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MOLYBDENUM-TITANIUM ALLOYS

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The present invention relates to high-melting-point alloys of molybdenum and titanium and more specifically to large, sound, cast molybdenum-titanium 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-titanium alloys containing minor quantities of other elements and to such alloys in which a part of the molybdenum has been replaced by tungsten.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 metals of high strength or hardness at both room and 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. 218,521, filed March 30, 1951, now abandoned.

The principal object of the invention is to provide improved cast alloys of molybdenum which have high melting points and which are capable of being worked at elevated temperatures.

It is a further object of the invention to provide improved molybdenum-base alloys as castings of substantial size which have increased strength and hardness at both room and elevated temperatures and which exhibit a pronounced tendency to retain at elevated temperatures hardening induced by working at elevated temperatures.

A still further object of this invention is to provide improved cast molydenum-base alloys which have a lower specific gravity than pure molybdenum and thus are particularly suited for such applications as gas turbine blades.

A further object is to provide molybdenum-base alloys in which the carbide phase is dispersed by the addition of the alloying element.

The terms "cast" and "casting" as used in this specification 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, highly desirable cast alloys of molybdenum are obtained when titanium is employed as the alloying element. Such alloys exhibit improved strength and hardness at elevated temperatures as well as a marked tendency to retain at elevated temperatures, hardness induced by working.

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 MoO_2. 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 MoO_2. 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 form oxides which either do not segregate at the grain boundaries or, if segregated at the boundaries, provide 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-titanium alloy castings of the present invention is similar to its effect in other molybdenum-base alloy castings, and consequently it is necessary to eliminate segregations of molybdenum oxide at the grain boundaries if the casting is to be worked at elevated temperatures. This is preferably done by incorporating carbon, aluminum or beryllium in the alloy, either singly or in com-