

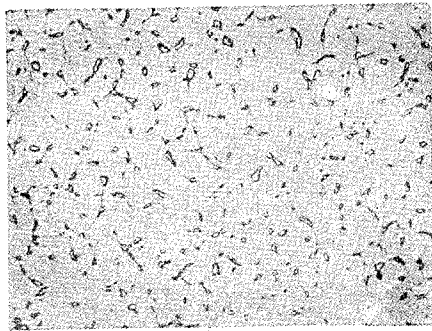
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TITANIUM BASE ALPHA ALUMINUM-COLUMBIUM-TANTALUM ALLOY

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MAGNIFICATION - 500X
8Al-2Cb-1Ta-TITANIUM ALLOY
ANNEALED 1650°F-½HR-AIR COOLED
MICROSTRUCTURE IS ESSENTIALLY
ALPHA WITH INCIDENTAL BETA
ISLANDS.
ETCHANT: 10%HF-5%HNO₃-H₂O

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BY

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1

2,864,699

TITANIUM BASE ALPHA ALUMINUM-
COLUMBIUM-TANTALUM ALLOY

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5 Claims. (Cl. 75—175.5)

The invention relates to titanium base alpha alloys and more particularly to a quaternary titanium base alloy containing aluminum, columbium and tantalum. More particularly, the invention relates to an all purpose titanium bar and sheet alloy which is useful both in the annealed and heat treated conditions, is weldable and has low density; and this application is a continuation-in-part of our application Serial No. 592,277.

Ever since the advent of the use of titanium and titanium alloys in the manufacture of parts for airplanes, airplane engines and other articles where high strength, corrosion resistance and minimum weight are important factors, there has been a problem in providing titanium alloy material and particularly sheet material which combines weldability with high strength at room temperature as well as at elevated temperatures; and in providing titanium alloy material which is highly weldable in sheet and bar form possessing high temperature strength with good formability and which is also heat treatable in sheet form, as by being capable of age hardening to high strength while still maintaining good ductility.

Certain prior aluminum-vanadium-titanium alloys have favorable high temperature properties and can be fabricated readily but they are not readily weldable, particularly in sheet material. Certain prior aluminum-tin-titanium alloys are weldable and may be formed, but are difficult to manufacture in sheet form and they do not have the room temperature and high temperature strength below 1000° F. of the aluminum-vanadium-titanium alloys.

In other words, for certain applications it has been necessary to sacrifice strength and use lower strength material in order to have a material which is weldable.

We have discovered that the quaternary alloy of the present invention of titanium, aluminum, columbium and tantalum has short time elevated temperature properties which show 20,000 p. s. i. higher strengths than prior aluminum-tin alloys in the temperature range from 400° F. to 1000° F. Stated in another way, the strength of the alloy of the present invention at 1000° F. exceeds the strength of prior aluminum-tin alloys at 800° F. and the strength of the alloy of the present invention at 800° F. exceeds the strength of prior aluminum-tin alloys at 600° F., giving a 200° strength advantage.

The alloy of the present invention has strength and tensile ductility at room temperature and elevated temperatures significantly higher than those of prior aluminum-tin alloys, and has bend ductility equivalent to that of prior aluminum-tin alloys, even though containing 8% aluminum without any evidence of directionability in sheet.

Further, welding tests on the alloy of the present invention indicate ready weldability with the same techniques used for commercially pure titanium. The bend ductility of fusion welded joints are reported to be satisfactory. Various methods of welding may be used such as air-comatic and heliarc methods, spot and seam welding, and resistance and butt welding. The welds are character-

2

ized by good bend ductility and mechanical properties comparable to the base metal.

The alloy of the present invention further is characterized by having significantly higher notch toughness than obtained with either the prior aluminum-tin or aluminum-vanadium alloys. Also, creep tests on both sheet and bar made from the alloy of the invention indicate a superior creep resistance at 750° F. and 50,000 p. s. i. as compared to prior aluminum-tin and aluminum-vanadium alloys. Likewise, creep stability, as indicated by tensile ductility after creep exposure, is superior for the alloy of the present invention.

Although the alloy of the present invention is weldable, it responds to heat treatment in sheet form. Tests indicate that the alloy is quench and age hardenable similar to prior aluminum-vanadium alloys. The alloy sheet can be solution treated and aged to 150,000 p. s. i. yield strength with 9 to 10% elongation which is favorable as compared with 4 to 8% elongation obtained with prior aluminum-vanadium alloy sheet material heat treated to the same strength level.

The improved alloy of the present invention can be forged or rolled to bar or sheet form with rollability to sheet gauges on production equipment comparable to prior aluminum-vanadium alloy sheet and superior to prior aluminum-tin alloy sheet.

In addition to the improved and favorable properties, characteristics and advantages indicated, the alloy of the present invention has the lowest density of all commercial titanium base alloys, that is, .158 lb./in.³ as compared with .161 for prior aluminum-tin and aluminum-vanadium alloys and .163 for unalloyed titanium. Further, the improved alloy of the present invention does not have a material cost appreciably in excess of the cost of other commercial titanium alloys.

Accordingly, it is an object of the present invention to provide a new quaternary alpha titanium alloy which is highly weldable in sheet and bar form, which possesses high temperature strength with good formability, and which is heat treatable in sheet, being capable of age hardening to high strengths while still maintaining good ductility.

Furthermore, it is an object of the present invention to provide a new quaternary titanium sheet alloy characterized by having a desirable and heretofore unattainable combination of weldability and high strength together with ease of fabricability and ready formability.

Also, it is an object of the present invention to provide a new all-purpose titanium bar and sheet alloy having the combined properties, characteristics and advantages enumerated.

Finally, it is an object of the present invention to provide a new quaternary alpha titanium alloy having the indicated advantages, characteristics, properties and uses without appreciably increasing the cost thereof as compared with other commercial weldable or heat treatable alloys.

These and other objects and advantages apparent to those skilled in the art from the following description and claims may be attained, the stated results achieved, and the described difficulties overcome by the discoveries, principles, compositions and alloys which comprise the present invention, the nature of which is set forth below—illustrative of the best mode in which applicants have contemplated applying the principles—and which are particularly and distinctly pointed out and set forth in the appended claims forming a part hereof.

The alloy of the present invention comprises a titanium base with 7.5% to 8.5% aluminum, 1.5% to 2.5% columbium and 0.5% to 1.5% tantalum and having a preferred nominal or intended composition of 8% aluminum, 2% columbium and 1% tantalum.

The alloy of the present invention may be prepared from either commercial titanium or high purity titanium. Where prepared from commercial titanium, a typical analysis of the material in addition to titanium, aluminum, columbium and tantalum is 0.02% C, 0.01% N₂, 0.10% O₂ and 0.005% H₂. However, the invention is not restricted to the use of material having the typical interstitial level indicated, as the level may be of the order of 0.15% C, 0.07% N₂, 0.20% O₂ and 0.025 H₂. In other words, presently available sponge having a sponge hardness of 120 BHN is suitable. The sponge hardness may range from 100 BHN to 200 BHN. In the tables below, titanium sponge having a typical interstitial level of 120 BHN was used in preparing the alloy evaluated.

In practice, the titanium is preferably melted by the electric arc process in a water-cooled copper crucible in an atmosphere such as argon and the alloying elements are added to the melt by the addition of aluminum and an alloy of aluminum, columbium and tantalum.

The alloy of the present invention after melting and casting may be processed in the usual manner and forged or rolled to form the desired semi-finished or finished product which may be either a bar or a sheet product. For instance, ingots of the improved quaternary alloy may be forged or bloomed to slab form, hot rolled to sheet bar, and the sheet bar may be rolled to form sheets of the desired gauge. Alternately, ingots of the improved alloy may be reduced to squares and then rolled to bars of the desired size and cross-section.

The typical room temperature properties of annealed sheet and bar products fabricated from the alloy of the present invention determined by evaluation are given in Table I below:

Table I

	.040 Inch sheet	5/8 Inch Bar
Ultimate Tensile (p. s. i.)	127,000	130,000
Yield Tensile, 2% (p. s. i.)	120,000	123,000
Elongation (percent)	16	16
Reduction in Area (percent)	38	38
Min. Bend Radius (Tr)	3-4	3-4
Charpy Impact, 70° F. (ft.-lbs.)	44	44
Charpy Impact, -40° F. (ft.-lbs.)	23	23
Modulus $\times 10^6$ p. s. i.	17.4	17.4

¹ Percent elongation in 2 inches.

² Percent elongation in 1 inch.

The data in Table I indicates comparable strength and ductility in both sheet and bar form, the strength values being high and good ductility being indicated by the 16% elongation values along with good formability in sheet form indicated by the 3-4 T_R value.

Short-time elevated temperature properties of the alloy of the present invention in annealed condition are given in Table II below:

Table II

Test Temp., ° F.	UTS (p. s. i.)	YS (p. s. i.)	Elong. (percent)	RA (percent)
Room Temp.	126,000	120,000	17	38
400	110,000	90,000	23	44
600	100,000	75,000	25	47
800	92,000	70,000	28	53
1,000	79,000	66,000	33	55
1,200	49,000	43,000	55	70

As has been pointed out above, the improved alloy of the present invention has short-time elevated temperature properties showing 20,000 p. s. i. higher strength than prior aluminum-tin alloys in the temperature range of 400 to 1000° F. Thus, the strength values shown in Table II represent a 200° strength advantage for the alloy of the present invention.

Typical properties of heat treated .040" sheet fabricated from the alloy of the present invention are given in Table III below:

Table III

	1,850° F. (3/4 hr.) WQ	1,850° F. (3/4 hr.) WQ, 900° F. (8 hr.) AC
UTS (p. s. i.)	157,000	167,000
YS, 2% (p. s. i.)	132,000	151,000
El. (percent in 2 In.)	11.3	9.4
Min. Bend Radius (Tr)	4.8	7.1

The values in Table III illustrate the marked response of the alloy of the present invention to solution treatment and aging, the yield strength being raised from the 120,000 p. s. i. value for sheet in Table I to the 151,000 p. s. i. value in Table III while still maintaining adequate ductility as represented by the 9.4% elongation value in Table III.

The creep properties and thermal stability of annealed sheet fabricated from the alloy of the present invention are given in Table IV below:

Table IV

Test Conditions	Permanent Deformation
Temp. 750° F. Time, 115 Hrs. Stress, 50,000 p. s. i.	.23%

Mechanical Properties

Before
ExposureAfter
Exposure

Ultimate Tensile (p. s. i.)	133,800	134,900
Yield Strength, 2% (p. s. i.)	122,400	123,700
Elongation (Percent in 2 In.)	15.5	12.0

The above properties show the alloy to maintain thermal stability after creep exposure at elevated temperatures and under stress for long times. This thermal stability is indicated by the lack of embrittlement shown by the properties after exposure to creep conditions. Under the severe conditions of 750° F. and 50,000 p. s. i. stress for 115 hours, the alloy of the present invention deformed elastically only .23%. This indicates a high degree of creep resistance.

In referring to annealing or to material in the annealed state, the treatment used is to stabilize the alloy at 1650° F. and air-cool the material from this temperature. Twenty minutes is a sufficient annealing time for sheet gauges while bar products preferably are stabilized at the indicated temperature for one hour and then are air-cooled.

The beta transus of the alloy of the present invention is 1920° F. plus or minus 20°. For maximum aged strength consistent with good ductility, the alloy should be solution treated for one-third hour while in the alpha-beta field and rapidly quenched and then aged.

The substantially all-alpha characteristics of the alloy of the present invention are illustrated in the drawing in which the figure constitutes a reproduction of a photomicrograph of a titanium base alloy in annealed condition containing an intended alloy composition of 8% aluminum, 2% columbium and 1% tantalum. This picture shows the microstructure to be essentially all-alpha with only incidental beta phase present.

The all-purpose character of the alloy of the present invention evident from the characteristics and properties described enable the material in bar and sheet form to

be used for fabricating parts where weldability is a required property, such as parts that must be welded after forming while retaining a minimum yield strength in the welded area of 110,000 p. s. i. The material also may be used in heat treated condition for structural members where high strength is required which is developed by heat treatment after forming in the solution treated condition.

The alloy of the present invention accordingly provides a quaternary alpha titanium alloy which is weldable, has high strength and low density and may be fabricated in various forms and used in the annealed or heat treated condition, presenting a combination of properties heretofore unattained in any known titanium alloy.

In the foregoing description certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are used for descriptive purposes herein and are intended to be broadly construed.

Having now described the invention, the features, discoveries and principles thereof, the characteristics of the new alloy, an example of a preferred embodiment of the new alloy, and the new and useful results obtained; the new and useful compositions, combinations, products, discoveries and principles, and reasonable mechanical equivalents thereof obvious to those skilled in the art are set forth in the appended claims.

We claim:

1. A weldable alpha titanium base alloy consisting of 7.5% to 8.5% aluminum, 1.5% to 2.5% columbium, 0.5% to 1.5% tantalum, and the balance titanium with incidental impurities.

2. A weldable alpha titanium base alloy consisting of 8% aluminum, 2% columbium, 1% tantalum, and the balance titanium with incidental impurities.

3. A weldable alpha titanium base alloy consisting of 7.5% to 8.5% aluminum, 1.5% to 2.5% columbium, 0.5% to 1.5% tantalum, the balance titanium with incidental impurities, and said alloy having as-annealed, a yield strength of at least 120,000 p. s. i. and elongation of about 16%.

4. A weldable alpha titanium base alloy consisting of 7.5% to 8.5% aluminum, 1.5% to 2.5% columbium, 0.5% to 1.5% tantalum, the balance titanium with incidental impurities, and said alloy having elevated temperature yield strength as follows:

Temperature, ° F.:	Yield strength, p. s. i.
Room	120,000
400	90,000
600	75,000
800	70,000
1000	66,000
1200	43,000

5. A weldable alpha titanium base alloy consisting of 7.5% to 8.5% aluminum, 1.5% to 2.5% columbium, 0.5% to 1.5% tantalum, the balance titanium with incidental impurities, and said alloy in sheet form having as solution treated and aged a yield strength of at least 150,000 p. s. i. and elongation of about 9.4%.

References Cited in the file of this patent

UNITED STATES PATENTS

2,754,204 Jaffee et al. July 10, 1956