Strain rate, temperature and structure effects on the flow and fracture stresses of metals and alloys under shock-wave loading

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ABSTRACT

Some new and obtained earlier experimental data on evolution of elastic-plastic shock waves in several metals and alloys at normal and elevated temperatures are systematized. The data on precursor decay include last measurements at micron and submicron distances where realized shear stresses are comparable with their ultimate ("ideal") values. Results of measurements have been transformed into dependences of plastic strain rate on the shear stress. It has been found the precursor decay may occur in several regimes which are characterized by different decay rates. Hardening of a material by decreasing grain size or by other method may appear or not appear in increase of the HEL value depending on the branch of the flow stress dependence upon the plastic strain rate which is realized for chosen sample thickness. Moreover, it was observed that harder ultra-fine-grained tantalum may demonstrate even lower HEL value than less hard coarse-grained one. Anomalous growth of the Hugoniot elastic limit with heating correlates with a fast decay regime and is not observed when the decay is relatively slow. An analysis of the rise times of plastic shock waves shows by order of magnitude faster plastic strain rates at corresponding shear stresses than that at the HEL. Results of measurements of the resistance to high-rate fracture ("spall strength") show gradual increase of the later with increasing rate of tension and approaching the "ideal" strength in a picosecond time range. The spall strength not necessary correlates with dynamic yield stress. Although grain boundaries, in general, reduce the resistance to fracture as compared to single crystals, the spall strength of ultra-fine-grained metals usually slightly exceeds that of coarse-grain samples. The spall strength usually decreases with heating although in less degree than the strength at low strain rates does. The temperature dependences of the spall strength do not correlate with dependences of the yield stress that points on larger contribution of the fracture nucleation processes as compared to the void growth.