CRACK RESISTANCE AND MICROMECHANISMS OF FAILURE OF DISPERSION-HARDENED MOLYBDENUM ALLOY WITH 30% TUNGSTEN,


Devising composites on the basis of high melting metals, especially tungsten and molybdenum, is one of the promising trends in the materials science of high melting structural materials [1]. This class of materials has comparatively good high-temperature properties and satisfactory technological suitability. However, with the development of branches using new techniques the requirements concerning materials become more stringent, especially as regards their ability to resist failure under conditions of complex thermal and mechanical loading that is characteristic of real operating conditions. One of the possible ways of optimizing the mechanical properties of high melting metals and alloys based on them is hardening by dispersive high melting oxides [2].

In the present work we studied the effect of the temperature on the crack resistance and on the micromechanisms of failure of the dispersion-hardened molybdenum alloy with 30% tungsten in the temperature range 293-2073°K.

The material was obtained by hydroextrusion (reduction $\varepsilon = 60\%$).

Crack resistance was investigated in static tension of small compact specimens $6.5 \times 10^{-3}$ m thick [3].

The test specimens were cut out from a rod in such a way that the direction of the initial crack coincided with the axis of extrusion.

The initial cracks with relative length varying within the limits $0.48 < l/b < 0.52$ were made by the method of static wedging with the application of controlled pressure on the end face [3].

Crack resistance tests were carried out on a high-temperature vacuum plant VTIR-1 [4] in a vacuum of $1.3 \times 10^{-3}$ Pa in the temperature range 293-2073°K. The specimens were heated at the rate of $12 \times 10^3$ °K/h held at the specified test temperature for 0.4 h.

Analysis of the micromechanisms of failure of the test specimens was carried out on a transmission electron microscope EVM-100 LM with the use of two-stage plastic replicas pre-shadowed by platinum.

As parameter of crack resistance we chose the theoretical stress intensity factor $K_Q$ [5]. Such an approach in the case of material such as tungsten of commercial purity [6] is justified because the parameter $K_Q$ is invariant to changes of thickness of the specimen, of the initial and current length of the arterial crack.

The special features of the change of resistivity to crack propagation of the dispersion-hardened molybdenum alloy with 30% tungsten are illustrated in Fig. 1.

It is characteristic of the temperature dependence of the crack resistance of the investigated material that the maximum lies at the temperature corresponding to the upper boundary of the temperature range of the viscoelastic transition $T^V_x$ (1073°K).

When the test temperature was raised within the range $293°K - T^V_x$ it led to increased crack resistance of the material with unstable crack development. The nature of the temperature dependence of the crack resistance of the investigated material is identical with the analogous dependence of the dispersion-hardened tungsten alloy [7].
Fig. 1. Temperature dependence of the crack resistance of the dispersion-hardened molybdenum alloy with 30% tungsten in the temperature range 293-2073°K.

Fractographic investigations showed that the failure of the molybdenum alloy in the mentioned temperature range was brittle and occurred along the surface of the seam (Fig. 2a). The process of lamination is a specific form of failure of materials with laminated or fibrous structure [2]. Lamination of deformed metals is characterized by crack propagation on certain surfaces which are parallel to the direction of deformation. It was established that in the investigated material lamination cracks propagated parallelly to the axis of extrusion along the grain boundaries (Fig. 2a).

At higher temperatures (above $T_v$) we found an irreversible decrease of the coefficient $K_Q$ with stable crack propagation. Failure was of a ductile nature with the formation of a pitted relief up to 1873°K (Fig. 2b). Beginning at 1673°K we noticed that a substructure formed (Fig. 2c). The depth and dimensions of the pits decreased with rising temperature (there was a tendency to decreasing dimensions of the pits). Unfortunately we did not manage to establish a correlation between the change of dimension of the pits and crack resistance because of the large scatter of the experimental data.

Fig. 2. Special features of the failure of dispersion-hardened molybdenum alloy with 30% tungsten in the temperature range 293-2073°K (electron fractography): a) $T = 293°K$; b, c) $T = 1073°K$; d, e) $1873 \leq T \leq 2073°K$. 