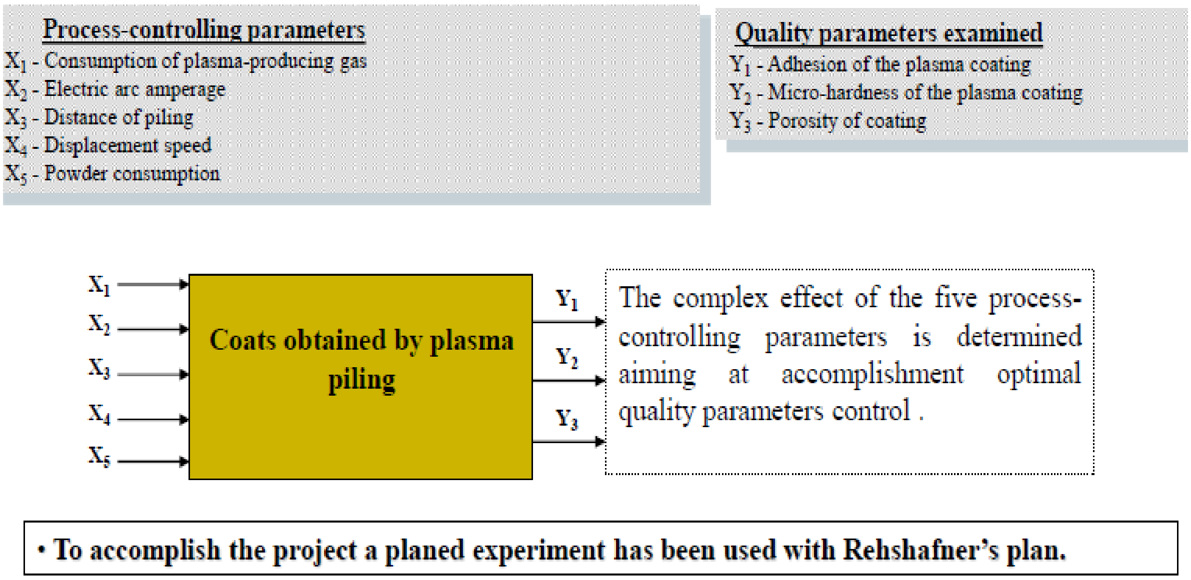

Fig 3. *Coats obtained by plasma pilling [14]*

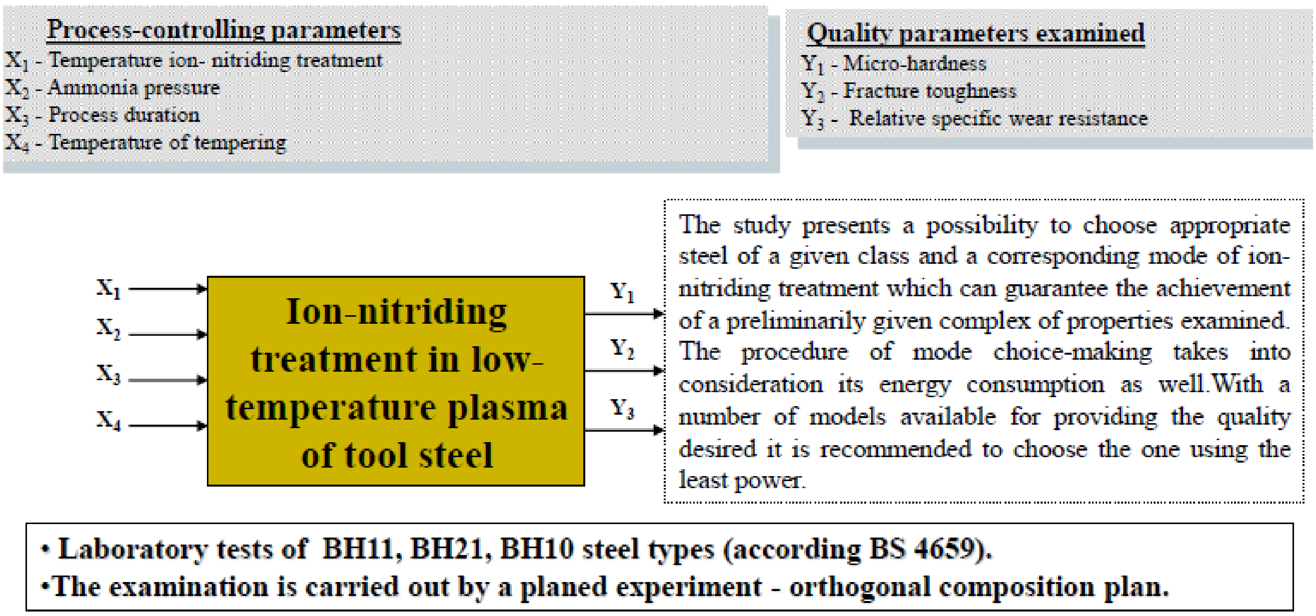

Fig 4. *Ion-nitriding treatmentin low-temperature plasma of tool steel [11, 13]*

COMPUTER SIMULATION OF WITHIN-YEAR CYCLE OF AN AQUATIC ECOSYSTEM LIFE

ИМИТАЦИОННОЕ МОДЕЛИРОВАНИЕ ВНУТРИГОДОВОГО ЦИКЛА ФУНКЦИОНИРОВАНИЯ ВОДНОЙ ЭКОСИСТЕМЫ

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Abstract: *We consider some experience of computer simulation of within-year cycles of aquatic ecosystems, which has group of lecturers and scientists of St. Petersburg State University. The experience includes designing point, reservoir and spatially non-homogeneous simulation models of aquatic ecosystems functioning, and carrying out numerical experiments with the models. The models are applied for investigations in the sphere of ecology, nature protection and nature management. Main attention in the report is devoted up-to-date state of the simulation.*
KEYWORDS*: AQUATIC ECOSYSTEM SIMULATION, ANTHROPOGENIC EUTROPHICATION, TOXIC CONTAMINATION*

1. Introduction

Modern global ecological crisis has been mainly caused by the Earth biosphere poisoning by anthropogenic contaminants. Oil is one of the most harmful one. Prognosis of an ecosystem behaviour and revealing of the weakest chains of the ecosystem is impossible without application to the computer simulation approach [1]. Institute of Earth Sciences of St. Petersburg State University has some experience in designing computer simulation models of aquatic ecosystems. The models were applied for investigations in the sphere of ecology, nature protection and nature management. Thus, Dr. Yuri Sergeev offered the general approach to the creation of simulation models of aquatic ecological systems in 1972 [2].

During 1970-1980s Dr. Yuri Sergeev leaded investigations in the direction. A very active participation in the investigations had Valery Kulesh, and Vasily Dmitriev. In 1970s the North Sea was studied, and as the result of the investigations in 1974 there was built a spatially non-homogeneous simulation model of the ecosystem [3]. Later, in 1980s, there appeared a number of simulation models of ecosystems of eastern part of the Finnish Gulf and the Neva Bay [4]. Victor Tretyakov built an aquatic-bottom reservoir model of the Neva Bay. His next computer model in 1994 was devoted to determination of specific features of Lake Ilmen ecosystem by means of computer simulation. It was a computer reservoir model of the ecosystem, which included blocks of the floodplain and bottom [5, 6]. At the same time Yuri Sergeev and Valery Kulesh designed spatial nonhomogeneous simulation model of Lake Ilmen ecosystem and model of economic and ecological development of Russia [6].

It should be said that all anthropogenic contaminants might be divided into two groups: those of total ecological influence and those of individual toxic impact. The first contaminants do not have any harmful effect on an organism but they change biogeochemical cycle of ecosystems. Eventually this can lead to the change of the ecosystem parameters and even structure. As an example of these contaminants, anthropogenic biogenic elements (that is nitrogen and phosphorus) may be considered. The contaminants of the second group affect directly some vital functions of the hydrobionts. The contaminants in turn may be divided into two groups: those, which stimulate some vital functions at low concentrations and depress these functions at higher concentrations and those, which depress the functions at any concentrations [7, 8, 9].

In 1999, V. Tretyakov designed a simulation model for the prognosis of the sea ecosystem behaviour in conditions of building and functioning of new industrial zone near Byorke-Zund Strait between Karelian Isthmus and Berezoviye islands in the Finnish Gulf. The zone includes a plant for producing liquid ammonia and granulated carbamide obtained from natural gas. In the model, a possible response of the ecosystem was investigated for the increasing of the anthropogenic impact. The model is the system of 102 non-linear differential equations, which are solved by Runge-Kutta method.

Later the model was modified for investigation of consequences of volley of toxicant sewage that is an abrupt discharge of considerable amount of the toxic substance into ecosystems of flowing water reservoirs with changeable volume, depth and river run-off. In addition, the model can reflect consequences of constant discharge of a toxic substance into an aquatic ecosystem. The model may be used for determination of ultimate acceptable anthropogenic impacts on aquatic ecosystems.

2. The model description

The alive components of the model are several groups of phyto- and zooplankton; bacteria, associated with detritus; babies of plankton-eater fishes, predatory fishes, benthos-phage ones, worms of Oligochaete class and molluscs.

The lifeless components of the model are plankton genic detritus, suspended mineral and organic matter, suspended matter of bottom silt; dissolved organic carbon, nitrogen, phosphorus, dissolved ammonia, nitrites, nitrates, phosphates; dissolved oxygen and carbon dioxide; concentrations of toxic contaminant in the organisms bodies, suspended organic matter and water body.

The model can be used for investigations of consequences of the following anthropogenic impacts: 1) Anthropogenic eutrophication of an aquatic ecosystem; 2) Constant discharge of a toxic substance into an aquatic ecosystem; 3) Volley of toxicant sewage that is an abrupt discharge of considerable amount of the toxic substance into an aquatic ecosystem; 4) A toxicant accumulation in the trophic chain of the simulated ecosystem; 5) Joint effect upon an aquatic ecosystem both anthropogenic eutrophication and the ecosystem poisoning by a toxic pollutant.

The model at present can simulate functioning of an aquatic ecosystem of an abstract flowing water reservoir with changeable volume, depth and river run-off. The simulated water body may be divided into two layers: the upper one that is epilimnion and the lower one – hypolimnion, or it can be non-separated aquatic ecosystem considered as a whole.

Temporal variability of the model components ensues both due to translocation processes within the ecosystem that is changes by matter between the model components and by reason of intermixing of the water body with inflowing river run-off which contains some of the ecosystem components.

The translocation processes are influenced by external ecological factors, such as temperature of water environment, solar radiation and so on. Concentrations of some ecosystem components in the inflowing river run-off can be also considered as external ones.

The external ecological factors which temporal dynamics affects the model ecosystem behaviour are: 1) Temperature of the upper layer or all water body as a whole if the model ecosystem consists of only a layer; 2) Temperature of the lower layer; 3) Share of the upper layer thickness relatively to the maximum depth of the reservoir; 4) Share of the river inflow entered into the upper layer; 5) Share of the outflow from the upper layer in the total outflow from the reservoir; 6) Photosynthetically active radiation – PAR; 7) Atmospheric pressure; 8) Wind velocity; 9) Run-off or level of the river inflowing into the reservoir; 10) Concentrations of the three groups of the river phytoplankton; 11) Concentrations of the two groups of the river zooplankton; 12) Concentration of the river bacteria; 13) Concentration of the river detritus; 14) Concentrations of the river dissolved organic carbon, nitrogen and phosphorus; 15) Concentration of the river dissolved organic matter excepting organic carbon, nitrogen and phosphorus; 16) Concentration of the river ammonium, nitrite and nitrate nitrogen; 17) Concentration of the river phosphate phosphorus; 18) Concentration of the river dissolved carbon dioxide; 19) Concentration of the river dissolved oxygen; 20) Concentration of the river suspended mineral matter; 21) Concentration of the river suspended organic matter; 22) Concentrations of the toxic pollutant in the first, second and third groups of the river phytoplankton; 23) Concentrations of the toxic pollutant in the first and second groups of the river zooplankton; 24) Concentrations of the toxic pollutant in the river bacteria; 25) Concentrations of the toxic pollutant in the river detritus; 26) Concentrations of the toxic pollutant in the river terrigenous suspended matter; 27) Concentrations of the toxic pollutant in the river water.

Within-year (annual) variability of the factors must be written into textual files separately for each month. Therefore, annual dynamics of each external factors have to written into 12 files. Extensions of the files must correspond to the month's numbers: January – "01", February – "02" and so on. Before a numerical experiment with the model, a user must prepare files of the initial values of the model components.

The model simulates the following processes: 1) Biosynthesis of the phytoplankton with consumption of biogenic elements in mineral forms and CO2 from the water and oxygen abjection; 2) Breathing and extracting processes of the phyto-, zooplankton, bacteria including destruction of the organisms tissues at metabolism, oxygen consumption, CO_2 and excretes abjection; 3) Bacterial detritus destruction, growth of the bacteria biomass, dissolved organic matter entering into the water; 4) Dissolved organic matter, NH_4 и NO_2 mineralization, oxygen consumption; 5) Zooplankton feeding; 6) Vital processes in the fish fauna including hatching, feeding, growth, breathing and metabolism with excretion, migration between the layers; 7) Vital processes in the benthic society including its influence upon the water body; 8) Turbulence interchange by the dissolved and suspended components between the layers; 9) Bottom silt stirring-up due to wind and waves; 10) Bottom silt organic matter destruction; 11) Change of the components concentrations due to the reservoir water body intermixture with the inflowing river; 12) Toxicant influence upon the vital processes; 13) Organisms dying off.

Formalization of the each simulated process demands setting of values of the process parameters and coefficients. Therefore, a user must prepare files of parameters of the simulated processes.

Besides that, a user must prepare the file of the reservoir parameters. In order to simplify the numerical experiments processing and escape possible mistakes it is better to prepare file of the data configuration. The file contains full addresses of all external data files and their names. The configuration file has rigid structure. A user can edit the file by means of any textual editor. He must not insert and delete the strings and delete in the strings the symbol of hyphen ("-"). Name and full address of a data file is written in each string to the right of the hyphen. In each string to the left of the hyphen, there is a brief explanation of the information, which is stored in the data file. A user can edit the explanation and even change its language. In addition, a user can edit the data file name and address to point new prepared file of data, template or the ones of a new file for the experiment results recording. Results of the numerical experiments are written into files of Microsoft Excel books format according to prepared files of templates. A user by the program interface must set the following features of a numerical experiment: 1) The reservoir type. The possible variants are: flowing, stagnant ones, marine estuary. By default, it is set the variant of a flowing reservoir. The variant of a marine estuary is now in stage of elaboration. 2) The type of the reservoir level. There is no a default variant: a user must make choice. In case of the stagnant reservoir this stage of the experiment features setting is skipped. 3) Simulation of a toxic matter cycle in the ecosystem. By default the feature is skipped. To switch on the feature a user have to switch on the corresponding checkbox in the program interface. 4) If the experiment includes simulation of the toxicant cycle, a user have to set the toxicant type. In case of the first type of toxicants a toxicant does not stimulate vital processes of the aquatic organisms at low concentrations of the toxicant in the organisms' tissues. In case of the second type of toxicants a toxicant stimulates vital processes of the aquatic organisms at low concentrations of the toxicant in the organisms' tissues. By default, the simulated toxicant is one of the first type. A user can set change the toxicant type on the second one. 5) Shape of the reservoir hollow. The possible variants are: cone, frustum of cone, ellipsoid, three-axial ellipsoid, cylinder, spherical segment. The variant of a spherical segment is set by default. 6) Number of the water body layers: one or two. 7) In the case of two layers a user have to select the variant of the layers thicknesses ratio. It can be constant or changeable one. 8) Share of the inflowing river water entering into the upper layer. It also can be constant or changeable during a year. 9) Share of the water from the upper layer in total outflow from the reservoir. It also can be constant or changeable during a year. 10) Windy stirring-up of the bottom silt. By default, the process simulation is checked on. In case of a one-layer ecosystem simulation the stages 7-9 are automatically skipped. After the stage 6 a user passes to the stage 10. In case of simulation of a two-layer ecosystem of a stagnant reservoir the stages 8 and 9 are skipped. 11) Taking into account the flood-plain influence upon the aquatic ecosystem (in the case of flowing reservoir). By default, the influence is checked off. The block of the influence has not yet been included into the program. Therefore, a user passes directly from the stage 10 to the stage 12. 12) Taking into account influence of atmospheric precipitation on the reservoir mirror. By default, the influence is checked off. The block of the influence has not yet been included into the program.

When the determination of the experiment specificity has been performed, a user have to input the experiment identifier into the textual field of the interface. The identifier can include any symbols. Then a user have to check on in the frame "To write the dynamics results" the checkboxes of the parameters sets which will be recorded into the external files of the experiment results. By default the checkboxes are checked off that is no any recording of the experiment results.

A user can check on recording of the following sets of the ecosystem functioning parameters: temporal dynamics of the non-toxic components values, toxic components values, and intensities of the non-toxic components matter interchange processes, intensities of the toxicant interchange processes, parameters of the environment quality estimation. A user can check on the sets in any combinations including all sets or no one.

Then a user by means of the interface have to point the data configuration file. After that, a user clicks the button "All parameters have been set" and the experiment starts.

The model simulates within-year cycle of an aquatic ecosystem life. The cycle begins on January 1 and finishes on December the 31-st. At the very beginning of the iteration body of the cycle the program determines if the ice cover exists or not. Then the program determines the number of the month. The program sets the number of splitting of daily step of the decision of the differential equivalences system by the month number. During the January-March period number of within-day steps is equal to 16, April-October period – 64, and in November and December – 32.

Then the program determines the number of the day within the month. If the day is the first day of a month then the program loads from external files into the main memory arrays of the external ecological factors values for a coming month. Then the program remembers the values of the external factors and the model components at the beginning of this and next day. If the day is the last day of the month, then the main program runs “Sledm” subroutine, which determines the extension of the files of the external factors for the next month. In this case, the next day is the first day of the next month. For the 31 of December it is January 1. The values of the external factors at the beginning of the next year are set as equal to the values at the beginning of this year. Then the main program examines if the temperature of the upper layer or the water body as a whole is enough for spawning or not. If it is enough then this day is set as the date of the beginning of the spawning. Of course, the temperature required for initiation of the spawning of various fishes may differ.

Then in the program, there is a block of automatic doubling of number of fractional steps within a day at the decision of the system of differential equations. This block is only performed in the case when during decision of the equations system at least a component becomes negative. Then the program returns the values of the components to the beginning of the day. At the initial calculation of the equations system for each day, the program skips the block. After that, the program performs the data preparation for decision of the equations system within a day. It is necessary to stress that the realization of the decision within a day does not refer to simulation of diurnal dynamics of the ecosystem processes. The diurnal cycle is necessary for decision of the differential equations system by the numerical Runge-Kutta method. At first, the program determines the size of a fractional step in part of a day by division of one by the number of the fractional steps in the day.

To ensure smoothness of the decision the program determines values of changes on the fractional step of the external ecological factors: water temperature, solar radiation, and atmospheric pressure, wind speed and so on. Then in the program, there is a block of simulation of within-year dynamics of individual weight of Oligochaete worms. This process is realized on the base of data for ecosystem of Ilmen Lake. Here the program also calculates change of the individual weight on a fractional step.

Then the program performs diurnal cycle of the equations system decision by means of iteration Runge-Kutta method of the fourth degree.

This method has the fourth degree of accuracy that is the total error at the final interval of integration is directly proportional to the value of the fractional step in the fourth degree. The above-mentioned method is realized in the subroutine «drob». The main program calls the subroutine 4 times according to the stages of calculation by the Runge-Kutta method. The subroutine calculates values of the external ecological factors. If the model simulates ecosystem of running water body ecosystem the subroutine also calculates values of parameters of the water body flowage and concentrations of the simulated substances in the inflowing river run-off for each fractional step and stage of calculation by the Runge-Kutta method. If the model simulates a cycle of a toxic matter, the subroutine calculates concentration of the toxic matter in the model components flowing into the water body with the run-off and in the river water itself.

Thus, we set the change within a day the following parameters of the model: the water temperature (if the water body has two layers, then in two layers separately), solar radiation, atmospheric pressure, wind velocity.

If we simulate ecosystem of a water body with changeable level then the model likewise calculates the change of the water body volume, its maximum and average depth, and surface area within a day. If the water body ecosystem divides into two layers then the model likewise sets changes within a day the ratio between the upper layer width and the maximum depth of the water body, maximum width of the upper and lower layers, volumes of the layers, and average widths of the layers. If we simulate change within a year the ratio between the input of the river water into the upper and lower layers of the water body then the model also sets change within a day share of the river inflow inputting into the upper layer. Likewise, the model sets change within a day share of water from the upper layer in the total outflow from the water body. At simulation of an ecosystem of a flowage water body the model likewise sets change within a day concentrations of the model components inflowing with the river inflow including a toxic substance, of course, if the model includes simulation of a toxic matter cycle.

After the end of a diurnal cycle of the calculation of the intensities and values of the model components in the main program there is block of the current values setting into cells of tables of Microsoft Excel format.

3. Results and discussion

Let us present some results of computer simulation by the model of functioning of an abstract flowing water reservoir ecosystem under various anthropogenic impacts and without any impacts that is at natural regime of the simulated ecosystem. In the standard (benchmark) numerical experiment with the model, the intra-annual dynamics of biogenic elements and organic matter concentrations in the inflowing river’s water reflects generalized seasonal dynamics of the substations upon condition of absence of anthropogenic impact. The reservoir parameters and external ecological factors correspond to conditions of the Russian part of the Finnish Gulf watershed. Parameters of the simulated water reservoir are the following: the rate of conventional water exchange – 4, the maximum depth at average water level of the reservoir – 5 m. As data for building of intra-annual dynamics of biogenic elements and organic matter concentrations in the inflowing river’s water, we used data of multi-year monitoring at 25 stations on medium and small rivers within Russian part of the Finnish Gulf watershed. According results of statistical analysis, we divided the rivers into four groups and separately the Mshaga River. There were carried out five benchmark experiments with the intra-annual dynamics of biogenic elements and organic matter concentrations in the inflowing run-off corresponded the generalized dynamics in the four river groups and the Mshaga River because biogenic and organic matter content in these rivers run-off practically does not include anthropogenic component. In the model experiments with anthropogenic eutrophication simulation, we increased the biogenic and the organic matter contents in few times. Intra-year dynamics of the toxicant content in the inflowing run-off was similar the one of chrome in the Smolyachkov stream in the Kurortnyiy district of St. Petersburg. The numerical experiments with the model included both separated simulation of anthropogenic eutrophication and toxic substance inflow, and joint impact of the eutrophication and the toxicant inflow.

4. Conclusions

Simulation of natural regime of the aquatic ecosystem with the intra-year dynamics of the biogenic elements and organic matter in the inflowing river water, which correspond the ones in the four groups of rivers of the Finnish Gulf watershed, shows intensive spring growth of the phytoplankton biomass. The reason of it is increased content of the biogenic elements during flood caused by streams of snowmelt water [10].

Dynamics of the biogenic elements content in these four groups of rivers show decrease of the content in the beginning of June. It results decrease of the phytoplankton biomass. Die-away of the phytoplankton leads to increase of the bacterial plankton biomass. There is autumn increase of the phytoplankton biomass caused by increase of inflowing run-off with the biogenic elements that is autumn flood. The maximum average annual phytoplankton biomasses were registered in the numerical experiments with simulation of the biogenic elements inflow from the Karelian and Central groups of the rivers. The average annual concentrations of total nitrogen and phosphorus in river water are maximal in these groups of rivers.

The numerical experiments with simulation of anthropogenic inflow of the biogenic elements have given the following conclusions. In all the numerical experiments, there were two blooms of the phytoplankton – spring-summer and summer-autumn ones. In all cases, the first spring-summer bloom is greater than the summer-autumn one for diatomic and blue-green algae. The group of rest algae shows inverse picture. The increase of the biogenic elements inflow influences at the beginning of the spring-summer bloom of the diatomic algae. The increase of the biogenic elements inflow leads to increase of primary production of the all phytoplankton groups. There is growth of the zooplankton biomass during periods of its maximum values without change of the peaks time. At increasing of the biogenic elements inflow there is decrease of dissolved oxygen concentration during summer and autumn due to the oxygen consumption for molding of the defunct organic matter [11].

The numerical experiments with simulation of toxic substance inflow have given the following conclusions. The toxic substance inflow leads to decrease of the phyto- and zooplankton biomasses. The benchmark numerical experiment with absence of anthropogenic impacts and the numerical experiment with minimal inflow of the toxic substance according to the intra-annual dynamics of chrome in the Smolyachkov stream shows very close dynamics of the model components. The experiment with minimal toxic matter inflow shows decreases of maximum biomasses of the plankton groups. Increase of the toxic substance in inflowing river water in three and five time leads to significant decrease of the plankton for the year, and peaks of the plankton blooms are essentially lower in comparison with the ones in the benchmark experiment. All the numerical experiments show evident spring peak of diatomic algae bloom. However, the autumn peak does not evident. The spring-summer peak of blue-green algae and other groups of the phytoplankton is below than the summer-autumn one. The spring-summer peak of the zooplankton biomass development is greater than the summer-autumn one. The toxic substance makes the feature more evident. Increase of the toxic substance concentration in three and five times the summer-autumn peak disappears [12].

The numerical experiments with joint simulation of anthropogenic eutrophication and toxic substance inflow have given the following conclusions. The toxic substance inflow leads to decrease of the phytoplankton biomass. Diatomic algae is most sensitive to the increase of the biogenic elements. The increase in three times leads to increase of the diatomic algae maximum summer biomass at 47%. The increase of the biogenic elements inflow accelerates the beginning of the spring-summer bloom of the diatomic algae. Additional inflow of the biogenic elements neutralizes the toxic substance negative influence upon the primary production [13].

The numerical experiments have given the following conclusions about the toxic substance distribution within the trophic net. In the experiments with simulation of the toxic substance inflow, there are insignificant decrease of the diatomic algae biomass with disappearing of the autumn bloom. Toxic pollution of the ecosystem leads to increase biomasses of the blue-green algae and other groups of the phytoplankton except diatomic algae. The maximum accumulation of the toxic matter in the phytoplankton organisms shows the experiment with the maximum concentration of the inflowing toxic substance. The toxicant inflow suppresses the autumn peaks of the phyto- and zooplankton. The phytivorous zooplankton and bacteria plankton shows the maximum average annual concentrations of the toxic substance in the ecosystem organisms. All the components of the biota except two-year age predatory fishes show increase of the average annual concentration of the toxic substance in the organisms at increase of the toxic substance inflow in the ecosystem. The two-year age predatory fishes show the minimal average annual concentration of the toxicant at its maxima inflow into the ecosystem [14].

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FULL USE OF MATHEMATICS – FOUNDRY

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Abstract: In this work, we present the necessity of using the full mathematics in the industrial branch of machine building of the example of the foundry. Obtaining the necessary structures is accompanied by research work even in micro-foundries, which is provided by powerful and new software products, i.e. knowledge transfer with computational mathematics, physics and education.

Keywords: MACHINE BUILDING, FOUNDRY, CASTING STRUCTURES, MATHEMATICS, EDUCATION

1. Introduction

The importance of mathematics is represented by a general block diagram of "The History of the Development of Knowledge of Civilization from Antiquity to Today" of Fig. 1

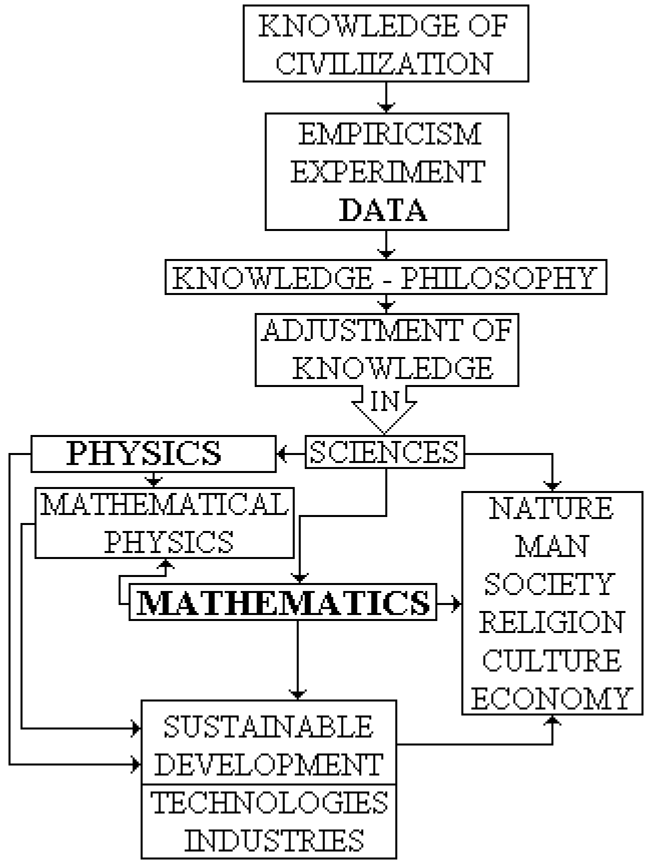

Fig. 1 *Block diagram - Developing the knowledge of civilization from antiquity to today [1, 3, 4].*

1 follows: 1. Initial knowledge is obtained through empiricism - obtaining and classifying experimental data; 2. Collecting knowledge in philosophy; 3. Knowledge is divided into separate sciences after Christ: 3.1 Physics - 18th Century; 3.2 Mathematics - the 19th and the beginnings of the 20th century; 3.3 Mathematics - Self Development; 3.4 Mathematics - a powerful tool for research: Description of physical processes and phenomena. Any theory is obtained only by using mathematics; 3.5 The term mathematical physics includes natural and theoretical physics; 4. Mathematics is in every area of human activity; 5. Sustainable development of civilization is based on: a sustainable society and economy - a challenge for every government; 6. Civilization only evolves by overcoming crises in society and the economy; 7. The challenge is the restructuring of the world by the fourth industrial revolution [1], involving education throughout every person's life, environmental technologies and industries.

The natural systems and the four main types of interaction forces in nature are classified in Fig. 2

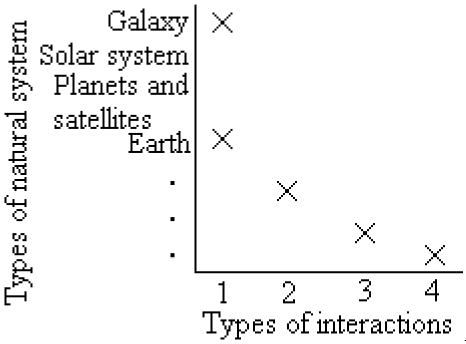

Fig. 2 *Scheme - Natural systems and types of interactions [2]: 1 - gravitational interaction (large-scale events in the Universe), 2 - electromagnetic interaction (holds electrons in atoms and binds atoms to molecules and crystals (chemistry, biology)), 3 - strong interaction connects the nucleons (it unites protons and neutrons in the nucleus of all elements), 4 - weak interaction determines the forces acting between the light particles (leptons: electrons, neutrinos and muons) and between leptons and heavier particles).*

The purpose of this work is to present the necessity of the complete mathematics in the foundry.

2. Foundry - physical and technological processes of structure formation

The casting structures are obtained in phase transition of 1st order is shown with the characteristic scale of the scheme of Fig. 3

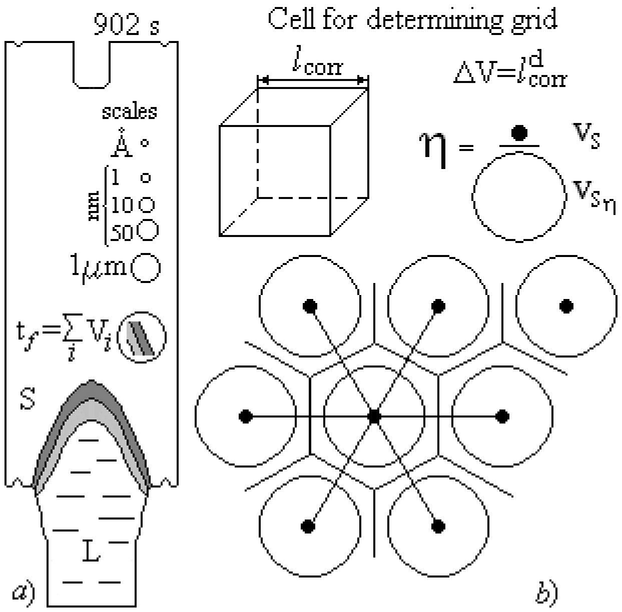

Fig. 3 *The casting structures are obtained in phase transition of 1st order (solidification) [5]: a) Numerical experiment: technological solidification of a cylindrical cast at 902 s, graphically represented by the geometry of the solidification zone (front) – between the liquid (L) and the solid (S) phases. Scales Å, nm, 1μm. t_f – local time of solidification. V_i – chosen local volume for description of structure formation; b) Cell for determining grid – l_{corr} for V_i, ΔV_i – changing the volume V_i from melting*

(solidification), d – direction of growth 1D, 2D or 3D, η – pacing density coefficient, v_S – volume of atom, $v_{S\eta}$ – volume cell, Wigner-Zeitz cell and structure.

The technological system of foundry we introduced on the example by the machine – Gas counter-pressure casting method Fig. 4

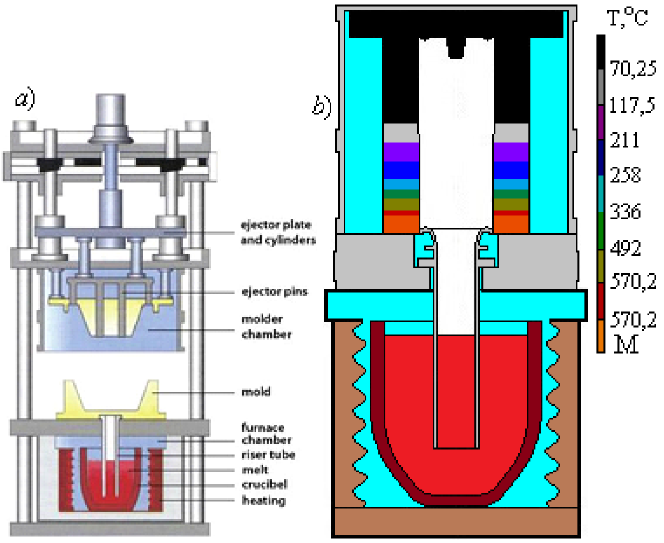

***Fig. 4** Casting technology system - Gas counter-pressure casting machine: a) General appearance of the casting machine; b) Technology for producing counter-pressure cylindrical castings. The technological regime shown (see Fig.2 a) is obtain with initial temperature of the mould without taking into account the filling process.*

The technological system (see Fig. 4) provides of macro-level to obtain the desired structure *average diameter of polycrystalline grains* [12]. The macro-parameters of the casting technology are **the overcooling of the melt** and **scattering of the latent heat of melting** [3, 5, 11, 12].

3. Mathematics in Foundry

It is well known, that the mathematics application in foundry is theoretical and applied thermodynamics [1, 2, 3]. The separation of each set of knowledge into science is achieved only by using mathematics, which definition is [3]: *Mathematics contains mathematical knowledge, foundation of mathematics, methodology of mathematics and philosophy of mathematics in a complex interconnectivity and continuous development.*

3.1 Mathematics in Thermodynamics and Foundry

The crystals are arranged in a solid state where the atoms or molecules are arranged in the form of a crystal lattice (structure). The crystals are obtained by a phase transition of first order by changing the aggregate state of the initial phase to the new solid phase. Bearer of the working properties of the castings is the crystalline structure, which is obtained in the phase transition of first order. Thermodynamics system in foundry is alloy (pure metal) (see Fig. 3 and Fig. 4). Casting is a fundamental branch of material science. It is known that the most advantageous technology for making castings with complex geometry is casting.

The description of the first-order phase transition is presented here in its historical development, i.e. the development of the classical theory of crystallization in atomistic approach. Table 1 presents: the description of thermodynamics; the theoretical description of nucleation like: thermodynamics and kinetics; crystal growth theory: Surface energy; Dyffusion; Surface nucleation; Screw dislocation

***Table 1:** Phase transition in foundry: Liquid(L) ↔(S)Solid.*

Liquid (L) ← *phase transition of* 1^{st} *order* → **Solid (S)**
THERMODYNAMICS OF THE TRANSITION L↔S

$G = H - TS$, *Gibbs free energy at* $T_e \to G_L = G_S$, (1,1,2)

$\Delta G = \Delta H - T\Delta S$; *and* $\Delta G = G_L - G_S$, $\Delta H = H_L - H_S$, $\Delta S = S_L - S_S$, (1,3,4,5,6)

$\Delta G = 0$ *is equilibrium at* $T_e \Rightarrow \Delta H = T_e \Delta S$, (1,7)

$\Delta G = \Delta H \Delta T / T_e$, *and* $\Delta T = T_e - T$, (1,8,9)

$\Delta G = \Delta S \Delta T$ *for melt growth*, (1,10)

$\Delta G = RT\ln(S_R)$ *growth depend to* supersaturation ratio S_R. (1,11)

In foundry the basic thermodynamics system is material from two phases; G – Gibbs's free energy of the system; H – enthalpy; S – entropy; T – temperature; $T_e = T_L = T_S$ – equilibrium temperature; $T_e - T$ – supercooling; Δ – change of G, H, S; R – gas constant.

NUCLEATION – IMPORTANT PHENOMENON IN CRYSTAL GROWTH

$$\Delta G = 4\pi r^2\sigma - \frac{4}{3}\pi r^3 \Delta G_v;\quad r^* = \frac{2\sigma}{\Delta G_v},\quad \Delta G^* = \frac{16\pi\sigma^3}{3\Delta G_v^2} \qquad (1,12,13,14)$$

$$\Delta G^* = \frac{16\pi\sigma^3\Omega^2}{3(kT\ln S_R)},\quad \textit{Gibbs-Tomson equation} \qquad (1,15)$$

$$J = J_0\exp\left[-\frac{\Delta G^*}{kT}\right],\ J = J_0\exp\left(\frac{16\pi\sigma^3\Omega^2}{3(kT\ln S_R)}\right),\ S_{R|Cri} = \exp\left[\frac{16\pi\sigma^3\Omega^2}{3k^3T^3\ln J_0}\right], (1,16,17)$$

where ΔG_v – change the Gibbs free energy of nucleus volume of new phase (L or S); r – nucleus radius; r*, ΔG* - critical parameters; σ – surface energy; Ω – atomic (molecular) volume; J – nucleation rate per *unit* volume; J_0 – is the total number of particles in the new phase; $S_{R|Cri}$ – critical supersaturation ratio; k is Boltzmann's constant.

CRYSTALS GROWTH THEORY

1. **Surface energy theory** is on the based to thermodynamics equilibrium state with minimal total surphace energy for given volume. There is contradiction theory-experiment: supersaturation and growth sides of crystal. At high supersaturation the growth is not uniformly of all directions and only of some sides.

2. **Diffusion theory** is on the base that there is a concentration gradient in the vicinity of the growing surface

$$\frac{dm}{dt} = \frac{D}{\delta}A(C - C_0) \qquad (1,18)$$

where dm/dt is the rate the mass deposited on the crystal surface with area A; D – diffusion coefficient; δ - thickness layer adjacent to the crystal surface; C and C_0 – actual and equilibrium concentration.

3. **Surface nucleation theory** is developed by Kossel [18], Stranski [19], Volmer [21], and Kaishev [23] (model KSVK): crystal growth on the surface with inhomogeneties of the type terrace, ledge and kink; guess that the growth is discontinues process of absorption of the material layer by layer on the crystal surface. The arriving atoms (molecules) do not get directly into the grid, but they migrate over the surface in a random walk process and finally get absorbed on these sites, where its energy is a minimum. Migration distance x_s is

$$x_S^2 = D_S\tau_S, \textit{where}\quad x_S \approx a[3\phi/2kT] \qquad (1,19,20)$$

where D_S – coefficient of diffusion; τ_S – life time of the absorbed particle on the crystal surface; ϕ is the nearest interaction parameter. Migrate atoms create diffuse flow at the surface of the growing crystal, and they are called adatoms. Migrate atoms create diffuse flow at the surface of the growing crystal, and they are called adatoms. For adsorption of adatoms on the crystal surface is need description of interaction between one adatom and elements of surface relief: one adatom at kink site have three chemical bonds for six first neighbor's atoms from of the crystal lattice surface; adatom and ledge have two chemical bonds; adatom and terrace have one chemical bond. Barton-Cabrera-Frank model (BCF) [22] gives: 1. the rate of diffusion flow of migrate adatoms V_{ST}: distant migration step is much higher than distant between two kinks (or middle migration distance is much higher than the mean distance between two adjacent kinks); 2. When the movement step covers the whole surface completely, further growth is only possible by creating a two-dimensional nucleus circle with a radius r and a height h with the necessary energy change ΔG_{td}. According to Volmer [21], this is possible due to heat fluctuations; 3. The growth rate of a single side is generally controlled by the degree of germ formation and the rate of step advancement $R_{J_{td}}^{V_{ST}}$

$$V_{ST} = 2S_{X_S}x_S\gamma\exp(-W/kT), \qquad (1,21)$$

$$\Delta G_{td} = 2\pi r h\gamma - \pi\tau^2 h\Delta G_V,\quad \Delta G_{tg}^* = 2\pi h\gamma - \pi\tau^2 h\Delta G_V, \qquad (1,22,23)$$

$$J_{td} = C_l\exp\left[-\pi h\gamma^2\Omega/k^2T^2\ln S_{X_S}\right] \qquad (1,24)$$

$$S_{X_S|Cri}^{/} = \exp\left[\pi h\gamma^2\Omega/k^2T^2\ln C_l\right] \qquad (1,25)$$

$$R_J^V = hJ_{td}^{1/3}V_{ST}^{2/3}, \qquad (1,26)$$

where γ is a frequency factori in (1,21) and the edge free energy in (1,22

and 23); W is the **total** evaporation energy; S_{X_S} is supersaturation for the mean migration distance x_S, and index cri is for critical supersaturation; C_l – concentration of liquid. 4. Burton, Cabrera and Frank [23] (BCF model) **screw dislocation theory**: on the surface of the crystal in the dislocation point a screw component with a height of the Burger vector projection acts as a continuous source of steps; the step provided by the screw dislocation is fixed at the point of displacement; growth is only by rotation around the point of dislocation, like the inner parts of the tread moving faster than the outer parts of the tread. This mechanism can provide a relation between the rate of growth R and the relative supersaturation s which are expressed with the equations $R = C(s^2/s_1)\tanh(s_1/s), \quad (1,27)$ $s_1 = 19\gamma\Omega/2kTx_S; \quad C = D_S \cap_{SE} \beta\Omega/x_s^2,$ where s – relative supersaturation; s_1 – a const for BCR model; $\cap_{se}$ - equilibrium concentration of growth units on surface; β - retardation factor; Ω – volume of the growth unit. The variation R with supersaturation thus depends on two parameters, C which determines the absolute value of growth rate and s1 which determines actual growth rate. The BCF model predicts nucleation at edge dislocation predicts that the growth rate is proportional (∝) to the square of the supersaturation for low supersaturation if $s \langle\langle s_1 \Rightarrow R \propto s^2$ and changing to a linear dependence at higher supersaturations if $s \rangle\rangle s_1 \quad R \propto s.$
Crystal growth in casting methodology – atomistic approach 1. Thermodynamics – thermodynamic driving force and work of nucleation. 2. Kinetics – nucleation rate and supersaturation number.
MACROSCOPIC LEVEL – SOLIDIFICATION [5] 1. **Heat Conductivity analytical solution:** 1.1 1D Stephan's problems; 1.2 1D Stephan-Schwartz problems; 2. **Numerical Solidification's Problems:** 2.1 1D Stephan's problems and 1D Stephan-Schwartz problems; 2.2 3D Stephan's problems and **the most important 3D Stephan-Schwartz problem**; 2.3 Numerical Methods: 2.3.1 Finite differentials method; 2.3.2 Finite elements method; 2.3.3 Boundary elements method.

Chemical bond short history introduction on the base table 7 page 199 in [13]: MendeIeev (1871) Eight as a maximum valence rule and the sum of me hydrogen and oxygen valences for higher types; Abegg (1904) Electrochemical interpretation of Mendeieev's rule of eight in terms of electron gain and loss; Thomson: (1904, 1907) Concept of chemical periodicity in terms of recurring outer electron configurations. Rule of eight as striving for completion of stable rare gas shells; Kossel (1916) Extension of ionic model. Eight as a maximum valence rule for polar corn pounds only; Lewis (1916) Continuity of bond type and electron pair bonding mechanism for octet completion; Langmuir (1919-1921) Elaboration and popularization of the Lewis model. Mathematical formulation of the octet rule.

As it is known, Koseel offers a kinetic theory of crystal growth [18] and Stranski offers the same model [19]. At their meeting at the suggestion of the Stranski model is a well-known Kossel-Stranski model. The 1930s saw the publishing of several important articles which Stranski co-authored with Kaishev [20, 23] and Krastanov [30], which is called Stransk-Krastanov's growth mechanism. Stranski [28] and Kaishev [23] have developed the method of average separation work, a molecular kinetic method, which has played a role in the development of the theory of crystal growth and growth. Kaishev and Stranski create: the model of the crystalline growth (layered crystalline growth); have merit clarifying the relationship between the two-dimensional germ formation and spiral growth of the crystals. Kaishev summarizes Wulff's theorem of the equilibrium crystal's form, Kaishev summarizes Wulf's theorem about the equilibrium shape of the crystal formed on a foreign substrate (Wulf-Kaishev's rule); Develops thermodynamics and kinetics of electro-crystallization and electrolyte nucleation. Application the Kossel-Stranski mechanism is [17].

Nucleation. Kashchiev's book [25] presents at the same time an introduction to the theory of nucleation; the new results, their role and the interaction of the new results with the full theory of crystalline growth; the directions of the development of the complete theory. Thermodynamics and kinetics are directed to saturation (driving force), nucleus size dependence and work of nucleation. Regular spiral growth and known mechanisms of crystal growth are considered. Regular layered, spiral growth and known mechanisms of crystal growth are considered. A great potential for the application of the results in [25] to describe the first-order phase transition in the foundry methodologically is: the theorem of nucleation; and the basic kinetic equation of the formation of new phases for variable saturation. **Epitaxy.** Markov's book [26] considers in four parts the nucleation at obtaining of thin films in epitaxial growth, on the base of equilibrium between crystal and ambient phase, nucleation and crystal growth. The crystal growth mechanisms are examined, and the barrier effects on crystal growth mechanisms and on morphology analysis of the growing crystal surface are also considered. The mechanisms of Frank and van der Merwe and Stranski–Krastanov are discussed. The Mechanism of Stranski-Krastanov is the formation of several complete monolayers followed by the growth of isolated 3D islands and is well known to all epitaxial growth researchers. Barrier effects reporting require rewriting of the nucleation theory. An atom in a barrier effect like Ehrlich–Schwoebel has less close neighbors, which is important for morphology of surface growth. **Morphology.** The morphology of growing surface is part of the crystal growing. In [14] is presented graphical method generalized by general theorem. Has developed a new model of interaction between an internal structure and the morphology of a growing crystal surface [15]. In work [16] is study the growth and the morphology of Study of growth and morphology of precious stones.

An important moment for the foundry (but also for material science) is the natural boldness between the works of Balevski [6] and Borisov [7]. By definition [6] – By definition [6] – Metal science is the science of the relationships between structure and properties, as well as the influence that thermal, mechanical and other impacts have on the structure, and hence on the properties of metals and alloys. Metal science as a science emerges in the second half of the 19th century, originated in physics, metal physics, and so on. The introductory first part is Theory of Metals and Alloys: electronic struction of atoms; interatomic connections; crystal structure of metals; crystallization; physical - properties and methods of measurement; due to the engineering direction of [6]: deformation (elastic and plastic), mechanical properties and tests. These rigorous scientific terms clearly show the required minimum number of scientific fields in metal science, and only by the engineering need It is further clarified that the scientific ideas in [13] are not only in the theory of metal science but also in the theory of all **material science**. Изключително важен момент е: *за описание свойствата на металите е създадена квантовата механика*; използва се във фундаментални изследвания на физиката и техниката, които вече са съвпадат. An extremely important point is: *quantum mechanics has been created to describe the properties of metals*; used in fundamental studies of physics and technology that have already coincided. The full theory of crystalline growth covers applications such as semiconductor materials and structures for nanoelectronics [...].

In [7] the introduction of solid state physics is based on quantum chemistry, i.e. the application of quantum mechanics for explanation of the chemical connection (electromagnetic interaction see Fig. 2). The interaction of the electron (atomic core) is coulon and the state of the electron in the atom lies as a solution to Schrödinger's amplitude wave equation. Types of solid bodies according to the type of interatomic connections [7]: ionic crystals - crystalline lattice consists of oppositely charged ions; valent crystals - the atoms are connected in a crystal lattice with a covalent (homoeopolar) bond; metals - a crystal lattice is made up of positive ions, the repulsive forces between them being equalized by the free electrons; molecular crystals - the lattice is made up of individual molecules or atoms interconnected with intermolecular (vandervals) forces. Metal alloys are the simplest chemical compounds - solutions. The crystal lattices of the alloys according to the size of the atoms are: solid substitution solutions; solid solutions of deployment. It can be said that work [7] binds work [6] with

quantum mechanics. Work [6] and [7] are expanded by [9] for electron theory in metals.

Full mathematics is called upon to create new purely mathematical theories. The new theories are evolving because Gödel's theorems of "incompleteness" clearly show that there is no complete mathematical theory. The history of mathematics shows the need for the development of pure mathematics, but it is challenging to suggest the assessment of the development of the necessary, for example, a "new mathematical field".

A scale of 1μm is a macro-scale. Scale for nm or Å requires modern methodologies based on [8, 9, and 10]. Generalized this is the mathematics, the theoretical and the mathematical physics presented in Fig. 5

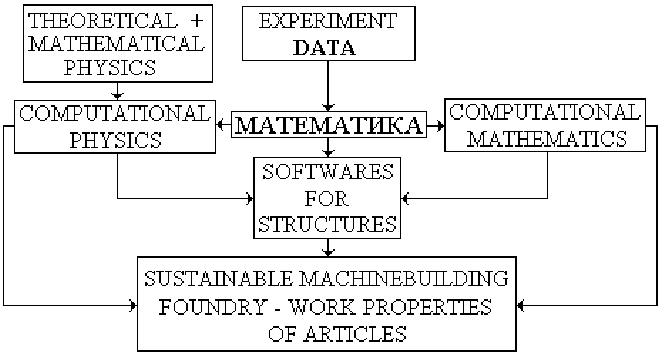

***Fig. 5** Scheme - Full mathematics is needed in Micro-Foundry and Industry 4.0.*

4. Conclusion

Mathematics is a powerful tool for research. Mathematics is needed in public development, for example "virtual factories", apart from technological, legal relations between companies, based on new experimental data, evaluations are also made for research ideas for development from "artificial intelligence". Hence Industry Change 4.0: "factories without people", and people naturally need life-long education.

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CONFIGURING CUSTOMIZED PRODUCTS IN VR USING HMD

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Abstract: *Until recently the Virtual Reality (VR) and its related technologies, e.g. Augmented Reality, Mixed Reality etc., were often thought of separately. However, in the Industry 4.0 model all they are observed as key elements and enablers. It is expected that the combination of VR related technologies with the advancements of Industry 4.0 will disrupt the traditional manufacturing, the existing business models and value creation chain and will reshape dramatically the industrial environment. According to White Paper of IDC considering the Digital Transformation in the Manufacturing industry published in 2016 a third of the industrial enterprises worldwide aims to use VR in their production and engineering environment in the upcoming five years aiming at applying VR for retail showcasing, customized products development, on-site assembly, engineering design, training, etc. Within this context, the so-called Head Mounted Displays (HMDs) represent a significant interest as promising end user devices that enable the wide penetration of VR into the engineering routines such as design activities, product configuration and validation. We make a brief overview of the common HMDs, their features and limitations. Further, a generic process for configuring the customizable product features using of HMD and its programming implementation are presented following by discussion of the results from the usability testing of the proposed interaction paradigm.*

Keywords: VIRTUAL REALITY, PRODUCT CONFIGURATOR, PRODUCT CUSTOMIZATION, HMD,

1. Product Customization and Virtual Reality

Nowadays the trend for creating the products precisely according to specific requirements of each customer is already a common practice of the product manufacturing companies. In order to be successful and competitive they, regardless of their scale or specialization, have to seek diverse innovative ways in order to adapt their products satisfying the individual needs of each customer while keeping the costs at the mass production level. Here, the innovation management has moved from a manufacturer to a customer centric process leading to anticipation of a new design and manufacturing paradigm for customization of the products wide known as Mass Customization. Nowadays the trend for creating the products precisely according to specific requirements of each customer is already a common practice of the product manufacturing companies. In order to be successful and competitive they, regardless of their scale or specialization, have to seek diverse innovative ways in order to adapt their products satisfying the individual needs of each customer while keeping the costs at the mass production level. Here, the innovation management has moved from a manufacturer to a customer centric process leading to anticipation of a new design and manufacturing paradigm for customization of the products wide known as Mass Customization.

According to [Dellaert & Stremersch 2005] two most serious issues related to the implementation of product customization from the customer perspective are the **cognitive cost** and the **complexity**. When the customer has a significant number of alternatives for making a choice, the cognitive effort for their evaluation may exceed the increased benefit from the availability of options to select from. This creates frustration due to so-called "paradox of choice". The existence of too many alternatives decreases their subjective value to the customer, which in turn shall lead to a postponement of the decision or shall classify this product as a "difficult" and undesired [Piller & Tseng 2010]. The most commonly used approach to avoid this is the use of a product configuration system also referred to as product configurator. The customer is given the opportunity to build a structured model of their needs and to obtain information on appropriate solutions based on interactive test between the model and the options available.

The product configurators can be observed as software tools that are used for performing “co-design” activities in an act of manufacturer-to-customer interaction [Khalid & Helander 2003]. The customer selects the attributes and attribute values from a finite set of options and combines them into a final customized product. The configurator systems perform various tasks and contain much more than calculating algorithms. The configurators check the specification of an individual product configuration for *completeness* (that all the necessary selections are made) and for *consistency* (that no rules are violated). Additional functionalities such as price and delivery time calculation, layout drawing etc. may be provided.

In the context of the product configuration the Virtual Reality (VR) and its related technologies respectively are considered as enablers for proactive participation of the customers in defining their needs, requirements and boundary conditions and for interactive multimodal validation of the configured product and its properties in near-real conditions and showcasing. By using VR the customers are allowed to carry our more efficient “mapping” of their requirements into the physical domain and they are able not only to observe or simulate the individual creation, but also to experience the product (through multiple sensorial modalities).

2. Product Customization and Virtual Reality

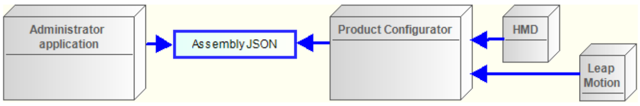
Head-mounted display or HMD is a display device worn over the user’s head. It features a display in front of one or both of the eyes that stream data, images and other information. Additionally, HMDs may feature position tracking and stereo sound, providing high level of immersion for the user. There are many variants of implementation of the head-mounted display system for various purposes with different characteristics starting with the very simple cardboard box and ending with sophisticated wireless devices [Romanova, 2017].

The VR HMDs as a concept and implementation are definitely not new, but in the last three years (2015-2017) there is a growing interest to head mounted displays (HMD) as end-user devices for immersive presentation of Virtual Reality. This is mainly caused by the investments in the sector from the major companies (e.g. Facebook, Alphabet, Sony, Samsung etc.) and the introducing on the market of a third wave of new affordable devices of different producers featuring acceptable performance characteristics including low-cost head-sets which integrate smart phones as display technology together with the correspondent SDI’s. However, the main focus for practical use of these HMDs are limited only to gaming, social VR, entertainment, showcasing and other similar topics. Engineering applications, in particular related to the product customization such as in [Yuan, 2017] are not commonly reported, but highly promising. According to the reports, it is expected that the Head-Mounted Display will reach USD 25.01 Billion by 2022 at an average annual growth rate of 38.8%. That implies high penetration in all spheres of the globalized economy, including Engineering. That means that HMDs have a significant potential to become a valuable tool for supporting engineers in performing their routines and decision making and bringing new dimensions for application of traditional CAD and CAE. In this term, the exploration of the specifics of the HMD interaction and user interface is of big importance. The analysis of the available on the market devices shows that the producers are experimenting intensively with various approaches and try to find the best relation of these properties for their customers. Another clear trend is the introduction of 3D audio components that become an obligatory aspect of the HMD device. However, the performance characteristics are still not optimal and there is a long way before reaching the required maturity.

4. Functionality and Architecture

For the purpose of this work, a simple VR-based product configurator functionality and architecture was defined as shown on Fig. 1. In term of these, it is adopted that the product, which is the main subject of the configuration process, constitutes an assembly built from multiple subassemblies and/or single parts presented in different variations (instances). The software application that implements a configuration process is known as a Product Configurator. It provides two main roles for the participants in the process: Administrator (Engineer) and User (Customer).

Fig. 1 *General architecture of VR-Based Product Configurator*



The Engineer prepares the assembly (Product) and creates a hierarchy of objects. Each object (assembly, subassembly, single part) has its own different properties that can be handled. An instance of a given subassembly can be incompatible with another instance from another subassembly. Beside other, the Engineer can configure this compatibility in order to enable implementation of real world scenarios. Upon the end of the configuration process, the Engineer can export Customer's configuration of the product as a Bill of Materials (BOM). The use of standard formats like JSON and XML enables an easy integration of the product configurator with existing or newly created upstream systems.

The Customer configures the Product based on the object hierarchy defined by the Engineer, handles it in the Virtual Reality environment and finally stores the configuration made. The configuration process can be restarted or performed multiple times. Thus, different configurations can be created, tested and compared. This provide better user experience, improved configurations and satisfaction. Both participants, the Engineer and the User, perform various tasks, which require different interactions and user interfaces. Therefore, the Product Configurator is divided in two sub-applications, which communicate through the standard JSON format. Because of this, they can be implemented using technologies that are best suited for the specific requirements. All properties of the assembly are stored in the JSON data such as id, name, color, label, position. Similar properties are available for the subassemblies and their instances. The Administrator application enables handling of this data, which is critical for the successful execution of the subsequent configuration process.

The main part of the Product Configurator is presented by the application, which provides a Virtual Reality environment accessed with a Head-Mounted-Displays (HMD) and interacted through a hand tracking system. In this environment, the user can look in arbitrary direction, move and resize the configured assembly object, change its properties (e.g. color, form, label, etc.) and undo and redo previous operations. The product configuration scenario is intended to be performed in a suitable virtual room that is near real furnished considering the specifics of the respective product as shown on Fig.2. This will provide better immersion for the users. Each operation is accompanied with appropriate sound for an optimal user experience. The user interaction with a hand tracking technology, which enables the Customer to execute most of the operations using virtual, hands (Fig. 2 *left*). The virtual hands are a graphical avatar of the Customer and represent the continuation of his/her hands in the virtual world. They react on every movement of the real hands and fingers of the Customer and repeat it in the VR. By using special gestures, the Customer can easily move the configured object, change its size and perform zoom-in and zoom-out operations. A user menu is integrated in one of the virtual hands as shown on Fig. 2 *right*. It provides access to variety of options and functions. Further, a text input is available through a virtual keyboard. The virtual room, virtual hands, virtual menu and basic gestures are presented in the following diagrams.

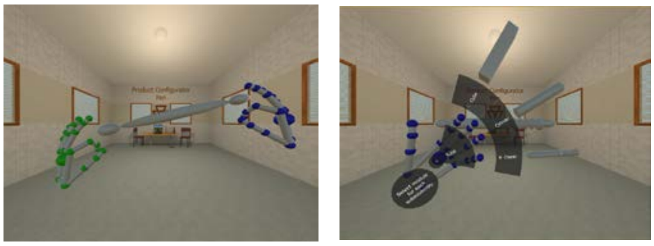


Fig. 2 *VR-based product configuration environment featuring virtual hands.*

The virtual hand menu has hierarchical structure and provides additional information to facilitate its use. It works intuitively and has a section with hints for the possible next operations. For some of the operations (like loading of previously saved configurations) an interaction with statically positioned menu is provided. The complete menu structure with possible options is shown on Fig. 3.

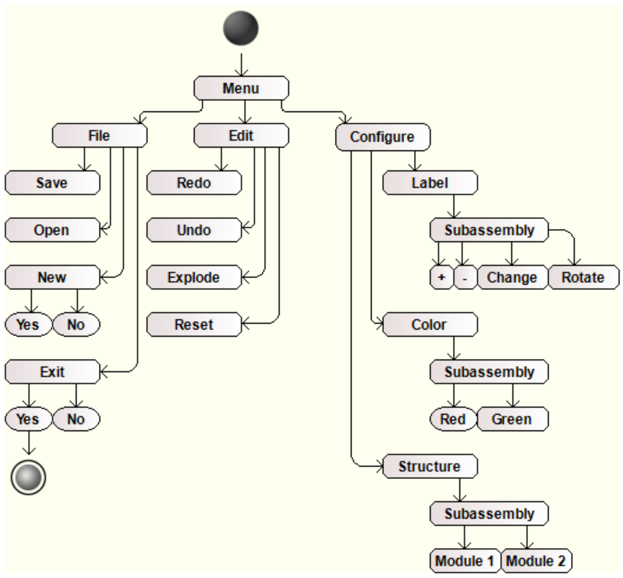


Fig. 3 *Configurator's menu structure*

5. Implementation and Integration

The Product Configurator application uses two interface devices: Leap Motion for user input and *Oculus Rift* HMD in its version *Development Kit 1* for immersive visual presentation. The Leap Motion device is placed on the front side of the HMD. In this way, the sensors can identify both hands also when the user moves his head in different directions. Both devices are connected to the computer through USB ports. The HMD is connected also through HDMI. Both require additional driver software to be installed. It was found that Oculus Rift has some compatibilities issues related to the used video cards, especially in the mobile computers. For the purpose of the development and testing the minimal computer setup with following parameters was determined: Windows 8.1 Pro 64bit, 8GB RAM, AMD A8 PRO7600B R7, 10 Compute Cores 4C+6G 3.10GHz (Fig, 3). This configuration is not powerful enough. Therefore, most of the elements of the virtual room are static and are calculated at compile time, which provides significant performance improvement and influences positively the user experience.

Fig. 4 Minimal hardware setup

It was found that Oculus Rift has some compatibilities issues related to the used video cards, especially in the mobile computers. For the purpose of the development and testing the minimal hardware setup with following parameters was determined: Windows 8.1 Pro 64bit, 8GB RAM, AMD A8 PRO7600B R7, 10 Compute Cores 4C+6G 3.10GHz (Fig, 4). This configuration is not powerful enough. Therefore, most of the elements of the virtual room are static and are calculated at compile time, which provides significant performance improvement and influences positively the user experience. The developers of Leap Motion and Oculus Rift provide software API for application development. This enables easy and fast beginning in the development process. Most of the basic functionalities come out of the box. As the technology is relatively new, often there is not backwards compatibility between releases and previously working code can malfunction. Therefore, version migration should be performed carefully dictated by the provided documentation.

The Administrator application is organized using the Model-View-Controller paradigm. Different packages are created to implement this separation. Under the models package all classes defining an assembly are created: Assembly, Subassembly and Module. A separate class is defined that contains the configuration information for each object. A singleton instance of *ConfigurableObjectManager* is provided, which implements all configuration operations. Fig. 5 presents its class diagram.

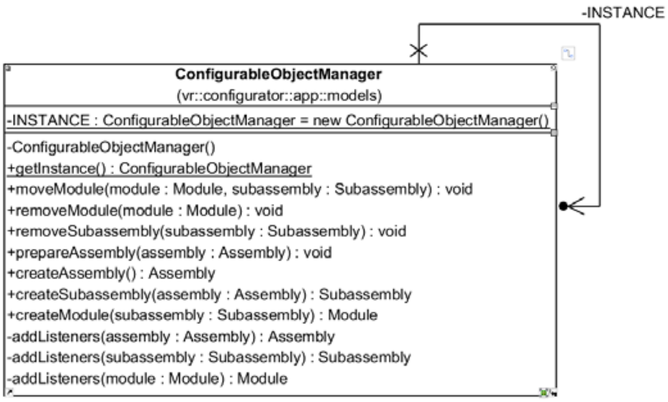


Fig. 5 ConfigurableObjectManager class diagram

The User application has more complex structure, because it models different kinds of interactions in the VR environment. The components are organized in packages based on their role in the overall architecture. The *Behavior* package contains again the definitions of all assembly related objects, but this time from the perspective of their manipulation and configuration. The *Config* package provides all settings prepared by the Administrator application. The architecture of the VR application is mostly event-driven. The user can perform operations in any order. Therefore, the Service package contains services, which are called when a specific event is fired. Fig. 6 shows the facade used for access to the object, text-material, sound, message and redo-undo services.

The Menu package contains definitions of all kinds of elements used for the VR interactions. They build an object hierarchy (Fig. 7), which is constantly manipulated and changed through the execution of the program.

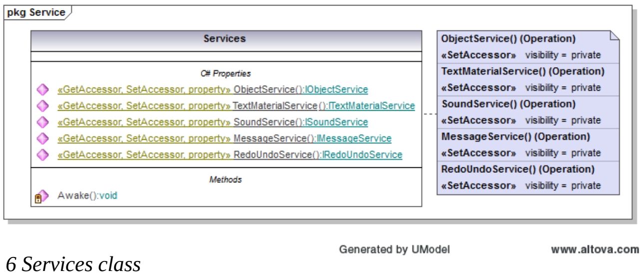


Fig. 6 Services class

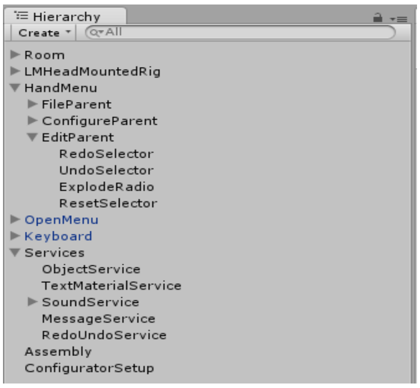


Fig. 7 Object hierarchy

6. Usability Testing

A simplified usability evaluation based on predefined testing procedure is performed to evaluate the proposed interaction paradigm as shown on Fig. 8. 16 participants took part in the testing with equal count of males and females. The age distribution is presented on Fig. 9. The participants of age of 18 - 24 years prevail.

Fig. 8 Performing testing of the product configuration using HMD

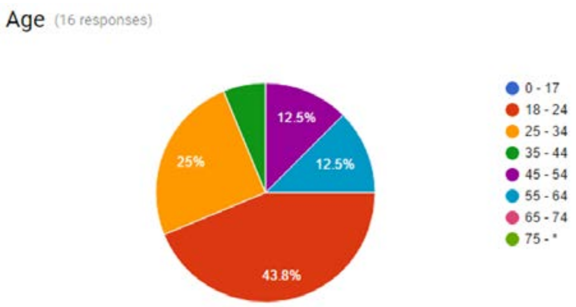


Fig. 9 Age distribution of the participants in the usability study

In the performed study, every testing person should configure his/her individualized version of a simple consumer product (a pen). The product consists of three subassemblies, each of them has three different variants (instances) as shown on Fig.13. Additional compatibility constraints are defined between some of them. At the beginning of test procedure, the purpose of the study is explained to the testing person. After that, he/she receives instructions about the way of use of the configurator and the virtual hands mechanics is explained. Each participant puts on the HMD by himself/herself and performs following tasks: assembly move, size change, configuration of the structure, color selection, defining and positioning of a label, saving the configuration. The first impressions are registered trough a personal interview upon completion of the testing procedure and then the user should complete a usability questionnaire.

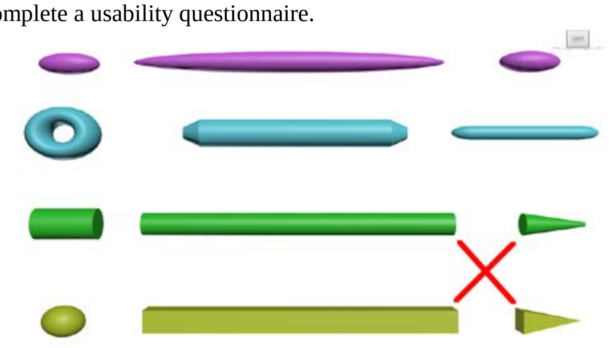


Fig. 10 *Test product structure*

The most of the user have good experience with the system as shown on Fig. 11. A half of them is completely satisfied with the product. One of the most important issue related to the Virtual Reality is the physical comfort of the user. Often after longer exposure to a virtual environment users show symptoms of so called cyber sickness such a general discomfort, headache, stomach awareness, nausea, vomiting, pallor, sweating, fatigue, drowsiness, disorientation. Manifestation of some of these symptoms with different extent are reported from five of the participants. The symptoms were severe only in one case.

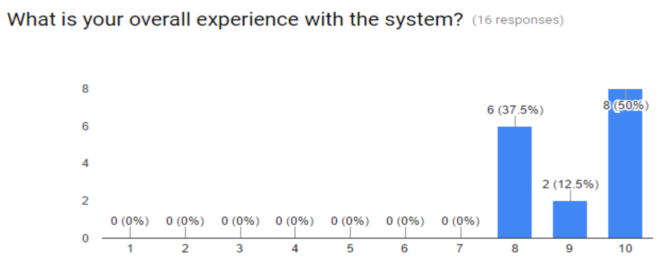


Fig. 11 *Overall experience with VR-based Product Configurator*

One aspect that plays important role is the resolution of the HMD. The experiments is performed by using the first Oculus Rift model and shows expected results. For most of the participants is the text with low readability and this hinders the interaction with the system. Nearly two-thirds of the participants like the control with the virtual hands. The rest report difficulties, which they overcame after a short period of time. This is valid for the most of the older participants who have problems to use the virtual hands. The size of the hand menu should not be so big because it is considered as an integral part of the hand. According to the majority of the users the menu is well structured and organized, but not perfect. It has to many options and is regarded as difficult. One possible solution of this issue is the use of voice commands or gestures related to additional tracking sensor. The menu icons and the menu colors facilitate the work. In the first version of the Product Configurator no icons or meaningful colors were used. Based on the feedback of the testing person these were implemented and 70% of participants find that the icons and colors provide them with important support into the configuration process.

Other important component for VR are the sounds. In the Product Configurator various sounds and audio effects are used for the occurring events. 60% of participants find these for appropriate and meaningful. According to the most of the participants, the immersion in VR environment enhances the experience as a whole. However, the opinions here varies in a wide range. On the one hand, VR supports and augments the configuration process and alters the user experience in disruptive way. On the other hand, some of the participants (10 %) rate the VR environment as distractive. Evident here is the problem for keeping balance between photorealistic appearance and functional requirements.

Generally, the results from the testing are positive and motivate the future development of the system. The negative aspects are not provoked form the Product Configurator itself, but from the performance characteristics of the user hardware equipment itself. The technology is improving continuously, therefore the low resolution, the latency and related to them sickness symptoms can be gradually overcame. In order to get better understanding the Product Configurator should be tested systematically with other HMD models. In our opinion the most of the reported issues can be avoided by the use of headset with better performing characteristics, e.g. HTC Vive. Based on the collected information from the testing the application can be improved in various ways. The user interface can be extended with new components, e.g. better color selector. The hand menu should be revisited, because it cannot support subassemblies with more than five modules. More optimal feedback mechanism should be provided for the single operations, e.g. when a given instance has been chosen it can change its appearance VR. The virtual room can be also improved. Additional spaces should be designed that support configurations of different assembly types. Another improvement that can provide a better immersion is the introduction of voice commands.

7. Conclusion

The field of Virtual Reality is rapidly going forward and givens new opportunities for software applications. Its integration in the Mass customization process involves even more the user and provides unique user experience. A new set of challenges arise from this innovation. The lack of standards and well-established methodologies motivates the experiments with new platform independent architectures, which should utilize all existing and future VR technologies. This work studies and proposes a generic architecture for product configuration, which can be easily deployed in an existing IT environment. It implements different approaches for the interaction between the user and the system. The described goals and principals are tested using a usability test. This evaluates the created system and gives guidance for the possible improvements. The overall positive results can be used as evidence for the growing potential of the VR technologies and strengthen its position in the constantly changing and evolving information technology world.

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PHYSICO-CHEMICAL PROPERTIES OF DISSIMILAR WELD

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Abstract: *Mechanical and electrometrical behavior of dissimilar welds between low Carbone steel (X70) and Carbone steel (42CrMo4), were studied using a combination of optical and electron microscopy. Thus, the influence of weld parameters on fusion zone and heat affected zone was investigated using two filler metals and two weld currents. The results of our work show that alternative TIG welding presents the butter combination between metallurgical and Mechanical comportment, also it was established in this study, that nickel alloy filler has the best electromecanical behavior for these types of welds.*

Keywords*: X70, TIG Welding, 42CrMo4, dissimilar weld*

1. Introduction

Dissimilar welds have been widely used in industrial applications and singing in their form of sheet metal, pipe or modified structures. They have found a wide range of applications especially in fusion welding processes thanks to their characteristics which can be adapted after heat treatments [1, 2]. Heterogeneous welds Stainless steel / steel, stainless steel / stainless steel, aluminum / steel and steel / steel are often obtained for different requirements [3,4], among which is a welding between a tempered steel tempering (42CrMo4) with a low steel on carbon (X70) which seems to be very interesting for the realization of a GMA crane in our center.

The main problem of heterogeneous welds is the formation of the metallic precipitations in the bonding zone between the two basic materials due to the difference between the tenants of the additive elements that exist in the two materials. that magnification of grain in the area thermally affect by thermal welding cycles [5,6].

Heterogeneous welding is the subject of several studies, Azizieh has evaluated the weldability between a quenching steel tempered (CK60) a low carbon steel (ST37) by a friction welding process[6]. It obtained very hard interfaces and mechanical and electromechanical properties that could be questioned through the microstructures presented and the welding method [7].

Our work is based on improving the physicochemical properties of heterogeneous welds by modifying filler metals and welding mode.

2. Materials AND METHODS

In this work, the base materials utilized are Carbone steel (42CrMo4) and low Carbone alloy steels (X70) (Table 1). Two filler metals were used to elaborate welded joints. It represents respectively Nickel alloy filler Ok60 and low Carbon E6010. The chemical composition of filler metals is given in Table 2. The base materials are welded using automatic tungsten arc welding (TIG) based on ASTM standard [8] (Table 3), According to moved table in order to set welding parameters. Sheet metal dimensions were fixed at 100x60x4mm (Fig. 1) (Fig. 2) with filler wire diameter of 1.5 mm. Standard polishing procedures were used for microstructural observations, Glycerine reactif was used with the conditions (20ml of nitric acid, 30 ml HCl acid and 30ml of glycerol) for 3min. The microstructure was characterized by optical microscopy. Hardness test was conducted using Vickers scale with a load of 0.2Kg ($Hv_{0.2}$). $Hv_{0.2}$ test was performed on the middle of weld joint, perpendicular to welding direction. Image J program was used to compute fractions and gain sizes.

To perform electrochemical tests, measurements have been done, these measurements comprise:

A EGC Princeton 263 Potentiometer / Galvanostat measures the potential difference between the working electrode (Et) and the reference of a three-electrode cell, passing a current Ic in the cell via the against electrode (Ec) and measure the current using the chemical drop across the resistor Rm. An electrochemical cell contains cylindrical thermostatic shape; it is formed by glass and double wall with a capacity of 250 ml. It is equipped with a conventional three-electrode mounting: Work (or sample), reference (a saturated calomel electrode (ECS) whose end is placed near the working electrode) and against electrode (or auxiliary electrode) which is a platinum grid (to ensure the passage of current).

Table 1. Chemical composition and mechanical properties of base materials

Elément	C	Si	Mn	P	S	Al	Cu	Cr	Mo	V	Nb	Ti	Ni
X70 (%)	0.08	0.7	2.39	0.01	0.001	0.06	0.01	0.04	0.1	0.05	0.4	0.09	0.02
42CrMo4 (%)	0.45	0.4	0.90	0.35	0.0.35	-	-	1.20	0.3	-	-	-	-

Table 2. Chemical composition of filler metals

Elément	Fe	Ni	C	Si	Mn
Ok 60 (%)	0.40	0.60	-	-	-
E6010 (%)	Rest.	-	0.10	0.20	0.50

Table 3. Welding parameters

Current	Electrode	Argon flowrate (L/min)	Medium voltage (V)	Average intensity (A)	Weld speed (mm/min)
CC	Ok60 (1)	6	10.65	100	35.24
	E6010 (2)	6	11.65	100	36.70
CA	Ok60 (3)	6	11.84	100	37.72
	E6010 (4)	6	12.4	100	37

3. Results And Discussion

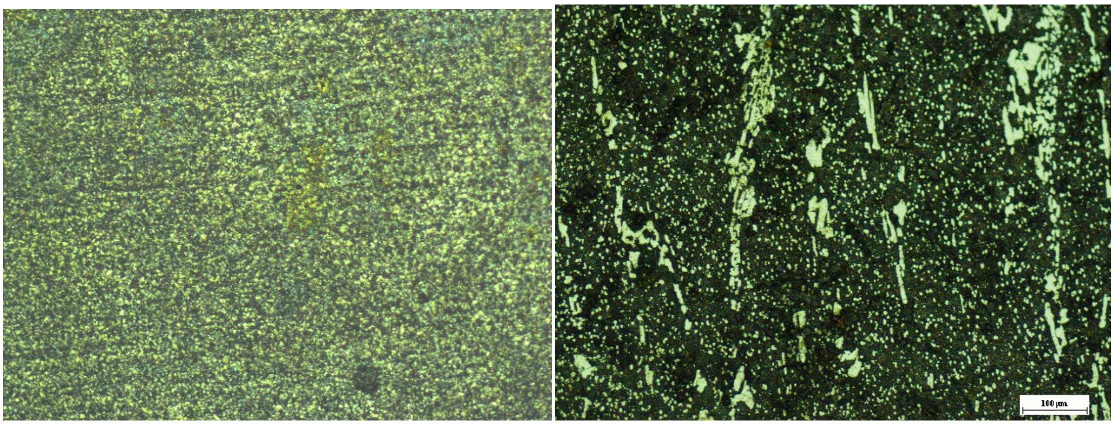

Figure1. Optical microstructure of the base materials X70 (right)

The micrograph of the two basic materials shows that: X70 microstructure is composed of ferrite and perlite, the latter consisting of ferrite and cementite, while 42CrMo4 steel is characterized by martensitic lattes in ferritic matrix with a small proportion of Cabrides (Figure1).

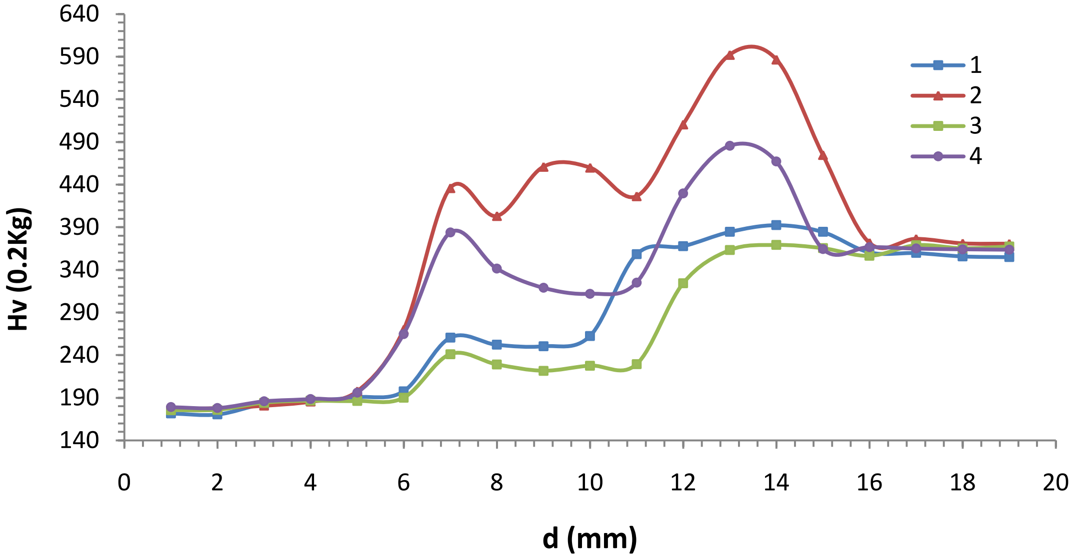

Figure2. Microhardness profile

Figure2 Shows the variation of the Vickers microhardness measured through fusion zone, both HAZ and the two basic materials. The four curves represent four samples, two samples (E3) and (E4) undergo alternating TIG welding and continuous TIG welding is applied to (E1) and (E2). When the microhardness curve stabilizes, it indicate the microhardness of steel, 175 Hv (X70) and 362 Hv for (42CD4).

From these graphs of microhardness profiles we can draw the following conclusions:

The welded samples undergo a large increase in microhardness in heat affected Zone (HAZ) compared to the two base materials, where there is a creation of relatively fragile structures rich in metal carbides (Widmanstatten, martensite ....) When from the welding operation, this wealth becomes huge in the 42CrMo4 side.

The variation of the microhardness is also related in a first degree by the carbon content, and second degree, by the effect of alloying elements which presents in each basic material. The role of the gamma elements (Mn, Ni) reduces significantly transformation temperatures of phases and moves the diagrams in continuous cooling to slow speeds. Manganese in particular has a important role on start temperature of martensitic transformations. The primary effect of the carburigenic elements (Cr, Mo) is to increase the quenchability, and more particularly for molybdenum, to increase the stability of the bainitic microstructure, by delaying germination of ferrite phase. In addition, these elements form carbides dispersed with iron in the course of the reciprocating cycles, whereas in the (CC) it forms dispersed carbides which are concentrated in the HAZ, which poses a risk of a sudden fracture.

In the case of AC current there, there is a decrease in the microhardness compared to the DC current, this reduction is due to the effect of thermal welding cycle which causes a rapid variation in the heating rate,

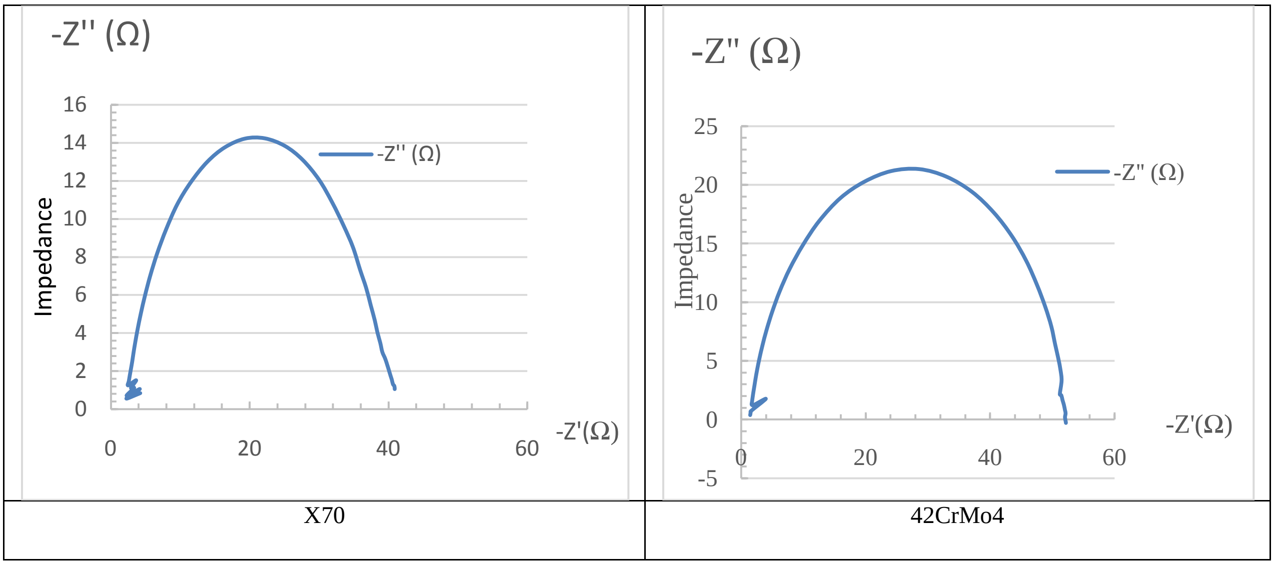

Figure 4. Impedance of base materials

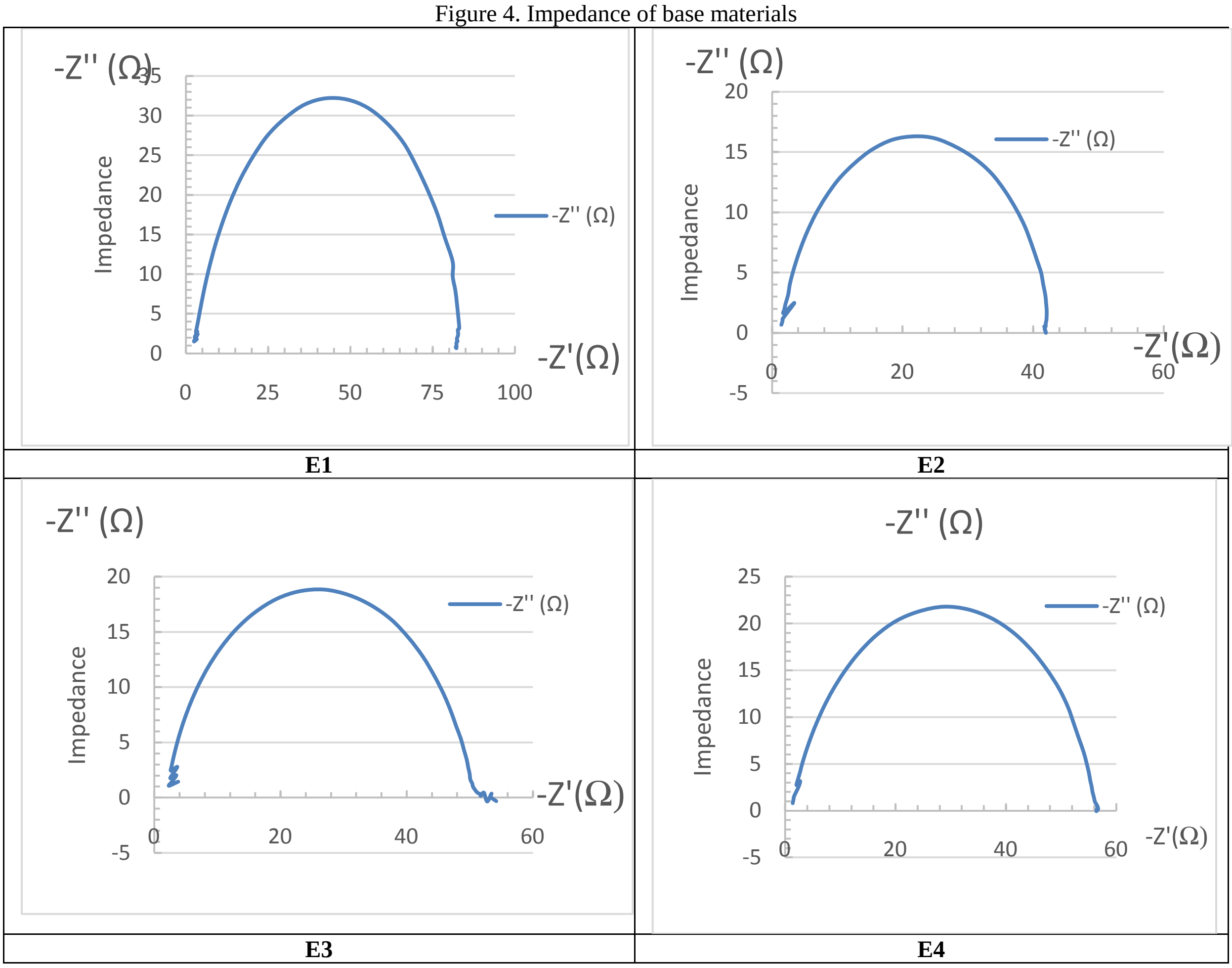

Figure 5. Impedance of weld joints

Figure 5 and Figure 4 show impedance diagrams of Nyquist Z plane at different welds joints in frequency range: 50 Hz - 100 mHz. the representation in the Nyquist plane was used here to determine Load Transfer Resistance and Sample Capacity. The interpretation of the diagrams makes it possible to determine the various processes that take place at the electrode and the charge transfer resistance.

From the impedance curves we can see that:

The impedance evolution in the Nyquist Z plane as a function of the welding parameters, the good electrochemical behavior results in an increase in the considerable resistance of charge transfer together with a decrease in the capacity of the sample. Electrochemical tests showed a good efficiency which observed in E3, as well as a good load transfer resistance observed in sample E1.

The polarization tests clearly show that the characteristics of the electrochemical behavior of the welds are generally found between the base material terminals except for the Ok.60 welded samples.

Corrosion rates significantly lower than the heterogeneous weld compared to carbon steel (42CD4). Thus the speeds in the welds (E1, E3) significantly lower compared to other samples. In addition, it is found that the weld (3) has a potential and a corrosion voltage lower than that of the sample (01). Compared to the other samples, the sample (E3) is passive and its polarization curve shows slight passivation levels, its corrosion current remains low. It is around

0.0022648 A and its corrosion potential is (-00.37561). From the linear polarization curves (Lp) we obtained the following results:

Table 4. Polarization results

Samples	ba (v/dec)	bc (V/dec)	E corr (V)	I corr (A)	Vitesse mm/an
X70	0.73402	0.21418	-0.37431	0.0025587	29.732
42CrMo4	1.1318	0.50853	-0.40282	0.0037302	43.345
01	0.47959	0.20530	-0.396	0.0018713	21.744
02	1.0276	0.46995	-0.40969	0.0032702	38
03	0.55053	0.19139	-00.37561	0.0022648	26.317
04	1.2367	0.42045	-0.39137	0.0035365	41.094

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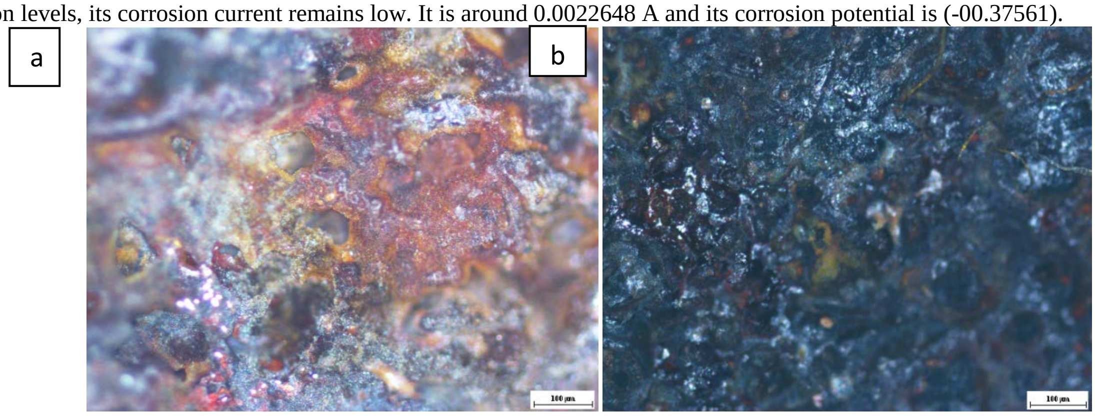
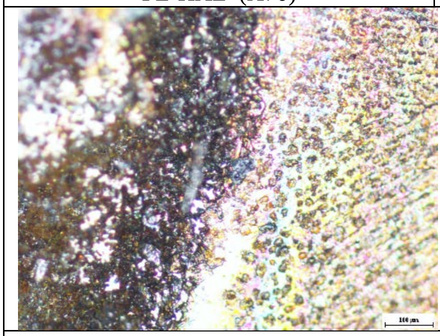
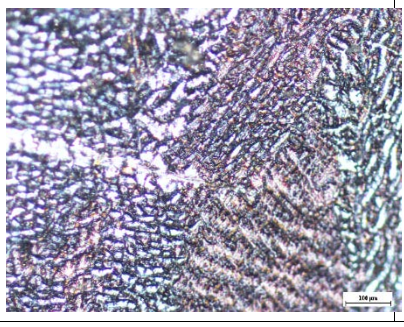
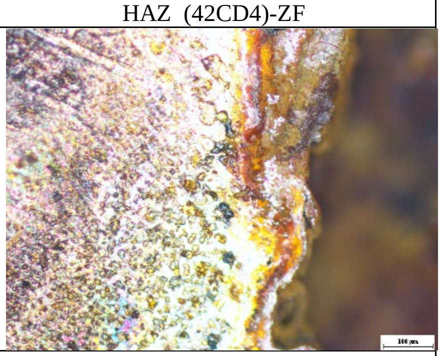
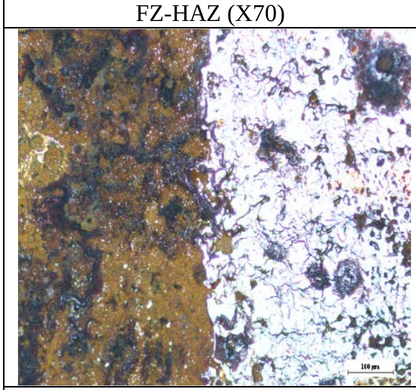
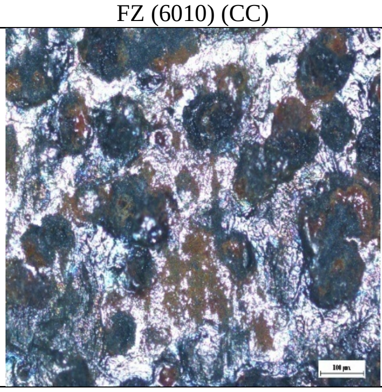
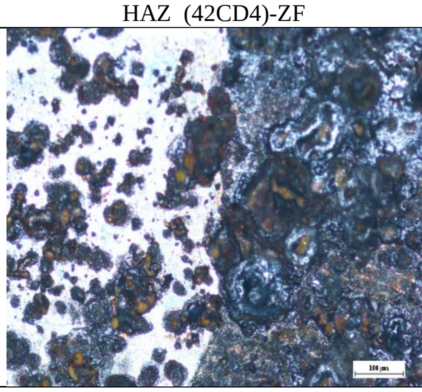


Figure 6. Micrographics of corroded base materials: (42CrMo4) and b (X70).

E1		
FZ-HAZ (X70)	FZ (OK60) (CC)	HAZ (42CD4)-ZF
		
E2		
FZ-HAZ (X70)	FZ (6010) (CC)	HAZ (42CD4)-ZF
		
E3		
HAZ (X70)	FZ (OK) (CA)	HAZ (42CrMo4)-ZF

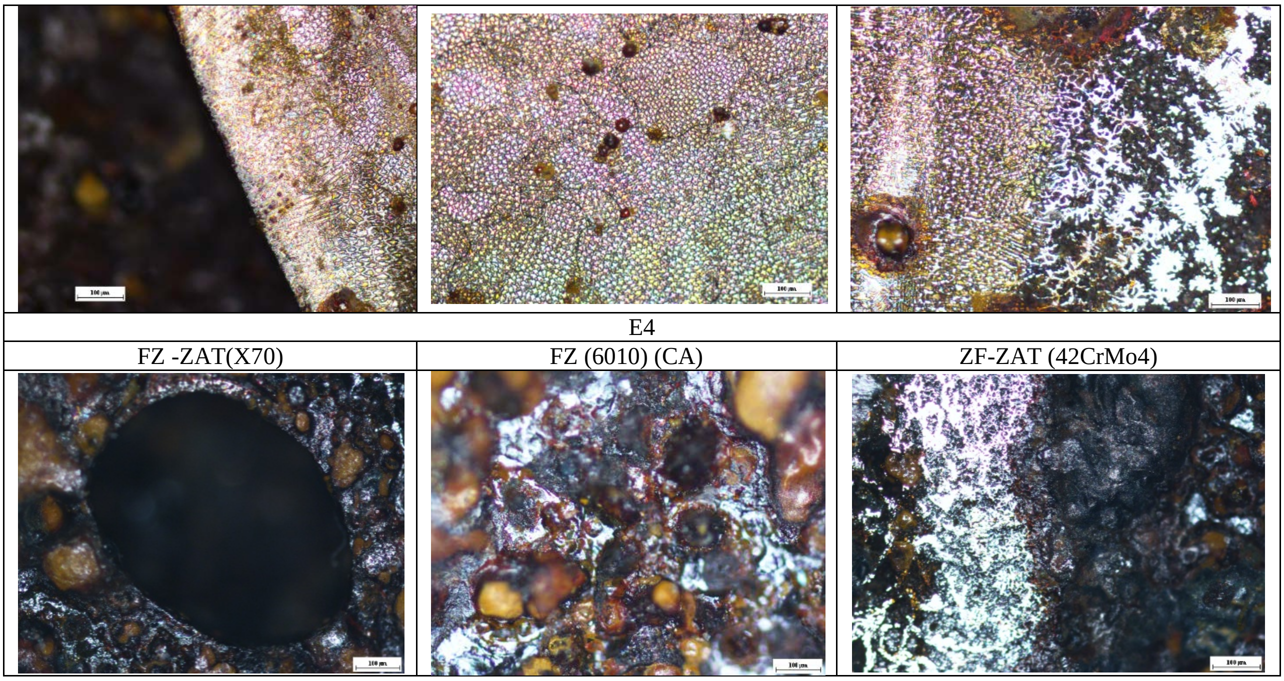


Figure 7. Micrographics of corroded welds

The figures (Figure 6, Figure 7) show the results of the optical observations of corrosion surfaces for magnifications (X100). These micrographs show a strongly etched structure in the 42CrMo4, with a high density of dissolution. On the other hand, the micrographs of the welds have strongly burned aspects in the welds (E4, E1). Also, the fusion zone of welds with Ok60 is the least to alter by the electrochemical tests. We also observe the presence of bites distributed randomly on the surfaces obtained, the number of these defects were too small in the samples welded by the Ok.60.

4. CONCLUSION

This work is only a modest contribution to understanding the different physico-chemical phenomena encountered related to the reliability of heterogeneous metal structures. In the ZATs of the carbon steel (42CD4) sides, the morphology of martensite became a dominant phase with an increase of the bainitic phase in the AC welded sample. This phase is favorable for the mechanical behavior. In addition, the ZATs of X70 steel have undergone a magnification of ferritic grains; this magnification becomes light in E3.

- Welding with E6010 low-alloy steel (E2, E4) allows to obtain melted zones with fine structures consisting of rough zones of solidification such as: proeutectoid and acicular ferrite, lamellar constituent of bainite and martensite.
- Nickel-based alloy welding induces melted zones consisting of columnar austenitic grains surrounded by ferritic precipitations; it is also observed that in the case of (CA) the austenitic grains undergo a grain coarsening.
- The use of the alternating current causes a decrease of the microhardness with respect to the direct current, this reduction is due to the effect of the welding thermal cycle which causes a fast variation in the rate of heating.
- The use of filler metal E6010 increases the microhardness compared to OK60 this is due to the effects of the additive elements.
  - Polarization tests clearly show that the characteristics of electrochemical behavior of Ok.60 welded joints has the better comportment.

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DISTRIBUTION OF NANODIAMONDS IN ELASTOMERIC MIXTURES.

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Annotation: *In the present work the distribution of ND in standard mixtures of natural rubber without the use of stearin acid was studied.*
KEY WORDS: *NANODIAMOND (ND), ELASTOMER, RUBBER, COMPOSITE MATERIAL*

I. Introduction

Nowadays, polymeric materials are applied practically in all areas of human activity and replace the increasingly used traditional metals and alloys from the modern fields of engineering, machine building, etc. The dynamic development of nanotechnology in the field of the processing of elastomers, determines the great importance of studying the structure of the elastomeric material.

One of the important components of a composite material (CM) - an elastomeric mixture (EM) is the filler. The importance of fillers is related to the production of materials with specified properties necessary for certain branches of the economy, research, medicine, etc.

II. Experiment

As regards nanotechnologies and fillers for elastomeric mixtures, the influence of nanodiamants (ND) as an element of the nanoparticles on the EM must first be studied before the formation of the supermolecular structure of the mixture and the vulcanization process preceding the manufacture of the rubber article. The influence of ND on the EM should be focused on the interfacial processes and superficial phenomena of the elastomer - filler, because precisely the changes occurring in them determine the emergence of a new complex of properties of CM. The diamond modification of carbon has the highest values of free surface energy [1], which leads to a high activity of nanoparticles in the modified material but is found in a powdery state in air, ND tends to agglomeration, leading to a reduction in excess surface energy deactivation. In order to increase the ND's modifying effect on the NR, in order to preserve the values of free surface energy, NDs should be introduced together with their inert storage environment, as they fall into the EM to maintain their activity.

The problems with the NR with ND are:

- developing methods for introducing ND into the mixture;
- Achieving the even distribution of ND in the mixture.

The following embodiments of the inert environment in the mixture are shown Fig 1:

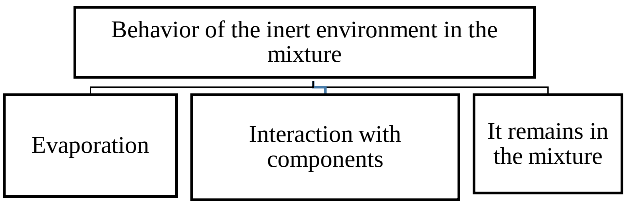


Fig 1: *Behavior of the inert environment in the mixture*

Confirmation of the claim is the [2] found in the ND of connected and sorbed water. It is not even released when drying at 393 K.

Ideally, we accept:

- ND do not chemically react with the individual components of the mixture;
- The values of free surface energy remain unchanged.

On the other hand, the dimensions of ND and their surface hardness will contribute to the formation of their own hierarchy of supramolecular structures, averaging the density of the packings of the macromolecule chains over the entire volume of the polymer matrix (PM) [3].

According to [4] the matrix is modified under conditions that the particle of the modifier (ND in the present case) exhibits its activity in the adjacent layer of the polymer with a thickness,

$$L = r\sqrt[3]{\frac{\rho_н}{C_н \rho_п}}$$, where:

L – film thickness,
r-particle size,
pn-density filler,
pp - density polymer,
CH-density filler

The formula follows that the amount of carbon cloud particles is in the range of 30-50 nm.

A natural rubber (NR) was used to carry out the experiment as an elastomeric matrix.

The EU has been developed in options:

- not filled without stearin with ND - 1,5 weight fraction per 100 weight fraction NR (C-1);
- not filled without stearin with introduced ND - in 3 weight fraction per 100 weight fraction NR (C-2);

As a method for demonstrating the distribution of ND in the mixture based on their size, the X-ray diffraction analysis method is used to study the structure of the substance in the Delay-Sderder distribution space.

Figure 2 *shows the results of both samples.*

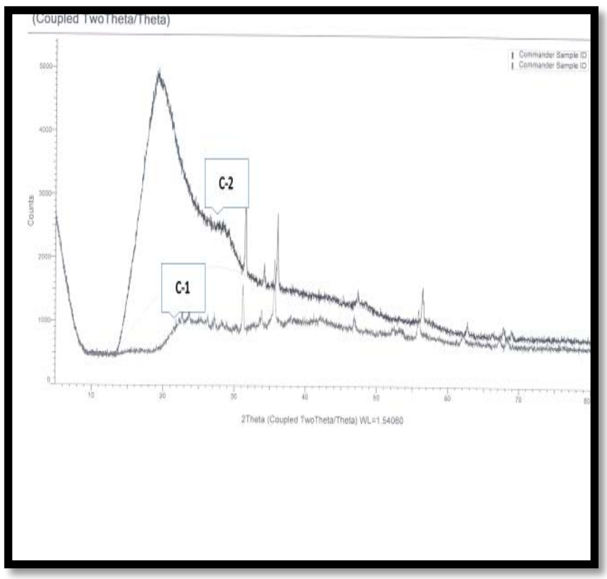
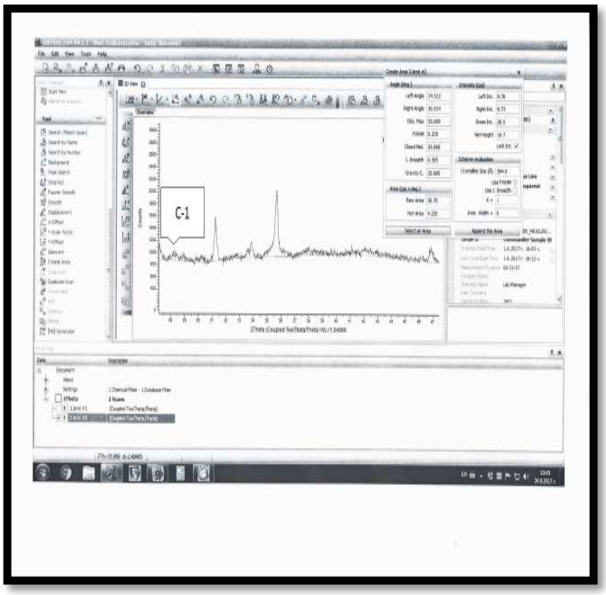
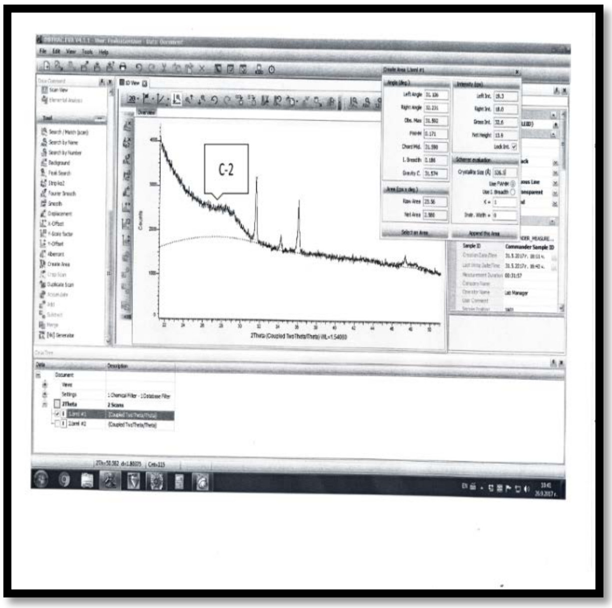


Fig. 3 and 4 *show the results of samples C-1 and C-2*





From the sample results shown, it can be seen that the size of the crystals is within the range, respectively:

- For sample C-1 at 1.5 weight fraction ND per 100 weight fraction NR, the crystals have a size of 394 Ä-39 nm
- For C-2 sample at 3 weight fraction ND, per 100 weight fraction NR, the crystals have a size of 536 nm - 54 nm

III.Conclusion

By using the above-mentioned composition and method of ND introduction into the EM together with the inert storage medium, a uniform distribution of ND is achieved by forming an own hierarchy of supramolecular structures with dimensions of 39-54 nm by:

- averaging the packing density of the macromolecule chains over the entire polymer matrix volume:
- uniform distribution of ND in the polymer mixture;
- enhancing the modifying effect of ND.

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NEW APPLICATIONS OF NANOSTRUCTURED MATERIALS IN THE PROSPECT ELECTRONIC DEVICES

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Abstract: *Nanostructured materials have unique properties which completely differ from the initial solid state condition. In this presentation we will discuss different techniques to fabricate such materials, their physical and optical parameters and characteristics, possible application areas. Main attention will be paid to aluminum and silicon nanostructured layers which are the promising alternatives of transparent semiconductors or metals as well as electroluminescent light emitting media.*

Keywords: INDUSTRY 4.0, NANOSTRUCTURED MATERIALS, OPTOELECTRONIC DEVICES

1. Aluminum nanostructured materials

Aluminum nanostructured layers are the promising alternatives of transparent semiconductors or metals. Main requirements for transparent conductive electrodes (TCEs) are good transparency in a limited and well-defined range as well as suitable conductivity. E.g., the wavelength interval constitutes 300 nm-2500 nm for photovoltaic and 400-700 nm for displays. Nowadays the best material to reach this goal is indium tin oxide (ITO). It is commonly used in many kinds of displays, light-emission diodes, solar cells and other optoelectronics devices.

The average transmission for ITO is approximately 80-90% depending on thickness variation. For smaller thickness, ITO has better transmission and resistance and vice versa. The range of ITO sheet resistance is 10-100 Ω/□ [1]. Assuming ITO is "ideal", novel TCEs should have the same properties or even better.

The metal-based thin transparent films are attractive due to their plasmonic properties and better flexibility. Planar metal films have poor optical performanse, however a special nanostructuring can increase the transmission. The cross-linked Cu layer with average 61 and 75% transmittance and sheet resistance 10 and 15 Ω/□ for 120 and 200 nm grating line width were demonstrated correspondently [2].

Another nanostructuring shape is a nano holey structure. The main feature of these structures is the independence on the light polarization at defined holes arrangement. In [3–5] data on transmission, reflection and absorption *vs* different hole size, inter hole distance and thickness are shown. In this paper, two simple methods of transparent conductive metal electrodes fabrication were proposed and realized. There optimal optical and electrical parameters were found and systematized.

2. Experimental results

A glass substrate with 200 nm aluminum (Al) is used for the first method of the TCEs fabrication [6]. The full process is illustrated on Fig. 1, where, for simplicity, the holey alumina (Al_2O_3) is not included.

When the electrochemical anodization of Al starts the holes grow with sphere shape. At time t_0 (step ***a***) the holes (sphere) contact with the substrate and an aluminum electrode is forming. At this position the transparency is small and a further anodization is required (step ***b***).

At time $t_1>t_0$ the transmission increases and at time $t_2>t_1$ has the biggest values. The conductance has opposite behaviour and has the smallest value at time t_2. Thus trade-off between transparency and conductivity is necessary.

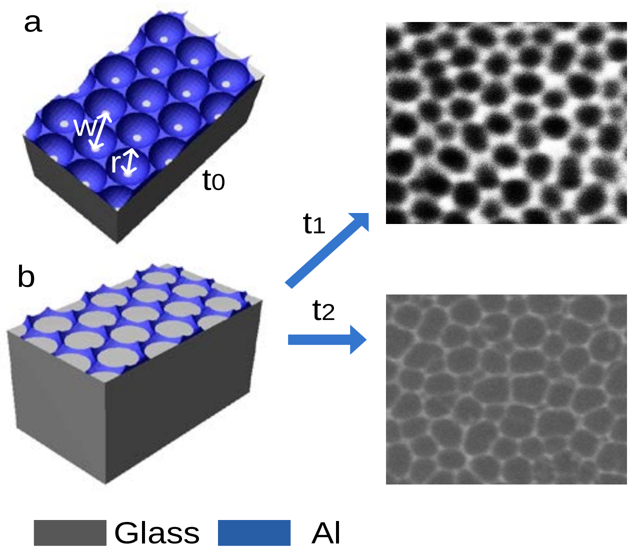

Fig.1. *First method of TCEs fabrication: a) The beginning of Al TCE formation (time t_0); b) The end of Al TCE formation (time t_1 or t_2)*

In order to find the optimal parameters the FDTD Lumerical [7] and COMSOL Multiphysics [8] packages are used for optical and electrical properties simulation accordingly.

The 10-20 Ω/□ sheet resistance for hole (sphere) radios *r*=60-70 nm and inter hole distance *w*=100 nm was obtained.

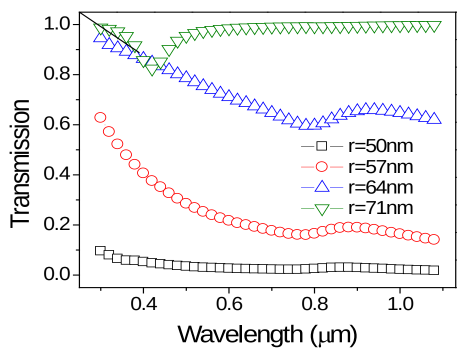

Fig.2. *Simulated optical properties for Al TCE with r = 50, 57, 64, 71 nm and w=100 nm.*

The simulated optical properties for hole (sphere) radii with r = 50, 57, 64, 71 nm and inter hole distance w = 100 nm is shown in Fig. 2. The r = 50 nm and r = 57 nm correspond to time t_0 and t_1 accordingly. The r = 57 nm is an intermediate time value and r = 71 nm is a value when conductance equals 0 Ω/□. In this case the trade-off between transparency and conductivity must satisfy condition 1.2-1.4r to obtain the average transmission 70-80% for range 300-1000 nm and 10-20 Ω/□ sheet resistance.

The second proposed TCE formation method includes three steps as illustrated on Fig. 3. The step ***a*** is aluminum deposition followed by anodization and holes widening in the solution containing phosphoric acid. Then the metal (gold Au in our case) is deposited by e-beam evaporation (step ***b***). The final step ***c*** is the transfer of obtained TCE to adhesive substrate.

Optical properties for Au TCE at different hole size r = 100, 150, 200 nm, inter hole distances w = 2r+25, 50, 75 nm and thickness d = 25, 50 nm are simulated using commercial software FDTD Lumerical [7]. The larger holes size provides better average transmission, when larger inter hole distance and thickness have opposite dependence. The Au electrode only absorbs a part of light for the range of 300-600 nm due to localized plasmonic resonance. At λ>700 nm the reflection increases.

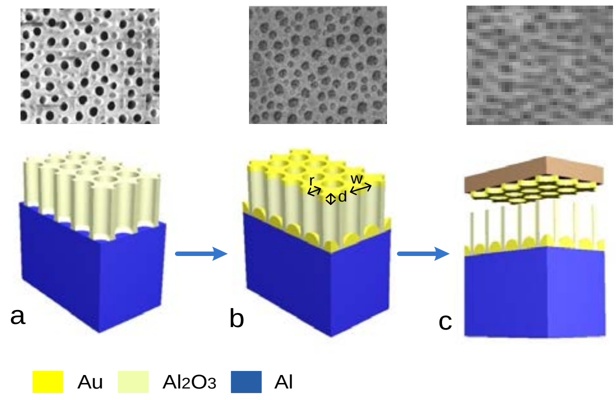

Fig.3. *Second method of TCEs fabrication:*
a) aluminum deposition, anodizing and holes widening;
b) metal deposition;
c) metal TCE transferring.

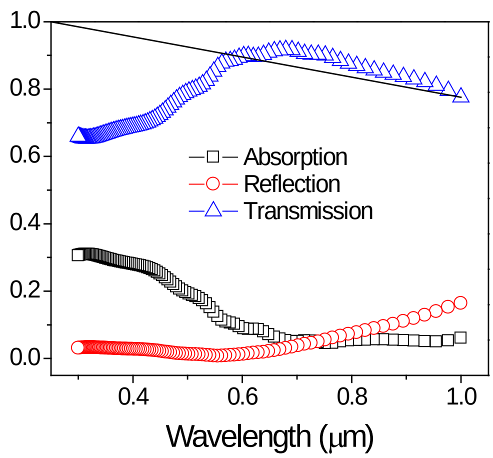

Fig.4. *Simulated optical properties for Au TCE with r=100, w=25 and d=25nm.*

The structure with r = 100 nm, w = 25 nm and d = 25 nm has better average transmission for the range 300-1000 nm (Fig. 4) and equals to 82.5%. The 10-20 Ω/□ values were obtained for 25-50 nm TCEs thickness by four probe method.

3. Silicon nanostructured materials

Integration of electronic and optoelectronic components on a silicon chip is the task of a great importance. One of the most difficult optoelectronic component to integrate onto a Si chip is a light emitting device because Si is an indirect band gap semiconductor, meaning that it normally can't produce light.

A standard technological method of high porosity nanostructured silicon formation as functional layer for light emitting devices is electrochemical etching in hydrofluoric acid solution. It is believed that the presence of two holes is necessary for the separation (or etch away) of one silicon atom. In our electrochemical process, after applying voltage, two fluorine ions approaching silicon atom (together with four molecules HF) etch away one Si atom from silicon surface.

The scheme of this process is illustrated by Fig. 5.

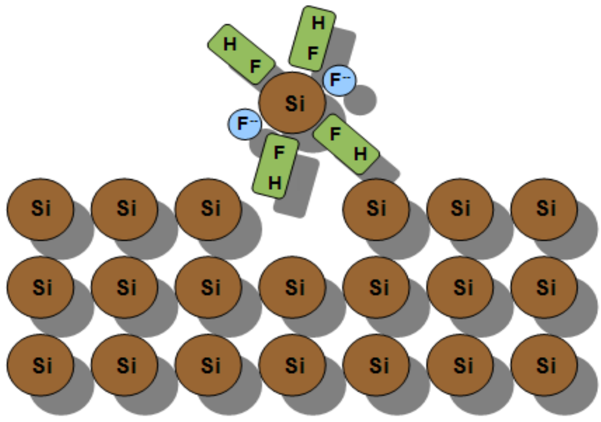

Fig.5. *The process of nanostructured silicon formation*

But this method has some inconveniences such as short anodizing time (few seconds for thin porous layers formation), toxic for operators and aggressive hydrofluoric acid which destroy aluminum interconnections. To avoid these inconveniences we propose to use a solution with low fluorine ions concentration. In this paper we are describing the stable and reproducible method for high porosity silicon formation in novel ammonium fluoride solution $NH_4F:H_3PO_4:C_2H_5OH:H_2O$.

By increasing of NH_4F concentration from 5 to 20 wt % the pore sizes are reducing from 20 to 10 nm. In addition, the reduction of current density also reduces the pores size. Thus, it is possible to change the pores size by varying of ammonium fluoride concentration and current density. Fabricated layers have a sponge like structure with the porosity in the range of 70-80 %.

Table 1. *The range of current densities and electrolyte concentrations*

Current density	Solution concentration $NH_4F:H_3PO_4:C_2H_5OH:H_2O$
0.01 - 0.1mA/cm^2	NH_4F – 1-3% H_3PO_4 – 20-70% C_2H_5OH – remaining

Therefore, highly uniform and ultrathin high porosity nanoporous silicon films can be fabricated under very low current densities and fluorine ion concentration in a reproducible manner. Structural and electro optical properties of nanoporous silicon films are also discussed.

4. Conclusion

Two methods of transparent conductive metal electrodes fabrication by electrochemical anodization technology are presented. The obtained transmission in the range of 300-1000 nm and its sheet resistance are the same as at ITO reference electrodes. These electrodes can be applied in the various optoelectronic devices.

In this work we also report the stable and reproducible regime of ultrathin nanoporous silicon layers fabrication under ultra small current density (down to 0.01 mA/cm^2) and fluorine ion concentration (1 % wt) by using NH_4F solution.

Acknowledgements

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MODELING AND SIMULATION OF CONVOLUTIONAL ENCODERS USING LOGISIM FOR TRAINING PURPOSES IN THE UNIVERSITY OF RUSE

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Abstract: *In telecommunication, a convolutional code is a type of error-correcting code that generates parity symbols via the sliding application of a Boolean polynomial function to a data stream. A general convolutional encoder consists of a k*L-stage shift register and n modulo-2 adders, where L is the constraint length of the encoder. Convolutional codes are used to achieve reliable data transfer in numerous applications, such as digital video, radio, mobile communications and satellite communications. These codes are often implemented in concatenation with a hard-decision code, particularly Reed-Solomon codes. The material presented in the paper is used in the educational process in the University of Ruse. In order to better perception of the material active learning methods are applied. An individual assignment is given to each student and he/she has to solve the task during the practical exercise and present it at the end of the classes to the lecturer. The student should synthesize a convolutional encoder with NAND/XOR gates and flip-flops and to simulate its operation using Logisim, an educational tool for designing and simulating digital logic circuits.*

Keywords: MODELING AND SIMULATION, CONVOLUTIONAL ENCODERS, LOGISIM, ACTIVE LEARNING METHODS

1. Introduction

In telecommunications, a convolutional code is a type of error-correcting code that generates parity symbols via the sliding application of a Boolean polynomial function to a data stream. Convolutional codes were introduced in 1955 by Peter Elias. In 1967 Andrew Viterbi determined that convolutional codes could be maximum-likelihood decoded with reasonable complexity using time invariant trellis based decoders – the Viterbi algorithm [1].

A convolutional code is described by three integers, *n*, *k*, and *L*, where the ratio *r* = *k*/*n* has the same code rate significance that it has for block codes; however, *n* does not define a block or codeword length as it does for block codes. The integer *L* is a parameter known as the *constraint length*. It represents the number of *k*-tuple stages in the encoding shift register. An important characteristic of the convolutional codes is that the encoder has memory – the *n*-tuple emitted by the convolutional encoder is not only a function of an input *k*-tuple, but is also a function of the previous *L* – 1 input *k*-tuples. In practice, *n* and *k* are small integers and *L* is varied to control the capability and complexity of the code [2].

Convolutional codes are used to achieve reliable data transfer in numerous applications, such as digital video, radio, mobile communications and satellite communications. These codes are often implemented in concatenation with a hard-decision code, particularly Reed-Solomon codes. Prior to turbo codes such constructions were the most efficient, coming closest to the Shannon limit. An especially popular Viterbi-decoded convolutional code used since the Voyager program has a constraint length *L* = 7 and a rate *r* = ½. Longer constraint lengths produce more powerful codes, but the complexity of the Viterbi algorithm increases exponentially with constraint lengths, limiting these more powerful codes to deep space missions where the extra performance is easily worth the increased decoder complexity. Mars Pathfinder, Mars Exploration Rover and the Cassini probe to Saturn use *k* of 15 and a rate of 1/6; this code performs about 2 *dB* better than the simpler *L* = 7 code at a cost of 256 times in decoding complexity (compared to Voyager mission codes) [1].

2. Convolutional encoding

A typical block diagram of a digital communication system and a version of this functional diagram, focusing primarily on the convolutional encode/decode and modulate/demodulate portions of the communication link, are presented in [2]. The input message is denoted by the sequence $\mathbf{m} = m_1, m_2, \ldots, m_i, \ldots$, where each m_i represents a binary digit (bit), and *i* is a time index. It is assumed that each m_i is equally likely to be a one or a zero, and independent from bit to bit. Being independent, knowledge about bit m_i gives no information about m_j $(i \neq j)$. The encoder transforms each sequence **m** into a unique codeword sequence $\mathbf{U} = G(\mathbf{m})$. A key feature of convolutional codes is that a given *k*-tuple within **m** does *not* uniquely define its associated *n*-tuple within **U** since the encoding of each *k*-tuple is *not only* a function of that *k*-tuple but is also a function of $L-1$ input *k*-tuples preceding it. The sequence **U** is partitioned into a sequence of codewords $\mathbf{U} = U_1, U_2, \ldots, U_i, \ldots$. Each codeword U_i consists of binary *code symbols*, often called *channel symbols*, *channel bits* or *code bits*; unlike the input message bits the code symbols are not independent [2].

A general convolutional encoder is shown in Fig. 1. It consists of a *kL*-stage shift register and *n* modulo-2 adders, where *L* is the constraint length.

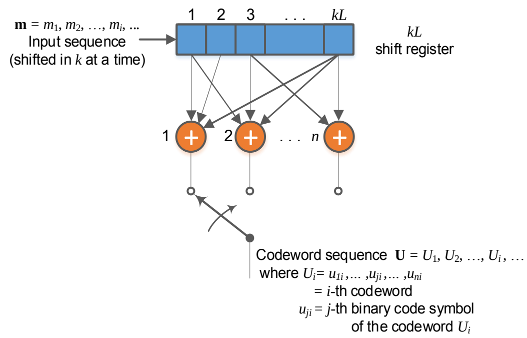

Fig. 1. *Convolutional encoder with constraint length L and rate k/n* [2]

The constraint length represents the number of *k*-bit shifts over which a single information bit can affect on the encoder's output. At each moment of time, *k* bits are shifted into the first *k* stages of the register; all bits in the register are shifted *k* stages to the right, and the outputs of the *n* adders are sequentially sampled to yield the *binary code symbols* or *code bits*. Since there are *n* code bits for each input group of *k* message bits, the code rate is *k/n* message bit per code bit, where *k* < *n* [2].

Only the most commonly used binary convolutional encoders for which *k* = 1 are considered in the paper. For the *k* = 1 encoder, at the i^{th} unit of time, message bit m_i is shifted into the first shift register stage, all previous bits in the register are shifted one stage to the right, and the outputs of the *n* adders are sequentially sampled and transmitted. Since there are *n* code bits for each message bit, the code rate is 1/*n*. The *n* code symbols occurring at time t_i comprise the i^{th} codeword $U_i = u_{1i}, u_{2i}, \ldots, u_{ni}$, where u_{ji} $(j = 1, 2, \ldots, n)$ is the j^{th} code symbol belonging to the i^{th} codeword. For the rate 1/*n* encoder, the kL-stage shift register can be referred to as a L-stage register, and the constraint length L, expressed in units of k-tuple stages, can be referred to as constraint length in units of bits [2].

For describing a convolutional code, the encoding function $G(\mathbf{m})$ needs to be characterized so that given an input sequence **m**, the output sequence **U** can be readily computed. Several methods are used for representing a convolutional encoder, the most popular being the *connection pictorial*, *connection vectors or polynomials*, the *state diagram*, the *tree diagram*, and the *trellis diagram*. In the paper the connection representation is used and described below.

The convolutional encoder, shown in Fig. 2, is used as a model for discussing convolutional encoders. The figure illustrates a (2, 1) convolutional encoder with constraint length $L = 3$. There are $n = 2$ modulo-2 adders; thus the code rate k/n is ½. At each moment, a bit is shifted into the leftmost stage and the bits in the register are shifted one position to the right. Next, the output switch samples the output of each modulo-2 adder (i.e., first the upper adder, then the lower adder), thus forming the code symbol pair of the codeword associated with the input bit. The sampling is repeated for each input bit. The choice of connections between the adders and the stages of the register gives rise to the characteristics of the code. Any change in the choice of connections results in a different code. The connections are not chosen or changed arbitrarily. The problem of choosing connections to yield good distance properties is complicated and has not been solved in general; however, good codes have been found by computer search for all constraint lengths less than about 20 [2].

Unlike block codes having a fixed codeword length n, convolutional codes have no particular block size. However, convolutional codes are often forced into a block structure by *periodic truncation*. This requires a number of zero bits to be appended to the end of the input data sequence, for the purpose of clearing or flushing the encoding shift register of the data bits. Since the added zeros carry no information, the effective code rate falls below k/n. To keep the code rate close to k/n, the truncation period is generally made as long as practical.

One way to represent the encoder is to specify a set of n *connection vectors*, one for each of the n modulo-2 adders. Each vector has dimension L and describes the connection of the encoding shift register to that modulo-2 adder. A one in the i^{th} position of the vector indicates that the corresponding stage in the shift register is connected to the modulo-2 adder, and a zero in a given position indicates that no connection exists between the stage and the modulo-2 adder.

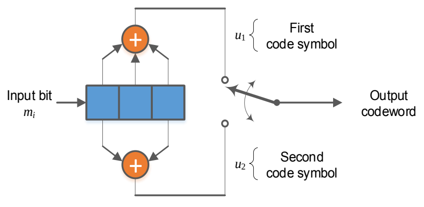

Fig.2. *Convolutional encoder (rate ½, L = 3)* [2]

For the encoder in Fig. 2, the connection vectors for the upper and for the lower connections are as follows $\mathbf{g}_1 = 111$, $\mathbf{g}_2 = 101$.

Let the message vector $\mathbf{m} = 101$ be convolutionally encoded with the encoder shown in Fig. 2. The three message bits are entered, one at a time, at times t_1, t_2, and t_3, as shown in Fig. 3. Subsequently, $(L-1) = 2$ zeros are entered at times t_4 and t_5 to flush the register and thus ensure that the tail end of the message is shifted the full length of the register. The output sequence will be 1110001011, where the leftmost symbol represents the earliest transmission. The entire output sequence, including the code symbols as a result of flushing, are needed to decode the message. Flushing the message from the encoder requires zeros, one less than the number of stages in the register, or $L-1$ flush bits. Another zero input at time t_6 is shown in Fig. 3, for verifying that the flushing is completed at time t_5. Thus, a new message can be entered at time t_6 [2].

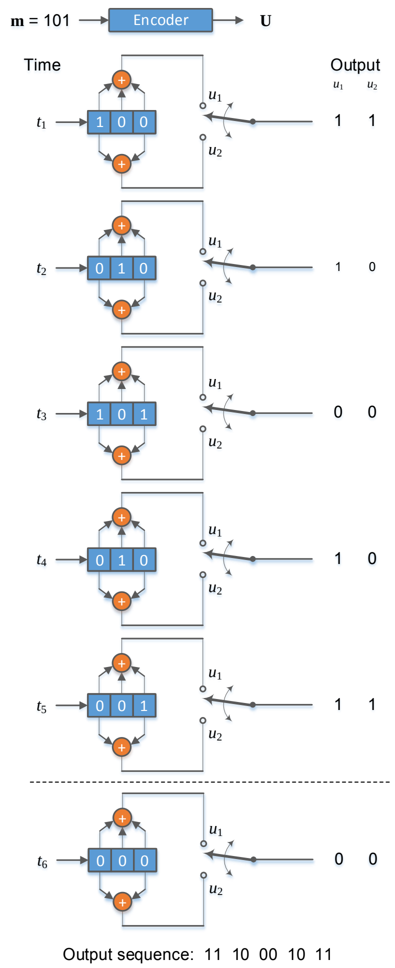

Fig. 3. *Convolutionally encoding a message sequence with a rate ½ and L = 3 encoder* [2]

The convolutional encoder can be presented in terms of its *impulse response* – the response of the encoder to a single "one" bit moving through it. The content of the register in Fig. 2, as a one moves through it, is considered below:

Register content	Codeword	
	u_1	u_2
100	1	1
010	1	0
001	1	1
Input sequences:	**1 0 0**	
Output sequences:	**11 10 11**	

The output sequence for the input "one" is called the *impulse response* of the encoder. Then, for the input sequence $\mathbf{m} = 100$, the output may be found by the *superposition* or the *linear addition* of the time-shifted input "impulses" as follows:

Input **m**	Output				
1	11	10	11		
0		00	00	00	
1			11	10	11
Modulo-2 sum:	**11**	**10**	**00**	**10**	**11**

It seems that the output is the same as that obtained in Fig. 3, demonstrating that *convolutional codes are linear*. It is from this property of generating the output by the linear addition of time-shifted impulses, or the convolution of the input sequence with the impulse response of the encoder, therefore the name *convolutional encoder* is derived.

The *effective code rate* for the example with a 3-bit input sequence and a 10-bit output sequence is $k/n = 3/10$ – quite a bit less than the rate ½ that might have been expected from knowing that each input data bit yields a pair of output channel bits. The reason for the disparity is that the final data bit into the encoder needs to be shifted through the encoder. All output channel bits are needed in the decoding process. If the message had been longer, say 300 bits, the output codeword sequence would contain 604 bits, resulting in a code rate of $300/604$ – much closer to ½ [2].

3. Logisim – an educational tool for designing and simulating digital logic circuits

Logisim is an educational tool for designing and simulating digital logic circuits. With its simple toolbar interface and simulation of circuits as the user builds them, it is simple enough to facilitate learning the most basic concepts related to logic circuits. With the capacity to build larger circuits from smaller subcircuits, and to draw bundles of wires with a single mouse drag, Logisim can be used to design and simulate entire CPUs for educational purposes. Logisim is used by students at colleges and universities around the world in many types of classes, ranging from a brief unit on logic in general-education computer science surveys, to computer organization courses, to full-semester courses on computer architecture. The main features of the product are: 1) It is free; Logisim is open-source (GPL). 2) It runs on any machine supporting Java 5 or later; special versions are released for MacOS X and Windows. 3) The drawing interface is based on an intuitive toolbar. Color-coded wires aid in simulating and debugging a circuit. 4) The wiring tool draws horizontal and vertical wires, automatically connecting to components and to other wires. So it is very easy to draw circuits. 5) Completed circuits can be saved into a file, exported to a GIF file, or printed on a printer. 6) Circuit layouts can be used as "subcircuits" of other circuits, allowing for hierarchical circuit design. 7) Included circuit components include inputs and outputs, gates, multiplexers, arithmetic circuits, flip-flops, and RAM memory. 8) The included "combinational analysis" module allows for conversion between circuits, truth tables, and Boolean expressions [3].

Features of the components used to build the encoder

The XOR, XNOR, Even Parity, and Odd Parity gates compute the respective function of the inputs, and emit the result on the output. By default, any inputs left unconnected are ignored if the input truly has nothing attached to it, not even a wire. In this way, the user can insert a 5-input gate but only attach two inputs, and it will work as a 2-input gate; this relieves the user from having to worry about configuring the number of inputs every time he/she creates a gate. The two-input truth table for the gates is the following [4]:

x	y	XOR	XNOR	Odd	Even
0	0	0	1	0	1
0	1	1	0	1	0
1	0	1	0	1	0
1	1	0	1	0	1

It seems that the Odd Parity gate and the XOR gate behave identically with two inputs; similarly, the Even Parity gate and the XNOR gate behave identically. But if there are more than two specified inputs, the XOR gate will emit 1 only when there is exactly one 1 input, whereas the Odd Parity gate will emit 1 if there is an odd number of 1 inputs. The XNOR gate will emit 1 only when there is *not* exactly one 1 input, while the Even Parity gate will emit 1 if there is an even number of 1 inputs. The XOR and XNOR gates include an attribute titled Multiple-Input Behavior that allow them to be configured to use the Odd Parity and Even Parity behavior. Otherwise, it is necessary to use two 2-input XOR gates to implement a 3-input XOR gate (Fig. 4). Many authorities contend that the shaped XOR gate's behavior should correspond to the odd parity gate, but there is not agreement on this point. Logisim's default behavior for XOR gates is based on the IEEE 91 standard. It is also consistent with the intuitive meaning underlying the term *exclusive or* [4].

Each flip-flop stores a single bit of data, which is emitted through the *Q* output. Normally, the value can be controlled via the inputs. In particular, the value changes when the **clock** input, marked by a triangle on each flip-flop, rises from 0 to 1 (or otherwise as configured); on this rising edge, the value changes according to the table below [4]:

D Flip-Flop

D	*Q*
0	0
1	1

T Flip-Flop

T	*Q*
0	*Q*
1	*Q'*

J-K Flip-Flop

J	*K*	*Q*
0	0	*Q*
0	1	0
1	0	1
1	1	*Q'*

S-R Flip-Flop

S	*R*	*Q*
0	0	*Q*
0	1	0
1	0	1
1	1	?

1) D Flip-Flop: When the clock triggers, the value remembered by the flip-flop becomes the value of the *D* (*Data*) input at that instant. **2) T Flip-Flop:** When the clock triggers, the value remembered by the flip-flop either toggles or remains the same depending on whether the *T* (*Toggle*) input is 1 or 0. **3) J-K Flip-Flop:** When the clock triggers, the value remembered by the flip-flop toggles if the *J* and *K* inputs are both 1 and the value remains the same if both are 0; if they are different, then the value becomes 1 if the *J* (*Jump*) input is 1 and 0 if the *K* (*Kill*) input is 1. **4) S-R Flip-Flop:** When the clock triggers, the value remembered by the flip-flop remains unchanged if *R* and *S* are both 0, becomes 0 if the *R* (*Reset*) input is 1, and becomes 1 if the *S* (*Set*) input is 1. The behavior in unspecified if both inputs are 1. In Logisim, the value in the flip-flop remains unchanged. By default, the clock triggers on a rising edge, i.e. when the clock input changes from 0 to 1. However, the Trigger attribute allows this to be changed to a falling edge (when the clock input changes from 1 to 0), a high level (for the duration that the clock input is 1), or a low level (for the duration that the clock input is 0). The level-trigger options are unavailable for *T* and *J-K* flip-flops, because the flip-flop behaves unpredictably when told to toggle for an indeterminate amount of time [4].

The clock toggles its output value on a regular schedule as long as ticks are enabled. A "tick" is Logisim's unit of time; the speed at which ticks occur can be selected from the Simulate menu's Tick Frequency submenu. The clock's cycle can be configured using its High Duration and Low Duration attributes. Logisim's simulation of clocks is quite unrealistic: In real circuits, multiple clocks will drift from one another and will never move in lockstep. But in Logisim, all clocks experience ticks at the same rate [4.]

The circuit of the convolutional encoder shown in Fig. 3 is drawn and tested in Logisim, to verify its operation. The circuit is built by inserting in the editing area its components – three 2-input XOR gates (XOR Gate) and three D flip-flops (D Flip-Flop) first as a sort of skeleton and then connecting them with wires. To add an input m and two outputs u1 and u2 into the diagram, the Input tool ( ) and the Output tool ( ) are selected and the pins are placed down. Then the Clock component (Clock) is placed down and connected to the flip-flops. The operation of the convolutional encoder in Fig. 3 is shown in Fig. 4. The results in Fig. 4 and its operation in Fig. 3 are identical.

4. Application in the Educational Process

The material is used in the educational process in the courses "Coding in Telecommunication Systems", "Digital Circuits" and "Pulse and Digital Devices" included in the curriculum of the specialties "Internet and Mobile Communications", "Computer Systems and Technologies", "Electronics", "Computer Management and Automation", and "Information and Communication Technologies" for the students of the Bachelor degree in the University of Ruse.

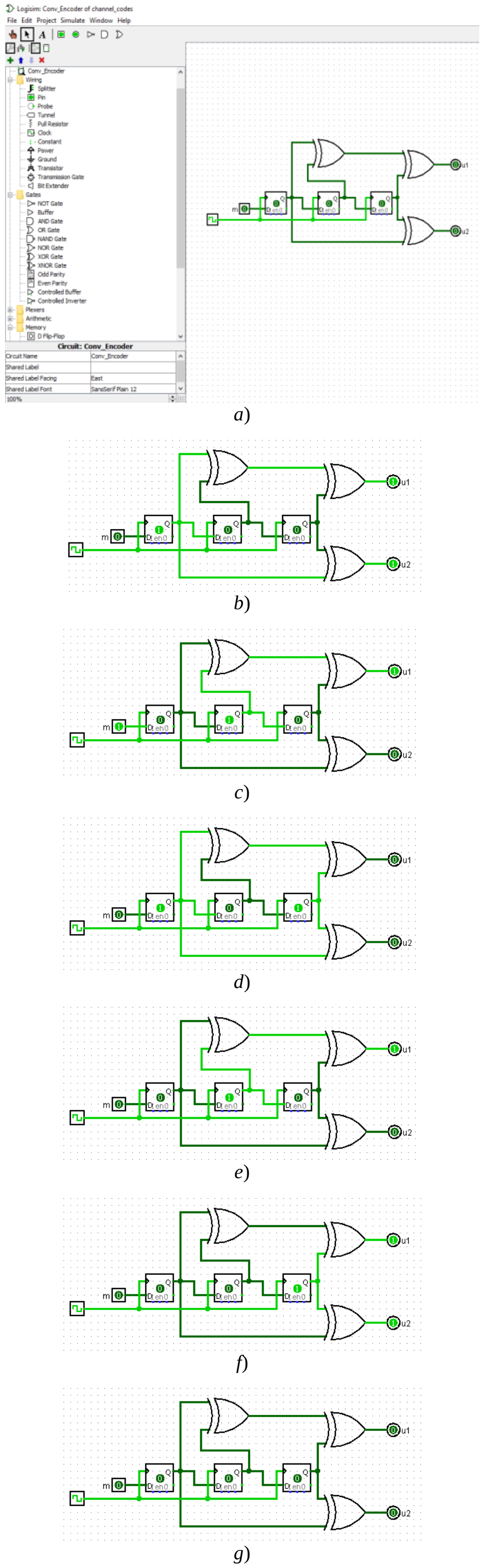

Fig. 4. *a) Logisim and its simple toolbar interface + the circuit of the encoder (initial state – all-zeros) and its operations at the instances…; b)* t_1*; c)* t_2*; d)* t_3*; e)* t_4*; f)* t_5*; g)* t_6

In order to better perception of the material active learning methods are applied in the educational process. An individual assignment is given to each student and he/she has to solve the task during the practical exercise and present it at the end of the classes to the lecturer. The student should synthesize a convolutional encoder with NAND/XOR gates and flip-flops and to simulate its operation using Logisim.

Table 1 presents the results of 10 options applied in the educational process for encoding the 3-bit message **m** = 101 using different convolutional encoders.

Table 1: *Results of 10 options applied in the educational process for encoding the 3-bit message 101 using different convolutional encoders*

№	Connection vectors for the …		Code bits
	upper adder	lower adder	
1	111	011	**10 11 01 11 11**
2	101	110	**11 01 01 01 10**
3	011	101	**01 10 10 10 11**
4	110	111	**11 11 10 11 01**
5	011	110	**01 11 11 11 10**
6	101	011	**10 01 01 01 11**
7	111	110	**11 11 01 11 10**
8	110	101	**11 10 10 10 01**
9	011	111	**01 11 10 11 11**
10	110	011	**10 11 11 11 01**

6. Conclusion

Incorporating active learning into the curriculum transforms the classroom into an exciting, dynamic learning environment. In order to easily assimilation of the material studied by students, active learning is applied. An individual assignment is given to each student. The assignment includes: 1) filling in the blanks for a given convolutional encoder (Fig. 3); 2) synthesizing a convolutional encoder with XOR gates and D flip-flops and simulating its operation using Logisim (Fig. 4); 3) synthesizing a convolutional encoder with NAND gates and D flip-flops and simulating its operation using Logisim; 4) synthesizing a convolutional encoder with XOR gates and J-K flip-flops and simulating its operation using Logisim. During the practical exercises, the student must solve his/her tasks of pre-prepared form published in the e-learning platform of the University of Ruse and submit to the teacher at the end of the classes. The opportunity for extra work is given to the curious students – for example, synthesizing a convolutional encoder with XOR gates and D flip-flops and simulating its operation using Logisim based on 4-bit or 5-bit shift registers with more than two output code bits. The material is used in the educational process in the courses "Coding in Telecommunication Systems", "Digital Circuits" and "Pulse and Digital Devices" included in the curriculum of the specialties "Internet and Mobile Communications", "Computer Systems and Technologies", "Electronics", "Computer Management and Automation", and "Information and Communication Technologies" for the students of the Bachelor degree in the University of Ruse.

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DIESEL ENGINE EXHAUST GAS EMISSIONS INVESTIGATION BY USING MEASUREMENT DATA AND NUMERICAL ANALYSIS

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Abstract: *Paper presents an exhaust gas emission investigation for a high speed turbocharged direct injection diesel engine MAN D0826 LOH15 during the fuel and air mass flow variation. Emission analysis is based on a two measurement sets at two different engine rotational speeds (1500 rpm and 2400 rpm). The analyzed diesel engine operates with a standard diesel fuel. Measured emissions were nitrogen oxides (NO_x), unburned hydrocarbons (HC) and soot emissions. Calculated emissions were carbon dioxide (CO_2) emissions by using equations from the literature. For the observed diesel engine, much higher NO_x and HC emissions were obtained at the lower engine rotational speed. Soot emission of the analyzed engine, in general, does not have to depend on engine rotational speed. Calculated CO_2 emissions depend primarily on the fuel mass flow and the carbon mass fraction in used fuel.*

Keywords: *DIESEL ENGINE, EMISSIONS, ENGINE MEASUREMENTS, FUEL MASS FLOW, AIR MASS FLOW*

1. Introduction

Engine measurements are unavoidable in internal combustion engines operating parameters analysis [1].

Investigation of diesel engines can be performed in several different ways [2]. Experimental analysis of diesel engines requires proper engine management [3] and repairing processes [4]. Along with diesel engine measurements, numerical simulations have been developed to make easier, faster and cheaper investigations of engine operating parameters. But still, each numerical model must necessarily be validated in a few measured operating points of the diesel engine, [5] and [6].

Emissions from the diesel engines are intensively explored [7] and researchers investigated ways for their reduction [8].

Instead of standard diesel fuels, alternative fuels and its blends with standard diesel fuels represent an alternative which can significantly reduce engine emissions [9]. A review of alternative fuels for diesel engines can be found in [10] while a review of performance, combustion and emission characteristics of bio-diesel fuels used in diesel engines is presented in [11].

Diesel engine optimization can provide further emissions reducing. Optimization methods are multi-objective optimization [12], genetic algorithm optimization [13] and optimization by using Artificial Neural Networks (ANN) [14].

This paper presents exhaust gas emissions of a turbocharged high speed direct injection diesel engine during the fuel and air mass flow variation. Emissions measurement and calculation were performed in two measurement sets, on two different engine rotational speeds. Measurements were obtained with a standard diesel fuel D2. Measured exhaust gas emissions were nitrogen oxides (NO_x), unburned hydrocarbons (HC) and soot emissions. By using equations from the literature, CO_2 emissions for each engine operating point were calculated. The aim was to examine the behavior of all mentioned emissions at different engine rotational speeds.

2. Turbocharged diesel engine specifications

The investigated diesel engine is turbocharged high speed direct injection diesel engine MAN D0826 LOH15. The main engine specifications are presented in Table 1.

Table 1. *Engine specifications*

The total operating volume	6870 cm^3
Number of cylinders	6
Peak effective power	160 kW
Cylinder bore	108 mm
Cylinder stroke	125 mm
Nozzle diameter	0.23 mm
Number of nozzle holes	7
Compression ratio	18

3. Diesel engine measurement results and measuring equipment

Engine measurement was performed in the Laboratory for Internal Combustion Engines and Electromobility, Faculty of Mechanical Engineering, University of Ljubljana, Slovenia.

The engine was connected to an eddy current brake Zöllner B-350AC, Fig.1. Measurements control was secured with a control system KS ADAC/Tornado. Cylinder pressure was measured with pressure sensor AVL GH12D, placed in an extra hole in the cylinder head. The cylinder pressure signal was led to a 4-channel amplifier AVL MicroIFEM. The crankshaft angle was measured by crank angle encoder Kistler CAM UNIT Type 2613B.

The heated measuring tube (tube temperature was maintained constant at 195 °C) was used for guidance of “wet” exhaust gases into the Horiba OBS-2200 exhaust gas analyzer [15]. Horiba OBS-2200 exhaust gas analyzer measure unburned hydrocarbons (HC) in FID cell (FID = Flame Ionization Detector) and nitrogen oxides (NO_x) in CLD cell (CLD = ChemiLuminescence Detector).

Soot emission was measured by Bosch EFAW 65A/6 smoke detector [16]. Obtained soot measurement results were re-calculated into the BSU (Bosch Smoke Unit).

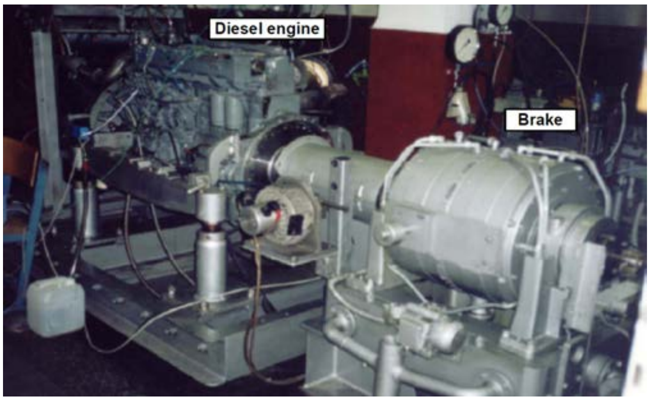

Fig.1. *Diesel engine MAN D0826 LOH15 during measurements*

From several obtained measurement sets, two measurement sets presented in Table 2 and Table 3 are selected for exhaust gas emissions analysis. Measurement Set 3 has almost constant engine rotational speed of 1500 rpm while measurement Set 4 has constant engine rotational speed of 2400 rpm. Fuel and air mass flow were varied in each observed measurement set, for every observed engine operation point. In each measurement set was used standard diesel fuel D2 with a lower heating value 42700 kJ/kg and with the carbon mass fraction of 85% in its chemical composition.

Table 2. Engine measurement results - Set 3

	Measurement No.	Fuel mass flow (kg/h)	Air mass flow (kg/s)	Rotational speed (rpm)	Effective power (kW)	BMEP* (bar)
SET 3	1	9.743	0.09761	1501	41.93	4.88
	2	13.977	0.10337	1498	61.82	7.21
	3	18.673	0.12048	1501	86.12	10.02
	4	23.358	0.13943	1500	108.66	12.65

***** BMEP = Brake Medium Effective Pressure

Table 3. Engine measurement results - Set 4

	Measurement No.	Fuel mass flow (kg/h)	Air mass flow (kg/s)	Rotational speed (rpm)	Effective power (kW)	BMEP* (bar)
SET 4	1	16.045	0.18775	2400	56.76	4.13
	2	21.961	0.21650	2400	87.92	6.40
	3	30.086	0.25726	2400	123.49	8.99
	4	36.001	0.28798	2400	145.56	10.60

***** BMEP = Brake Medium Effective Pressure

4. Engine measured and calculated emissions with discussion

Fig.2 presents nitrogen oxides (NO_x) emission change in ppm (ppm = parts per million) for measurement Set 3 and Set 4. In those two measurement sets trend lines of NO_x emission change are not the same and in both sets were not found continuous and permanent change of NO_x emissions during the increase in fuel mass flow.

In Set 3 NO_x emission for the lowest fuel mass flow of 9.743 kg/h amounts 1958 ppm. With an increase in fuel mass flow from 9.743 kg/h to 13.977 kg/h, NO_x emission increases from 1958 ppm to 2449 ppm. Further increase in fuel mass flow resulted with a decrease in NO_x emission. Therefore, for the fuel mass flow of 18.673 kg/h NO_x emission amounts 1897 ppm, while the lowest NO_x emission in this measurement set amounts 1647 ppm for the fuel mass flow of 23.358 kg/h.

Measurement Set 4 showed different behavior in NO_x emissions change in comparison with measurement Set 3. For the fuel mass flow of 16.045 kg/h NO_x emission amounts 995 ppm. With an increase in the fuel mass flow on 21.961 kg/h NO_x emission amounts 955 ppm, what is the lowest value in Set 4. With further increase in fuel mass flow, NO_x emission increases, firstly at 1082 ppm for the fuel mass flow of 30.086 kg/h and then at 1211 ppm for the highest fuel mass flow in this measurement set of 36.001 kg/h.

If compared measurement Set 3 and Set 4 for the same fuel mass flow (fuel mass flow range from 16 kg/h up to 23 kg/h), it can be seen from Fig.2 that much higher NO_x emissions were obtained in Set 3, at the lower engine rotational speed (1500 rpm).

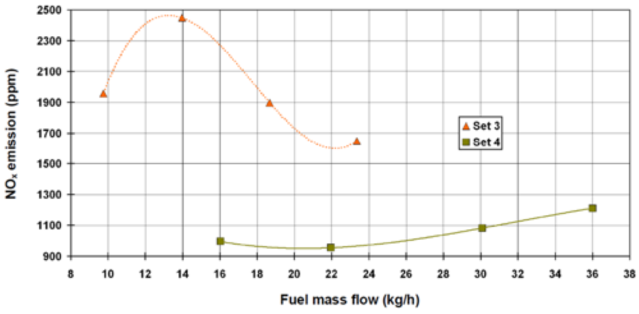

***Fig.2.** Measured NO_x emissions for measurement Set 3 and Set 4*

For measurement Set 3 and Set 4 unburned hydrocarbons (HC) emission is presented in Fig.3. Trend lines of HC emissions are not the same in both measurement sets. In both measurement sets HC emission have no continuous and permanent change during the increase in fuel mass flow.

In measurement Set 3, HC emission for the lowest fuel mass flow amounts 107 ppm. With an increase in fuel mass flow, HC emission increases to 114 ppm for the fuel mass flow of 13.977 kg/h and to 126 ppm for the fuel mass flow of 18.673 kg/h. In the last operating point in Set 3, for the fuel mass flow of 23.358 kg/h, HC emission decreases to 115 ppm in comparison with the previous observed operating point.

An HC emission in measurement Set 4 has a different trend in comparison with measurement Set 3. At fuel mass flow of 16.045 kg/h, HC emission amounts 94 ppm, after which decreases to 61 ppm at fuel mass flow of 21.961 kg/h. With the further increase in fuel mass flow, HC emission firstly increases to 80 ppm at fuel mass flow of 30.086 kg/h, after which decreases to 62 ppm at the highest fuel mass flow in this measurement set.

When compared HC emissions in measurement Set 3 and Set 4 for the same fuel mass flow, from Fig.3 can be seen that at lower engine rotational speed (1500 rpm - Set 3) HC emissions are significantly higher in comparison with Set 4 (2400 rpm).

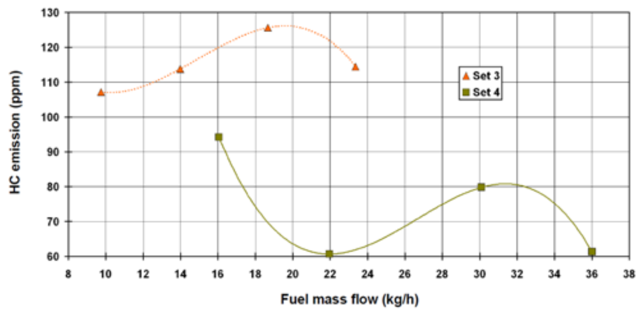

***Fig.3.** Measured HC emissions for measurement Set 3 and Set 4*

In measurement Set 3, soot emission continuously increases during the increase in fuel mass flow, from 0.1 BSU at fuel mass flow of 9.743 kg/h up to 0.45 BSU at fuel mass flow of 23.358 kg/h, Fig.4. The trend line of soot emission change in Set 3 is not nearly similar to trend line of soot emission change in measurement Set 4.

Soot emission in measurement Set 4 amounts 0.3 BSU at the lowest observed fuel mass flow of 16.045 kg/h. During the increase in fuel mass flow in Set 4, soot emission firstly increases to 0.65 BSU at fuel mass flow of 21.961 kg/h, after which follows decrease to 0.45 BSU (fuel mass flow of 30.086 kg/h) and to 0.2 BSU (fuel mass flow of 36.001 kg/h).

When compared above mentioned emissions (NO_x, HC, soot), soot emission is the only one where for the same fuel mass flow, higher emissions were obtained at higher engine rotational speed of 2400 rpm (Set 4) in comparison with the lower engine rotational speed of 1500 rpm (Set 3).

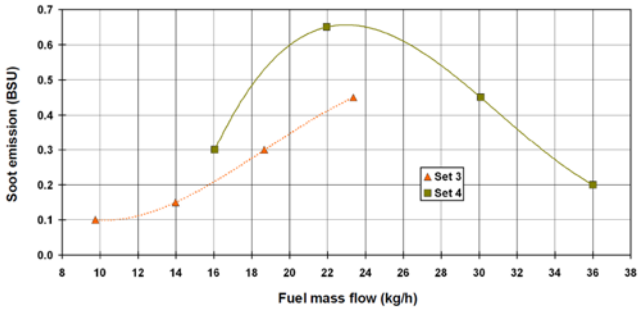

Fig.4. Measured soot emissions for measurement Set 3 and Set 4

Carbon dioxide (CO_2) emissions were calculated by using equations from [17] and [18]. The main components of these equations are the fuel mass flow and the carbon mass fraction in used fuel during the engine measurements.

CO_2 emissions in kg/h were presented in Table 4 for measurement Set 3 and Set 4. From Table 4 can be seen linear dependence of CO_2 emissions on fuel mass flow. With the increase in fuel mass flow, CO_2 emissions proportionally rise.

In measurement Set 3 the lowest CO_2 emissions were 30.366 kg/h at the lowest fuel mass flow and then continuously rises up to 72.798 kg/h at the highest fuel mass flow. In measurement Set 4, CO_2 emissions were much higher, due to higher fuel mass flow if compared with measurement Set 3. In Set 4, CO_2 emissions were in the range from 50.006 kg/h up to 112.203 kg/h from the lowest to the highest used fuel mass flow.

CO_2 emissions can be significantly reduced by using fuels with higher heating values or by using fuels with lower carbon mass fraction in its composition. Research and development of bio-fuels and other alternative fuels for use in diesel engines can fulfil the goal for CO_2 emissions reduction.

***Table 4.** Calculated CO_2 emissions for measurement Set 3 and Set 4*

	Fuel mass flow (kg/h)	**CO_2 emission (kg/h)**
SET 3	9.743	30.366
	13.977	43.562
	18.673	58.197
	23.358	72.798
SET 4	16.045	50.006
	21.961	68.446
	30.086	93.767
	36.001	112.203

5. Conclusion

Change in exhaust gas emissions for a high speed direct injection turbocharged diesel engine MAN D0826 LOH15 during the fuel and air mass flow variation was presented. Analysis is based on a two measurement sets at two different engine rotational speeds (1500 rpm and 2400 rpm).

During the engine laboratory experiments were measured nitrogen oxides (NO_x), unburned hydrocarbons (HC) and soot emissions in each observed measurement point. Carbon dioxide (CO_2) emissions for the all measurement points were calculated by using equations from available literature.

Presented measurement and calculation results showed that much higher NO_x and HC emissions are observed at the lower engine rotational speed (1500 rpm) in comparison with the higher engine rotational speed (2400 rpm).

Soot emissions change for the observed measurement sets are opposite to NO_x and HC emissions. On a wide range of fuel mass flow rates, soot emission is higher at engine rotational speed of 2400 rpm - Set 4 in comparison with the lower engine rotational speed of 1500 rpm - Set 3.

According to equations from the literature, CO_2 emissions depend primarily on the fuel mass flow and the carbon mass fraction in used fuel. This fact was confirmed also for the engine analyzed in this paper.

In future research of this diesel engine will be interesting to compare the same emissions with those obtained when engine uses alternative fuels or its blends with standard diesel fuel.

6. Acknowledgments

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COLLABORATION AND EVOLUTION SCENARIOS FORDIGITAL PRODUCTS, NETWOKS, ENTERPRISES AND DIGITIZATION OF THE EUROPEAN INDUSTRY

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Abstract: *From the mid 70-es, when the microelectronic devices could be integrated into industrial product and production equipment, the cooperation among European countries entered into a new era. The author's personal carrier has touched several areas of automation and networking technology aspects throughout this progress domain. Cooperation and international networking for industrial research and development has evolved along the development of ICT technologies that finally led to the advent of cyber-physical systems, IIoT and many related technologies as BigData, Cloud-computing, Analytics integrated with Artificial Intelligence, DeepLearning, remote and tele-operations, AR&VRetc. This paper gives selected samples form the vast initiatives presently accessible for those, who take up actions along the Industry4.0 global arena, as EU FPs, EUREKA, ManuFuture ETP,etc..*

Keywords: ESPRIT, MAP-TOP, standardization, User groups, EUREKA, Technology Platforms, INDUSTRY4.0,

1. Introduction

International cooperation on high-tech topics had not been performed at large scale before the middle of the last century. Each country had its secrets to save its know-how for preparing for warfare. The history of factory automation based on electronics and computer technology had started around 4 or 5 decades ago, basically when the solid state components replaced the magnetic-mechanical switches within machine control circuits. Nowadays, when we deal with cyber-physical products and production systems [1] we declare the present as the birth and outbreak of the 4th Industrial Revolution, - the 1st being the emergence of the steam-power; the 2nd being accepted as the introduction of the mass-production technology, the 3rd industrial revolution was along the introduction of computer (and IT) technology at the shop floors. [2]. Among the European countries international R&D cooperation had started after the Rome Treaty, that took place just 60 years ago by the cooperation agreement among the 6 largest European countries. Another 20 years had passed, before the EUREKA initiative appeared, directly to advance the technology-R&D cooperation among a dozen of countries. By now around 30+ countries have signed partnership in EUREKA, and also the EU has launched till now 8 Framework Programs to foster the benefits of sharing experiences in international scientific cooperation actions.

This paper highlights the key milestones of the evolution of ICT shop-floor communication technologies, ICT in manufacturing, ICT for manufacturing together with the industrial user groups, "human-networking" models along the decades.

The term networking has two areas worth to differentiate: (1) when telecommunication channels get more advanced than just point-to-point interconnection; (2) when groups and communities share and jointly discuss, evaluate, generate harmonized opinions, prepare standards, debate, vote or agree on joint initiatives, regulations, etc.

In this paper the author reflects to gained experiences in several networking scenarios, covering industrial networking topics throughout the 4 past decades, in both aspect..

Sections of this paper will recall the General Motors' MAP initiatives, [3] the global networking efforts to gain applicable international standards, international CIM pilots, emergence of the European international EUREKA initiative, the Technology Platforms within the EU, the national TP-levels, the INDUSTRY 4.0 German, -EU, -GLOBAL networking.

While 4 decades ago the targeted industrial communication application field consisted of connecting a couple of controllers (PLCs, CNCs, Process Controllers, Robot-controllers, shop-floor terminals), by now, with the advent of IoT (Internet-of-Things) and IIoT (Industrial IoT), the task is not just a multiplication factor (quantity) issue, but quality-complexity issue too.

The paper referss to the vast area of IoT, highlighting the relative small sub-domain of INDUSTRY 4.0 being addressed for the manufacturing and robotics applications. [4]

Due to its very timely issue, the paper highlights the present-day's industrial communication requirements within the automotive industry. The need for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) communication solutions is a prerequisite for the autonomous driving era already being asked for. The paper ends with commenting on the real needs, and services to be applicable, finally will show the plans of the Hungarian test field for the autonomously driven vehicles.

2. CHANGES FROM LATE 1970'S

The innovative technical directors at General Motors formed a "MAP TASK FORCE", to set a long-term technology leap for connecting industrial controllers and computers applied in the factories of the company. By 1980, the "MAP –Manufacturing Automation Protocol had been declared to be a future set or "stack" of standards, mostly planned (later on based) on the ISO-OSI 7-layer model. At the time of the definition, declaration, no such products were available at all. The user requirements were simple: Layer 1-2 were stable, allowing the options for Token-bus 802.4, or CSMA/CD 802.3 9 and newly defined layer 7 protocols had to be developed, defined and implemented at various HW-SW platforms. At the Application layer 7, FTAM, X500 directory service, Network management and the most novel MMS (Manufacturing Messages Standard) were defined for implementing general industrial tasks at the factory level.

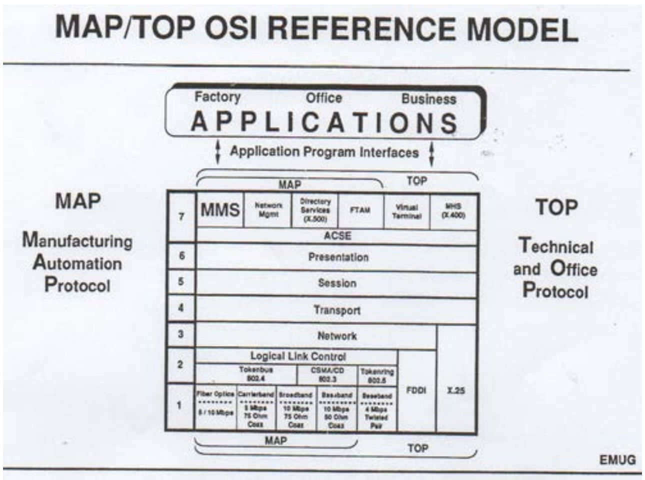

Fig.1. MAP/TOP Reference Model

The GM Task force soon realized that the harmonized solution must be a stable, and global answer to the user's needs and requirements. To gain acceptance, not only technology-demonstration events (fairs, expositions, demos) are needed, networking is also fundamental to involve experts and real users-vendors. Thus following demos, user groups were formed, like North-American MAP/TOP Users Group, European MAP Users Group, Australian and Japanese. By 1988, the Munich located SYSTEC exhibition demonstrated the operational, partly European, partly American products based implementations.

III. CIM DESIGN RULES BY ESPRIT

European countries (EC) decided to launch jointly funded research projects under several Frameworks. By 1990 (under FP4) an ESPRIT project report was published on the Design Rules for CIM Systems [10]. The project team summarized the state of the art for industrial communication, and for a generalized CIM environment collected 14 strategy points (rules or directives) to be considered in planning and designing factory communication systems. These points can still be considered valid today, and are still part of the present day's university lectures.

IV. USERS GROUPS FOR MAP/TOP IN EC

The IEEE 803 set of OSI standards had to be developed for ISO-acceptance, it means the international standards ISO committees had to accept or reject proposals from IEEE 803.xx versions. The World-Federation of MAP/TOP Users Groups decided to open the consultations with the East-Europeans, including the Soviet Union. The author was offered to help this process by setting up the Hungarian Group (HMUG) and promoting the regional East-European Interest Group that could work in harmony with the EMUG and the World Federation. A significant result of the HMUG was to set up a MAP training Centre, and for many years this laboratory served as a teaching factory for CIM students. Robot-controllers, PLC-controllers and CNC machine controllers were networked with FLEXCELL and similar Cell Controllers, as a development of MTA SZTAKI, managed by the author. Results were proudly demonstrated within the SYSTEMS and SYSTECH international exhibitions in Munich. [5]

V. CRACK AT A SINGLE SOLUTION

The North-Americans, pushed by the GM key players, were unalterable on the inclusion of Ethernet, CSMS/CD protocol for real-time applications. For them the deterministic status of the Token-bus protocol was their first priority. They were seconded by the Japanese and also supported by the Australians.

EMUG opinion was for Ethernet due to its very affordable price (almost zero, since most computers and controllers contained them as default interface), while the cost of a Token-bus interface was comparable to the price of the devices planned to get connected. There were several other obstacles, why companies did not buy MAP solutions. [26].

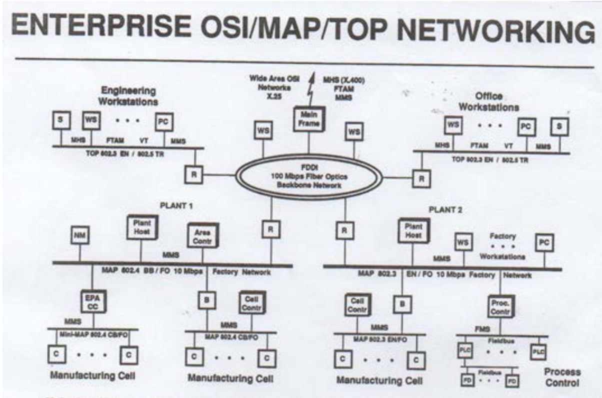

Fig.2. Enterprise network by MAP/TOP

VI. TEN YEARS LATER, IN A NEW ERA

Dozens of industrial networking solutions were designed and implemented, since technology developments allowed newer and newer chips, interfaces and protocol-versions to address sector-specific requirements. CAN bus for the automotive sector, Bitbus, Modbus, PROWAY, Interbus, HART and PROFIBUS, dedicated versions for home or building environments, FIELDBUS versions, FIELDBUS FOUNDATION standards emerged with many subsets from the MAP's MMS. SERCOS network was again a specific application area for drives to be controlled with real-time synchronization.

Together with the technological advancements, also the cooperation models had evolved. User Groups, technology demonstration cites, centres were set up also to promote the technology, but also to give test facilities.

Some far-ahead-looking scientific experts with good engineering expertise had the chance to suggest a European (EUREKA) level initiative based European Commission decision: to care for the next generation of efficient European manufacturing solutions. The idea was soon enlarged, and the European ManuFuture Technology Platform was established [6] as a bottom-up initiative to give scientific-technical suggestions to the EC and the EP for preparing a better Europe. This voluntary based group worked on a harmonized Europe-wide vision, followed by a consensus-based list of research needs (Strategic Research Agenda) and concluded by a RoadMap, how the visions could be reached with the given resources. There are a number of European Technology Platforms, each having dedicated technology domains, areas of interest, while some (e.g. 10) work as a sub-platform of ManuFuture ETP.

The EC understands the power behind the sectors involved, and treats the ManuFuture ETP and a key partner to set the goals for the research Framework Workprogramme and basic decisions regarding technology advances.

VII. MANUFUTURE TP GETS LEGAL ENTITY

To be able to deliver industrially operational research results the EC supported the establishment of the EFFRA, the EUROPEAN FACTORY-OF-THE-FUTURE RESEARCH ASSOCIATION. [7] The EFFRA is an open group of enterprises, research institutions, academic or university departments that can form consortia to make and deliver results.

EFFRA finances the projects based on the EC decisions, matching the PPP (Public-Private-Partnership) concept. EFFRA is open for any European partnership, but its main focus is on SMEs, as a grand challenge for Europe to raise SME involvement on high-tech.

The ManuFuture ETP with the business power of EFFRA has been working on the also high-priority European Grand-Challenge: the digitization of the industry.

In the EU countries each government had committed itself to a harmonized and nationally supported, pushed action: besides raising digitization at all governmental and other sectors agreed to give special focus to the digitization of the industry.

The German Prime Minister Angela Merkel, when received a briefing on the possible positive aspects of the connected, digitalized industry, suggested and actively supported that Germany should be the forerunner in it. Other countries and regions also had and have similar ideas, but the German version was the very first phrase for the 4th Industrial Revolution: INDUSTRIE 4.0. [8]

All around Europe and by now also in all other regions, INDUSTRY 4.0 is the strong symbol of harmonized, standards-based efforts to use interconnected IT solutions in the industry. In the USA the terms Connected Industry or networked industry are rather applied.

VIII. HELPING INDUSTRIAL FIRMS

To push the firms for faster digitization of the industry, several EU-level and national level governmental initiatives were established. Most efforts followed the German actions performed by the German INDUSTRIE4.0 Platform, together with the VDMA,VDI, and the Government. Readiness level definitions and measurements technology had been developed All around Europe and by now also in all other regions, INDUSTRY 4.0 is the strong symbol of harmonized, standards-based efforts to use interconnected IT solutions in the industry. In the USA the terms Connected Industry or networked industry are rather applied. Also an EUREKA INTRO4.0 German-Hungarian RTD project had been initiated for the support of SMEs to take up the speed. Large and multinational companies, like Bosch, Rexroth, pwc, RockwellAutomation, etc, directly target industrial firms to evaluate their readiness and resources for the fast implementation of Industry4.0 solutions.

IX. NETWORKING FOR INDUSTRY4.0

As the German initiative got governmental support and push, other nations within the EU decided to set up national task force groups. Hungary also declared its commitment at the level of Secretary of State to push the digitization of our industry at a very steep, fast scenario. The National Technology Platform IPAR4.0 had been initialized already in Spring 2016, and 7 working groups had been formed to care for strategy, education, pilot implementations, test sites, standards, and legal entity development. More and more companies are eager to join and learn on advancements, benefits, chances of the platform.[9] A mayor topic is the readiness level of SME-s.

Networking at international level is also important. EU Commissioner had pointed out the need for national-level projects with national government commitments in each and every EU member-state. The Commission intends to generate EU-wide joint harmonized actions in this specific area of interconnected digitization. The explicit aim is to set European industry to be a forerunner in the digitization of the economy.

X. THE STATUS OF TELECOM STANDARDS

At ISO level, TC-299 has recently sent invitation for initiating the joint ISI-IEC SMART Manufacturing-Standards-Map-Task-Force. There is a huge advancement of new telecom standards, and an excellent recent survey in IEEE has drawn a detailed map of standards and SW modules, interfaces worth to mention [14]. Copyright had been requested from the authors to refer this mapping of standard from 1970 onwards,

Regarding the INDUSTRY4.0 domain, the very basic applicability question is still open: Industrial processes are time-sensitive, real-time and the available telecom standards are all limited in certain resources. The Ethernet-based developments to address Real-Time needs offer presently 3 classes. Class A manages RT services at 100 msec cycles times, Class B allows 10 msec, (both with extensions to IEEE802) while Class C runs with a 802.1 TSN method, where Ethernet operates with priorities and in addition with scheduling at the lowest layers (with 1 msec range).

Time Sensitive Networks (TSN) are under development, but significant results cannot yet be predicted for the next year.

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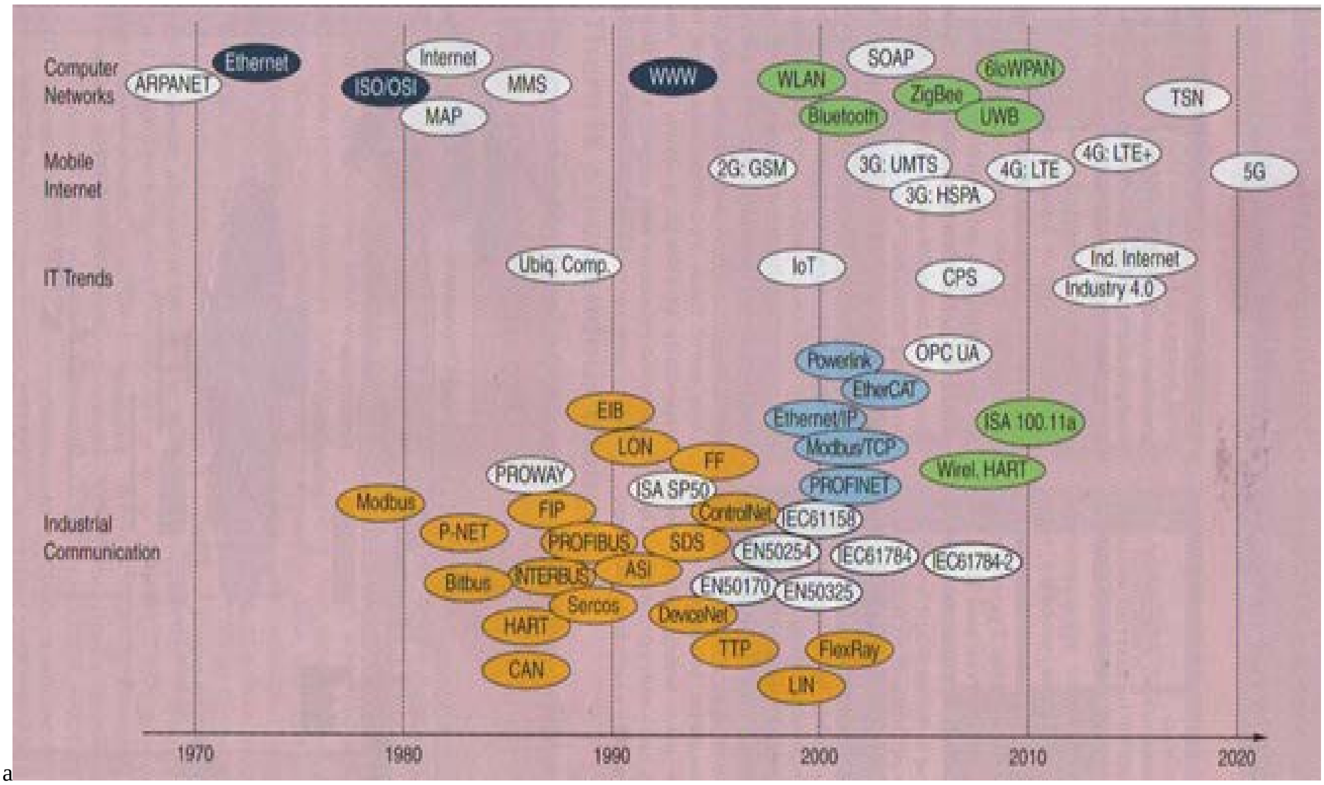

Fig. 4. Milestones in telecom standards [14], (Requested courtesy diagram from the authors)

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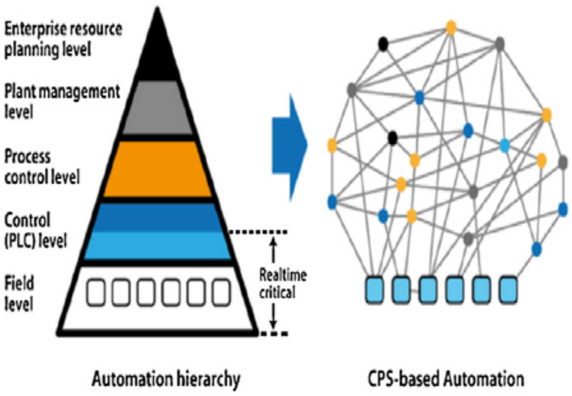

Fig.5. The trend from the pyramid to the SOA model

As the future tasks to be solved are more complex, the networks to support the solutions get more heterogeneous, more mobile and multivendor. The 5G networks will need to manage very hard limits of compromise.

For the present applicability, the EtherCAT and the OPC-UA [11], [12] are verified as possible bases for the Industrial Interoperability of IIoT elements and controls. It appeared at around 2005, at the time, when Service Oriented Architecture concepts got world-wide industrial acceptance, and the G3 started to be securely operational. Regarding the INDUSTRY4.0 standardization process, the global-level, international work is referencing RAMI4.0 based on the OPC-UA communication technology. [13]

For IIoT and CPS areas, the trend shows a shift from the ISA95, ISO factory control "Pyramid" model, towards the distributed, service oriented concept as shown in the following Figure 5. [1], [25]. The IIoT communication with devices will rarely happen directly. Sensors and device information will rather be published and consumers can subscribe to this information. Typically they will communicate via IP-networks among each other and with cloud based BigData and Cloud-Services applications. [12]

Requirements are: - independence from the communication-technology from manufacturers, OS or programming language; - Scalability, -Vertical and horizontal across all layers; -Secure transfer and authentication at user and application layers; - SOA transport via established standards for live and historic data, command and events; - Mapping of information content with any degree of complexity for modelling of virtual and physical objects; - Unplanned and adhoc communication for plug-and-produce functions; - Integration into engineering and semantic extensions;- Verification of conformity with the defines standard; as mapped in [12].

The industrial automation environment is just a subdomain within the field of IoT, as already shown in Figure 4. There are several other, mayor fields, where services can be built up at similar vertical stacks of standards. Figure 7 gives examples for application areas handled by Mobile Broadband Services and also for application area of the Automotive sector.

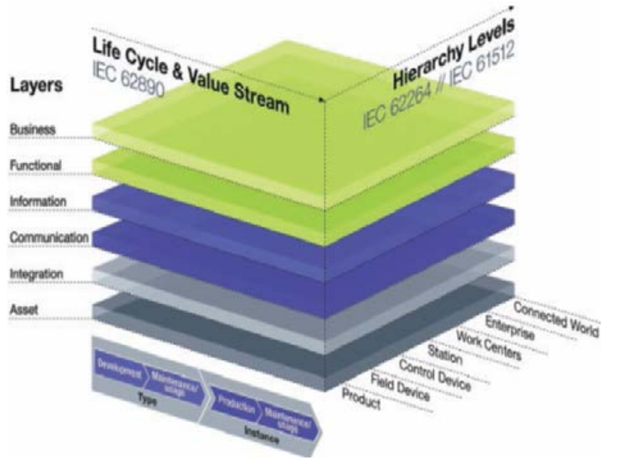

Fig.6. RAMI4.1, Reference Architecture Model for INDUSTRY 4.0

XI. COMMUNICATION CASES FOR THE AUTOMOTIVE INDUSTRY

The state-of-the-art of vehicle communications is usually abbreviated as V2V, V2X (or as "car": C2X). There are significant global and local challenges to manage and tasks to solve, since transportation is a major contributor to GDP, but also the cause for losses and negative consequences of emission, death tolls, congestions, resource underutilization, etc.

What are the main issues for communication along the transport and automotive sectors? Some are listed here: -The presently available automotive products, with their lifespan of more than 15 years, need to be part of an active environment; - Newly manufactured vehicles must be ready for a new intelligent transportation environment; - Personal- and community transport vehicles, or heavy-duty vehicles, lorries, trucks need services with overlapping services; - Security and safety is a most demanding requirement; - Real-time services are needed with fast and very fast mobility speeds (TGV, airplanes, drones; - Addressing needs geographical, and relative extensions to present addressing methods; - A large variety of mobile platforms, operating systems are involved; - Intelligent infrastructure is essential to take active role in the operation of services; - Responsibility for data validity, availability, accessibility needs a harmonized agreement; - Vehicle manufacturers keep responsibility for the data management and communication within the transport vehicle; - Interactive multimedia needs higher bandwidth; - Real-time data must be verified for out-datedness, - Time-sensitive standards are needed to be available, - Autonomous driving of vehicles are about to be available at any site, while the infrastructure and targeted services are not yet available.

V2V and V2X scenarios use G3 and G4, later on planned G5 technologies, IP and non-IP (for safety messaging). It needs access to global resources and also to local sensor networks. GeoNetworking introduces addressing features to open connections with mobile nodes located in a given geographical vicinity, e.g. with vehicles in front, behind the back, on its side, or at a defined global area nearby of far away.

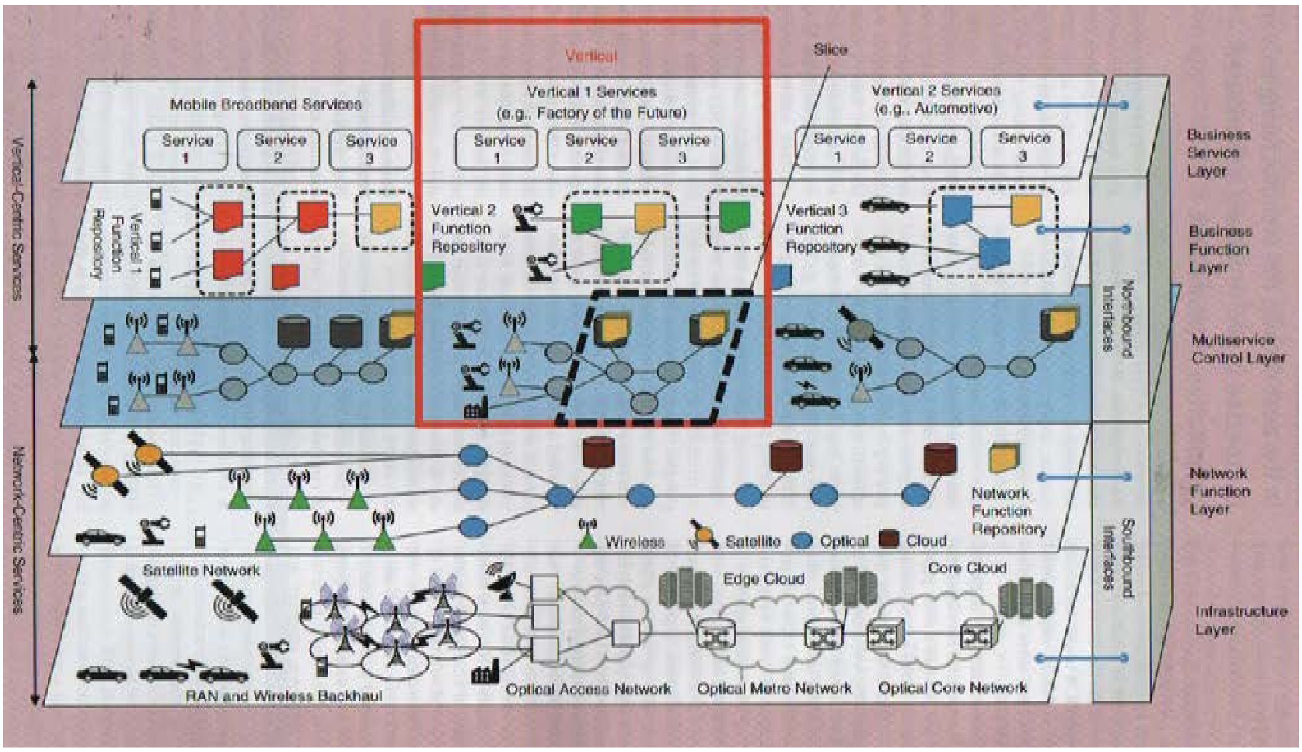

Fig. 7. Vertical and Horizontal integration: Service architectures for mobile, FoF and automotive sectors. (Requested courtecy diagram from the authors of [14])

Important feature is the time-sensitivity, and the speed in respect to the environment. To name just the most common commercial services of V2X: - Accident, incident warning; - Weather condition warning; - Roadwork Information; - Lane utilization information; - In-vehicle speed limit information; - Traffic congestion warning; - Road Tolling; - Route navigation.

A different series of services are reflecting traffic efficiency and road safety services: - Lane departure prevention and lane change assistance; - Road quality warning; - Obstruction detection; - Collision avoidance; - Radar view and neighbor supervision; - Safety margins; - Local danger alerts; - Road side safety information display; - Enhanced driver awareness. [15] These are supporting services to assist the drivers or modules to advance autonomous driving and are under development at MTA SZTAKI, Budapest, Hungary.

XII. DEMONSTRATORS, TESTING THE USE-CASE SCENARIOS FOR INDUSTRY (CPS) AND FOR THE AUTOMITIVE SECTORS

As it can be seen many countries and also within the EU's Horizon 2020 projects pilots and joint demonstrator sites are financed to spread the best practice examples, and to promote harmonized solutions, e.g. for software and hardware solutions, service oriented architecture based implementations, etc. For the Cyber-physical Manufacturing Systems an example of CPPS is detailed in the simplified architecture of the Smart Factory demonstrator at MTA SZTAKI, Budapest, Hungary.[16] Within the Hungarian IPAR4.0 National Technology Platform, the 7 Working Groups are getting to be active after being set up last Spring. Nation-wide "open factory-night" event was launched to allow citizens to visit factories with demonstration use-cases. The mobile-phone application by SZTAKI has helped to select the most interesting factory-examples, and helped to navigate the user to reach the demo sites.

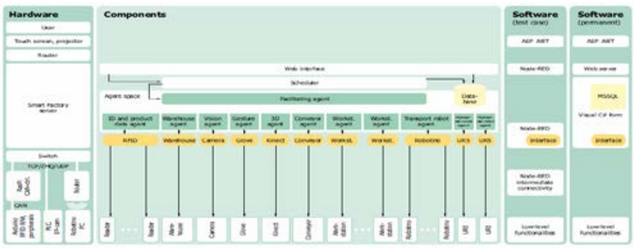

Fig. 8. SMART FACTORY pilot at MTA SZTAKI [16]

The Strategic-planning Working Group has submitted a 150+ page detailed Strategy [27] to the Ministry of National Economy. Five main pillars are giving the backbone for the strategy: Digitization and business development, - Production and Logistics, - I4.0 Labor market development, - R&D&I, -I4.0 ecosystem. For each pillar, 3 dimensions were defined –as Technology, Society and Business. Within such a matrix, tasks had been listed, and for each block, priorities had been selected

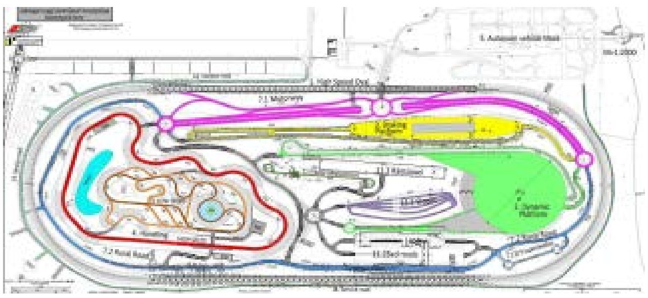

Fig. 9. Hungarian test environment plan for autonomously driven vehicles [18], [19]

. The Government will soon define the national supporting and promoting Grants and Calls based on these priorities. MTA SZTAKI has also been developing a test facility at the Gyor University premises, in addition to the Budapest based SMART-FACTORY demo and test environment. Regarding test environment for autonomous driven cars, the Hungarian Government recently decided to develop and implement a test base in Western Hungary. [17], [18] and [19] Further details for standards SOA and intelligent transport services are referenced by [20], [21], [22], [23] and [24]. Though vehicle test environments are already available in Europe [22], this new one will be unique to handle many new features, functionalities, services for assisted driving, and fir autonomously driven vehicles.

XIII. MANUFUTURE TECHNOLOGY PLATORM

The driving force for setting the future of European Manufacturing culture is done by the ManuFuture ETP. The working documents for VISION-2020, for SRA (Strategic Research Agenda) and ROADMAP had been and are the fundamental elements for the H2020 FP- The FoF, EFFRA etc, are based on those. Presently the work is continuing on the Manufacturing Vision-2030, to be available by early 2018.

XIV. CONCLUSION

The need is still high for applicable communication standards. Networking among groups of key players is more essential than before, global end-user requirements cannot allow individual solutions. Testing, verifying sites, training environments are trying to foster the development of best practices, good and sound solutions. A prime test environment for testing autonomous vehicles and advanced driving services is being developed in Western Hungary, while pilot sites for INDUSTRY 4.0 are under implementation at several sites throughout Hungary, MTA SZTAKI and HEPENIX Ltd, develop I4.0 Use-Cases in respect to INTRO4.0 EUREKA project. [28].

Networking at international level is also important. EU Commissioner had pointed out the need for national-level projects with national government commitments in each and every EU member-state. The Commission intends to generate EU-wide joint harmonized actions in this specific area of interconnected digitization, the digitization of the European economy.

ACKNOWLEDGEMENT

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THE ROLE OF PROJECT MANAGEMENT FOR SUCCESSFUL PERFORMANCE AND SUSTAINABLE BUSINESS GROWTH

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Abstract: *Today's business environment is highly dynamic, unstable, and characterised by many unpredictable challenges. This paper provides a review of the role of project management for improvement of performance, as well as for establishment and implementation of strategies for sustainable growth. Project management is considered as an effective approach for efficient planning, risk management, provision of informed decision-making about the company resources, monitoring, and measurement of performance results. On the basis of these advantages, the paper will also present practical recommendations for integration of project management at the levels of business strategy, structure, and processes.*

Keywords: PROJECT MANAGEMENT, BUSINESS PERFORMANCE, SUSTAINABLE GROWTH

1. Introduction

Today's business environment is highly dynamic, unstable, and characterised by many unpredictable challenges. To gain a competitive advantage, organisations have shifted their focus towards elaboration and implementation of strategies for successful project management, which turns out to be a necessary condition for sustainability and long-term results in the context of organisational development.

Principles of project management are becoming very popular in traditional management of business organisations, providing foundations for high performance and sustainable growth. Project management is applicable in every business process management framework, which ensures additional value, competitiveness, and progressive growth; "in fact, the only way organisations can change, implement a strategy, innovate, or gain competitive advantage is through projects." (Shenhar and Dvir, 2007)

This paper provides a review of the role of project management for improvement of performance, as well as for establishment and implementation of strategies for sustainable growth. Project management is an established framework for efficient planning, risk management, provision of informed decision-making about the company resources, monitoring, and measurement of performance results. On the basis of these advantages, the paper will also present practical recommendations for integration of project management at the levels of business strategy, structure, and processes.

2. Conceptual framework

Within the conceptual framework of project management and its principles, a variety of definitions need to be clarified, specifically definitions concerning the correlation between project management and its integration as a good practice for successful performance of business organisations.

The PMBOK gives the classical definition for project management as "application of knowledge, skills, tools and techniques to project activities to achieve project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing" (Project Management Institute, 2000). According to Larry Richman project management is a "set of principles, methods, and techniques that people use to effectively plan and control project work. It establishes a sound basis for effective planning, scheduling, resourcing, decision-making, controlling, and re-planning." Another definition suggests that "the purpose of project management is to predict as many of the dangers and problems as possible and to plan, organise and control activities … This process should start before any resource is committed and must continue until all work is finished." (Lock, 2007).

These definitions specify project management as a process related to application of certain tools and methods for achievement of predefined goals. (Koleva and Kasamska, 2017) In comparison with the general management, which "did prove in many cases to be inadequate, with the result that time and cost targets were allowed to slip", project management applies strategic principles that can increase the performance of business organisations, ensuring a competitive privilege and more organised structure of business processes management (Woodward, 1997).

On the other hand, business performance is "traditionally a topic that leaders of large companies pay a good deal of attention to, because it gives vital information about the state of the company, its success, development and future outlook" (Vasan, 2015) Usually performance is a subject of measurement, monitoring, and further analysis in order to ensure an appropriate results-oriented business strategy. Business performance measurement (BPM) in the context of organisational management is defined as "set of metrics used to quantify both the efficiency and effectiveness of actions" (Neely, 1995). Mike Biere defines BPM as a "process of providing accurate information for defining, measuring, and adjusting key areas of the business to keep all elements of an organisation in sync and provide a clear understanding of the things they are measured upon, responsible for, and any changes in the business" (Biere, 2011). All measurement and monitoring processes of business performance is implemented with the aim of guaranteeing continuous development and sustainable results within the organisation, as well as in the interaction with its main customers and competitors.

In recent years, business organisations are "obsessed" with achieving a sustainable competitive advantage and securing a position within an industry that turns them into leaders on the market (Rajagopal, 2016). Sustainability in results, performance, and growth is essential, especially in the current highly unstable business conditions of globalisation and competition. When organisations strive for sustainable growth, they need a different kind of management, decision-making, monitoring, and risk management. Andrew Lester defines this as growth management, which "requires individuals to work with a different style to running day to day operations … those who buy into the concept and processes early on will help lead the organisation in delivering sustainable growth" (Lester, 2009). Sustainable growth requires an innovative perspective in management, necessary for a variety of operations – from initiation to implementation, from planning to execution, from reaching growth to ensuring sustainable success.

After clarifying the main definitions, the current paper will focus on applying the principles of project management as the necessary different styles of business processes management, providing high business performance, sustainable growth, as well as long-term competitive advantage.

3. Project management principles for improved performance and sustainable business growth

The concept of project management lies in differentiation of several successive phases, interrelated with structured processes and principles.

According to the project management framework, the main project phases are defined as *initiation, planning, execution, and closure* (Figure 1). Each of them is characterised by its own specifics that can be applied in traditional management with the aim for improvement of performance, as well as for establishment and implementation of strategies for sustainable growth.

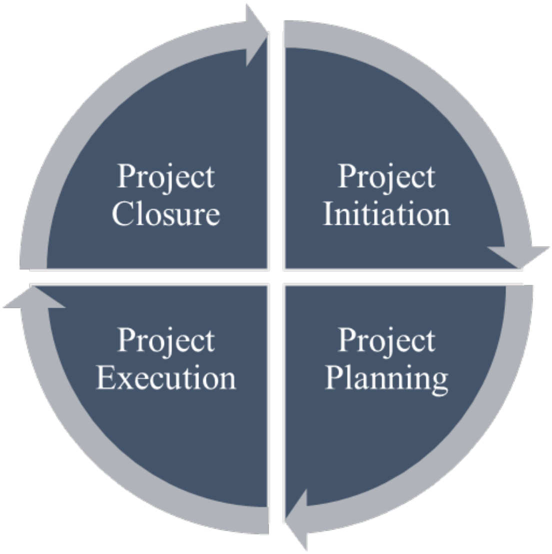

Figure 1. Phases of the Project Life Cycle

2.1. Project Initiation

Initiation is the process of "formally conceiving, approving, and launching a new project … The time and thought invested during initiation lays the groundwork for all the work that follows" (Wiegers, 2007). During this phase a specific problem or opportunity is identified, then the possible solutions, objectives, and scope are determined. Other processes that occur are related to documentation of costs and budget, appointment of a professional team, and distribution of responsibilities.

There are several key project management principles in the initiation phase that could be further used by organisations for improving of their business performance and reaching of sustainable growth as a competitive advantage.

One of the main processes during this stage is *needs assessment*, which usually refers to the "collection of data bearing on the need for services, products, or information" (Soriano, 2013). Needs assessment is used mainly in Customer Relationship Management (CRM), especially when the organisation is new for the market or it releases a new product or service. The information from the needs assessment is synthesised, analysed, and transformed into customer requirements. Sheila Kessler summarises several tools that could be used to gather customers' needs:

Figure 2. Tools for Needs Assessment, Source:

Customer Satisfaction Toolkit for ISO 9001:2000 (Kessler, 2003)

Another essential process of the initiation stage is *analysis of the stakeholders*. Effective stakeholders management requires continuous interactions in two main directions – on the one side, within the business organisation, on the other side, with the external actors that would be impacted both positively or negatively by the implemented actions. Mapping of the main stakeholders, their needs, opportunities, and challenges defines all the future interactions with key actors for the company – customers, partners, competitors. When implementing a new business strategy, releasing a new product, or making a structural change in the business processes, the first step is stakeholder analysis to find out whether there are powerful stakeholders who will want the action success or be able to hinder it (Eskerod and Jepsen, 2013).

Appointment of a team and distribution of responsibilities are also a significant part of the initiation activities. When aiming towards improvement of performance and sustainable growth, business organisations need to take into account some factors, including "team size, composition, governance, identity, interactions, and a common team mindset" (Cobb, 2012). A general principle of team management is building and sharing a common mission and vision. Successful business performance is nearly impossible without a "clear sense of direction, and both the mission and vision provide that direction" (Lewis, 1998).

On the other hand, *distribution of roles and responsibilities* is often implemented on the basis of specific expertise, professional experience, and proven competences in the respective field. According to The Project Management Question and Answer Book, the role structure of the team defines the content and distribution of differentiated roles. "The knowledge and ability to use the structure of roles within the team is a strong and efficient instrument of human resource management in the project team" (Newell and Grashina, 2004).

The presented project management principles of the initiation phase – needs assessment, analysis of stakeholders, appointment of a team and distribution of team roles, could be used for improvement of business performance and sustainable growth. The main idea is integration of project management at the levels of business strategy, structure, and processes.

2.2. Project Planning

The second phase of the project life cycle is planning that is used to "ensure that the activities performed during the execution phase of the project are properly sequenced, resourced, executed and controlled" (Westland, 2006).

Planning as a business process is extremely important for implementation of both day-to-day operations and long-term strategies. It gives more details and a clear structure for the issues raised during the initiation phase, placing them in a timeframe. Planning gives a detailed analysis of the scope, the activities needed for reaching of the desirable results. Further, the activities are broken-down into specific tasks that could be further monitored and measured, linking them to specific intermediate results and control points. This is a process which provides a logical arrangement of the activities required to accomplish the general objective. Jack Gido suggests development of a network diagram for structuring the activities during the planning stage: “First the project objectives must be determined, then a list is made of all activities necessary to accomplish the project objectives, and finally these activities must be arranged in the form of a network diagram according to certain network principles and rules.” (Gido, 1985)

Another benefit of the planning process that could be applied for improvement of business performance is the appropriate *allocation of resources* – physical, intellectual, financial, human. For each task of the planning phase the necessary resources and timeframe need to be determined to ensure effective implementation and control of the further execution. When doing this, the critical path activities should be taken into account, as “giving to activities of less significance illustrates poor judgement” (Kliem, Ludin and Robertson, 1997).

A distinctive process for planning is risk management. It starts at this stage, but is further monitored and implemented during the execution phase. The purpose of risk management is “identifying potential risks, analysing risks to determine those that have the greatest probability of occurring, identifying the risks that have the greatest impact on the project if they should occur, and defining plans that help mitigate or lessen the risk’s impact or avoid the risks while making the most of opportunity” (Heldman, 2005). A process of risk management that is critical for business performance and sustainable growth is *risk impact assessment*, which encompasses evaluation of the risk probability and consequences, including cost, schedule, scope, quality, technical performance, as well as capability or functionality impacts. Risks are assessed and prioritised according to their potential implications for having an effect on achieving the preliminary defined objectives and expected results.

The planning phase is crucial for defining strategies for improvement of performance and sustainable growth within business organisations. It results is a structure with well-formulated tasks, allocation of resources, and risk management strategies, which provide the necessary basis for future implementation and control of these strategies.

2.3. Project Execution

The execution stage is realisation of every aspect that needs to be implemented for reaching a higher performance and sustainable growth. To ensure all activities are executed in correspondence with the predefined plan, *monitoring and control* processes are performed. Their purpose is to “track all major project variables – cost, time, scope, and quality of deliverables” (Gudda, 2011). Tracking the implementation of predefined actions offers the benefit of knowing the status according to preliminary determined both quantitative and qualitative indicators. On the basis of these metrics, via monitoring and control tools and techniques measuring of the variables is implemented, analysing comparatively the planned and actual executed activities.

The key process at this stage is identification of need for corrective actions, which is necessary when differences between ‘planned’ and ‘implemented’ is discovered. In case a deviation occurs, a measure for adjustment is triggered, which ensures effective implementation in compliance with the planned baseline metrics.

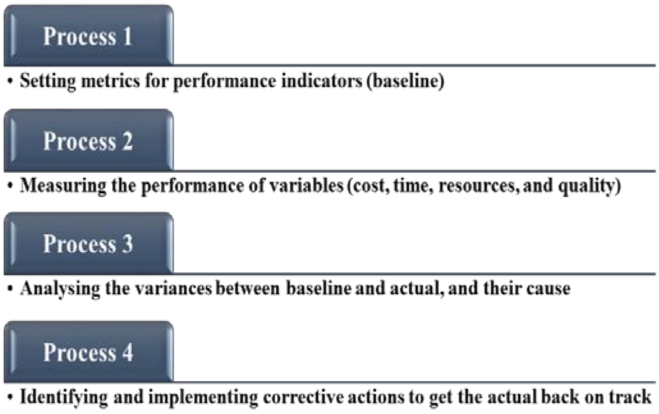

Figure 3. Monitoring and Control Processes, Source: Project Control (Pico, 2013)

Another project management principle that could be applied for improvement of business performance is *quality management*. This process is applicable for all kinds of businesses, as “it is not possible to produce a desired quality and maintain it consistently over a length of period unless adequate control is exercised at every stage” (Jain, 2001). The start of the quality management process involves setting of quality targets, which are consolidated within the business organisation, corresponding to its strategic goals and desired performance indicators. Then assurance and further monitoring are undertaken to measure and report the actual quality. The benefit of this process is meeting the organisation's requirements, which ensures compliance with its strategic goals and regulations in the most cost- and resource-efficient manner, creating opportunities for expansion, sustainable growth, profit, and improvement of business performance.

2.3. Project Closure

The last project life cycle phase is closure. Its purpose is mainly related to review of the project completion and its overall success. “Success is determined by how well it performed against the defined objectives and conformed to the management processes outlined in the planning phase” (Method123, 2003)

One of the main processes that is used for improvement of performance in the context of organisational management is *evaluation.* It is a final review assessment of efficacy of the business to include organisational support, policies, procedures, practices, techniques, guidelines, action plans, funding patterns, and human and non-human resource utilisation. Evaluation is carried out on several levels: internal level (project and organisation), content level (subject area), external level (impact, exploitation, sustainability) (Kasamska, 2017).

Another process during the project closure stage is *reporting*. Communication is a key element in improvement of business performance and sustainable growth. This communication is guaranteed by reports and documents distributed within the business organisation to provide information about the project, its implemented activities, as well as achieved outputs and outcomes. Reporting is not used in the project closure phase only as a means of evaluation and validation, but also as a monitoring tool. “In this case, reporting provides tracking, identifies potential risks that contribute to the project risk management strategy, as well as facilitates cost management, showing full visibility of the budget and expenditures” (Koleva and Kasamska, 2017)

Project evaluation and reporting are distinctive processes for the last project life cycle stage – the project closure. Both of them are widely used by organisations for fostering of business performance.

3. Conclusion

This paper provided a review of the role of project management for improvement of performance, as well as for establishment and implementation of strategies for sustainable growth. The presented research also focused on applying the principles and processes of the main project life cycle phases. Practical recommendations for their integration were defined and could be summarised as follows:

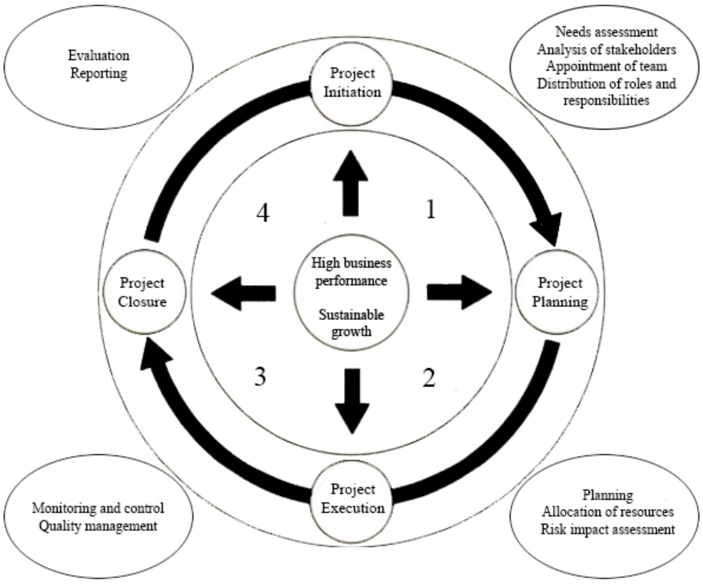

Figure 4. Recommendations Based on

Project Management Processes

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WHAT DOES INDUSTRY 4.0 MEAN FOR SUSTAINABLE DEVELOPMENT?

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Abstract: *Sustainable development is an integral part of economic development in all countries, even when attention is driven away from it. The balance between the need of humanity to produce and the desire to not destroy the planet in the process is constantly questioned and shaken. With the disruptive new models that Industry 4.0 has shown to the world, and with the constantly expanding opportunities for technologies, production, and improvement of the way businesses function, the question of sustainability stands. How will the new business models affect sustainable development, and will they manage to put humanity's future in the spotlight? This paper explores the opportunities to sustainable development, introduced by Industry 4.0.*

Keywords: SUSTAINABLE DEVELOPMENT, INDUSTRY 4.0, BUSINESS MODELS

1. Introduction

Industry 4.0 – the fourth industrial revolution, is changing how the world of business functions. Baldassari and Roux[1] summarize that this new revolution of not only production, but also way of creation and design of products, processes and organizations, has come to existence because of the inclusion of various new actors into the way society and business function: artificial intelligence, machine learning, the combination of potential of hardware, software, and humans.

As this rapid transformation of businesses is creating a new atmosphere – one with more efficient manufacturing methods[2], collaborative industrial networks and optimized supply-chain processes[3] to start off, one with a new outlook on design and execution of production – there should also follow the question of how sustainable development fits into the unfamiliar and unique environment.

Sustainable development (SD) – the idea of living, working and developing as a society, while preserving the planet at least in its current condition, is one that more and more businesses and individuals consider as crucial. In this new setting, with abundant opportunities arising for businesses, the question of sustainable development remains.

This paper aims to showcase the threats, which should be tackled and the questions answered for SD to work, as well as the opportunities, which Industry 4.0 presents for SD.

2. Sustainable development in Industry 4.0

In order to understand how sustainable development can fit in the framework of Industry 4.0 the paper will compare the defining elements of Industry 4.0 with the challenges SD is currently facing. In finding the meeting points of the two, the best-case developments can be uncovered. The comparative analysis below is based on research in various countries and conclusions drawn in the last 5 years.

2.1. Elements of Industry 4.0

According to the Boston Consulting Group's 2015 report[4] on Industry 4.0, there are specifically nine technological advances, which have created the fourth revolution: autonomous robots, simulation, horizontal and vertical system integration, the industrial Internet of Things, cybersecurity, the cloud, additive manufacturing, augmented reality, and big data and analytics. Below, all these elements are more thoroughly discussed to give a better idea of how they could be used later in solving the challenges of SD.

- **Robotics** (which includes autonomous robots, as well as expert systems, digital assistants) is a constantly growing market all over the world[5]. Because of the vast capabilities in storing information, together with the possibility of using that information in increasingly intelligent ways (thanks to AI), improved human-computer interactions, as well as a stronger presence from the digital to the physical world (for example 3D printing), robotics are gaining traction in all fields and with countless applications – from manufacturing, to services, to personal development and beyond.

- **Modeling and simulation technologies** are a key factor for the development of Industry 4.0. They are crucial for the modern design, piloting and support of new products.[6] The new possibilities of virtual prototyping, as well as automation in manufacturing industries, increase efficiency and improve the quality of production.

- **Horizontal and vertical system integration** portray an integration between different value chains and between functional layers in an organization.[7] This integration allows for a greater understanding of all processes, as well as improved synergies in and between organizations.

- The **Industrial Internet of Things** is the increased connectivity of technology in the worlds of manufacturing, agriculture, mining, transportation, healthcare, etc. The integration and connectivity within those fields creates an entirely new relationship between humans and computers, and lays the groundwork for a completely different way of work with innovative job positions for all sectors – namely, decrease of jobs, which are unsafe and have low skill qualification needs, while more energy would be needed in engineering, data management and analysis, etc. [8]

- **Cybersecurity** in Industry 4.0 more than ever before comes to the forefront of businesses. Novel issues arise constantly, putting at risk not only brands but design, creation, continuous manufacturing of products. A wholly innovative approach is needed to deal with cybersecurity in Industry 4.0 – one that involves not only the basis of security and reactivity, but vigilant resilience, a proactive effort to keep security at the only acceptable level in Industry 4.0 – impeccable.[9]

- **Cloud technologies** are not only a way to integrate services and cut costs in IT expenses – they are an enabler of disruptive

[1] Baldassari, P. and Roux, J. D. (2017) Industry 4.0: Preparing for the Future of Work. People & Strategy. Summer2017, 40(3), pp. 20-23

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innovation and a path-creator for a so-called business fast-lane. In manufacturing, but also everywhere else in business, cloud technologies are changing the processes and the people, which operate them, opening the doors for approaches and results never imagined before. It could even be said that cloud technology "democratizes" access to information, learning and communication.[10]

- **Additive manufacturing**, which portrays development in the world of design, testing, manufacturing, etc. such as 3D printing. This idea of true and effective, fast connectivity between customer, data, and production, is shifting the way products, as well as their separate pieces, are being made. Through rapid prototyping, solid free-form fabrication and 3D printing itself, additive manufacturing is changing processes, planning, design ideas, opportunity for creation, and not lastly – rapidly lowering costs all around this manufacturing line. Additive manufacturing is still spreading through its capabilities and it is yet to be seen what other opportunities will arise through it.[11]

- **Augmented reality** creates a bridge between virtual reality and data, which has been gathered with physical methods of analysis. This allows for a new approach to designing and repairing components and whole products. Through the creation of a suitable digital toolbox, designers, engineers, or technicians can improve their problem-solving capabilities, as well as vastly expand on their options for optimizing products and processes. Augmented reality also helps with connecting customers with their desired products more effectively, through the ability to see the possibilities with all necessary technical specifications, for example.[12]

- **Big data and analytics** are taking on newer meanings and new depths constantly. It has been noted multiple times by media and academics that data is the driver of the century, a commodity more valuable than oil.[13] With the increased capabilities of collecting vast amounts of data and even more than that – analyzing it in faster and smarter ways, big data and analytics pave the way for a transformation of understanding, producing, selling, etc. Now, more than historical data – real-time physical data like vibrations, noise levels and pressure is used in factories, as well as predictions, data on similar processes and various out-of-field innovations.[14]

These nine elements of Industry 4.0 work in synergy to incorporate each other in all aspects of all scopes of business, and slowly – all facets of life. Focus is starting to shift overall from labor-intensive jobs to high-qualified positions, which demand managing systems, still beyond the imagination of humanity.

With this in mind, it is not impossible to imagine that the new technologies and amazing capabilities, which are being developed, could be key for solving some of the world's most important problems.

2.2. Challenges for Sustainable development

Even though challenges for SD could be defined in many ways and though many approaches, the universally accepted measure of SD improvement and challenges is the UN's General Assembly's Resolution and Agenda on Sustainable Development.

In 2015, when setting the major goals for 2030, the UN outlined specifically 17 major goals with 169 targets for humanity with the overarching goal to "end poverty, protect the planet, and ensure prosperity for all"[15]. Accepted by world leaders and formulated as a continuation of the Millennium Development Goals, these goals are separated into five major categories: People, Planet, Prosperity, Peace, Partnership.

The categories are illustrated in the table below:

Table 1: SD goals

Category	Goals
People	• No poverty • Zero hunger • Good health and well-being • Quality education • Access to clean water and sanitation • Gender equality • Reduced inequalities
Planet	• Climate action • Life below water • Life on land
Prosperity	• Affordable and clean energy • Decent work and economic growth • Industry, innovation and infrastructure • Sustainable cities and communities • Responsible consumption and production
Peace	• Peace, justice and strong institutions
Partnership	• Partnerships for the goals

The challenges for achieving the set goals in these categories vary. Some of the goals and targets are believed to be **too optimistic**, **too vague**, or just **unachievable** for the span of time, laid out in the goals. Compared to their predecessors, it should be noted, the goals are extremely **wide in scope** and cover a far greater amount of actions needed.

Even focusing on a single thought stream from the goals – for example, something very related to production, namely – limiting CO^2 emissions and finding alternative sources of energy – brings on a plethora of unanswered questions. This issue is often regarded as the biggest challenge for SD because of the scale in which this problem affects the planet and society's dependence on energy, produced by coal and other non-green energy sources.

As Meléndez-Ortiz[16] points out, this challenge has even bigger implications when taking into account the changing consumer patterns around the world and specifically in developing countries such as China and India. Even with emerging green energy sources, this challenge remains as valid as ever to the idea and goals of SD.

On a different note, as Singh[17] discusses, other key challenges for the timely achievement of the set goals are: **lack of substantial leadership** (to inspire not only policy change, but also investment, inclusion, awareness, and mobilization towards the goals), an **understanding of** the underlying tones of **the goals** (meaning an overall shift in the way people work, produce, consume, and spend their time), as well as **unification of** some of **the targets** for all countries (for example, setting universal standards for clean water, clean air, etc.).

[10] Oracle (2016) Cloud: Opening up the road to Industry 4.0

[11] Lopes da Silva, J. (2016) Industry 4.0 and Additive Manufacturing. Cepal, May 2016

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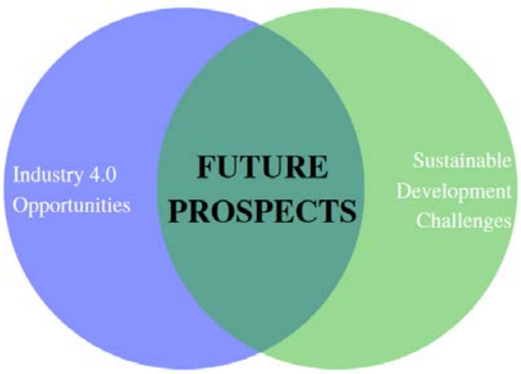
According to Lucci[18], some of the major challenges in the way of achieving the SD goals are **lack of access to information** of governments, **low quality of prioritizing** of the existing goals, as well as **lack of capacity of governments** to face the scale of the SD goals. As the cited article discusses, governments find many difficulties in fighting for the achievement of the goals because of lack of structured and abundant data globally, but also inside their own borders – how cities truly function, what the life is in the less-developed parts, etc. Without that data, as well as without the needed capacity of governments to even plan correctly the needs of their citizens for getting closer to the targets, the goals cannot be achieved.

The challenges for the achievement of the 2030 SD goals seem many and some of them – unsurmountable. However, another way to see the goals is as ambitious, and – fundamentally – as created with the goal to lead the planet and all its inhabitants to a better reality and better future. In the following sections, this paper will explore the intersections between the opportunities, provided by the development of Industry 4.0 and the challenges to SD, identified here. Through this, the paper aims to showcase how Industry 4.0 can assist the achievement of the SD goals.

2.3. Intersection of Elements of Industry 4.0 and Challenges of SD

As was already discussed, the developments, related to the emergence of Industry 4.0 can be related to the challenges of SD in an effort to solve the latter.



In the following table, the proposed solutions to challenges of sustainable development will be presented, in order to be later discussed in depth.

Table 2: Practical solutions for SD challenges

SD Challenge	Possible Practical Industry 4.0 Solution
Phrasing of goals: vagueness, overly optimistic targets, etc.	Robotics Modeling and simulation technologies (virtual prototyping)
Scope of goals	Robotics Augmented reality Big data and analytics
Lack of leadership	
Lack of understanding of the goals	Robotics Virtual prototyping
Lack of unified standards	System integration Cloud technologies Big data and analytics
Lack of access to information	Big data and analytics System integration Cloud technologies Augmented reality
Low quality prioritizing	Virtual prototyping Big data and analytics
Lack of governmental capacity	Robotics System integration Cloud technologies Augmented reality

[18] Lucci, P. (2015) Five challenges the sustainable development goals present to city leaders. CityMetric

As Industry 4.0 exemplifies interconnectivity, it stands to reason that more than one of its elements would constitute a possible solution, many times in synergy with others.

Robotics appears with either virtual prototyping or augmented reality as complementary elements. While the computational powers of robotics can create many options, virtual prototyping in this context can play out the created scenarios for easier decision-making. Augmented reality, on the other hand, will create a much clearer picture not only of the current state of the art, but will shine a light on the depth of the created possibilities – clear out the scope of the goals for policy-makers, for example, or demand fewer human resources for governments to handle the planning and execution of those plans.

Big data and analytics adds to this with the unlimited opportunities for gathering and analyzing data. This availability, if applied correctly, can be the key to solving some of the challenges even as a stand-alone tool: namely the lack of access to information, and the lack of unified standards. Big data and the powerful analytical capabilities, inherent in Industry 4.0, together with virtual prototyping can also create an easy-to-use way for policy makers to prioritize the SD goals according to the state their country is currently in, as well as to better understand the situation they are facing.

System integration can be the source of amazing synergies to help expand the capacities of governments, but also to combine information from many different fractions, which should be more integrated, but still are not. This will bring unification of standards – naturally – but also more transparency and greater availability of information across the border.

Finally, cloud technologies – they, of course, lower costs and provide wider accessibility, while making many processes, related to improving capacity, easier, faster, and significantly more effective. In that way, cloud technologies create staggering opportunities for the effective and efficient achievement of the SD goals – by providing wide and affordable availability of solutions for unification, awareness raising, spreading of information, processing, etc.

The penetration of Industry 4.0 is still ongoing and more and more of these processes and opportunities are still not completely available to governments for the achievement of the SD goals, which stand before all nations. Moreover, finding a solution for the lack of substantial leadership and motivation for investment, awareness, etc. is possibly one of the few challenges in front of SD, which have to be tackled not by advancements of technology, but by people themselves.

However, there already are examples of solutions, related to the innovations of Industry 4.0, which help along with making societies better, saving lives, creating efficiencies, interconnectivity, and ultimately - sustainable development.

Below, some of those examples are discussed as good practices before reaching the conclusions of the paper.

3. The future of Sustainable development

The future of SD has already started to unfold through the opportunities, which Industry 4.0 is providing.

For example, machine learning (AI) and an algorithm which collects and analyses data have identified a sex trafficking ring, thanks to the work of Rebecca Portnoff[19]. Through the combination of tracking transactions of bitcoin and using machine learning, Portnoff achieved results, which are undoubtedly resonant with the SD goals, as a part of her PhD thesis. The full potential of the software – but also of the ideas, which lie in the basis of this discovery, are yet to be discovered.

Another example of Industry 4.0 already assisting in the efforts to improve human lives and health is the AI, which together with augmented reality diagnoses patients with heart disease and gives them an estimate about their future condition[20]. This, the AI achieves with the help and based on aggregate data from many patients, historical data for the specific patient, as well as current data being collected on the vitals of the patient. Based on the diagnosis and the in-depth analysis, doctors can prescribe better treatment and improve the chances of patients to live. This technology may also be translatable to a wider scope of health irregularities, not only for heart conditions.

Not to be missed is also the developing notion and action of predictive policing – the assistance of big data and analysis to law enforcement, which prevents crime.[21] When implemented, big data can generate possible crime centres in the future, which can enable police to act before any harm has been done. This, as the cited article discusses, lowers restitutions and crime rates, and keeps communities calmer and safer. Further, predictive policing – in softwares such as PredPol or HunchLab, use various metrics and differing approaches to reach the same goal, and this means that there is still wide field for evolution. As of late, predictive policing is starting to be used internally, with bigger integration. instead of like a third-party software – like it has so far.[22] This suggests not only its advancements, but also developments of new features, such as software tactics suggestions and further Industry 4.0 upgrades.

As for government use of the benefits of Industry 4.0 – steps are being undertaken to get most governments ready for the cloud space[23], for example. Though this step, many more could be taken to immerse government in the vast possibilities of the new revolution. The current manifestation of this process is based on considerations on one of the less mentioned in this article elements of Industry 4.0 – cybersecurity. As governments are very aware of the potential risks of cloud computing, many measures are being considered and undertaken as part of a complete transfer.

Overall, there is no denying that Industry 4.0 is the future for many, if not all areas of life, including sustainable development. The many doors, connecting the increasing capabilities of technology and the innovative nature of humans can bring about countless opportunities for growth and success in achieving humanity’s set goals. More than that – the future has already started and is evolving rapidly, involving more parts of life and showing more signs of consideration of the future to come.

4. Conclusions

This paper explored the connection of future prospects, created by the needs and challenges of sustainable development and the available opportunities, presented by Industry 4.0. Through comparing the two sides, the paper drew the attention to:

1) The importance of achieving the sustainable development goals;
2) The unexplored opportunities, presented by the existence of the Fourth Industrial Revolution.

As was discussed, there are many prospects, which are already being explored in this direction. However, what should be kept in mind is the number of targets of the 2030 SD goals, as well as the needed time period to test and integrate many of the possible solutions. These considerations show the pressing imperative of connecting Industry 4.0 and sustainable development.

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SUGGESTED INDICATORS TO MEASURE THE IMPACT OF INDUSTRY 4.0 ON TOTAL QUALITY MANAGEMENT

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Abstract: *The development of "Smart Factories", featured by the arrival of "Internet of Things", "Cyber-Physical Systems", "Cloud Computing", "Big Data" etc., became widely deployed at the industrialized economies. Several researches highlighted the impact of utilizing such technologies (so-called Industry 4.0) on the industry; i.e. enhancement of products' quality, manufacturing processes, and customers' satisfaction. However, very few researchers focused on determining the impact of Industry 4.0 on enhancing the practice of Total Quality Management (TQM). This paper identified the set of qualitative and quantitative measures that can be used to determine the impact of implementing Industry 4.0 technologies at any industrial firm from a TQM perspective. The paper explored the TQM principles, identified qualitative and quantitative measures to be assessed, and suggested the means of data gathering sources and analysis techniques, hence, it would be possible in further research to determine the quantitative impact of Industry 4.0 on TQM*

Keywords: Total Quality Management, Quality Assurance, Industry 4.0, Big-data

1. Introduction

The tremendous development in every technological field reached an outstanding position in the recent decade, communication and networking technologies are quietly advanced, evolution of broadband and wi-fi connections, Internet of Things, Big Data, artificial intelligence and Cloud Computing, paced up an intelligent era symbolled by "Cyber-Physical Systems", which accordingly paved the way for further revolutions in several fields, hence, the industrial fields.

Industry 4.0, interpreted by several literatures as the "fourth industrial revolution", appeared firstly in 2011, and publicly announced in 2013 during the Hanover fair in Germany as the next industrial vision (Qin, Liu, & Grosvenor, 2016; Scheer, 2013; Zezulka, Marcon, Vesely, & Sajdl, 2016). Industry 4.0 came because of the increasing demand for innovative solutions in production and logistics, producers are focusing on creating greater value for customers, who are becoming more aware and demanding more advanced, reliable, personalized and high-quality products (Witkowski, 2017). Industrial businesses are seeking more competitive position through acquiring flexible production lines, zero inventory, efficient resources allocation, high responsiveness to market demand, lower logistics and labor costs, and to acquire more competitive advantages above other competitors (Rennung, Luminosu, & Draghici, 2016; Wang, He, & Xu, 2017).

The impact of utilizing technological solutions on the quality of industrial production was mentioned in several researches. Modern technologies assisted several quality approaches such as quality control and quality assurance techniques. Real-time quality monitoring and failure prediction models were developed by the help of new sensing technologies and big data analysis (Jiang, Jia, Wang, & Zheng, 2014).

The aim of this paper is to identify a set of qualitative and quantitative measures that can be used to determine the impact of implementing Industry 4.0 technologies at any industrial or business firm from a TQM perspective. The first section of this paper explores Industry 4.0 competences, and its impact on industrial advancement. The second section reviews the TQM principles, identify qualitative and quantitative measures to be used as assessment measures for good TQM practices. Accordingly, the discussion section will suggest the meeting point between Industry 4.0 and TQM, hence, determine the quantitative and qualitative indicators to assess the impact of Industry 4.0 on TQM.

2. Industry 4.0

The evolution of industrialized economies passed through three previous industrial revolutions; ***mechanization***, ***electrification*** and ***information*** (Zhou, Liu, & Zhou, 2016). ***Mechanization*** represent the first industrial revolution, initiated in the 18th century and symbolled by the utilization of mechanical production using water and steam power. The emergence of ***electricity*** at the beginnings of 20th century revolutionized the industry for a second time; electricity enabled industrial automation using electrical conveyors and assembly lines, this facilitated mass production in order to respond to the accelerating population growth after second world war. The third industrial revolution was symbolized by the further usage of mechanical ***automation***, using programming (programmable logic controllers) and mechanical robotic arms. (Blanchet & Rinn, 2015; Keller, Rosenberg, Brettel, & Friederichsen, 2014; Qin et al., 2016; Zezulka et al., 2016; Zhou et al., 2016)

The fourth industrial revolution (***Industry 4.0***) came as further ***evolution*** for the three previous revolutions, it came as a result of the advancement occurred in information and communication technologies (ICT), and the integration of this sector with industrial technologies, establishing the so called: "Cyber-Physical Systems", introducing the "Intelligent Factory" (Zhou et al., 2016), where machines, products, human became able to interact to each other and act autonomously.

There is no single definition for Industry 4.0, several definitions were introduced by several scholars. In his literature review (Lu, 2017) highlighted three definitions for Industry 4.0. ***Firstly***, Consortium II Fact Sheet, defined Industry 4.0 as "the integration of physical machinery systems with networked sensors and software used to predict, control and plan for better business and societal outcomes." ***Others*** defined Industry 4.0 as "a new level of value chain organization and management across the lifecycle of products.". A ***third*** opinion defined Industry 4.0 as "a collective term for technologies and concepts of value chain organization." Industry 4.0 is characterized by the integration occurred based on the Cyber-Physical Systems, Wi-Fi connectivity, Smart robots and machines, big-data, and smart factory to build an intelligent manufacturing system, emphasizing consistent digitization and linking of all productive units in an economy (Blanchet & Rinn, 2015). A core aspect of Industry 4.0 is the continuous connection between human, machines, and products during the production process (Albers et al., 2016).

Industry 4.0 is characterized by three key features; ***Interconnection***, ***integration***, and ***big data*** (Wang et al., 2017). ***Interconnection*** is the core feature of Industry 4.0, it means that all kinds of machines doing various jobs are interconnected together, forming an intelligent digitized value chain, where the product can hold readable information that can be understood by machines, thus, the machines can process the product, and when it is needed, it can re-adjust, diagnose, and repair production tactics until achieving an optimal situation (Zhou et al., 2016).

Integration is the ability of Industry 4.0 to perform vertical, horizontal and end-to-end integration. ***Vertical Integration***, refers to the networked smart business units; e.g.: smart factory, smart logistics, smart marketing, and services (Mrugalska & Wyrwicka, 2017), where manufacturing units are coordinating and communicating smoothly. ***Horizontal Integration*** over the value chain, refers to the forward to backward (customer to supplier) integration. Horizontal Integration enabled the manufacturing environment to become collaborative during the stages from development to production, resulting more efficient, reliable and effective manufacturing. ***End-to-End*** integration is the total integration of the entire process, performing a decentralized system where all participating entities have real time access to information and control is distributed to the production floor instantly (Keller et al., 2014).

The rapid development of internet and networking, produced huge amount of information which needed innovative methods and tools to handle (Blanchet & Rinn, 2015). ***Big Data*** and cloud computing granted the ability to conduct quick and efficient management for the constantly growing databases. Big Data consists of four dimensions: Volume, Variety, Velocity, and Value. These so called (4Vs) refers to the characteristics which allow Big Data to analyze data at a more advanced level than traditional tools (Witkowski, 2017).

The above described features, enabled the Industry 4.0 to provide solutions for different fields in the industry, advanced monitoring and analysis techniques, process and functional optimization, decision supporting at different organizational levels, moving from centralized to decentralized model of management, and upgraded the management approach from the traditional popular model to a modern one at several sides. This advancement came synchronized with the recent global trends in business, where the world is becoming more connected; global business models are expanding, and customers are more open to online shopping, demanding innovative products, with more personalized specifications. Moreover, new emerging economies are coming as key players at the global industrial stage, leading industrialized economies are experiencing key challenges, such as aging communities, the open competition with Asian economies of scale. All these challenges became the foundations of adopting Industry 4.0 technologies (Blanchet & Rinn, 2015; Federal Ministry of Education and Research-Germany, 2014).

To sum up, Industry 4.0 aims to obtain a flexible and automatic adaption of value chain, to offer the ability to customize products and maintain mass production at the same time, and to facilitate communication among all production elements; products, machines, human and resources. Furthermore, it aims to optimize production and to provide advanced level of interaction and coordination between different resources.

3. Total Quality Management (TQM)

Quality is defined as “the conformance of a product to customer requirements”, this implies that all tasks and activities made during the production fulfill the specifications translated from the requirements of the customer. Quality is a continuous approach aims to satisfy customers, it is not limited to screening out defective products, but also to reduce defects completely through building up enough knowledge about processes and functions (Kanji, 1990).

Total Quality Management (TQM) is a managerial approach that leads an organization to achieve a world-class position by insuring that its products and services satisfies customers, meeting their requirements and expectations (Yusof & Aspinwall, 2000). The Term “Total Quality Management – TQM” was first suggested and leaded by the American scientist Deming, who traveled from the United States of America to Japan to help the Japanese industrial firms to recover from the World War II. During his work, he implemented the statistical quality control and process control, as tools to trace production errors and to identify the source of products’ defects (Kanji, 1990). Later, he met with Juran, who was stressing to focus on customers’ satisfaction through producing fit-to-use products that fulfills the customers’ needs. Shortly, both Deming and Juran successfully caught the attention of market all over the world, their innovative ideas increased the production rates in Japan, and contributed very strongly to the Japanese well-known successful industrial miracle (Kanji, 1990).

Since then, the philosophy of TQM has been enhanced and expanded, several TQM approaches were suggested to guide the good implementation of TQM at organizations. The goal was to benefit business stakeholders, where everyone at the organization as well as the business processes are cooperating to produce value-for-money products and services, that fulfils and positively exceeds customers’ expectations (Dale, 2015). Researchers found strong evidences that TQM has improved the organizational effectiveness, flexibility, competitiveness, excellence, creating positive attitude, and a source of creating continuous improvement culture at the organization (Anu P. Anil & Satish, 2016).

Generally, the successful implementation of any managerial practice is measured by several success factors and the well implementation of several practices (Mrugalska & Wyrwicka, 2017). Based on several literatures, there are several approaches to achieve TQM, the most popular practice to attain TQM principles are those identified in (ISO 9001: 2015) model, which highlights the following practices to be the most effective for application: Customer focus, Leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management (International Organization for Standardization, 2015).

Other practices were identified in different literature, such as; top management commitment, Continuous improvement, supplier quality management, employees’ involvement and empowerment, education and training, strategic management, utilizing statistical quality control and quality assurance techniques, developing the quality culture among the organization, benchmarking, process and product management (Anu P. Anil & Satish, 2016). However, it should be emphasized that these practices are finally aiming to support the competitive advantage of the organization by producing high quality products or services and enhancing customer satisfaction.

4. Influencing Total Quality Management by Industry 4.0

The features of Industry 4.0 provided a solid rock for supporting business excellence; interconnectivity provided the ability of businesses to perform more efficiently by utilizing networking technologies, sensors and actuators. The whole value chain of production became interconnected, machines are connected to each other as well as to products and labor. Production processes can re-adjust itself to the optimal production scenario even when an urgent change occurs, early maintenance alerts are better to predict, logistics, warehousing, resources are allocated efficiently and effectively.

Integration of all business units, customers, and business partners (horizontal, vertical, and end-to-end integration) reformed the business model from linear to networked form, where all business units are connected to each other, and flow of work is running smoothly and efficiently.

In terms of Quality Assurance, the utilization of Industry 4.0 will upgrade the employees’ role from routine activities, to higher level of control and regulation for the manufacturing process, based on situation and context sensitive targets. The employees focus will be on creating innovative and value-added activities, which will be reflected to improve the quality assurance practices (Henning, Wolfgang, & Johannes, 2013). Moreover, Industry 4.0 will provide a real-time process monitoring to ensure that quality specifications are met during processing. Real time quality control will also enhance the quality control activities and will provide an early alarm for changes in products' quality. Internet connectivity will also provide the ability to track the product even after sale and gather information about its performance during operation. (Lee, Kao, & Yang, 2014)

Industry 4.0 can influence the best practices of implementing Total Quality Management principles. As mentioned before, TQM practices are known to be like the ISO 9001:2015 model, which are: customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management (International Organization for Standardization, 2015). Industry 4.0 will be able to serve the successful implementation of these principles as following:

- **Customer Focus**: Industry 4.0 will enable organizations to improve their customers' satisfaction through improving their products and services, fulfilling and innovate new products that exceed customers' requirements and expectations. Industry 4.0 will enable industries to provide customized products at a regular time, away from the complexity of changing mass production systems. Moreover, Industry 4.0 will provide businesses with early forecasting about consumption behavior and trends, thus, providing a competitive advantage for the business by providing proper products at the proper time.

- **Leadership**: Evidences showed that Industry 4.0 had a significant impact on information flow over the production line, integrating the business processes and supporting the ERP systems to optimize manufacturing management (Lee et al., 2014). Industry 4.0 will provide transparent production processes, thus, aligning resources such as labor and machines to demand will be efficient and optimized.

- **Engagement of people**: Industry 4.0 will support the communication and collaboration of all players inside the organization, it will stimulate innovation, encourage individual contributions. Data provided by Industry 4.0 outcomes will help people at their functional positions to use this data to avoid risks and suggest solutions, hence, be more initiative.

- **Process approach**: Industry 4.0 will support the transparency of business and production processes in the organization, it will help to optimize processes, improve efficiency and resources allocation. Industry 4.0 will provide the possibility to simulate processes in a virtual environment, adjust and modify virtually before real implementation on the floor, this will enhance processes to achieve optimum situation (Husti, Daroczi, & Kovacs, 2017). Moreover, Industry 4.0 will facilitate tracing production bottleneck, defects' sources, and minimize production cost. Additionally, it will improve the supply chain responsiveness, through total integration from market demand back to suppliers (Wang et al., 2017). Industry 4.0 will provide accurate information about processes (time, risks, resources, critical constraints) thus, it will help the planning level of key-processes to maintain continuity and efficiency.

- **Improvement**: Industry 4.0 will provide a basis for continuous improvements at the product, process and the business level for an organization. Totally connected production and supply chain will improve performance and responsiveness of the system. Experiments showed the ability of products (automobile industry as an example) to send information to the producing companies about operating problems, thus, enhancing future products to overcome such problems.

- **Evidence-based decision making**: Industry 4.0 and the new IT solutions such as big data, afforded a great capacity to improve the decision-making process in real time (Husti et al., 2017). Machines are self-learned, connected to each other forming a collaborative community, collecting and analyzing data, providing ability to make independent decisions. Experiments show that Industry 4.0 techniques can send earlier prognostics about machine health, reducing downtime and afford maintenance on time.

- **Relationship management**: total integration and effective communication between all stakeholders of an organization became one of the benefits of Industry 4.0. Suppliers are connected with production systems, understanding the organization needs, and responsive to markets demand more than ever before.

Accordingly, the impact of Industry 4.0 on the successful implementation of TQM will be measured by identifying a set of indicators that represent each of the TQM principles identified earlier in this paper. The following list of indicators are identified based on the TQM principles and the measurement means based on Industry 4.0 technologies. Table 1 summarizes the sets of indicators assigned to each of the TQM principles:

Table 1: Set of indicators used for measuring Industry 4.0 impact on Total Quality Management.

TQM Principles	Indicators for improvements	Industry 4.0 impact Indicators	Means of Measurement
Customer Focus	• customer satisfaction & loyalty, • growth % in customers' base, • Improved organization's reputation.	• Response time to customers' orders, product customization, and new product developments • Easy to gather customer feedback through smart product connectivity • Realtime in-field performance product monitoring	• Internet of Things, Wi-Fi and Big-Data will be utilized as data gathering and analyzing tools.
Leadership	• Unity of purpose among the organization, • Aligned strategies, policies, processes and resources, • Effective communication between all administrative levels.	• Effective allocation of different resources (operational effectiveness) • Increased revenues due to optimized allocation of resources	• Realtime resources monitoring and automatic regulation and reallocation. • System monitoring dashboards, ERP systems
Engagement of people	• Increase motivation of people, • Increasing innovative ideas, • Enhanced people satisfaction, • Self-evaluation and self-improvement culture.	• Number of innovative ideas or initiatives created or taken by employees • Increased value (%) of employees' satisfaction • Increased revenues due to less human related failures • Number of problems solved by employees	• Human Resources smart systems • Statistics and data gathered during production
Process approach	• Identify key processes and points of improvements, • Optimized performance and effective process management, • Manage processes, and interrelations, as well as dependencies.	• Number of process re-design activities made because of data analysis and enhancement decisions • Production lead time • Suppliers' responsiveness to new supply orders • In-process real time quality control activities (percentage of defects) • Decreased percentage of processing downtime	• ERP system (integrated with customers and suppliers) • Sensors and actuators within production process • Process related big-data analysis • Internet of things (machines data) • Maintenance management system
Improvement	• Responsive systems to customer requirements, • Enhanced ability to react to development of processes, products and market needs, • Support drivers for	• Enhanced percentage of response time (production lead time) • The range of customization options that can be	• ERP system and CRM system • Big-data themes • Customers feedback

	innovation.	fulfilled by the business without affecting the productivity normal rates • Number of newly developed products and time needed to introduce it to markets	
Evidence-based decision making	• Clear and agreed decision-making process, • Data availability and clarity, • Effective past decisions, • Analyze and evaluate data using suitable methods and tools.	• Increased revenues due to recently take decisions • Number of reporting and automatic recommendations learned by or from the smart production system • Ease of data mining and friendly presentation of results and recommendations	• Big-Data analysis • ERP system
Relationship management	• Stakeholders are identified and suitable communication tools to each are known, • Stakeholders are satisfied, and their feedback is considered, • Suppliers are responding to materials requests on time and at the required quality, • Supply chain is stable and no downtime due to lack supply.	• Number of received to processes communications from stakeholders. • Rate of satisfaction for stakeholders is improving continuously • Improved suppliers' responsiveness rate • Percentage of downtime due to lack of supply is in its minimum value	• ERP system (integrated with customers and suppliers) • Sensors and actuators within production process • Process related big-data analysis • Internet of things (machines data)

5. Conclusion and further research topics

Industry 4.0 positively influenced the successful implementation of Total Quality Control, technologies and approaches utilized by Industry 4.0 improved the quality assurance and quality control experience. Communication and big-data sources improved better understanding and enhanced responsiveness for customers' requirements, hence, improved their satisfaction. Smart factory, smart product, and smart machines, are new terms referring to high connectivity and integration of smart technologies in the value chain, this resulted more dynamic production processes that are able to adjust according to optimum real-time requirements.

There are several researches that mentioned the positive impact on quality, but these researches highlighted this impact briefly and in qualitative manner. However, it is important to conduct further applied research to translate the indicators suggested by this paper into active and real-time measures. It is important also to reflect the changes occurred and the capabilities offered by Industry 4.0 on the quality management models. Hence, developing a new quality management model which should be based on Industry 4.0 technologies, considering that quality requirements in the ongoing present and coming future is different and advanced

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SOCIAL ASPECTS OF THE DEVELOPMENT OF THE CONCEPT "INDUSTRY 4:0": RISKS AND PROSPECTS FOR THE TRANSFORMATION OF HUMAN RESOURCES

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Abstract: *The formation and development of the concept "Industry 4: 0" is associated with significant changes in the structure and characteristics of human resources. It concerns the problems of the new structure of employment, the transformation of the educational system, the deepening of regional disparities. At the same time, the actions developed within the concept, including various programs, don't pay due attention to possible social risks and measures to reduce them.*

Keywords: HUMAN RESOURCES, CONCEPT OF "INDUSTRY 4:0", SOCIAL RISKS

1. Introduction

The objective tendencies of social development at present are linked with the "INDUSTRY 4:0" concept, which proposes a pivotal change in the manufacturing process of products and services as well as in the work force. It is no longer about innovation, but about essential transformations at the base of production, which change the traditional representations of the laws of economy, economic behavior, and educational and scientific systems.

The components of the "INDUSTRY 4:0" concept have relatively recently become the subject of active interest among the scientific community and practitioners; however, we can observe the phenomena and involvement processes of all spheres of social life transforming into something new.

If we analyze the publications, opinions, reports, and facts relating to this concept, then we can say that most of the attention is drawn to the technical aspects and emerging opportunities, the changes in production methods and in the methods and areas of interaction between producers and consumers, the economic resources, analysis of the technical prerequisites for realizing a new wave of innovation, the formation of new types of cities, and more.

At the same time, changes in production methods and economic activity cannot not lead to social transformations, the depth of which can perhaps be compared to the first industrial revolution. These transformations are certainly not always considered to be positive. The realization of the "INDUSTRY 4:0" concept relies on the objective preconditions, with its development focusing on achievements in technology, including informational. However, it is necessary to analyze the possible social consequences for society and identify the social risks in order to find mechanisms to reduce them. This has to do with problems of the new employment structure, transformation of educational system, and deepening of regional disparities.

The *objective* of the theoretical research is to look at possible changes in human resources and emerging soical risks connected with the "INDUSTRY 4:0" concept being realized.

2. *Overview of the formation of prerequisites for the "INDUSTRY 4:0" concept in relation to social risks.*

The works dedicated to the "INDUSTRY 4:0" concept highlight the development of Internet of Things (IoT) which suggests significant changes in the activities of enterprises [1, 2, 3]. In traditional markets, enterprises represent a relatively autonomous socio-economic system in which business processes are organized in a particular way, and resources are consumed and transformed influence from the personnel. IoT suggests that various participants in the market are joined in order to satisfy consumer demands and be flexible in responding to consumers' requests by using a single platform based on cloud services.

This changes the interactions within the enterprise and the role of the personnel. For traditional enterprises, it is the personnel who is a management resource, influencing the main kinds of resources, while an exchange of information takes place among people. The IoT system of management directly affects actuating devices in enterprises, and here the information and means of processing it are already a basic resource. In this sense, a number of processes in the future will be fully automated (according to specialists, examples of possible fields would be transport infastructure and transport logistics). Accordingly, this will cause a reduction of personnel employed in similar fields as well as a change of the professional demands of those who remain.

The commercial Internet of Things, based on the principles of digital economy, makes it possible to combine resources (not only manufacturing and transportational but human as well) into "software-controlled", virtual resource pools, forming a shared economy in the industrial sphere, whereby the user is not provided with the devices themselves, but with the functions of the devices (the results of their being used), formed by joining and realizing cross cutting business processes and production processes.

Modern enterprises are now changing to a much larger degree under the influence of management technology, rather than production technology.

The consulting group J'son & Partners Consulting [4] notes the important tendencies of the modern economy that are related to the growth of IoT and to organizational and technological changes, such as:

- growth of access to data on the nature of equipment and product use (related to the growth of number of embedded devices) forms the possibility for new business models and services to develop;

- the economy's growth potential is ensured by the producers and internet-service providers themselves, who come to traditional spheres and transform them using cloud technology (taxi service, reservation of accommodation, etc);

- using new technology in the production chain and virtualizing the production functions create the possibility of producing a single product or a small series while taking into account the individual preferences of the consumer, thereby earning the manufacturer a profit;

- opportunities for sharing production infrastructure, thereby increasing the accessibility of resources for small businesses and widening the potential offers of various services.

Aside from the tendencies mentioned, the consulting group noted another one which directly impacts human resources:

"the functioning of various branches of economy will become continuously more complicated under the influence of technological development and will increasingly by carried out due to automatic decision making by machines themselves based on analyzing a large amount of data from connected devices, which will lead to a gradual reduction of the personnel's role, including qualified personnel. Quality professional education, including in engineering, as well as special educational programs for workers, and training will be required." [5] Therefore, the number of work places, including ones with qualification requirements, are expected to decrease in the future, thus forming a risk of unemployment.

When looking at the role of the service industry in a postindustrial economy, the majority of researchers noticed its role was in providing jobs and dampening the effect of reduction in the work force on industrial enterprises (for example, due to automation). However, when realizing the "INDUSTRY 4:0" concept, this dampening of social risks will not work. Moreover, the service industry itself will be at risk.

Russia is also under the influence of the new tendencies and processes related to the new technology paradigm. This is connected not only with the development of various local markets, but also with the formation of government programs.

We will hightlight a number of points noted in literature and from internet sources.

The Internet of Things is actively developing in the transport sector. This includes not just remote monitoring systems. Nowadays, smart phones are very popular among users (around 50% of all mobile devices), and this has acted as a catalyst for the development of such services as Uber and YandeksTaksi, while systems for monitoring road congestions on maps have been constructed [5].

The same tendencies exist in freight transport (logistics); the start ups GoCargo and iCanDrive are based on IoT. Specialists name such producers of remote vehicle tracking devices as Omnicom, "AutoGRAF Satellite Vehicle Tracking and Control System", GalileoSky, "Fort", Naviset, "Incotex", "Shtrih-TahoRUS", "Granit Navigator", M2M Cyber and others.

According to predictions, it will be the transport sector leading the new economy.

The company Ovum believes that transportation will significantly surpass the other economic sectors on income from the market of the Internet of Things [6] .

This growth will be driven by the cost reduction of special equipment as well as the reduction of costs relating to implementing innovative solutions.

Accordingly, the employment structure in the transport sector will change (and is already changing).

According to the opinion of Machina Research and the company Nokia [7], income from the global market of the industrial Internet of Things will reach 484 billion euros by 2025, and the main sectors will become transportation, manufacturing, utilities, health care, and smart house application.

German scientists are considering ideas of a cyber platform, which would combine three types of networks: internet of people, internet of things, and internet of services (academy Acatech). It is noted that the development of "INDUSTRY 4:0" changes all social relationships, therefore problems in improving technology, technics, and production relations should be studied and solved by considering socio-cultural and demographic factors [8].

The consulting company IDC presented a new annual report, Russia Internet of Things Market 2017-2021, according to which expenses for the internet of things will reach over $9 billion in Russia by 2021 (for comparison, data on this company show 2016 expenses at $3.48 billion). Investments in equipment, software, services, and communications, which are involved in creating solutions for the internet of things in Russia, will grow on average 22% annually. Other factors highlighted for their contribution to these dynamics are: the interest and support from the government, the active digital transformation of companies, and the creation of partner systems for solution providers [9].

The "Digital Economy" program was adopted in Russia in July of 2017. The adoption of the program was due to a number of reasons, including Russia lagging behind in readiness for a digital economy, as noted in the program's text. It is pointed out that, according to a World Economic Forum's Global Information Technologies report, "The Russian Federation holds the 41st place in readiness for a digital economy at a significant distance from ten leading countries: Singapore, Finland, Sweden, Norway, the United States, the Netherlands, Switzerland, Great Britain, Luxembourg, and Japan. In terms of economic and innovative results for using digital economy, the Russian Federation comes 38th, lagging far behind leading countries like Finland, Switzerland, Sweden, Israel, Singapore, the Netherlands, the United States, Norway, Luxembourg, and Germany" [10].

World Economic Forum's Global Information Technologies report 2016 says «The Russian Federation remains in 41st place this year, as in 2015. The country places in the top third of the rankings for Readiness, Usage, and Impact, yet continues to be held back by a weak and deteriorating regulatory environment. As mobile and fixed Internet tariffs are very low and dropping further (10th place overall on affordability), individual usage continues to rise in almost every dimension, leaving Russia in 40th place in this category. However, the data suggest that infrastructure build-out is not keeping up with demand as Russia sees its availability of Internet bandwidth per user falling. Although Russia is close to the median in terms of business use overall, online sales to consumers (as opposed to other firms) are particularly strong (35th place). The positive impact of ICTs is felt both in the economic and the social dimensions, as reflected in rankings in the top third for both impact pillars» [11].

The goals of the program are: "to create a digital economy ecosystem in which digital data are a key factor in production in all spheres of social and economical activity and where effective cooperation is provided including across borders, in business, in the scientific and educational community, in government, and among citizens; to create the necessary and adequate conditions of an institutional and infrastructural nature, to eliminate existing obstacles and limits on creating and/or developing high-tech businesses..., to prevent new obstacles and limits from arising; to increase competition on the global market both in individual sectors as well as in the economy as a whole."

Three levels of digital economy are highlighted that in close cooperation affect the lives of citizens and society as a whole: economic markets and sectors; platforms and technology; an atmosphere which "creates conditions for developing platforms and technology and for the effective cooperation of subjects of the economic markets and sectors (spheres of activity), and which also covers regulation, information infrastructure, personnel, and information safety."

It is pointed out that the Program focuses on the two lower levels of digital economy, the directions being: forming a suitable environment (particularly personnel and education, and forming research skills); forming the basic infrastructure elements for digital technology (informational infrastructure, information safety) [10].

Thus, it is possible to acknowledge the influence digital technology has "on the lives of citizens and society as a whole." The health sector can be named as one of the branches of economy primarily affected by the transformations. Also presented in the course of the program are social aspects relating to changes in the system of education and personnel training. The following aims are considered: "create key conditions for training the personnel of digital economy; improve the education system, which should provide a digital economy with competent personnel; labor market, which should be based on the demands of the digital economy; create a system of motivation to develop the necessary competencies and for personnel to take part in the development of the digital economy of Russia." Changes in the activities of educational organizations on all levels are envisaged on the "road map" of the program and propose the development of "digital competencies" and the formation of "a personal development trajectory.

The influence on human resources and society is considered in terms of its challenges and threats: "the problem of ensuring human rights in the digital world, including in the identification and preservation of digital user data, as well as the problem of ensuring the citizens' trust of the digital environment; the threats to individuals, business, and government, which are related to the tendencies of building complex hierarchical information and telecommunication systems that widely use virtualization, remote (cloud) data storage, as well as various communication technologies and terminals." [10].

However, possible social problems and risks are practically not given any attention in this government document (risks for the labor market, for the education system), as a result of which there are not even any indicators of the need to develop measures to mitigate possible negative phenomena.

One important problem, which is not only technical but social as well, is the ensurance of protection against unsanctioned access to user data. A lack of adequate protection can lead to threats to social safety increasing.

According to data from the company Avast, a research of smart devices in Russia showed that almost 24% of these devices were not protected against cyber attacks (for example, "nanny cams"), unsecured printers (27%), routers (almost 70%); this could lead to a violation of privacy and an increase in crimes. Unsecured devices can be used for connecting to other devices, for example, connected to a smart house, and can be used to control their function and can even cause harm [4]. Children can fall under this threat. The potential risks of using the My Friend Cayla dolls (an interactive toy that can hold a conversation with a child by using special devices hooked up to smart phones and tablets, as well as voice recognition technology), turned out to be so great, that the FBI (USA) were forced to warn the parents about the dangers of the innovative toy. Audio files recorded by the toy were collected by the corporation Nuance Communication, and a private database was made up of 30 million voice samples. In February of 2017, the federal network agency of Germany recognized the doll as covert spyware and obliged parents to get rid of the toy [12]. Even if the manufacturers of similar toys use the collected information to improve their performance, breaking into databases and leaking information is still possible (mass media provides the example of theft of data from a database which was collected by the manufacturer of the smart plush toys CloudPets) [13].

The recommendations given by the company Avast are to change passwords and software. However, a significant amount of users have little knowledge of the technical details and subtleties of devices. Accordingly, educating users is necessary in order to ensure an acceptable level of social safety.

It seems social risks relating to changes in the demands of the labor market and employment structure are much higher. According to company research from World Skills Russia and The Boston Consulting group (BCG), by 2025 the most in-demand workers in Russia will be those from the so-called "knowledge" category, who are capable of analytical work, improvising, independent solutions, and working in uncertain situations. As of now, approximately 17% of workers perform creative or analytical tasks (in European countries - 29-45%), around 50% are employed in predominantly routine work. 35% of workers are employed in positions that do not require special training (the most common professions are: driver (7%), salesperson (6.8%), security guard (2%)). It is suggested that around 10 million people may be unemployed in Russia [14].

Personnel of low qualifications are at the most risk of losing their jobs (janitors, assistants, drivers, salespeople). Also at risk are workers who perform algorithmic work and technical work according to instructions (administrators in the service industry, workers of individual specialties, and workers from the service industry), as they can easily be replaced by machines, robots, and computer technology (according to Citibank's estimates, there will be around 57% of such professions in the next 10-15 years). The work of the mentioned groups is characterized by routines, standard tasks, decision making based on instructions, and physical labor.

It is worth noting that Russia is noticeably behind advanced countries when it comes to the level of robotics (1 commercial robot for every 10 thousand in 2017), therefore, problems of changes in employment will arise somewhat later than in other countries. However, active steps in the development of a digital economy can move this period noticeably closer. Workers who are let go due to this will be defined by quite low qualifications, while new work places for them may simply not be found. This could cause a growth in marginalized groups of society, a higher crime rate, and a lower quality and standard of living.

The international service provider Orange Business Services together with iKS-Consulting conducted a study of six Russian industry leaders of the enterprise market of the internet of things (IoT) - transport, finance, agriculture, retail, construction (smart building), and industry (August 2017). According to the analysts' estimates, traditional automation systems in the leading industries are used on average by a third of enterprises (CRM-, ERP- and SCM-systems, as well as automatic control systems; the M2M solutions, which appeared on the threshold of the transition to the internet of things, stand out separately) [15].

Researchers believe that the biggest growth in the implementation of the IoT-solutions is expected in retailing by 2020. In 2017, there were 1.4 million connected IoT devices in this sector; around 4 million are expected by 2020. Furthermore, this sector has seen a high level of implementation of CRM systems (23%) and SCM systems (12%), and a high level of competition which encourages the development of high technology, for example tracking goods using radio frequency tags (RFID), monitoring shoppers' movements using mobile devices based on technology that tracks the movement of buyers on store floors and using face recognition systems. This will change the requirements for personnel employed in retailing in the future. If today's trade sector successfully absorbs workers who have been let go, then the situation may change in the future.

S. Yezyk, general director of "Center 2m" notes that the transport sector is showing interest in IoT solutions, and the number of participants in information exchange is increasing. Thus, a "connected" car can provide information to insurance and leasing companies and the municipality, and processing this data makes it possible to predict malfunctions and recommend methods to fix them. [16].

In the Russian IoT market, pilot projects are being developed and introduced, technology is being tested, and completed industry solutions are being replicated. This allows us to conclude that the potential social risks will keep growing.

Incentives and barriers in the path of IoT development in Russia have been analyzed in the research from PwC [17]. In particular, the researchers noticed a limit on the side of consumer demand, namely the low income level. Thus, according to official statistics, the poverty level (population with an average income lower than the subsistence level) on average makes up about 13% of Russia (the subsistence level being 10,329 rub. – around 150 euro). This must also be taken into account, since there is a risk of excluding a large portion of the population from the consumption of modern technology, and this can lower their standard of living even more. On the other hand, this portion of the population often performs unskilled work and could lose it with the launch of an industrial revolution, and effective demand will decrease even more. In other words, consumers will not have the means to buy smart things.

At the same time, the Russian consumer market of smart things has a particular specificity (for example, purchasing expensive mobile devices on credit, saving for months to buy a desired gadget, etc.). Thus, the proportion of iPhones in the smart phone market in Russia continues to grow and makes up more than 10% of sales in natural numbers.

Specialists have named the following as other social factors constraining the development of IoT: lack of specialists (inconsistency of the education system with future tasks), and inadequate knowledge and skills in working with smart devices.

It is worth noting the significant social effect that IoT technology can have for the health sector where micro and nanosensors will help improve the quality and accuracy of diagnostics.

IoT technology will have a multiplicative effect on the economy sectors due to an increase in workforce productivity and a reduction in costs. Accordingly, unemployment will increase. At the same time, not all those who will have lost their jobs will be able to learn the necessary professions, since changing from routine activities to creative ones is very difficult, especially for those with a long work history.

3. Solution of the examined problem

When considering the tendencies in the development of a new economy and the potential risks that may arise, it is necessary to provide social dampers and preventive measures to reduce risks.

A solution to part of the social problems can be linked to global changes in taxation principles, creating special social funds formed at the expense of super profits of companies (leaders of the new industrial revolution) or with taxation on robots. This idea was already put forward during an interview on the American internet portal Quartz by the founder of the Microsoft corporation, Bill Gates, who thought that due to the ubiquitous replacement of human labor by machines and robots, the work of the latter should also be taxed. He believes that employees pay taxes into a social insurance fund and personal income tax, so if the job of a worker has been replaced by a robot, this amount of taxes should be left. The created monetary funds could be used to pay social obligations for the elderly, unemployed, and large families. This would only be possible with state coercion, as employers will not make such deductions voluntarily. However, the European Parliament rejected the initiative to tax robot labor; according to the head of the European sector on digital economy Andrus Ansip, taxing the results of progress will lead to the technological lag of the European Union [18].

The problem of social risks in a new economy is recognized by the International Bar Association (IBA). According to research conducted by the association, around a third of people could lose their jobs due to the use of new technology. Therefore, it is necessary to change the labor legislation and new approaches to the right to work, since existing laws will not be capable of protecting people against the new reality. Gerlind Wisskirchen, IBA GEI Vice Chair for Multinationals and coordinator of the report, commented: «Certainly, technological revolution is not new, but in past times it has been gradual. What is new about the present revolution is the alacrity with which change is occurring, and the broadness of impact being brought about by AI and robotics. Jobs at all levels in society presently undertaken by humans are at risk of being reassigned to robots or AI, and the legislation once in place to protect the rights of human workers may be no longer be fit for its purpose, in some cases» [19].

In the opinion of the association, governments must think about which jobs will be left to people and which jobs can be given to robots. It is worth providing job quotas for people. They also suggest introducing the special label "Made by human". Mechanical labor is not the only area shrouded by the threat. Lawyers also support the idea of a robot tax.

We should also highlight the problem of social adaptation to a digital economy, particularly, as concerns the need for continuous professional development and the development of new skills in the digital field. Experience in implementing internet technologies in the activities of various social organizations in Russia shows a high level of momentum, especially in provincial regions. One frequently noticed situation is where an interactive space is created formally (to meet law requirements, standards, etc.), but fails to work in reality. This can be concluded, for example, by analyzing the websites of many provincial houses of culture, primary schools in towns, passport offices, etc., even though the introduced technology is fairly simple. Thereby, a regional inequality between the central and provincial regions is formed.

Overcoming the risks of social security in connection with the use of innovative devices contributes to the growth of digital literacy among the population. This problem is consistently included in the Russian government program of digital economy.

The development of a new industrial revolution leads to a new social stratification. Expanding access to data and new solutions helps eliminate barriers for business and this provides new opportunities for a portion of the population. For those who are unable to adapt to the new challenges, a reduced salary, higher chance of unemployment, a lack of benefits, and a loss of economic status will become their new reality. At the same time, the funds for reducing social risks using traditional methods (taxes, insurance premiums) will be scarce.

The increasing inequality between various countries and regions can be cited as a global social risk. For those governments which are developing the IoT concept, the result is a strengthening of their position in the global system of division of labor and, as a result, the growth in the amount of quality jobs and the general growth of quality of life in these countries. Reducing the demand for low-skilled workers leads to a change in migratory behavior; however, those who have already come to a country, will probably create new social problems (employment, benefits, etc.). Poor countries practically lose the chance of a normal existence, since they will not even be able to supply human resources in the future. Therefore, it is necessary to think about global funds for social assistance, since the risks of social security will increase in this case.

4. Results and discussion

The examined social risks certainly do not cover all the possible negative social consequences and emerging issues. Experts also point out issues of work hours and issues of responsibility for decisions. The question arises, where does the responsibility of a human, robot, and automated decision making system start and stop? This is already relevant for such sectors like transport, where driverless vehicles are becoming more widespread. Another problem is the social responsibility for the work of technically complex systems (cost of error).

5. Conclusion

The development of the "INDUSTRY 4:0" concept carries with it great technical opportunities, including the growth of all economic indicators and improvement of the quality of consumption.

At the same time, the social consequences of a new industrial revolution are ambiguous, and a whole range of emerging social risks can be highlighted.

The most significant social risks are:

- social risks of realizing the newest technological solutions: social safety of device users, protection from criminal actions;

- social risks of deep changes in the labor market: inconsistency of labor legislation with ongoing changes, risk of unemployment and deepening inequality, risk of reduced income;

- social risks of inconsistency of activities of educational institutions (including teachers) with the demands of the new labor market;

- social risks of lack of financial resources for helping the unemployed, for retraining, etc. (including as a result of reduction of tax revenue on personal income and contributions to social insurance funds);

- social risks of a new regional inequality forming, due to international competition, including the fact that human resources of some countries will be unclaimed in the new economy; the same competition could appear within a country as well, between regions and between the central and provincial areas;

- risks of social exclusion of people who are unable to master digital competencies and provide flexibility in professional activities.

Possible courses of action to reduce the potential social risks are:

- global change of taxation principles relating to the creation of special social funds formed at the expense of super profits of companies (the leaders of the new industrial revolution) or with taxation of robots;

- significant changes in international and national labor legislation focused on protecting human labor against robot labor (a job quota, special labels on products, etc.);

- development of measures aimed at social adaptation to a digital economy, increasing digital literacy.

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ON THE WAY FROM INDUSTRY 4.0 TO INDUSTRY 5.0: FROM DIGITAL MANUFACTURING TO DIGITAL SOCIETY

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Abstract: *Nowadays the world is surviving the fourth industrial revolution named Industry 4.0, which combines physical world of real things with their "virtual twins". The man with his intellect, creativity and will lies beyond this ideology. Now the image of a new paradigm of Industry 5.0 could be seen. It involves the penetration of Artificial Intelligence in man's common life, their "cooperation" with the aim of enhancing the man capacity and the return of the man at the "Centre of the Universe". The paper outlines modern technologies – from IoT up to emergent intelligence, being developed in organizations where authors work. The convergence of these technologies, according to our minds, will provide the transformation from Industry 4.0 to Industry 5.0.*

Keywords: PARADIGM OF SOCIETY 5.0, RETURN OF THE MAN, EMERGENT INTELLIGENCE, EVERGETICS, ONTOLOGY AND KNOWLEDGE BASE, MULTI-AGENT SYSTEMS, INTERNET OF EVERYTHING

1 Introduction

The breakthrough in new information technologies ensured the world to stand on the threshold of the 4-th industrial revolution, named «Industry 4.0».

During the implementation of concepts of "Industry 4.0" the technologies of design and production of difficult technical products cardinally changed. The view of a role of computers in control of the enterprises and, first of all, regarding to methods and means of industrial automation of the plants and factories which passed the way from use of sensors and automation of technological processes – to integration and visualization of data and intellectual support of decision-making by users, changes, too.

It is known that the term "Industry 4.0" was first publicly introduced in 2011 by a group of representatives of Germany business, political and scientific community. It was defined as means to achieve a competitiveness of the industry through the reinforced integration of "cyberphysical systems" (CPS) into productions [1]. At the same time, if 3-4 years ago the concept of "Industry 4.0" was viewed by many people as the next advertizing course, then now the interest in it has developed into real investments and results. According to researches of PwC the annual volume of investment into digital technologies within "Industry 4.0" will exceed 900 billion US dollars by 2020 [2].

It is necessary to note that still now the term "Industry 4.0" remains rather foggy and dim. The words of one of a production site manager with automotive manufacturer "Audi" could serve as a confirmation of this. He told that: "Even though Industrie 4.0 is one of the most frequently discussed topics these days, I could not explain to my son what it really means" [3].

In [4, 5] Industry 4.0 is determined as «an umbrella term used to describe a group of connected technological advances that provide a foundation for increased digitisation of the business environment». It is consistent with the definition of Industry 4.0 made by McKinsey as "the next phase in the digitization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing" [6].

There are usually identified four key components (CPS, Internet of Things (IoT), Internet of Services, and Smart Factory) and 6 major technologies (the Industrial Internet of Things (IIoT) and CPS, additive production (3D - the printing), BigData, an artificial intelligence (AI), Collaborative Robots (CoBot) and the virtual reality) to develop Industry 4.0 [3]. At the same time the main attention concentrates around technical aspects of their implementation. And the man, with his mental, creative and will abilities, lies beyond this ideology [7]. The only thing that is given a deal regarding human resources is possible changes of labor market caused by the Industry 4.0 [8-10].

Such situation is unsatisfactory and it finds reflection in a number of the articles devoted to the Industry 4.0. In particular, in [11] it is marked that «the world of work in Industry 4.0 will still be inconceivable without human beings» The author of [12] asks the fundamental issues «How can people and society benefit from Industry 4.0?»

Moreover, in spite of the fact that Industry 4.0 is only at the initial stage of the development and the main achievements can be expected not earlier than 2020-2025 [10], the image of a new paradigm of Industry 5.0 could be seen. It involves the penetration of Artificial Intelligence in man's common life, their "cooperation" with the aim of enhancing the man capacity and the return of the man at the "Centre of the Universe".

In this regard, probably, the more exact term instead of Industry 5.0 is "Society 5.0" (SuperSmart Society) that was offered in 2016 by Japan's most important business federation, Keidanren and being strongly promoted by Council for Science, Technology and Innovation; Cabinet Office, Government of Japan. [13]. Unlike the concept of Industry 4.0, Society 5.0 is not restricted only to a manufacturing sector, but it solves social problems with the help of integration of physical and virtual spaces. In fact, Society 5.0 is the society where the advanced IT technologies, IoT, robots, an artificial intelligence, augmented reality (AR) are actively used in people common life, in the industry, health care and other spheres of activity not for the progress, but for the benefit and convenience of each person [14].

The paper outlines modern technologies – from IoT up to emergent intelligence, being developed in organizations where authors work. The convergence of these technologies, according to our minds, will provide the transformation from Industry 4.0 to Society 5.0.

2 On the way to Society 5.0: directions and prospects

This fig. 1 depicts the conventional "pyramid of sciences and technologies" which convergence, in our opinion, can provide the transition to Society 5.0. Distribution of layers in a pyramid to its top comes from the bottom in process of abstraction from the world of real objects (may be with some elements of AI), to concepts of Society 5.0, which can include the Evergetics – a new theory of intersubjective management processes in everyday life, and emergent artificial intelligence.

2.1 New types of distributed computers and "Swarm of Robots"

These technologies are the hardware base for creation of the intellectual self-organized systems of different types.

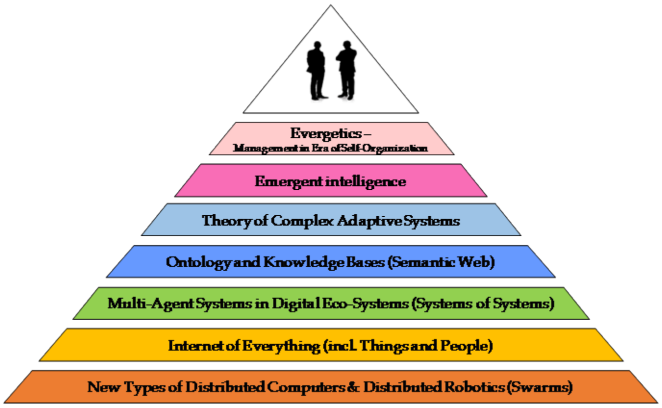

Fig. 1 *Convergence of sciences and technologies in Society 5.0*

The distributed computer networks have complex topological network design and provide multithreaded parallel and asynchronous computings.

"Swarms of robots" represent the self-organized groups of robots. And here we do not refer to the anthropomorphous robots only, but to the distributed smart technical systems. The intelligent gas-turbine engines with smart blades can be an example of this technology. In such engines each blade "agrees with neighbors" about its position (how it should be turned) in an air-gas path to provide optimum conditions of working medium (gas) flow and to prevent emergency state of the power plant [15].

These technologies also include the self-organized groups of small spacecrafts (nano- and piko- satellites) which, like the swarm of bees, can be multifunctional and flexibly configured in order to solve a particular problem, reliable and stable in the most different situations during the Earth observation, objects research in open space, telecommunication problem solving and other various tasks [16-18].

Another example is the "swarm" of pilotless tractors and other farm vehicles which are "… speaking with each other …" and are "… in constant communication among themselves, collaborating with each other" [19, 20], etc.

2.2 Internet of Things and People

IoT (including industrial IoT (IIoT)) is intensively developing technology that complement traditional and usual to us Internet of people, and is an automation basis in Industry 4.0 and Society 5.0.

As it is given in official Recommendation ITU-Y.2060 - Overview of the Internet of Things, IoT is a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies [21]. At the same time, generally, the "thing" means an «object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks» [21].

In 2013 Cisco offered the term “Internet of Everything” (IoE), which is considered to be wider than IoT. Cisco determines IoE as ”the networked connection of people, data, process and things. The IoE is made up of many technology transitions, including the Internet of Things” [22].

It is obvious that implementation of IoT (IIoT, IoE) requires development of a number of perspective technologies, including sensor (intellectual sensors, smart dust, …), telecommunication (RFID, NFC, Wi-Fi, 6LoWPAN, ...), etc. It will allow the "intelligence" to be encapsulated in a "thing" at a stage of its production. At the same time in Society 5.0 (as, however, and in Industry 4.0) IoT (IoE) should not be a technology for the sake of technology. Its opportunities should be directed to the benefit of the person, to improvement of quality of his life.

2.3 Multi-Agent systems and technologies

Implementation of IoT (IIoT) technologies assumes transfer of computation to the virtual world ("cloud") where each "virtual" twin of objects of the real world acts according to the selected algorithm and rules. For communication of the real and virtual worlds intellectual agents are used. They can perceive information from the real world, make decisions and coordinate them with other objects or users in real time. At the same time real objects can independently work or be parts of more difficult objects (household things, the flexible production line, group of drones, etc.)

The multi-agent system in [23] is defined as a network of weakly connected solvers of private problems (agents) which exist in the general environment and interact among themselves for achievement of these or those purposes of system. Interaction can be carried out by agents in a direct path – by message exchange, or indirectly, when some agents consider the presence of other agents through changes in the external environment with which they interact.

Multi-agent systems and technologies can be applied to the solution of extremely difficult tasks (for example, planning and optimization of resources and knowledge acquisition of the class of Big Data and Small Data), and to creation of digital ecosystems ("the systems of systems") of the services capable to cooperate and compete among themselves, allowing the transformation of simple IoT in smart Internet of people and things (The Internet of agents).

2.4 Ontology and Knowledge Bases

Ontology is a knowledge representation system about data domains [24-26]. As it is marked in [27], the ontology "is often understood as "the specification of conceptualization" … or even as a synonym of "a conceptual domain model" (more precisely, a set of the coexisting conceptual models)…" In the same source [27] it is said that "in the simplest case ontology is defined as "some general dictionary of the concepts used as construction bricks in information handling systems". Usually it describes hierarchy of the concepts connected among themselves by the categorizing relations" [27].

Ontological approach was widely adopted in the multi-agent systems, where ontologies actually are those knowledge bases of intellectual agents which contain both knowledge of specific data domain, and knowledge, belonging to methods of the decision-making [28]. On the basis of ontologies, agents have an opportunity to make search in knowledge bases and apply them to message exchange (for example, in the modern versions of languages of agents communication (ACL, etc.)) [23]

At the same time, according to [24], in case of integration of ontology and multi-agent system it is possible to select three qualitatively different from each other approaches:

- each agent stores the ontology containing knowledge and concepts available only to it;
- the ontology is unified for all agents and is stored on a centralized basis (as a rule, on the special agent);
- the ontology is partially unified, and partially – is distributed.

In [24] is also marked that application of ontologies in the multi-agent systems will provide standardization of knowledge representation, will simplify information exchange between agents and also "will allow in case of impossibility of communication between agents, which is often found in real projects, to recover or predict with some accuracy a behavior of other agent on the basis of the known parts of his ontology".

2.5 Theory of Complex Adaptive Systems

The theory of complex adaptive systems appeared in the 90^{s}. One of the most famous researchers in this area is J. Holland [29]. The kernel of J. Holland’s theory is that irregular shapes of live systems arise from the adaptive behavior of simple one, and the adaptive behavior can be reduced to the sequences of micro-interactions with the environment of which consists a dynamics of more complex structures (for example, an anthill, a swarm of bees, flock of birds, etc.) [30].

The complex adaptive system according to J. Holland [29] has properties of aggregation (hierarchy of elements when simple elements of lower level form elements of higher level – aggregates), nonlinearities, flows of resources (constant exchange with the environment and maintenance of internal level of conversion of the arriving resources), diversity (absence of an equilibrium status). J. Holland refers tagging (the marking providing visibility and identification of system from the outside), internal models (allow system to trace and predict the environment's dynamics) and building blocks (structural elements of system) to mechanisms of the adaptive systems' organization. At the same time J. Holland believes that these properties belong to any complex system.

Thus, it can be regarded that the theory of complex adaptive systems is a base of the multi-agent systems. It establishes a connection between multi-agent systems and non-linear thermodynamics when the solution of any complex task is reached during self-organization and is treated as "stable disbalance" (a temporal consensus).

2.6 Emergent Intelligence

Emergent intelligence (intellectual resonance, swarm intelligence) is a phenomenon of unexpected properties whereby larger entities arise through interactions among smaller or simpler entities such that the larger entities exhibit properties the smaller/simpler entities do not exhibit [31].

In [32] emergence is determined as «global behavior of a complex system emerges from the interaction of agents and, in turn, constrains agent behavior». At the same time it is noted that «emergent behavior is unpredictable but not random; it generally follows discernible patterns (a new order)».

The key feature of emergent intelligence consists of dynamics and unpredictability of decision-making process by means of a large number of interactions (hundreds and thousands) which cannot almost be traced. Therefore the emergence property is often connected with multi-agent technologies which realize interactions of rather simple "smart elements" (agents) during their self-organization for the solution of a specific objective.

2.7 Evergetics

Evergetics is the emerging postnonclassical science of intersubjective management processes in the society. "Evergetics" in Greek (Ευεργέτης) means "benefactor" and already in its title there is an orientation for "good actions" in management processes (decision-making). It distinguishes evergetics from classical management science and cybernetics, invariant to any values [33, 34]. At the same time D.A. Novikov ranks evergetics in his navigator on cybernetics as cybernetics of the third order for interacting subjects of control [35].

In [36] the author of evergetics professor V. Vittikh defined it as «…the science of management processes organization in a developing society, each member of which is interested in augmenting his cultural heritage he is producing, which entails a raise of cultural potential of the society as a whole and, as a consequence, an increase in the proportion of moral and ethical managerial decisions and corresponding to them benevolent actions in public life». On the V. Vittikh's opinion «this interdisciplinary science must rely on both humanities and social sciences, as well as on the Control theory, Informatics and on some other disciplines related to the category of the exact sciences. Such multi-disciplinary nature is due to the fact that the man in Evergetics is considered, on the one hand, as a subject, armed with methods and means to research situations and to make decisions how to settle them, and on the other hand, as the object of education, training, world outlook formation and skill to communicate with other people, etc.» [36]. At the same time V. Vittikh's evergetics does not reject traditional "system" approach to the control of socio-technical systems at all, but adds and expands its opportunities. [37].

The theory of intersubjective management processes [38] in which each active person can prove as the non-uniform "actor" realizing himself, "dipped" in some problem situation and ready to participate in its settlement together with other actors [39], is the cornerstone of evergetics. If you have a large number of actors the solution of any task is very laborious procedure and here the multi-agent systems, which provide a real-time (at the situation development) decision-making, can be used. At the same time the decision is made on the basis of the consensus which is based on mutual beliefs, compromises, concessions, etc. It creates a barrier to manifestations of violence, the evil, aggression and other defects because in processes of negotiations and decision-making people switch on value factors which cannot remove, but "smooth" these negative phenomena [40].

All mentioned above allows to assert with confidence that evergetics as a science about management processes in socio-technical systems, is aimed on use of knowledge, will and energy of people, disclosure of their talents for the benefit and convenience of each person. It completely corresponds to the concept of Society 5.0. Therefore in fig. 1 evergetics is placed on top of "a pyramid of sciences and technologies" in Society 5.0 on which a man leans.

3 Scientific and technical backlogs: eligibility and development

The key sciences and technologies that make possible a transition to Society 5.0 and that were briefly introduced in section 2, are and will be in researchers' and IT-developers' focus in the nearest and distant future. The organizations represented by authors are not an exception. We have all necessary competence and experience in development of similar systems, being pioneers in many of the directions sited above. At the same time, in the considered context, our main interests and achievements are concentrated on the development of multi-agent systems, ontological data analysis and evergetics.

Multi-agent systems and technologies are being developed in Samara more than 25 years (since 1990) [41]. Initially there was directivity on the development of new methods and tools for solving of complex problems based on the principles of self-organization and evolution (the fact that "the emergent intelligence" is called). In particular, successful examples of development of the multi-agent systems were connected to models of networks of needs and opportunities (NO-networks) and method of the conjugate interactions for resource management in real time. This approach was developed in V. Vittikh and P. Skobelev's works [42, 43].

According to this approach the NO-networks are created. There can be marked agents (roles) of the needs and opportunities, by determination representing entities with opposite interests which work within virtual "market" of system and can both compete and cooperate with each other [41]. At the same time the role of needs bears in itself knowledge of the "future", and an opportunity role – knowledge of the "past". Such approach allows to view the different processes of the solving of complex multicriteria tasks of resource management of any nature (static or moving, separated, renewable, etc.) absolutely from the new side. In this case they are considered as a process of self-organization with detection and the conflict resolution between agents by negotiations with concessions for achievement of consent (consensus) by them [40].

The methods and multi-agent systems realized on their basis were used for the solution of a wide range of tasks – from clustering and understanding of texts up to dynamic resource management of the space, transport systems and the industrial enterprises [44-51]. Their industrial implementation proves efficiency of the developed approach and defines perspectives for the solution of a wide range of complex tasks within the concept of Industry 4.0 and further Society 5.0.

As it was already noticed, the organization of knowledge system about data domain and methods of knowledge deployment in the multi-agent systems is carried out on the basis of ontologies which allow to describe the heterogeneous, multicoupling and incomplete knowledge that can contain incorrect information and be connected not only hierarchical, but also by network structures, etc. [26]. Pioneer works in the field of ontological data analysis were made by S. Smirnov [25, 52-54]. He made an essential contribution to the solution of one of the significant problems in this area: the automation of formation of ontologies of data domains on the basis of measurements [55]. The technique of detection of conceptual structure (the formal ontology of experimentally researched data domain) offered by S.V. Smirnov is based on the analysis of the formal concepts [54]. He generalized the standard object-and-features data model and used for its processing the multiple-valued vectorial logic.

It is also necessary to mark that the formal ontologies can be a theoretical and technological framework for implementation of the bases concepts of created theory of intersubjective management processes – evergetics [56] (it was described in detail in item 2.7). In particular, for identification of a sense of a problem situation for the actor it is possible to use a method of ontological data analysis. The basis of this method is theoretically well reasonable analysis of the formal concepts. And the communicative semantic model of a problem situation, that is necessary for all actors, can be received as a union of actors' subjective ontologies.

4 Conclusion

The provided review shows that the growing popularity of digital economy and uncountable number of practical applications have created a strong basis for development of Industry 4.0 technologies already now and in the long term can serve as the launch pad for creation of Society 5.0. And the evergetics which returns "ordinary" people from everyday life to the world of intellectual systems and gives the chance to use personal intellectual resources of each person and to do the habitat attractive to people, "area of an attraction", but not a zone of their temporary residence, can form a theoretical basis for this "future society".

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CHARACTERISTICS OF RADIATION AND SOURCES OF RADIATION AS A RESULT OF HUMAN ACTIVITY

ХАРАКТЕРИСТИКА НА РАДИАЦИЯТА И ИЗТОЧНИЦИ НА РАДИАЦИЯ, В РЕЗУЛТАТ НА ЧОВЕШКАТА ДЕЙНОСТ

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Abstract: *The main features of the radiation environment in the surrounding environment are presented. Over the last 5 years no values other than the natural ones have been observed, with the lowest values in Veliko Tarnovo. The main characteristics of the radiation in operation in nuclear power plants and the major accidents resulting from the operation of the NPP in the development of humanity are shown. Radiation as a result of the uranium mining and uranium processing industry in Bulgaria is also under consideration. It also shows the actions of radiation as a result of other people's activities.*

Keywords: *radiation, features, natural, NPP, uranium mining, actions*

1. Common feature

Detection of radioactivity is one of the greatest discoveries of mankind. Only a few weeks after the X-rays were discovered (in 1896), French physicist Henri Becquerel, having studied the phosphorescent properties of various substances, started an experiment with potassium uranium sulphate. The experience was that, after exposure to daylight, the mineral, well wrapped in light-tight black paper, had been checked for some time whether it was phosphoresciated [1]. The silhouette of the mineral emerged under the influence of strong radiation with great penetrating ability on the photomulsion. Thus, the presence of new urinary bears called Becquerel was found, and the phenomenon was called by Maria Curie radioactivity [2].

This discovery is rapidly entering medicine and the first X-ray machines that have led to a revolution in medicine have been created. Subsequently, advanced and upgraded X-rays from the latest generations increase the repetitive accuracy of diagnostic activity and allow the rescue of hundreds of lives.

At the same time, it is found that radioactive beams are also a serious environmental pollutant with an extremely strong impact on the vital and physiological activity of organisms, ranging from stimulation to killing.

It is well known that all of our plans are designed to prevent the natural and anthropogenic, terrestrial and spacecraft from irradiating beams, ie. in the field of the natural and manufac tured radioactive waste. Ionizing rays accompany the life of the planet in various issues at all stages of the phenomenon [3].

Prez godinite After switching Vtorata svetovna voyna poradi razvitieto na atomnata promishlenost and osobeno usilenoto izpitvane na yadrenoto orazhie iznikva with golyama ostrota vaprosat charter radioaktivnoto zamarsyavane na planetata.Sled atomen blast in vazduha produktite na atomnoto delene zamarsyavat atmosferata, sushata, vodite, rasteniyata, zhivotnite, hranitelnite products and others.

The importance of the problems arising from the radioactive contamination requires the emergence of new sciences that integrate and investigate various aspects of contaminants with radio-nuclides, emerging and developing new scientific disciplines and approaches. Their radio frequencies are aimed at studying the efficacy of migrating radioactive substances into the biosphere and the effects of ionizing radiation on living organisms. The study is considered to be a specific issue for the surface area of the country, which provides life for the living and living world and plays an extraordinary role in the future of the world. [4]

It is only natural radioekologiyata na pochvata depend from the razvitieto na biofizikata, biohimiyata and fizikata na pochvata, but as her predmet is the study of zakonomernostite na vzaimodeystvie na produktite na delene na urana and plutoniya with pochvata, tyahnata sorbtsiya, desorbtsiya, migration, a well and influenced by the food chain of animals - animals - humans [5].

1.1. Classification

The natural gamma background is a physical feature of the environment and is the gamma ray field in which all living organisms on Earth are found. Sources of this ionizing radiation are secondary cosmic radiation and natural radionuclides found in atmospheric air, soil, water, food, and the human body [6]. The measured magnitude is gamma background dose power and is specific for each point, region, region.

Gamma radiation dose data for the country is obtained in real time from 27 permanent monitoring stations of the National Automated System for Continuous Radiation Control (NASCRGP), administered by the Executive Environment Agency (EEA).

The automated system provides operational information in case of accidental increase of the radiation background, both in case of nuclear accident on the territory of our country and in cross-border transmission of radioactive contamination. The system provides with real-time data the Emergency Center of the Nuclear Regulatory Agency and the General Directorate for Fire Safety and Protection of the Population Directorate at the Ministry of Interior (MoI), which provides the opportunity in case of a radiation accident, to implement timely appropriate measures to protect the population and the environment.

Over the last 5 years no values other than the natural ones characteristic of the respective point have been observed [7]. The lowest average annual dose rate for 2016 is determined at the local monitoring station Veliko Tarnovo -59 nGy / h and the highest peak at Orelyak peak - 133 nGy / h [8]. In Fig.1.1. the average annual values of the radiation gamma background for the period 2012 ÷ 2014 are presented in all 27 permanent monitoring stations in the country, including the monitoring station of "Permanent repository for radioactive waste" - Novi Han, owned by the Radioactive Waste . The station in Novi Han is fully integrated into NASCRGF.

It is known that natural radionuclides: uranium, radium, thorium and the products of their decay, as well as the radioactive isotopes of potassium, rubidium, etc., have a wide spread in the earth's crust. Due to their specific physicochemical properties, they have a specific presence in the composition of the individual components of the environment: lithosphere (rocks, soils), hydrosphere (underground, river, lake and sea waters), atmospheric air, flora and fauna. Their ionizing radiation, along with secondary cosmic radiation, forms the natural gamma-background background, which inevitably affects all living organisms.

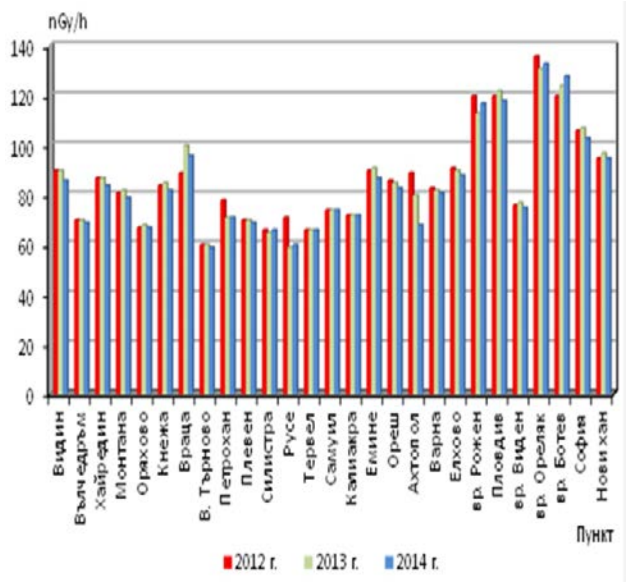

Fig. 1.1. *Annual average values of the background gamma background in Bulgaria [9]*

As a result of the human activity, the environmental elements with natural and technogenic radionuclides and their spatial redistribution are further enriched. These anthropogenic sources of radioactivity determine the technogenic component of the radiation background. The following should be addressed:

• Waste water and weighed rock in the mining of heavy and rare metals;

• gas-aerosol discharges from the nuclear power and thermal energy objects;

• sludge and ash from solid fuel stations;

• mineral fertilizers derived from certain phosphorites;

• building materials other products [8].

The National Radiological Monitoring System aims at early detection of deviations from the radiation parameter values in the main environmental components and provision of available radiological information to detect both the natural and the nuclear accidental radiological status. Particular attention is paid to areas with potential radioactive contamination, such as Kozloduy NPP.

Fig. 1.2. *Radiation characteristics of the environment [9]*

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In the use of nuclear technology in the national economy, medicine, research and others, too, a small amount of radioactive substances fall into the environment. Gaseous waste in small quantities is discharged into the atmosphere by nuclear fuel reactors and plants, from which they fall into the soil and through the path of food chains reach plants, animals and humans.

Let us not forget that the stimulatory and lethal doses of radiation for the different types of organisms are very different. Studies have shown that some plant species have a fairly high dose of radiation, and under the conditions of increased radiation, the populations of some insect pests, for example aphids, are rapidly growing and causing great damage to agriculture.

Under normal operating conditions of nuclear installations and appliances, too small quantities of radioactive substances are released in the rivers. Compared to radioactive contamination and exposure to nuclear explosions, especially in the atmosphere, these sources of pollution are usually insignificant. Nevertheless, the large number of isotopic laboratories increases the risk of radioactive contamination in the event of non-compliance with the rules on waste handling and storage. We also have such an example for our country when, in an inconsiderable work in June 2011, in one of the companies working with radioactive elements, several workers received a higher radiation dose than the eligible one and were sent to treatment in France.

2. Radiation characterization

2.1. Radiation characterization of NPP operation

In nuclear power plants, nuclear reactors, all radioactive substances are in closed systems and can only be thrown out in an emergency. In water cooled reactors, water is activated and contaminated with radioactive substances, but prior to discharge, it is subjected to complex purification and is passed through columns of ionites to contain the radioactive pollutants. Irrespective of the most stringent safety measures in the operation of nuclear reactors through valves, pumps, etc., sometimes leakage of contaminated water and air is allowed. It is quite natural that emergency situations are the most dangerous in terms of radioactive contamination [10].

Serious levels of radioactive contamination are allowed in reactor failures of nuclear power plants, although all known precautions against accidents are taken in the design and construction of nuclear reactors. The failures that have occurred in reactors in England, the United States, Ukraine and Japan undoubtedly show the great danger to mankind when the atom drops out of human control.

Statistics show that in case of reactor failures at nuclear power plants, despite all the known precautionary measures taken in the design and construction of nuclear reactors, radioactive contamination reaches enormous scale. The consequences of the major accidents in the nuclear power plant are similar to the consequences of the explosion of atomic bombs and, on their scale, are close to geological disasters.

In modern nuclear reactors with a high degree of safety, all radioactive substances are in closed systems and can be ejected out only in emergencies [11]. In water cooled reactors, water is activated and contaminated with radioactive substances, but prior to discharge, it is subjected to complex purification and is passed through columns of ionites to contain the radioactive pollutants. Irrespective of the most stringent safety measures in the operation of nuclear reactors through valves, pumps and others, it is sometimes possible to leak out contaminated water and air that directly or indirectly through rainfall reaches the soil. The most dangerous for radioactive contamination are the emergency situations.

This is the example of the Wynskeeil accident in England. On 8th of October 1957 in reactor No. 1 the temperature rose sharply, the operators failed to control the process. The grid melts and the fuel starts to run out and burn. The chimney of the reactor begins to mimic radioactive smoke and pollute the environment. Workers from the plant receive a 150-fold higher dose of radiation above the permissible, and the area nearby - more than ten times higher. The radioactive clouds hang over North England, Scotland and part of northern Europe. On the 4th day after the accident, the fire was extinguished. Fortunately, during the accident, there are no deaths. Contamination of the pastures, and hence the cow's milk with radioactive iodine, is responsible for throwing huge amounts of milk into the ocean. Radiological Protection Council data show that in the 30-year period in England 33 people died and died as a result of exposure.

As in most such cases, the UK authorities for political reasons do not reveal the causes and nature of the Wynskeeel accident. This was done only after 30 years.

The accident at Three Mile Island - USA, which took place on March 29, 1979, was also huge. Despite the significant damage to the reactor core, the integrity of its protective shell was not impaired, and the radioactive discharge and pollution of the atmosphere and inside the emergency station proves to be very small. The temperature of the accident in different parts of the upper half of the core reaches 2800 ° C. The transfer and deposition of fission products in the TM -2 sheath are limited by inert gases and only very small quantities of the product fall into the atmosphere, although more than 20% iodine and more than 50% cesium have been ejected initially. Subsequently, these radioisotopes are found in the lower layers of the atmosphere. After thorough analysis of the causes and extent of the accident, valuable lessons have been learned about the construction and technical safety of the reactors.

The biggest accident at the NPP is in Chernobyl, Ukraine. On April 26, 1986, the Chernobyl NPP's 4th bloc collapsed, causing severe consequences for the country, its neighbors and almost all European countries.

The Fukushima I nuclear accident in Japan is a radiation incident of the highest seventh grade on the international scale for nuclear events.

The power plant owned by the Tokyo Electric Company (TEPCO) has 6 power units with water-jet reactors and is the world's largest nuclear power plant.

It was triggered by the earthquake and the tsunami that followed in early March 2011. The Japanese official authorities said it was a localized accident, but it subsequently turned out that as a result of the weekend accident on the US west coast they measured an increased level of radioactive background. In May 2011, even in the southern hemisphere of the Earth, there are radioactive isotopes and an increased background background that is the result of the Fukushima NPP disaster.

On July 5, 2012, the Japanese and world media reported that a report by the special parliamentary committee said that "The Fukushima-1 accident was not a natural but a technogenic disaster. The nuclear power plant was not prepared for either a strong earthquake or a tsunami. " The Commission blames the operator, the TEPKO company, and the government's nuclear services.

In the earthquake, blocks 1 - 3 are self-extinguished, and the back-up power generators that supply the electronic control system and water pumps to cool the fuel rods are included. This is necessary because after stopping the chain reaction, the fuel rods continue to emit a large amount of heat due to the natural radioactive decay.

The power plant is protected by a breakwater with a height designed to contain a tidal wave up to 5.7 meters high, but the tsunami that hits the shore about 40 minutes later is about 14-15 meters high. Wave floods the plant, damages the power and electronics in the units and interrupts the external power supply to the plant. The earthquake disruptions prevent rapid external intervention in the affected area.

This conclusion differs from the conclusion of the TEPKO's internal investigation at the end of 2011 that the main cause of the accident was the tsunami wave whose height of 15 meters exceeded the forecasts of seismologists.

Some of the most catastrophic nuclear incidents are those we have never heard of. When we think of a nuclear disaster, we usually think of Chernobyl and Fukushima or Hiroshima and Nagasaki.

No matter how devastating they may be, during the Cold War the warring powers are conducting nuclear experiments, the results of which were the same, if not worse, consequences of the nuclear incidents and detonations that dominate the history books.

Between 1946 and 1958, the US carried out 23 nuclear tests on the remote Pacific Bokini Atoll. Among these attempts is Castle Bravo, which the United States carried out in 1954, and is the most powerful nuclear device the country has ever detonated. It is 1000 times more powerful than the bombs placed over Hiroshima and Nagasaki, and causes radioactive particles to reach as far as Australia, India and Japan.

After Castle Bravo, the inhabitants of neighboring atolls had to be evacuated, but that was not enough to be safe. After detonations, atol residents reported an increase in cancer and infant with disabilities. Forced emigration is a critical moment in US nuclear tests, although it is debatable how much Americans have been concerned about the local population. Residents of the Bikini atoll are sent to neighboring atolls, but they are not adapted to such a large population and people are starving.

Moreover, despite the assurance that the locals will be able to return to their homes after military attempts, these attempts make the atoll unfit for habitation. Pollution of water and soil makes fishing and farming impossible there. To date, radiation levels there are too high for safe habitation.

In December 1950, President Truman established New County, a Nevada site for the sole purpose of conducting nuclear trials. Ultimately, US governments are testing a total of 928 nuclear bombs, mostly underground, although many people report seeing clouds in the shape of a sponge from overground tests in the Las Vegas area.

Field workers called a particularly heavy bomb "Dirty Harry" because of the huge number of nuclear particle deposits after her detonation. Residents reported that the explosion made the sky "beautifully red" and left a "metallic taste in the air." Another explosion called Sedan has left an incredibly large crater and has infected more US residents than any other experience in the history of the country.

Today the polygon is open to visitors, but some things remain secret because visitors can not wear cameras and mobile phones, perhaps because there are still trials there.

In October 1961, the USSR detonated King's Bomb - the most powerful man-made explosive device in human history. It is detonated on Cape Suoyi on the North Island, off the coast of Northwestern Russia. The mushroom cloud was huge - seven times taller than Mount Everest. "King Bomb" was three times more powerful than Castle Bravo and 1570 times more powerful than the bombs placed over Japan by the Americans.

Although the USSR is trying to modify the bomb so that radioactive deposits do not have such an enormous impact on the environment, it destroys all buildings in the North and interrupts radio communications for an hour.

France conducted nuclear attempts at two atolls in French Polynesia from 1966 to 1996 despite the protests by the Polynesian Territorial Assembly. The first test bomb sucks all of the water from the atoll lagoon and the atoll itself starts to "die dead fish," says

Greenpeace. The bomb scatters radioactive particles to Peru and New Zealand.

2.2. Characteristics of uranium mining

Many specialists believe that the liquidation of uranium mining in Bulgaria in 1991. was carried out hastily, as a result of which in a number of areas there were no complete technical solutions for this activity [12].

The monitoring of the environmental status of the MOEW in the vicinity of former uranium mines includes the field radiometric measurements and laboratory analysis of soils, waste products in tailing ponds and landfills, bottom sludge, underground and surface run-off. Radiological parameters of soils, bottom sludge and waste materials are assessed by analyzing samples from the EEA for the control of potential pollutants [13]. The water samples are analyzed radiochemically with respect to the indicators laid down in BDS 2823 "Drinking Water" - total beta radioactivity, uranium content and radium content [14].

With the entry into force of Decree of the Council of Ministers № 74 / 27.03.1998 on eradication of the consequences of the mining and processing of uranium raw materials, Ecoinengineering -RM EOOD is responsible for organizing and controlling the activities related to the technical liquidation, the technical and biological reclamation, water management and the conduct of complex environmental monitoring of environmental components. Despite the existence of a legal basis, monitoring networks are not built and operated at all sites, as recommended by the Chairman of the Energy Committee "Instruction for Organization of System for Monitoring, Design, Construction and Operation of Environmental Surveillance Networks Influenced by uranium industry regions "[15].

Under the Phare Program "Complex Program for Cleaning and Monitoring of the Areas Affected by Uranium Production and Processing in Buhovo", in March 1999 a Local System for Basic Environmental Monitoring in the Buhovo - Yana Region (LBMM) . The system consists of two monitoring containers located in Buhovo and Yana, two reception centers - in Rare Metals EOOD, Buhovo and in the EEA - MOEW, as well as a information board for continuous informing the public, installed at the Buhovo cultural home .

LMPMM aims to continuously monitor environmental performance before rehabilitation activities, over time and long-term after completion of restoration work in the area. The monitoring containers are equipped with measuring equipment for continuous control of total dust, radiological parameters: gamma radiation dose rate, radon concentration in ground air, meteor parameters: wind direction and wind speed, temperature and humidity of the ground air, atmospheric pressure and rainfall [16].

The results obtained and their comparison with the applicable normative documents give grounds for some general assessments and conclusions.

• in the settlements located close to the former uranium production areas studied and the adjacent agricultural areas, the concentration of natural radionuclides in the soil and the level of the radiation background are not altered.

• Following the liquidation of uranium mines, access to some of them is not sufficiently limited.

• Places where the radiation background is several times higher than the natural background should be restricted by population access, despite the minor radiation risk.

• Liquidation procedures should be completed in the "Grazovitsa" loading ramp and the soil should be deactivated on a limited area [17].

A concrete wall should be erected around the embankment of uranium ore at the Rivers of Nevi, in the village of Dobralak, avoiding scattering and inappropriate use of the ore.

The results of the surveys were also provided to the relevant municipalities in order to inform the local public and to limit the phenomena of radio-phobia or frivolity by the people in the mentioned areas. Besides, the assessments carried out more broadly will contribute to the conduct of an adequate economic policy in the surveyed regions.

The problem with the content of uranium and alpha particles in the drinking water of Haskovo, Parvomay and Velingrad from April 2017 was highlighted here. Then increased uranium content was found in four wells of the nine supplying cities of Haskovo. Survey data from September 2016, but only in the public domain came out this year. Specific values for the overriding meanings have not yet come out officially, but there is a number of over-norms mentioned. Similar data are available for other settlements. In immediate proximity to these settlements there were uranium mines, which are no longer functioning but not preserved according to the requirements of the Bulgarian and international legislation. Money for mine closure has been absorbed, and work has not been done to the best of its quality. So rainwater and underground rivers flow through the former mines safely and extract radioactive isotopes and particles.

Regardless of the reasons for the increased content of uranium, it is inadmissible to silence the truth in pursuit of purely economic or political ends and thus to put people from different regions of the country at risk for their lives.

2.3.Characterisation of radiation from other activities

Air crews and passengers traveling on high-flying airplanes, i. at high heights, can also receive increased cosmic exposure. Its intensity depends on the duration of the flight, the solar activity, the latitude, etc.

Often electronic and luminous devices, research apparatus, watches, toys and others contain radium - 226, strontium - 90, tritium, etc., which contribute to the increase in the human radioactive dose. In modern life and production, many of the apparatuses, machines, utensils, and articles of use contain radioactive materials and imitate radiation in their use.

For example, uranium is used in dentistry as a glaze of ceramics, this element as well as fertilizer add firmness to materials used in dentistry. Radioactive materials have entered the industry and bust at a violent pace after the Second World War.

The peaceful atom enters the medical procedures, especially in well-developed countries, where the population is significantly more exposed to radioactive exposure. Research laboratories and some industries emit radioactive waste, which can be a source of pollution if the purity and safety guidelines for handling such substances are not strictly observed [18].

Already at the beginning of the 20th century, under the influence of information on the stimulating action of radioactive radiation on plant development, the interest in radioactivity increased and various preparations and fertilizers containing radioactive elements were placed on the market. Interestingly, even after the end of World War II and the atomic bombing over Hiroshima and Nagasaki, the interest in radioactive substances such as fertilizers has also increased and increased in some countries such as the United States, Canada, Denmark where a large number of vascular and Polish experiments to test the effect of radioactive substances on field, vegetable and other crops.

Many scientists and specialists have convincingly demonstrated as a result of numerous vascular and field trials that increasing crop yields can be achieved by developing new agro-technical methods and technologies and applying many other substances, fertilizers and activities instead of use radioactive substances that hinder the risk of increasing the radioactive background of the soil and the environment [19].

It has been shown that certain quantities of radioactive substances are introduced into soil with mineral fertilizers that may pose a risk to human health. According to agrochemists and fertilizer specialists, the potassium element - 40 (0.012% of the permanent isotopic composition of natural potassium in whatever minerals, salts, substances) is always introduced into the soil - is not a threat to the living organisms.

Phosphorous fertilizers are also known as uranium and radium, but as traces of only theoretical significance as dangerous components. It has been found that the amounts of uranium and radium in phosphorites from different sources are different. Grounds for concern are the results of checks on the accumulation of uranium and radium in greenhouse soils where mineral fertilizers are applied at very high levels. It was found that in these soils, compared to neighboring normally fertilized fields, the uranium content increased by 75% and the radius by 10-70%, for a 5-10 year intensive use of greenhouses. The uranium and radium content of superphosphate and phosphorus is 10 and 50 times higher than soil content. According to the calculations for the introduction of optimal doses of phosphorous fertilizers, there is no practical danger of reaching uranium and radium limit values in the near future, but adherence to optimal fertilization standards with phosphorous fertilizers is mandatory. The results of the agrochemical and biochemical studies did not show an increase in the concentration of uranium, radium and thorium in the country's greenhouse soils.

From the point of view of environmental and food security, it is necessary to periodically monitor the radiation status of intensively fertilized soils with phosphorus [20].

Fertilizers and agrochemistry specialists argue that there is a real danger of using phosphors in the construction or chemical melioration of salted soils with the radioactive elements contained therein. The analyzes show that phosphorus does not differ significantly in the content of radioactive elements from the soil into which it is introduced. Batch phosphogies with higher radioactivity are encountered, but it is always lower than the superphosphate radioactivity. According to some hypotheses, the technological operations for the production of phosphorous fertilizers in which the phosphogypsum is a waste do not include the phosphorus-containing radioactive elements and, regardless of the fact, this product is administered at a dose of 20-30 tonnes per hectare of phosphogypsum at Soil melioration This product is not capable of enriching soils with radioactive elements. However, during meliorative activities, specialists should refrain from very high doses of phosphogypsum, although they may be introduced into the soil once, as some of its properties may deteriorate.

3.Conclusions:

1. The formation of radioactive contamination and its behavior is of interest for both preventive measures and after a nuclear or nuclear accident at the NPP.
2. Radioactive contamination in a radiological or nuclear accident will be determined by a wide range of factors that determine the contamination of tropospheric air, soil, water, plants and the overall environment.
3. Optimized control of radioactive contamination following an accident contributes to the proper organization of evacuation rescue operations as well as to the decontamination of contaminated areas and food products.

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