MODEL OF EQUATIONS OF STATE FOR REFRACTORY METAL ALLOYS IN PROCESSES OF INTENSIVE MECHANICAL LOADING

N. N. Seredkin, K. V. Khishchenko

Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russia

The equation of state for matter is used in hydrodynamic modeling of processes of high-intensity mechanical loading to close the system of equations of motion of the medium. In this paper, equations of state of several refractory metals (tungsten, rhenium and others) and their alloys (mixtures) at high pressures and temperatures are proposed.

When constructing the equation of state of matter, the thermodynamic potential of the specific Helmholtz free energy (F) in its natural variables was chosen as a basis: $F = F(V, T)$, where V is the specific volume; T is the temperature. In the proposed model, free energy consists of three terms, one of which takes into account the cold part (at an absolute temperature equal to zero), and the other two take into account the thermal contribution of atoms and electrons. From the thermodynamic potential F, functional dependencies are obtained for the specific internal energy $E = E(V, T)$, i. e., the caloric equation of state, and pressure $P = P(V, T)$, i. e., the thermal equation of state, according to the thermodynamic relations $E = F - T(\partial F/\partial T)_V$ and $P = -(\partial F/\partial V)_T$. For each refractory metal considered in the work, the free parameters (constants) of the equation of state were selected based on the condition of best agreement with the known experimental data on shock compression of matter at high pressures and temperatures.

The equations of state for alloys are constructed on the basis of another thermodynamic potential– the specific Gibbs free energy (G) in its natural variables: $G = G(P, T)$. With this approach, it follows from thermodynamic relationships that the Gibbs energy of a mixture can be calculated by adding the Gibbs energies of the components, taking into account their mass fractions. The volume and internal energy of a unit mass of a mixture are found using the formulas $V = (\partial G/\partial P)_T$ and $E = G - T(\partial G/\partial T)_P - P(\partial G/\partial P)_T$.

Based on the proposed equations of state for refractory metals and their alloys, calculations of the thermodynamic characteristics of these materials were carried out in a wide range of pressures and temperatures. From a comparison of the results of these calculations with the available data on shock compression of materials, a conclusion can be drawn about the adequacy of the constructed equations of state.