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MECHANICAL CHARACTERISTICS AND STRUCTURE OF MOLYBDENUM ALLOY CM-10 IN TEMPERATURE RANGE OF 298 – 1473 K

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The influence of a test temperature on the mechanical characteristics of the molybdenum alloy samples of CM-10 is considered. It is shown, that deformed by rolling molybdenum alloy has anisotropy of mechanical characteristics. The maximum value of strength properties is reached on transversal samples. The maximum value of relative elongation corresponds to longitudinal samples. Strength properties of samples are monotonically reduced while test temperature increasing. Plastic properties in the temperatures range of 273 – 1273 K are reduced, and then they sharply increase reaching 25 – 35 % at test temperature of 1473 K.

Introduction

The making and successful usage of materials intended for operation at high (higher 1300 K) temperatures is an actual problem of modern materials technology. The basic requirement to the products made up from heat resisting materials is retention of serviceability of rigid space developed construction working under condition of high temperatures, hostile environment and high-cycle alternating-sign loading. At the same time initial semimanufactured products made of heat-resisting alloys should have satisfactory manufacturability at mechanical processing, shaping and good welding.

Experimental results

The perspective class of heat-resisting materials is high-melting metals and alloys on their basis. Among all high-melting metals as constructional materials it is possible to consider molybdenum, tungsten, niobium and tantalum. Among all of these metals molybdenum represents ones of the most perspective one and, what is very important, it is cheap. It possesses a complex of the important physical-mechanical characteristics, such as high high-temperature strength, considerable specific strength at high temperatures, high elasticity coefficient, good thermal conduction and small value of temperature coefficient of linear expansion, exclusive corrosion resistance in liquid metal heat carriers mediums and others. The low-alloyed molybdenum alloy CM-10 possesses all these properties to necessary extent. At the same time information about behavior of this alloy at high temperatures is restricted. Present research shall consider mechanical characteristics of molybdenum alloy CM-10 in a temperature interval within room temperature to temperature of 1473 K. The value of mechanical characteristics in a wide temperature interval will allow not only to determine a temperature limit of its usage, but also to find an optimum temperature interval of such technological operations as deep elongation, rolling, bending etc.

Alloy CM-10, as well as any molybdenum sheet deformed by rolling [1; 2], in the state of delivery has a fibrous microstructure.

Such a structure in a sheet plane represents equiaxial cells of 2–5 microns average diameter and high density of dislocations inside them.

The temperature dependence of strength and plastic characteristics of sheet specimens of the alloy, cut in three directions, is represented in fig. 1.

The character of the tensile stress-strain diagram and strength properties diminution at test temperature enhancement, absolute value and modification of plastic characteristics demonstrate that the deformation of considered alloy is accompanied by processes of dynamic return (temperature interval of 500–800 K), polygonization (900–1300 K) and recrystallization (above 1300 K).

The structure of molybdenum alloy in the initial state (rolling and annealing) is shown on fig. 1, *d* The annealing of an alloy leads to considerable coarsening of grain due to disappearance of their boundaries in the temperature interval up to the 1223 K (fig. 2, *b*).

The further rise in temperature of annealing is accompanied by intensification of cells growth process (fig. 2, *c*), and primary recrystal-lization process is practically completed at temperature 1523 K (fig. 2, *d*). However structure, specified by elongation of grains in the direction of sheet rolling is still saved and the grain size is within limits from 4 to microns.

It is also necessary to note, that, inspite of the fact that there are some differences in grain structure, distribution of grains according to their sizes has small differences (fig. 3).

The grain size and annealing temperature dependence is represented on fig. 4.

As follows from introduced data, the mechanical characteristics of the sheet molybdenum alloy CM-10 are anisotropic, down to test temperature of 1273 K. Strength properties are monotonically reduced with rise in test temperature. At first the percent elongation is reduced with rise in test temperature up to 1727 K and than it rather sharply increases and reaches 32 – 37 % at test temperature 1473 K.

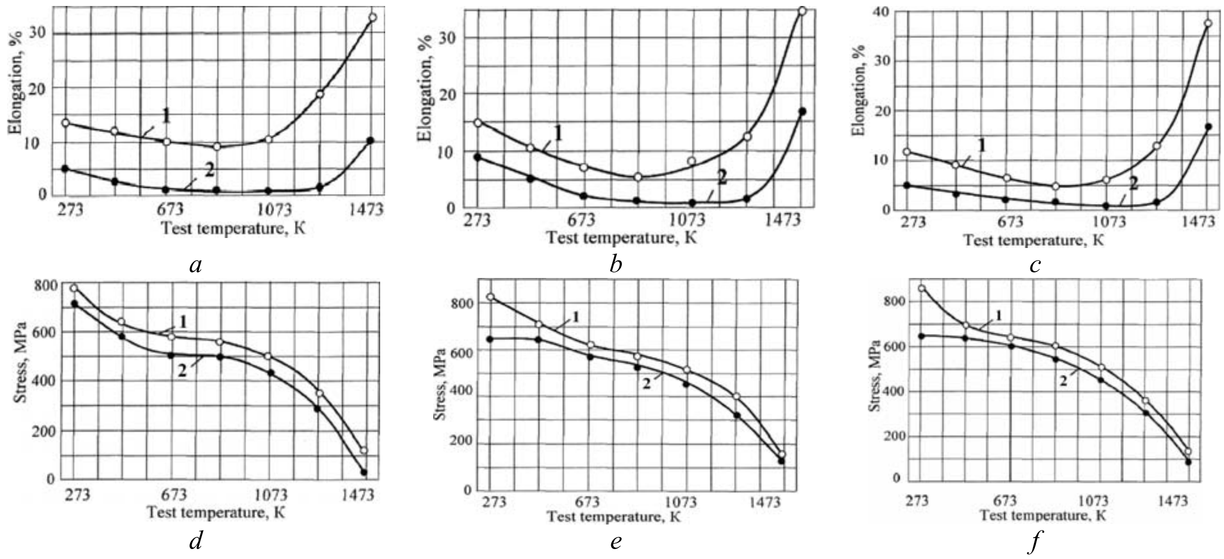
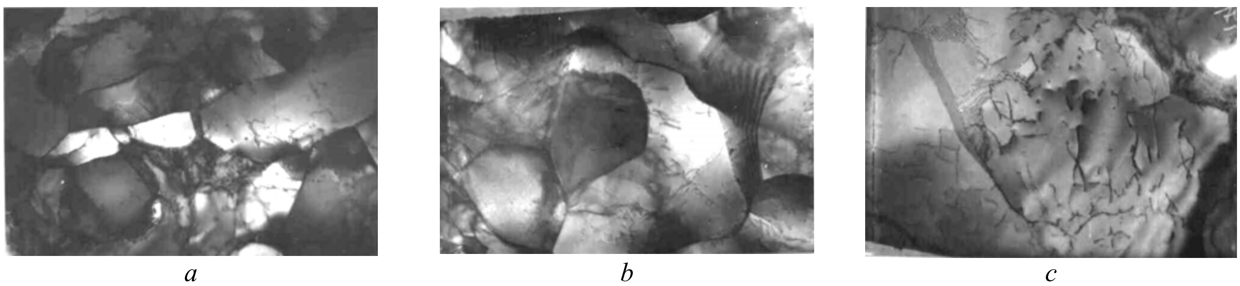


Fig. 1. Temperature dependence of plastic characteristics (*a, b, c*) and strength (*d, e, f*) obtained on longitudinal (*d*), transversal samples (*d, e*) and samples, cut at the angle 45 ° (*c, f*) to the direction of rolling in initial state:
a, b, c: *1* – percent common elongation; *2* – relative uniform elongation;
d, e, f: *1* – ultimate strength; *2* – yield point



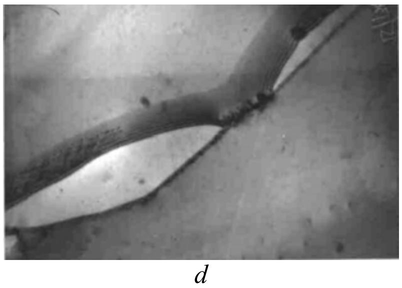


Fig. 2. Dislocation structure of molybdenum alloy after different temperatures of annealing:
a – initial deformed state; *b* – annealing temperature 223 K; *c* – annealing temperature 1423 K; *d* – annealing temperature 1523 K

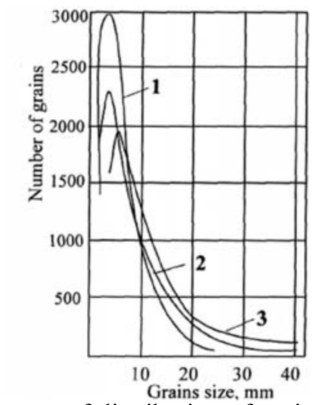


Fig. 3. Histogram of distribution of grains number as to their sizes in three dimensions of sheet after annealing at 1423 K:
1 – section is normal to the sheet plane and is perpendicular to the rolling direction; *2* – section is normal to the sheet plane and is parallel to the rolling direction; *3* – section is in a plane of a sheet

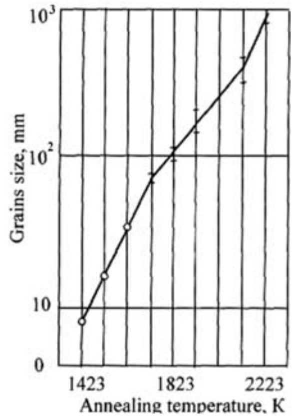


Fig. 4. Grain size on annealing temperature dependence

The mechanical characteristics anisotropy of sheet molybdenum alloy deformed by rolling is stipulated by two factors: first, structural texture, namely, grain elongation in the direction of rolling and strong flattening along the sheet width [3].

If the average size of a structure element in a sheet plane equals 2–5 microns, the width of a structure element does not exceed 0,1 micron. Second, during rolling the particular crystallographic texture in sheet molybdenum alloy is formed. This crystallographic texture is due to the fact that planes (001), (111) go out in sheet plane, and the directions [110], [112] coincide with the rolling direction respectively. The detailed research of a possibility of elimination of mechanical properties anisotropy of molybdenum rolled at low temperature as a result of annealing is represented in article [4]. However estimation of anisotropy of plastic characteristics as regards temperature of cold brittleness is not always justified. The analysis of conditional yield point and uniform percent elongation, gives a more objective estimation of anisotropy of mechanical characteristics.

After annealing at temperature 1423 K (this value of temperature is 100 K higher than temperature of primary recrystallization) the structural texture practically disappears, and the difference in grains sizes increases. After such temperature of annealing there are a great number of equiaxial grains sized up to 10 microns, and there are grains sized 30–40 microns.

Further enhancement of annealing temperature is accompanied by disappearsence of cellular structure and formation of equiaxial grain structure. Thus the grain size increases from 10 microns up to 800 microns with enhancement of annealing temperature from 1423 K up to 2223 K accordingly (fig. 4).

Conclusion

1. Sheet molybdenum alloy CM-10 in a deformed state has anisotropy of mechanical characteristics. Thus the maximum values of strength properties are reached on transversal samples, and minimum – on samples cut at the angle 45^0 to the direction of rolling.
2. Strength properties monotonically reduce throughout the temperature interval with the test temperature rise.
3. The plastic characteristics with the test temperature rise up to 1073–1273 K reduce, and at further enhancement of test temperature they sharply increase.

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Механічні характеристики і структура молібденового сплаву ЦМ-10 у температурному діапазоні 298– 1473 К

Розглянуто вплив температури випробування на механічні характеристики зразків молібденового сплаву ЦМ-10. Показано, що деформований прокаткою молібденовий сплав має анізотропію механічних характеристик. Максимальне значення характеристик міцності досягається на поперечних зразках. Максимальне значення відносного подовження відповідає подовжнім зразкам. Зі збільшенням температури випробування характеристики міцності монотонно знижуються. Пластичні характеристики знижуються в області температур випробування 273–273 К, а надалі різко збільшуються до 25–35 % при температурі випробування 1473 К.

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Механические характеристики и структура молибденового сплава ЦМ-10 в температурном диапазоне 298–1473 К

Рассмотрено влияние температуры испытания на механические характеристики образцов молибденового сплава ЦМ-10. Показано, что деформированный прокаткой молибденовый сплав обладает анизотропией механических характеристик. Максимальное значение прочностных характеристик достигается на поперечных образцах. Максимальное значение относительного удлинения соответствует продольным образцам. С ростом температуры испытания прочностные характеристики монотонно снижаются. Пластические характеристики снижаются в области температур испытания 273–1273 К, а в дальнейшем резко возрастают до 25–35 % при температуре испытания 1473 К.