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TITANIUM ALLOY

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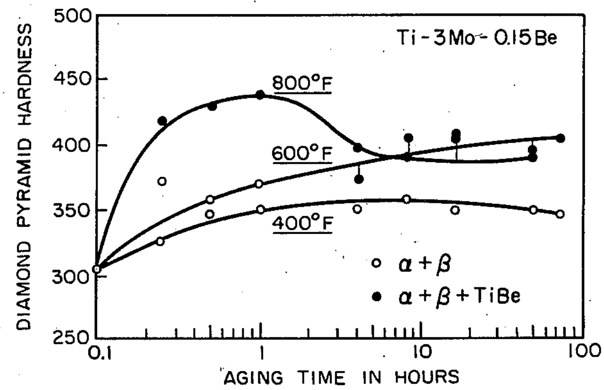

FIG. 1

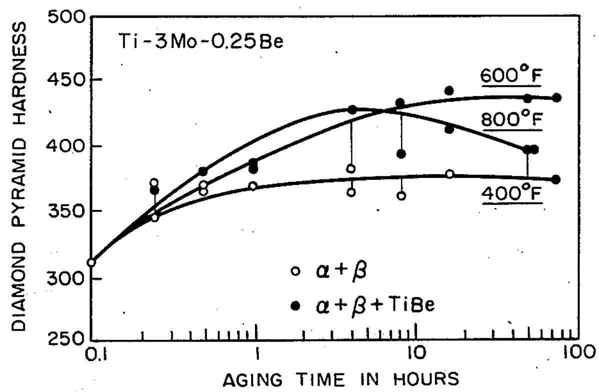

FIG. 2

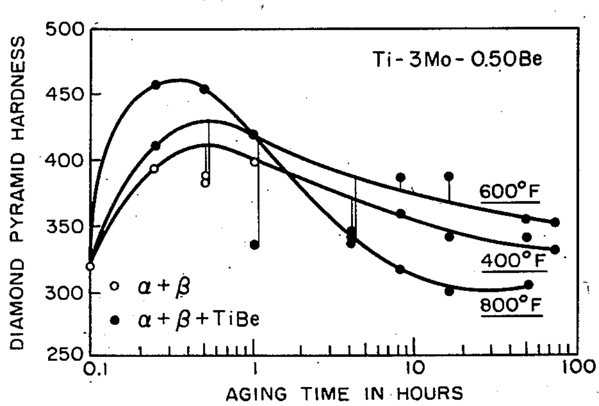

FIG. 3

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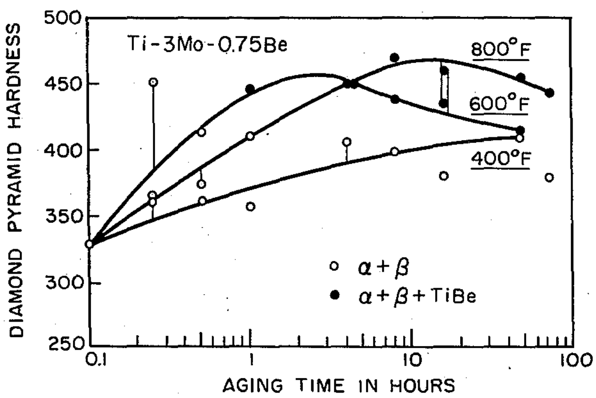

FIG. 4

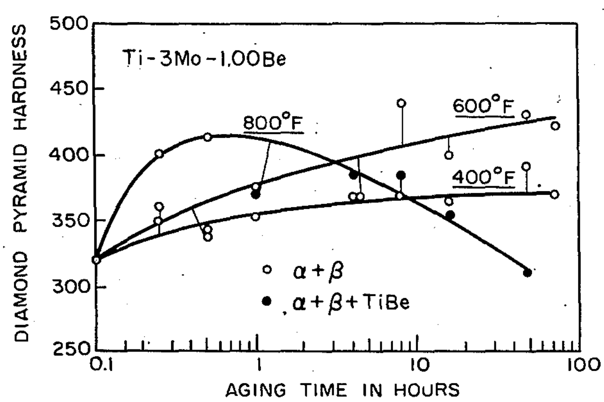

FIG. 5

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TITANIUM ALLOY

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6 Claims. (Cl. 75—175.5)

This invention relates to titanium base alloys and more particularly to a unique titanium molybdenum-beryllium alloy which illustrates superior properties.

Although titanium base alloys have been known for several years such alloys have in most cases possessed properties which left something to be desired in one respect or another. In general they tended to lack the requisite combinations of strength and ductility and/or combinations of tensile strength and impact strength for toughness. Also such alloys appear to be unable to retain high strength at high temperatures or to retain ductility at high temperatures. Furthermore, the formability properties of such alloys left something to be desired particularly when alloy formulations giving a high ultimate strength were desired.

According to the instant invention it has been discovered that valuable alloys suitable for plate and bar purposes and the like can be produced by the use in combination of titanium, molybdenum and beryllium. A poly-phase alloy consisting primarily of the alpha-form or phase of titanium together with at least one other distinct micro-crystalline phase that is known as the beta form of titanium is created.

It is therefore an important object of the instant invention to provide an improved titanium base alloy.

It is a further object of the instant invention to provide an improved titanium-molybdenum-beryllium alloy having superior physical and metallurgical properties at low and high temperatures.

Yet another object of the instant invention is to provide an alloy which may be age hardened to increase its strength and to achieve an optimum combination of strength, ductility and stability for application at elevated temperatures.

A further object of the instant invention is to provide a titanium base alloy that may be easily fabricated and which has the property of developing increased strength upon aging.

A still further object of the instant invention is to provide a titanium base sheet material having good formability and weldability with high strength.

Other objects, features, and advantages of the present invention will become apparent to those skilled in the art from the following detailed disclosure thereof.

The instant invention consists in an improved alloy composed essentially of 2% to 4% of molybdenum, 0.15% to 2% beryllium and the balance titanium.

In the accompanying curves, attached hereto and incorporated as a part hereof, age hardening characteristics of the present invention are illustrated. Figures 1 to 5 represent a portion of our experimental data on an alloy comprising 3% molybdenum throughout, varying amounts of beryllium, and balance titanium. In the drawings:

Figures 1 to 5 are curves of the aforementioned alloy having 0.15%, 0.25%, 0.50%, 0.75%, and 1.00% beryllium respectively.

The process used to produce the instant invention consists basically of a two-part heat treatment. The initial step consists of heat treating at a temperature sufficiently high to put the precipitating agent into solid solution. The solid solution is then quenched rapidly from the solution annealing temperatures to room temperature. This retains the elevated temperature condition and gives rise to a non-equilibrium super-saturated structure.

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Subsequent to the quenching the alloy is fabricated into the form desired as the finished product. As is seen from the herewith incorporated graphs, Figures 1–5, at this stage the material is relatively soft and its fabrication is a relatively simple matter.

The titanium base metal used in the present alloys may of course contain as impurities the so-called interstitial constituents such as carbon, oxygen, and/or nitrogen which are found in either high purity or commercially pure titanium. The titanium used may be commercial titanium such as may be produced by a magnesium reduction process of the type described in Kroll, U. S. Patent No. 2,205,854; or the titanium may be of high purity as produced by the "Iodide" process in accordance with the teachings of Van Arkel, U. S. Patent No. 1,671,213; provided however, that the contents of various impurities are such as to avoid appreciable alteration of the advantageous physical and metallurgical properties of the instant alloy. In general the amount of oxygen in the alloy may range from a mere trace quantity (i. e., about 0.01%) up to about 0.1–0.2 percent. (As used herein the terms percent and parts mean percent and parts by weight unless otherwise designated and the percent here given are based on the final alloy weight.) The amount of nitrogen in the alloy may range from a mere trace amount (i. e., about 0.01%) up to 0.25 percent; and the total oxygen, nitrogen, and carbon contents should not exceed about 0.5% if the alloy is to possess the superior physical and metallurgical properties herein obtained.

One contaminant which has been found to be of distinct importance is hydrogen and it is particularly desirable to prepare the instant alloy in the substantial absence of hydrogen since excessive amount tend to impair the physical and metallurgical properties thereof or at least to subtract noticeably from its superior characteristic properties. Although the amount of hydrogen in the alloy may range from a mere trace (i. e., about 0.005%) up to .02% most preferably the content is not more than 0.0125 percent.

As indicated, the amount of molybdenum in the instant alloy ranges from a minimum effective amount for appreciably increasing the strength, of about 2% of the alloy, to a maximum amount of molybdenum, of about 4 percent.

While the molybdenum concentration within this range produces alloys having superior properties we have found that a 3% alloy has optimum properties.

As previously mentioned, the amount of beryllium used in the practice of the instant invention may range from a minimum amount of about 0.15% to 2 percent. We have found that the 0.25% beryllium provided an alloy of exceptionally fine quality and this concentration is the preferred embodiment.

The preferred method for compounding the instant alloy is a two stage heat treatment. The alloys may be fabricated either solely in the temperature range of the beta field, or in the alpha-beta field. However, we have found that fabrication in the alpha-beta field yields a more desirable finished product.

The two stages of heat treatment are a solution heat treatment followed by aging at elevated temperatures. During the first stage the temperature may range from 1300° to 1800° F. for a period of from one-half to forty-eight hours. Following this stage the alloy is quenched in a water bath. After quenching the second or aging heat treatment phase commences. We have found that aging at a temperature range from 600° to 1000° F. for a period of from one to forty-eight hours produces the end product alloy having the aforementioned desirable properties. Longer aging times correspond to lower aging temperatures.

As hereinbefore mentioned, the alloy of optimum composition consists of 3% molybdenum, 0.25% beryllium, balance titanium. This alloy may be produced as follows: the temperature of the mixture is raised to 1470° F. and maintained at said temperature for a period of four hours; the heated mass is then water quenched; an aging treatment at 800° F. for sixteen hours then completes the alloy formation process.

In order to form the titanium alloy sheet from this optimum composition we have found that rolling at a temperature up to 1500° F. maximum can be utilized. This sheet, after such rolling, illustrates all of the superior properties of the instant invention.

Alloys compounded according to the instant invention and fabricated into sheet form according to the hereinbefore mentioned process were subjected to various techniques to determine their physical properties. Some results of such tests are shown in the following tables and graphs:

TABLE A

Bend ductility of solution annealed specimens

Alloy	Solution Heat Treatment	Diamond Pyramid Hardness	Minimum Bend Ductility
3 Mo—0.15 Be	1,470° F.—1 hr.—WQ	305	4T [1]
3 Mo—0.25 Be	1,470° F.—1 hr.—WQ	310	3T
3 Mo—0.50 Be	1,470° F.—4 hrs.—WQ	318	(2)
3 Mo—0.75 Be	1,470° F.—16 hrs.—WQ	330	4T
3 Mo—1.00 Be	1,470° F.—16 hrs.—WQ	320	6T

[1] T—Thickness of sheet.
[2] Failed at 10T.

TABLE B

Results of chemical analysis

Nominal Composition	Analyzed Composition	
	Percent Mo	Percent Be
3 Mo—0.15 Be	2.78	0.15
3 Mo—0.25 Be	2.91	0.22
3 Mo—0.50 Be	2.91	0.50
3 Mo—0.75 Be	3.05	0.71
3 Mo—1.00 Be	2.93	1.06

Curves showing age hardening response are shown in Figures 1 to 5. From these curves and the bend ductility table above presented, one skilled in this art will readily recognize that the combination of bend ductility and age hardening properties of the Ti–3% Mo–Be alloys to be unusual and outstanding. The data presented not only indicates such superior and unique properties, but further indicate that the so-called "creep" resistance is excellent and that a tensile strength of approximately 160,000 pounds per square inch may be predicted.

We claim as our invention:

1. An age-hardened polyphase alloy composed essentially of 2% to 4% molybdenum, 0.15 to 2% beryllium, balance titanium, the titanium containing up to 0.02% hydrogen and trace amounts of oxygen, nitrogen, and carbon.

2. An age-hardened polyphase alloy composed essentially of 2% to 4% molybdenum, 0.15% to 2.0% beryllium, balance titanium, the titanium containing up to 0.02% hydrogen, up to 0.2% oxygen, up to 0.25% nitrogen, and trace amounts of carbon.

3. An age-hardened polyphase alloy composed essentially of 2% to 4% molybdenum, 0.15% to 2% beryllium, balance titanium, having alpha, beta and TiBe phases.

4. An age-hardened polyphase alloy composed essentially of 2% to 4% molybdenum, 0.15% to 2% beryllium, balance titanium, the titanium containing up to 0.02% hydrogen, said alloy having alpha, beta and TiBe phases.

5. An age-hardened polyphase alloy composed essentially of 3% molybdenum, 0.15% to 1% beryllium, balance titanium, said alloy having alpha, beta and TiBe phases.

6. An age-hardened polyphase alloy composed essentially of 3% molybdenum, 0.25% beryllium, balance titanium, said alloy having alpha, beta and TiBe phases.

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