# Study of Materials at Negative Pressures Using Picosecond Laser Pulses*

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In the present work, the dynamic strength of Al, Pb, Cu, and Ta was studied by the method of generation of shock waves under the action of laser pulses of 70 ps duration. The use of such short pulse make it possible to realize in these experiments strain rates exceeding $10^7$ s$^{-1}$.

We used a neodymium glass laser of the Kamerton-T facility in GPI RAS. The basic radiation was transformed to the second harmonic with the wavelength of 0.527 $\mu$m and the laser pulse energy of 2.5 J. Irradiated spot on a target surface was of 0.2 to 0.8 mm in diameter. Then the maximum energy density of the laser radiation flux in the focal area was $6.2 \cdot 10^{13}$ W/cm$^2$; the ablation pressure was about 1.35 TPa. Targets made of Al, Pb, Cu, and Ta had the form of plates 50 to 100 $\mu$m thick.

In our study, we have used an approach [1] that has allowed us to determine the strain rate and the spall strength of the material. This approach is based on both the measurement of the spallation depth after the laser-pulse action on the target and the subsequent numerical simulation of the shock-wave process in the matter under study.

For calculations, we used a numerical code [2], which is based on the hydrodynamic equations solving on the Courant–Isaacson–Rees scheme. Equations of state for the materials in question were taken from [3].

Figure 1 presents the obtained in this work spall strength values for Al versus the strain rate. Data from previous experiments [4–11] are also shown.

The data obtained under conditions of laser action on the target with pulse duration of 70 ps show that, at moderate amplitudes of shock loading, spall strength values are in agreement with the known functional dependencies of the strength upon the rate of deformation. With greater loading pressure (data set 4 in figure 1), there is a sharp growth of spall strength, that indicates the strengthening of the material as a result of loading. The registered growth of spall strength of aluminum is connected with the fact that, in the experiments, the increase of the rate of deformation was achieved not only by shortening of the pulse duration, but also by the increase of the amplitude of loading. The latter increase leads to hardening of the material under study. In this case, defects, which cause the premature spallation of the material, may be disappeared.

* This work is supported by the Russian Foundation for Basic Research (projects 11-02-12003, 11-08-01225, 12-02-00625, 12-02-00746, and 13-02-91057), the Russian Academy of Sciences (programs 2P and 13P), and the President of the Russian Federation (grants NSh-368.2012.2 and NSh-7241.2012.2).

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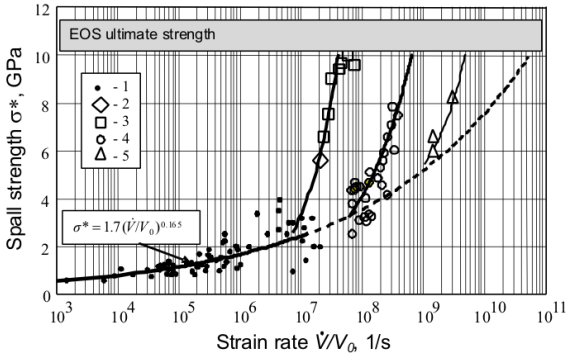


Figure 1: Spall strength of Al versus the strain rate. Solid curve (marked by arrow) approximates 70 experimental points reported in [4–9]. Dashed curve extends the solid curve into a region of high strain rates. Experimental data: 1 — [4–9], 2 — [4], 3 — [10], 4 — this study, 5 — [11].

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