HEAT RESISTANT METALS AND ALLOYS

THE TECHNOLOGICAL AND MECHANICAL PROPERTIES OF SOME TUNGSTEN ALLOYS


The technological ductility of arc-melted tungsten can be improved by alloying with titanium [1]. However, W–Ti alloys are no better than unalloyed tungsten as regards strength at high temperatures [2]. Data reported in [3] indicate that alloying tungsten with 10–15% molybdenum raises its strength properties at temperature up to 2000°C without seriously reducing its technological ductility in working under pressure. Addition of about 0.1% zirconium sharply increases the strength of tungsten, but introduces considerable difficulties into its deformation at temperatures up to 1650°C [2, 3].

In the present investigation we have studied the mechanical and technological properties of W–0.5 Ti, W–10 Mo–0.5 Ti, and W–0.5 Ti–0.1 Zr alloys (the figures correspond to the content (%) of the alloying elements). The alloys were made up in a vacuum arc furnace using a consumable electrode. Melting was carried out with ac in a crystallizer of 70 to 80 mm diameter.

The electrodes used in making the alloys were prepared from metalloceramic tungsten rods having the following chemical composition: O and N 0.003% each; H 0.0003%; C 0.005%; Sn, Pb, Cd, Bi, Zn, and Sb 0.0001% each; Cu and Mg 0.0005%; As 0.0004%; Al 0.0006%; Fe, Si, P, and S 0.001% each.

In developing the melting technology the effect of 0.1–2.0% Ti on the macrostructure and purity of the ingot was investigated. It was found that on increasing the amount of titanium added from 0.1 to 0.5% the oxygen content in the ingot usually decreases by 1.5–2 times. Adding 1% or more of titanium to tungsten does not lead to any further reduction in the oxygen content, but the quality of the surface and periphery of the ingot deteriorates; hence 0.5% Ti was chosen as the optimum addition to be made in melting.

Fig. 1. Macrostructures of tungsten alloy ingots containing: a) 0.5% Ti; b) 10% Mo + 0.5% Ti; c) 0.5% Ti + 0.1% Zr.

Fig. 2. Dependence of the specific extrusion pressure of tungsten alloys on the natural logarithm of the extension (temperature 1600–1640°C): 1) 0.5 Ti–0.1 Zr extruded in a shell; 2) 0.5 Ti–0.1 Zr without a shell; 3) 10 Mo–0.5 Ti with a shell; 4) 0.5 Ti with a shell.
The titanium additions investigated had no significant effect on the macrostructure of the ingot. The addition of 0.1% Zr refines the macrostructure, while alloying with 10% Mo leads to very marked grain refinement of the cast metal (Fig. 1). Moreover, alloying with molybdenum eliminates from the peripheral regions of the ingot the porosity which is common in the W-0.5 Ti alloy, so enabling ingots with a good surface to be produced.

In order to study the technological ductility of the W-0.5 Ti, W-10 Mo-0.5 Ti, and W-0.5 Ti-0.1 Zr alloys during hot working and to choose the optimum working conditions, a batch of ingots of each alloy was made. The actual molybdenum and zirconium contents in the W-10 Mo-0.5 Ti and W-0.5 Ti-0.1 Zr alloys were 10-10.2% and 0.07-0.1%, respectively. The contents of the remaining elements in all the melts were as follows: 0.02-0.03% Ti, 0.003-0.004% C, 0.0006-0.002% O, 0.002-0.004% N, and 0.0002-0.0004% H. The hardness of the case alloys was: for W-0.5 Ti alloy HV = 365-378; for W-10 Mo-0.5 Ti alloy HV = 319-339; for W-0.5 Ti-0.1 Zr alloy HV = 374-408.

For extrusion most of the ingots were machined down to 61 mm diameter, and the remainder to 50 mm; the angle of taper was 110°. The tungsten alloys were extruded from a container 63 mm in diameter on a 800 ton vertical hydraulic press. The 50 mm diameter billets were extruded in carbon-steel shells with an external diameter of 61 mm and a wall thickness of 5 mm. The shells were in the form of a container with a conical (110°) end.

In the extrusion, dies made of 3Kh2V8 tool steel heat treated to a hardness HRC of 42-44 were used, and also dies coated with aluminum oxide. The angle of the entry cone of the die was 120° and the diameter of the hole 40-20 mm; this produced an extension between 2.5 and 10.

Before being extruded the billets were heated to 1600-1650°C in a chamber resistance furnace under a protective atmosphere of hydrogen.

The shells were heated separately to 700-800°C in order to secure the requisite ratio between the mechanical properties of the steel and those of the tungsten [4]. Glass was used as lubricant in extruding the billets both with and without shells.

The experiments showed that it is possible to produce by extrusion rods of good quality, either with or without the use of shells. Rods of the highest quality were obtained by using dies coated with Al₂O₃ and an extension coefficient of not less than 4, since with such a degree of deformation the cast structure of the billet is adequately broken down [5].