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MOLYBDENUM-ZIRCONIUM ALLOYS

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The present invention relates to alloys of molybdenum and zirconium, and more specifically to large, sound cast molybdenum-zirconium alloy ingots, which are capable of being worked at elevated temperatures by forging, pressing, rolling, extrusion and other similar methods. This invention is also concerned with molybdenum-zirconium alloys containing minor quantities of other elements and to such alloys in which a part of the molybdenum has been replaced by tungsten. Such alloys are useful in applications which require high hardness and strength at elevated temperatures, and more specifically in such applications as electrodes for heating molten glass, die-casting dies for brass and other metals, etc. This application is a continuation-in-part of applicants' copending application, Serial No. 218,525, filed March 30, 1951, now abandoned.

This invention has as its principal object the provision of improved cast molybdenum-base alloys which are capable of being worked at elevated temperatures.

A further object of this invention is to provide improved cast molybdenum-base alloys which are characterized by improved hardness and strength both at room and elevated temperatures.

A still further object of this invention is to provide cast molybdenum-base alloys which are characterized by a dispersed carbide phase and refined grain size.

The terms "casting" and "cast" as used in this application are intended to designate the product resulting from the melting of metal and solidifying the same in a mold, whether or not the metal has been subjected to subsequent working or machining. The term "casting" is also used to designate any process or method which involves melting metal and solidifying the same in a mold.

In accordance with this invention, it is found that molybdenum-base alloys exhibiting enhanced strength and hardness are obtained when small quantities of zirconium are used as an alloying element. It has been found, however, that maximum strength is fully realized in cast alloys only when the alloy contains limited amounts of oxygen, and that such alloys can be worked at elevated temperatures only if they contain limited amounts of both oxygen and zirconium.

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It has previously been established that the presence of minute amounts of oxygen in a casting of molybdenum or a molybdenum-base alloy seriously impairs or destroys the capacity of the casting to be worked at elevated temperatures if the oxygen is segregated at the grain boundaries in the form of certain metallic oxides. The detrimental oxide is visible on microscopic examination of intergranular fractures and is believed to consist largely of MoO₂. However, the oxides of certain other metals, if present, are also detrimental. In any event, when examined microscopically, castings which can be worked at elevated temperatures have no similar visible oxide segregations at the grain boundaries which are similar to the manifestations of MoO₂. Cast molybdenum containing less than about .001% oxygen can be worked at elevated temperatures but it is very difficult in the production of cast ingots of molybdenum and its alloys to reduce the oxygen content of the metal to such a low value.

As set forth in the patent to Frederick P. Bens et al., No. 2,580,273, the detrimental oxide segregation is not found in molybdenum castings containing not more than .005% oxygen if small amounts of carbon are present. Such castings can be worked at elevated temperatures.

It is now found that the detrimental oxides may also be eliminated by incorporating in the casting certain metals which have a stronger affinity for oxygen than does molybdenum and which form an oxide which either does not segregate at the grain boundaries or, if segregated at the boundaries, provides greater intergranular cohesion than does the oxide of molybdenum. Aluminum and beryllium have been found to fulfill these requirements, and forgeable castings of molybdenum and molybdenum-base alloys containing up to a maximum of .05% oxygen have been produced by incorporating small quantities of aluminum or beryllium or both in the casting. Carbon may also be present, if desired, and small quantities of carbon or aluminum are particularly beneficial in molybdenum-base alloys containing beryllium.

The effect of oxygen on the molybdenum-zirconium alloy castings of the present invention is similar to its effect in other molybdenum-base alloy castings, and consequently it is necessary