The paper presents the results of investigation into dynamic response of austenitic stainless 12Cr18Ni10Ti (close analog – 304 stainless steel [3,4]) steel and magnesium MA14T1 alloy to the shock action under both elevated and low temperatures. Single-stage light-gas gun was used to carry out the experiments. Stress-wave profiles were measured using two-channel VISAR interferometer.

The influence of temperature on the strength properties of structural materials has not been studied in detail yet. In particular, there are the alloys whose dynamic elastic strength demonstrates anomalous growth with the increase of temperature. The spall strength usually shows little change with temperature, i.e. it decreases insignificantly up to 85% of the melting point, which is followed by a drastic degradation of strength properties. As for 12Cr18Ni10Ti, its tensile strength is observed to decrease significantly (about 50%) in the cause of low-strain-rate deformation. Investigations at normal and elevated (100˚C and 200˚C) temperatures using Kolsky method with the split Hopkinson were performed to measure strain yield.

Variation of both the impact velocities in the range from 0.1 to 1.5 km/s and the sample temperatures from 90 to 750˚K allowed us to show up the intricate nature of changes in the elastic and viscous-plastic properties of materials as well as the complex dependences of spall strength on various parameters, i.e. on temperature, strain rate, loading pulse amplitude, etc. Experimental impact velocities ranged from 90 m/s to 1600 m/s. Investigations were focused on the range of loads corresponding to the spall fracture incipience; thus, impact velocities varied from 90 m/s to 350 m/s. Push-pull type interferometer [6] allowed us to measure velocity to a precision of < 5 m/s with time resolution of about 2 ns. Impact velocity to a precision of < 0.8 % as well as to control the tilt of impact surfaces (< 4 milliradians) and the orientation of this tilt were used.

Test samples made of 12Cr18Ni10Ti steel and magnesium MA14T1 alloy were manufactured to have the shape of disks with diameter of 32 mm and the thickness of 3, 4, and 6 mm.

Measured velocity profiles were used to determine [5,7] velocity at the front of elastic precursor $W_{hel}$, longitudinal stress $\sigma_{hel}$, maximum velocity on the free-surface velocity profile $W_{max} = W_{pl} + W_{hel}$, and length of the primary plastic wave $\tau_{pl}$. We calculated spall strength $\sigma_{sp}$, strain rate determined on the portion of unloading from the shock-compressed state, and spall thickness $h_{sp}$. Calculated value of spall thickness $h_{sp}$ was in good agreement with that measured on diametral section of recovered sample. The obtained results were used to construct the plots of spall strength versus shock compression amplitude and temperature $\sigma_{sp}(P)$ and $\sigma_{sp}(T)$, versus strain rate $\sigma_{sp}(\partial\varepsilon/\partial t)$, as well as versus tensile stress gradient. The ratio of tensile stress in the spall plane to spall thickness $\sigma_{sp}/h_{sp}$ was used as the tensile stress gradient.

Determined is the amplitude of shock-wave loading at which the incipience of spall fracture occurs in the 12Kh18N19N steel samples. The dependencies of spall strength versus shock compression amplitude, versus strain rate on the portions of compression and unloading, versus tensile stress gradient as well as versus temperature are measured. Interrelation between the results of dynamic measurements and the parameters of damage distribution in the recovered samples is shown.

The recovered samples were investigated using metallography and fractography that made it possible to obtain the data on the damage distribution in samples under the conditions of spall fracture incipience and development as well as on the microhardness distribution in the recovered samples made of steel and magnesium alloy. The analysis of recovered samples helped to prove the presence of
polymorphic transformation during the spall fracturing of 12Cr18Ni10Ti steel and to identify those thermodynamic parameters at which this transformation takes place [2]. Experimental data demonstrated that the recovered 12Cr18Ni10Ti steel samples could obtain ferromagnetic properties. The obtained results demonstrated that while the temperature was rising up to ~ 250 °C, the spall strength of 12Cr18Ni10Ti steel was decreasing. This could be due to the fact that 12Cr18Ni10Ti steel lattice becomes less stable.

The effect of localization of strain-induced martensite in 12Cr18Ni10Ti steel was revealed for the first time ever with the help of X-ray diffraction method [2]. The investigations that were carried out allow us to more precisely predict the behavior of structures made of these materials at the high-rate branch of deformation (10^3 .. 10^8 s^-1). And the data on both damage distribution and spall fracture incipience is essential for the adjustment of parameters of spall fracture models. It is demonstrated that variations in chemical properties and structure of 12Cr18Ni10Ti steel can change the elastic-viscous-plastic properties of this steel by 25..45% as well as the spall fracture by 25..30%.

The performed investigations demonstrate that within 90 … 750°K, the spall fracture of magnesium MA14T1 alloy has special features that are to be considered when predicting the behavior of the given material. The influence of temperature on the elastic precursor shape and amplitude is also shown.

REFERENCES


