Shear and Spall Strength of Hardened 30KhGSA Steel under Explosive Loading in the Range of Solid-Solid Phase Transformation

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Summary: Additional results on the dynamic properties of the hardened 30KhGSA steel are presented. These results are needed for more exact determination of the calculation models parameters and for verification of 2D-software complexes

Introduction

The *purpose of this work is to* demonstrate potentialities of the optical lever method [1-3] and to gather new data on:

- shock wave compression of the hardened 30KhGSA steel (HRC 35…40);
- shear and spall strength of this steel under high-rate strain in the initial phase range and in the range of reversible solid-solid phase transformation;
- kinetics of stress relaxation at the fronts of the elastic and phase precursors from different initial states.

Subjects of research – wedge samples of the hardened 30KhGSA steel (HRC 35…40) with the dimensions 50´ 30´ 13 mm^3 and angle 12°00¢ The minimum thickness of wedges is 3 mm, the maximum thickness – 13 mm.

Explosive loading of wedge samples – through the 12Kh18N10T base-plate with the 5-mm thickness by normal detonation of the 5-mm PETN-based plastic explosive layer in experiment 1 or the 10-mm HMX-based explosive layer in experiment 2.

Recording Techniques and Results

The well-known optical-lever method is used for wave processes registration [1-3]. Results are presented in the form of streak-camera records and the recovered samples.

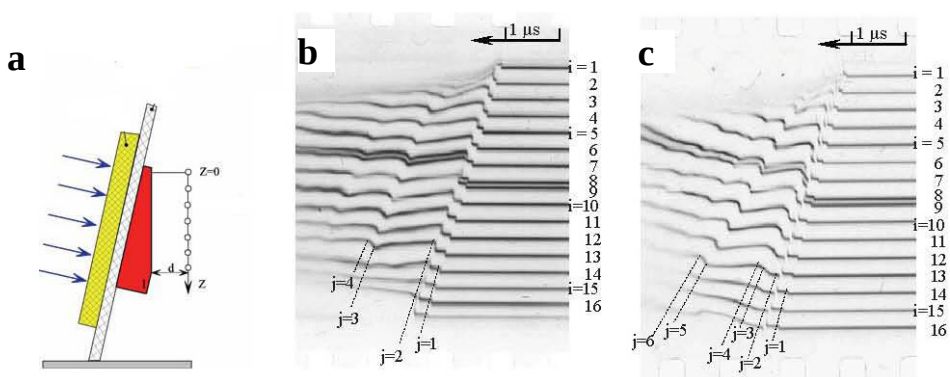

Figure 1. Schematic explosive loading of wedge samples (a) and streak-camera records (b,c) from experiments 1 and 2.

Processing of streak-camera records and investigation of recovered samples provided all the needed quantitative data just after two explosive experiments. In Figure 2, symbols show the experimental data on the kinetics of stress relaxation at the front of the elastic precursor from two different initial states and curves – the approximation of experimental data according to the statistical thermofluctuation model [2].

Figure 2 shows data on stress relaxation at the front of the elastic (HEL) and phase (PhP) precursors, as well as on the principal wave attenuation throughout the wedge thickness *h* in experiments 1 and 2. In the first explosive loading mode, conditions for solid-solid phase transformation are realized only in a narrow layer $h < 5$ mm being adjacent to the loading surface. In the second explosive loading mode, transformation is observed throughout the entire sample.

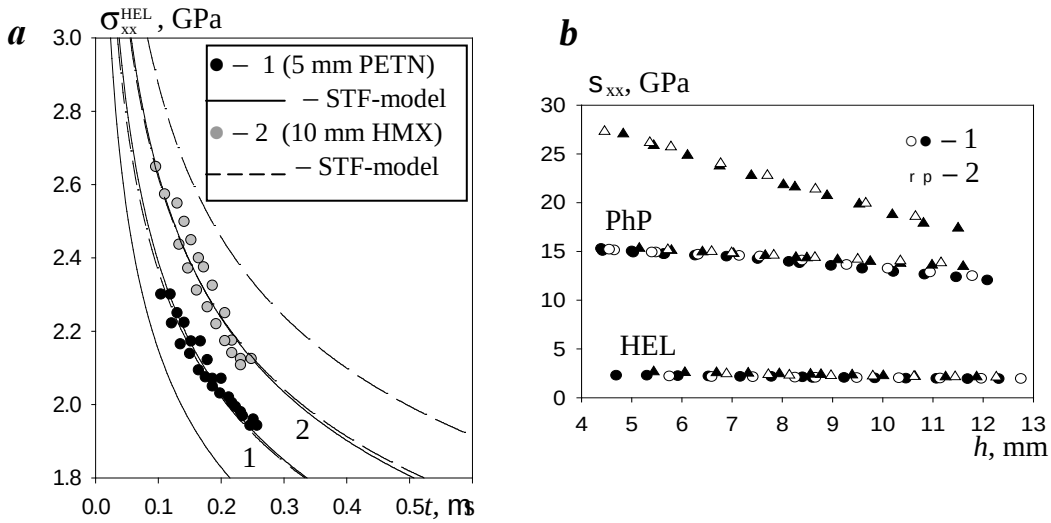

Figure 2 – Experimental data on the kinetics of stress relaxation at the elastic precursor front in the hardened 30KhGSA steel from two different initial states and results of their approximation by the statistical thermofluctuation model [2] at a_0=12.129±0.011 (1s) and a_0=12.508±0.018 (1s) (*a*) and amplitudes of longitudinal stress at the front of the elastic and phase precursors, as well as the principal plastic wave (b) in wedge samples when they are loaded in experiments 1 and 2.

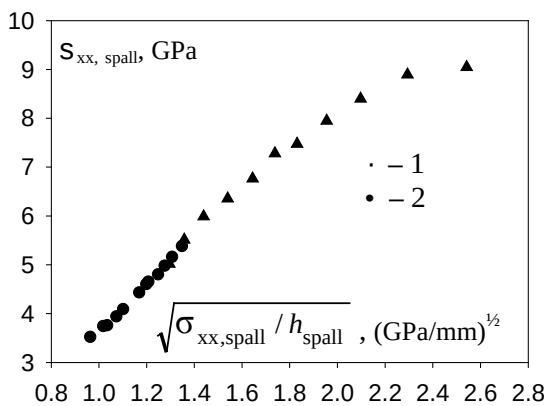

Figure 3 – Spall strength of the hardened 30KhGSA steel (HRC 35…40) versus square root of the stress gradient in the tensile range

Figure 3 shows results of experiments 1 and 2 on the spall strength of the hardened 30KhGSA steel (HRC 35…40) at high-rate deformation in the initial phase range and in the reversible solid-state transformation range. Results of two experiments are in a good agreement between themselves and with the previously published data [2 and references thereto].

Conclusions

Demonstrated is the high information capacity of the optical lever method that made it possible to obtain important quantitative data just in two explosive experiments. New experimental results on the dynamic properties of the hardened 30KhGSA steel (HRC 35…40) were used to verify and certify modern kinetic multiscale models and 2D-software complexes.

[1] G.R.Fowles, “Shock wave compression of hardened and annealed 2024 aluminum,” *J. Appl. Phys.* **32** [8] 1475-1482 (1961).

[2] E.A.Kozlov “Shock adiabat features, phase transition macrokinetics, and spall fracture of iron in different phase states,” *High Pressure Research* **10** 541-582 (1992).

[3] E.A.Kozlov, V.I.Tarzhanov, I.V.Telichko, D.G.Pankratov, A.V.Vorobyov, D.M.Gorbachev, V.I.Stavrietsky, “Registration of Free Surface Velocity Dispersion of Iron and Steel Samples by Optical Lever Method,” in *Proceedings of VIII Zababakhin Sci. Talks* (Snezhinsk, RFNC-VNIITF, 2005), eds. E.N.Avrorin, V.A.Simonenko (Melville, New York: Am. Inst. Phys. Conf. Proceedings 849, 2006) pp.393-398.