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MOLYBDENUM-VANADIUM ALLOYS

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This invention relates to alloys of molybdenum and vanadium, and more specifically to large, sound, cast molybdenum-vanadium alloy ingots, which are capable of being worked at elevated temperatures by forging, pressing, rolling, extrusion and other similar methods. The invention is also concerned with molybdenum-vanadium alloys containing minor amounts of other elements and to such alloys in which a part of the molybdenum has been replaced by tungsten.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 requiring metals of high strength or hardness at both room and elevated temperatures and more specifically in such applications as piercing points for forming seamless steel tubing, 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. 218,522, filed March 30, 1951, now abandoned.

The principal object of this invention is to provide improved cast alloys of molybdenum which are capable of being worked at elevated temperatures.

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

Another object of this invention is to provide cast molybdenum-base alloys in which the intergranular cohesion of the grains is improved and the grain size reduced by the addition of the alloying element.

This invention has as another of its objects the provision of molybdenum-base alloys which are of lower specific gravity than pure molybdenum and which for that reason have particular utility as gas turbine blades.

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 the addition of vanadium increases the strength and hardness of cast molybdenum and molybdenum-base alloys.

Cast alloys of molybdenum and vanadium can be hot-worked only when the vanadium is present within certain limits and oxide and carbide impurities are present in amounts less than certain maximum quantities.

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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 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 visible oxide segregations at the grain boundaries which are similar to the manifestations of MoO_2. Cast molybdenum containing less than about .001% oxygen does not contain a detrimental quantity of grain boundary oxides and 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 that 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-vanadium 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