March 4, 1952 R. I. JAFFEE 2,588,007

TITANIUM-MOLYBDENUM-CHROMIUM ALLOYS

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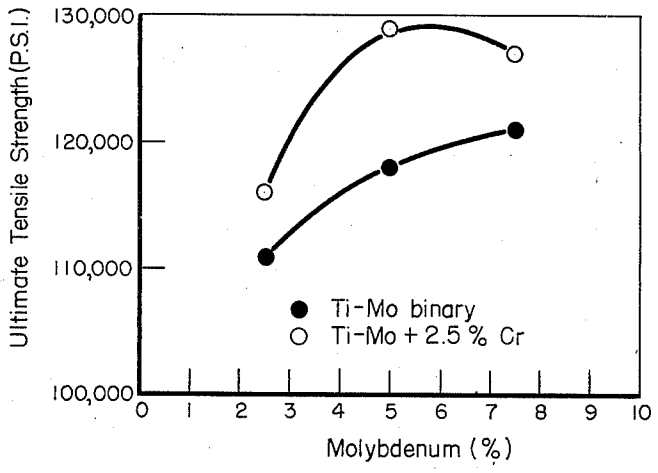


FIG. 1

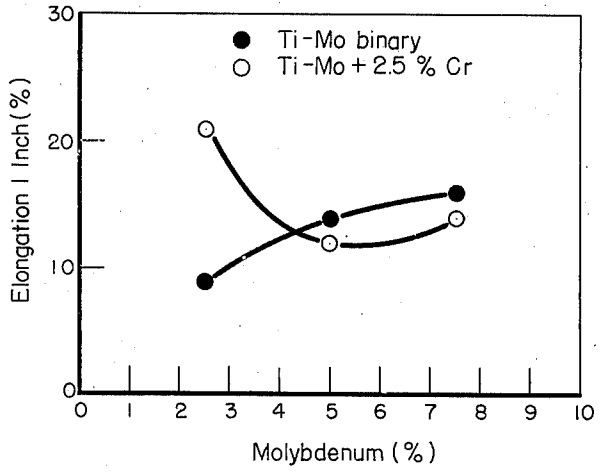


FIG. 2

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TITANIUM-MOLYBDENUM-CHROMIUM ALLOYS

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1 Claim. (Cl. 75—134)

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This invention relates to titanium base alloys and more particularly to ternary alloys containing titanium, molybdenum, and chromium.

Some work has been done on certain binary alloys of titanium, but these alloys proved to be brittle and unsatisfactory for commercial working practices. Because of the poor properties found by early investigations in the titanium field, further development was discouraged and no ternary alloys using titanium as a base have been made public up to the present time. The present invention, however, is concerned with the production of ternary alloys of titanium which have highly desirable properties and which are believed to be completely new in the alloy art.

It is, therefore, an object of this invention to provide ternary alloys of titanium with molybdenum and chromium.

A further object of this invention is to produce high-strength, ductile titanium base alloys which include chromium and molybdenum as the only added alloying ingredients.

Yet another object of this invention is to provide titanium base alloys suitable for structural purposes.

Other advantages and purposes of the present invention will become apparent from the following disclosure thereof, when considered in conjunction with the accompanying drawings wherein:

Figure 1 is a graph illustrating the effect on the tensile strength of adding 2.5% Cr to various Ti-Mo alloys, and

Figure 2 is a graph which shows the effect that the same addition to Ti-Mo alloys has on the elongation of the alloys.

In general this invention relates to ternary alloys comprising 1 to 10% molybdenum, 0.5 to 2.5% chromium and the remainder essentially titanium. Certain advantageous elements such as oxygen, nitrogen, carbon, etc. may be present.

The alloys of this invention may conveniently be prepared by powder metallurgy methods. For example, several metals may be mixed together as powders, compacted at about fifty tons per square inch, sintered in a high vacuum for about four hours at about 1100° C., enclosed in a steel envelope to prevent reaction with the air, and rolled at about 750° C. to 900° C., and finally stripped from the steel envelope. It will be understood that the various conditions enumerated are not critical. For example, sintering could be accomplished at a lower temperature if the sintering time were increased. As an alternate powder metallurgical procedure, the sintered compact might be cold rolled and then vacuum annealed.

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The present alloys may also be obtained by melting the component metals into an ingot in an arc furnace.

As an example of the beneficial effect of alloying molybdenum and chromium with titanium, Table 1 below shows ultimate tensile and ductility data for a control titanium metal, for binaries of titanium and molybdenum, and for ternaries formed by adding 2.5% chromium to the Ti-Mo binaries.

Table 1

Metal	Ultimate Tensile Strength (p. s. i.)	Per cent Elongation (1-inch)
Ti	89,000	18
Ti+2.5% Mo	111,000	9
Ti+5.0% Mo	118,000	14
Ti+7.5% Mo	121,000	16
Ti+2.5% Mo+2.5% Cr	116,000	21
Ti+5.0% Mo+2.5% Cr	129,000	12
Ti+7.5% Mo+2.5% Cr	127,000	13

These data are further presented and the results illustrated in the graphs in Figures 1 and 2 wherein it is clearly shown that the effect of the addition of chromium is to increase the tensile values without producing an objectionable decrease in ductility. The strength values of all the ternary alloys are considerably in excess of the 89,000 p. s. i. possessed by the control titanium metal. At the same time the ductility values are quite sufficient to permit commercial working of the alloys.

In addition to their desirable strength and ductile properties, the alloys of the present invention have excellent strength/weight ratios, equalling or surpassing aluminum and several aluminum alloys in this respect. This is illustrated in Table 2 below wherein the strength/weight ratios of Ti-Mo-Cr alloys are compared with those of several aluminum alloys.

Table 2

Alloy (as annealed)	Ratio of Ultimate Tensile Strength to Density	Ratio of 0.2% Offset Yield Strength to Density
2 S	4,800	1,850
14 S	9,600	5,000
24 S	9,700	4,000
75 S	11,800	5,400
Ti-2.5 Mo-2.5 Cr	25,100	21,000
Ti-5.0 Mo-2.5 Cr	27,800	24,500
Ti-7.5 Mo-2.5 Cr	26,700	24,000

Note.—Data on aluminum and aluminum alloys were taken from 1948 edition of the ASM Handbook.

The Ti-Mo-Cr alloys are also heat treatable. Table 3 shows how the hardness of Ti-Mo alloys is increased by quenching from temperatures in the range from 700° to 1000° C. and it is known that chromium additions up to 10% further enhance these heat treating characteristics.

Table 3

Alloy	Annealed Hardness [1]	Quenched Hardness [1]			
		700° C.	800° C.	900° C.	1000° C.
Ti+2.5% Mo	280	275	320	365	365
Ti+5.0% Mo	290	285	330	395	410
Ti+7.5% Mo	300	290	355	372	395

[1] Vickers Diamond Pyramid, 10 Kg. load.

All of the properties mentioned and demonstrated go to make the present alloys valuable, and it will be apparent that these alloys are suited for use as structural materials, for example in aircraft structural parts. Other uses and applications are available and will readily suggest themselves to persons skilled in the art.

What is claimed is:

An alloy comprising 2.5 to 7.5% molybdenum, 0.5–2.5% chromium as the only alloying elements and the remainder essentially all titanium.

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