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TITANIUM BASE ALLOY

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1

This invention relates to new and useful titanium base alloys.

This application is a continuation-in-part of our copending application Serial No. 90,776, filed April 30, 1949, now abandoned.

Titanium base alloys generally as known heretofore, in the form of sheets or other mechanically worked shapes, have had only limited utility for structural purposes. They lack the requisite combinations of strength and ductility.

According to this invention, it has been discovered that valuable alloys suitable for such structural purposes can be produced by compounding a titanium base with aluminum and molybdenum so that stable alloy structures composed essentially of the alpha form of titanium together with another distinct microcrystalline phase that probably is the beta form of titanium are obtained.

The presence of the stable second phase in the alloy structure results from incorporating molybdenum as well as aluminum in the titanium base. That phase appears to account for a pronounced increase of strength, accompanied by retained ductility sufficient for mechanical working requirements, which alloys embodying the present invention show as compared with binary titanium-aluminum alloys of similar aluminum content. The latter exhibit a single-phase microstructure composed of the alpha form of titanium.

Alloys possessing desirable combinations of strength, hardness and elastic properties may be obtained according to this invention by incorporating about 2.5 to about 8% of aluminum and about 1 to about 8% of molybdenum in a titanium base.

When the contents of aluminum and molybdenum total more than about 10%, the proportion of beta titanium to alpha titanium is such as to produce a different microstructure and different physical properties. While strength is high ductility is low. Compositions giving excellent strength and elastic properties result when at least 90% of the whole alloy is titanium and

2

the molybdenum content is between about 2 and about 5%. Within these limits which represent preferred embodiments are alloys, for example, which, after being hot rolled and annealed at 850° C., exhibit proportional limits of from 122,000 to 142,000 p. s. i. and ultimate strengths of from 139,000 to 152,000 p. s. i., together with elongations of at least 11% in one inch, and the capacity to undergo cold rolling reductions of 50 to 70% or more without edge cracking.

The titanium base metal used in the present alloys may contain substances or impurities besides titanium, as normally found in either high purity titanium or commercially pure titanium.

It may be, for example, a high purity or "iodide" process titanium as produced according to the Van Arkel United States Patent No. 1,671,213. Alternatively, it may be a commercial titanium as produced, for example, by magnesium-reduction processes, such as the process of United States Patent No. 2,205,854 to Kroll or modifications thereof; provided that the carbon, oxygen and nitrogen contents of these alloys, hence of the base metal, should not exceed 0.5%, 0.25% and 0.15%, respectively, nor should they total more than about 0.5%, if the alloys are to possess good ductility as cast or as worked and annealed.

It has been found, however, that the presence of between 0.1 and 0.3% of carbon, with or without about 0.01 to 0.15% each of oxygen or nitrogen or both, is generally quite beneficial. Among the least high-strength alloys of this invention are those made either with a commercial titanium base meeting such specifications, or with a high purity titanium base containing similar amounts of added carbon or added carbon and oxygen, nitrogen, or oxygen and nitrogen. Important embodiments of this invention therefore may be defined as alloys composed essentially of from 2.5 to 7.5% of aluminum and from 0.5 to nearly 10% of molybdenum in a titanium base containing from 0.1 to 0.3% of carbon, or 0.1 to 0.3% of carbon and about 0.01 to 0.15% of oxygen and/or nitrogen.

Illustrative compositions and properties of al-

loys embodying this invention appear in the following table, which also shows properties of a comparable binary titanium-aluminum alloy:

vacuum annealed for about three hours at about 850° C.
Example 18 of the foregoing table shows that

Composition		As Hot Rolled and Annealed at 850° C.							
		Strength Properties—X1000 p. s. i.							
		Al	Mo	10 kg. Vickers Hardness	Prop. Limit	0.1% Offset	0.2% Offset	Ultimate	
TI Base-----									Per Cent Elongation in 1"
1	High Purity-----	5		273	44	62	64	78	18
2	do-----	5	1	298	56.9	81	83.6	103	15
3	do-----	5	2.5	289	66	83	85	104	12
4	do-----	5	5	282	61	101	104	117	11
5	HP+0.1C-----	5	2.5	306	75	103	106	120	16
6	HP+0.25C-----	5	2.5	320	98	121	121	134	18
7	HP+0.1N-----	5	2.5	314	88	106	108	123	12
8	HP+0.2N-----	5	2.5	356	107	124	125	138	13
9	HP+0.1O ₂ -----	5	2.5	307	92	104	108	121	13
10	HP+0.2O ₂ -----	5	2.5	333	94	112	114	134	10
11	HP+0.1N+0.1O ₂ -----	5	2.5	343	110	122	123	138	10
12	HP+0.25C+0.1O ₂ -----	5	2.5	363	122	134	136	148	12
13	HP+0.25C+0.2O ₂ -----	5	2.5	386	128	144	148	160	12
14	HP+0.25C+0.1N-----	5	2.5	373	134	137	137	152	8
15	HP+0.25C+0.1O ₂ +1N-----	5	2.5	408	151	159	160	169	4
16	HP+0.25C-----	6	2.5	351	122	131	133	145	12
17	HP+0.25C-----	7	2.5	370	139	141	142	152	12
18	Commercial (0.25C)-----	7.5	2.5	330	123.6	129.2	129.6	141.3	11
		5	2.5	375	118		128	140	15

In addition to desired strength, hardness and ductility properties, the alloys of this invention possess valuable properties of corrosion resistance. Many of them retain a hardness exceeding that of cast commercial titanium, at temperatures as high as 1000° F., and they can be made with extraordinarily high ratios of strength to weight, since alloys of very high strength can be obtained by using, for example, only about 2.5% of the heavy metal molybdenum with twice as much light aluminum in a titanium base.

The alloys herein disclosed have the second or beta phase in their structure dispersed intergranularly in a matrix of alpha titanium. When they are quenched from 950° C. some increase in hardness results, while quenching them from 1050° C. increases their annealed hardness by about 50 to 80 Vickers points. Aging them after quenching at 400° C. for periods up to 16 hours does not substantially alter their quenched hardness. Alloys containing more than about 10% molybdenum have more finely dispersed phases in their microstructure and respond to heat treatment in a substantially different manner.

The alloys of this invention are preferably prepared by the arc melting of an admixture of their constituents in a comminuted form. Carbon, oxygen or nitrogen may be added, if desired, in the form of solid compounds thereof with titanium. To insure that none of the alloying element is lost, such compounds may be enclosed in a titanium capsule, which is then arc melted. Other methods of alloying are, of course, applicable.

Fabrication of the present alloys into sheets is preferably effected by hot rolling. For example, the metal may be heated at a furnace temperature of about 850° C., reduced in thickness about 10% in each pass through rolls, and reheated after each pass. When the desired thickness, say 0.04 inch, has been secured, the sheet may be mechanically cleaned and then

an alloy having outstanding properties may be obtained by use of a commercial titanium base containing 0.25% of carbon with 5% of aluminum and 2.5% of molybdenum. The commercial titanium here used showed at 10 kg. Vickers hardness as cast of about 170, while the alloy fabricated as above described to a thickness of 0.045 inch, showed a 10 kg. Vickers hardness of about 375. Strips of this alloy could be bent to a $\frac{3}{16}$ inch radius without cracking.

What is claimed is:

1. An alloy composed essentially of 2.5 to about 8% of aluminum and 0.5 to about 8% of molybdenum, balance titanium.

2. An alloy composed essentially of 2.5 to about 8% of aluminum and 0.5 to about 8% of molybdenum, balance titanium containing 0.1 to 0.3% of carbon.

3. An alloy composed essentially of 2.5 to 8% of aluminum and 2 to 5% of molybdenum, balance titanium, the titanium content being at least 90%.

4. An alloy composed essentially of 2.5 to 8% of aluminum and 2 to 5% of molybdenum, balance titanium containing 0.1 to 0.3% of carbon, the titanium content being at least 90%.

5. An alloy composed essentially of about 5% of aluminum and about 2.5% of molybdenum, balance titanium.

6. An alloy composed essentially of about 5% of aluminum and about 2.5% of molybdenum balance titanium containing about 0.25% of carbon.

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REFERENCES CITED

The following references are of record in the file of this patent:

FOREIGN PATENTS

Number	Country	Date
718,822	Germany	Mar. 24, 1942