IMPACT OF LOW-ENERGY MAGNETIC FIELD ON ELASTIC-PLASTIC WAVE PROPOGATION PROCESS AND CONSERVATION OF THIS IMPACT OVER TIME

V. Kats[1], V. Morozov[1]
[1]*St-Petersburg University, Math. and Mech. Faculty., 28 University pr., Petergof, St Petersburg, 198504, Russia*

Abstract: Application of the low-energy (weak) magnetic as an implement of reversible control of the dynamic strength of materials pilot-tested. Change of parameters of propagation of the elastic-plastic waves initiated by a short-timed intensive pulse of mechanical loading after exposure with weak magnetic field investigated. Characteristics of conservation of this effect analyzed.

Keywords: elastic-plastic wave, low magnetic field, magnetic-plastic effect, Hugoniot elastic limit, wave attenuation, properties reversal

1. Introduction

Magnetoplastic effect (MPE) is known in physics and mechanics of solid state till the mid-'80s [1]. The essence of this phenomenon is the rebuild of the quantum state of the dislocation structure under the action of magnetic field possessing energy weak for direct interaction with the media. This phenomenon also acts on the macroscopic properties of the bodies indirectly.

Hugoniot elastic limit (HEL) should be noticed among such parameters as a parameter determining the rate of the wave attenuation with the hydrodynamic mechanism. Reversible nature of MPE is well known in many cases. So, if the impact of the magnetic field on parameters of the propagation of elastic-plastic wave also appears reversible, MPE may be considered as the base to develop an effective method of high-rated mechanical processing of materials.

2. Hydrodynamic mechanism of elastic-plastic wave attenuation

Here we perform qualitative research of propagation of the short-timed mechanical pulse of loading wave through the media. Schematic evolution of such pulse was analyzed by a number of researchers [2] and shown of Fig. 1 a. Real waveforms of pulses after propagating through the media were registered in our research are shown on Fig. 1 b.

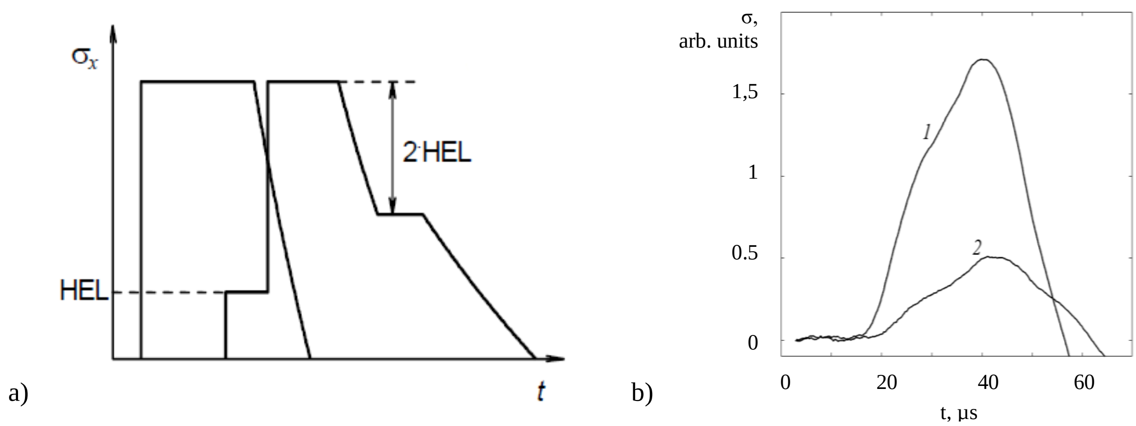

Fig. 1. Schematic evolution of the elastic-plastic pulse of uniaxial loading (a) [2] and real waveforms of propagation of such pulse through the media obtained by us (b).

[1] Corresponding author
e-mail address: v.kats@spbu.ru (V. Kats)

During propagation through the sample, the wave splits into two parts: elastic precursor and plastic wave. Velocities of propagation of these parts are respectively c_ℓ and c_b, while. $c_\ell > c_b$ [2]. HEL σ_{HEL} is a boundary value of stress to switch wave propagation to the plastic model. Discharging wave propagates in the opposite manner. For stresses of $\sigma > \sigma_{max} - 2\sigma_{HEL}$, where σ_{max} is the wave amplitude, the wave propagates with c_ℓ velocity and for lesser stresses with c_b velocity. So, for relatively short-timed pulses discharge wave will run after the loading process and cause attenuation of the pulse amplitude. It looks obvious that lowering of the HLE will lead to decrease of the pulse amplitude value with the hydrodynamic attenuation.

3. Experiment setup

We used extended by us for the case short pulses experimentation setup introduced in [3, 4]. The scheme of the experiment setup is provided on Fig.2. The setup consists of plain coil mounted on massive basement and covered by the aluminum plate. The sample is placed on the plate and pinned to it by the waveguide of the piezo-probe. The contact surfaces are lubed to provide pure acoustic contact.

The electric current through the coil provided with discharging of the capacitor (C) of 0,5μF charged up to 18kV by the high-rated switch (SW). Both waveforms of current and mechanical loading pulse are registered with Rogovskii coil and piezo-probe respectively. These waveforms are shown on Fig. 3.

This setup allowed us to obtain pulses of 20μs duration with amplitudes up to 15MPa. These pulses are able to create conditions of previously discussed hydrodynamic attenuation of wave amplitude in used by us NaCl samples. Examples of such pulses provided in Fig. 1 b.

The pulse of mechanical loading in the plate is generated by the magnetic force directed perpendicular to the plate [4]:

$$F = \frac{\partial W}{\partial \xi} = \frac{1}{2}\left(\frac{\partial L_s}{\partial \xi}\right) i^2 = M\ddot{\xi} .$$

Where $W = Li^2/2 = CU^2/2$ is electric-magnetic energy of the setup ($L = L_c + L_s$ is inductance of the coil (L_c) and the dissipation inductance (L_s), C and U are capacity and voltage of capacitor), ξ is displacement of the plate, M is the mass of the plate, and *i* is current through the coil. Inductance of the coil gives no contribution to the force as it is directed in the same plane as the plate. With expectation that $\partial L_s / \partial \xi = const$ we can conclude that

$$i^2 \propto W \propto \ddot{\xi} \propto \varepsilon .$$

Here ε is strain of the plate and the sample.

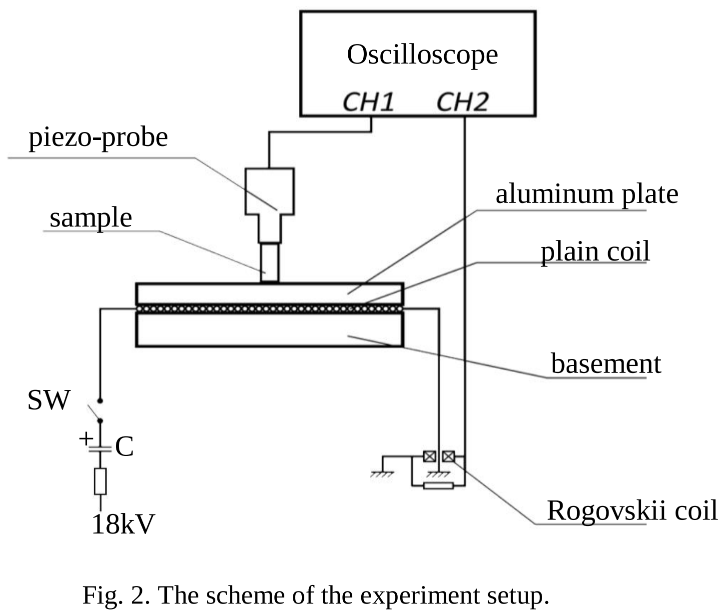

Fig. 2. The scheme of the experiment setup.

The setup allowed us to determine and lock in the energy of the pulses propagated through the samples by locking the charging voltage and electric current through the setup. So, the evolution of the wave amplitude attenuation depending on the sample properties may be registered.

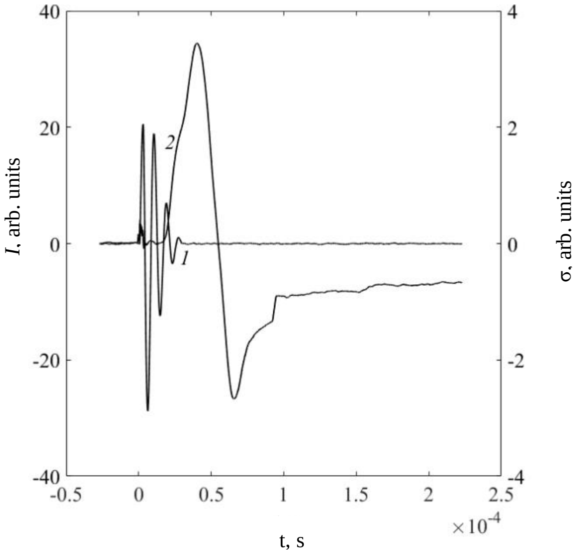

Fig. 3. Waveforms of the electric current through the plain coil (1) and mechanical loading pulse generated in the plate (2).

4. Decreasing of the HEL by the MPE and suspend of this effect

We used NaCl specimens from two independent sources as samples for our research. The samples were exposed with the weak magnetic field of 37mT during 8 minutes and were kept at rest for a while isolated from any electrical and magnetic actions.

After this, the samples were tested in the described setup. The energy of mechanical pulse was constant and big enough to guaranty their amplitude being higher than HEL. The waveform of such pulse presented in Fig. 1 b, waveform 2.

Thus, we obtained dependence between the amplitude of the mechanical pulse being propagated through the sample and time instant between field exposure and mechanical testing shown on Fig. 4 for series 1 of the samples. The amplitude of pulses in non-exposed samples was used as a reference value.

Series 2 shown the same performance.

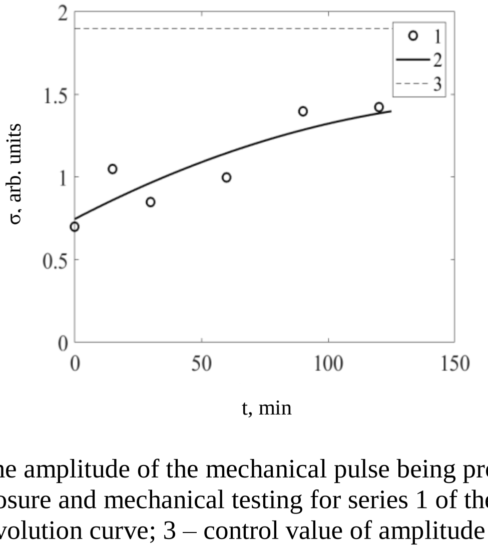

Fig. 4. Dependence between the amplitude of the mechanical pulse being propagated through the sample and time instant between field exposure and mechanical testing for series 1 of the samples: 1 – average amplitude values; 2 – amplitude evolution curve; 3 – control value of amplitude for non-exposed samples.

Exposure in the weak magnetic field causes 3-4 times decrease of the HEL in the samples being tested just after exposure. For the samples being kept at rest for a while after exposure the effect decreases unevenly.

With two hours of the rest before testing we obtained reduction of the effect to 1.3-1.4 times decrease of the HEL and halted our experiments for 15-hour rest. This time instant was enough to completely suspend the action of the weak magnetic field on the value of HEL.

5. Conclusions

The form of obtained dependence points on the reversible nature of the action of the weak magnetic field on the dynamic mechanical properties of the samples. The effect decreases unevenly and completely suspends after 15-hour pause.

This outcome has well correspondences with known researches [5] and points on the possibility of using a weak magnetic field as a base to develop methods of augmentation of methods of high-rated mechanical processing of materials.

6. Acknowledgements

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