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3,069,259

TITANIUM BASE ALLOY

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4 Claims. (Cl. 75-175.5)

This invention relates to high strength, tough, ductile titanium base alloys and is more particularly directed to a complex alloy system containing aluminum, vanadium, and tin as essential constituents.
It has been found that a desirable combination of high

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tion in ductility and toughness heretofore encountered along with the increased strength. For example, as shown in Table II below, the addition of 0.50% Fe and 0.25% Cu to a Ti-5.5Al-5.5V-2Sn alloy heat treated as indicated for the C1 alloy increases the tensile strength up to a maximum value of 208,000 p.s.i. or about 22% greater than the comparably heat treated B1 alloy with only a nominal reduction in the elongation value and little or no change in the reduction in area and impact energy absorption values. In fact, a comparison of the C1-4 alloys with the B1-4 alloys indicates that in some cases, the elongation and reduction in area values are significantly improved in those instances in which the increase, in tensile strength does not reach the maximum referred to above.

Table I

No.	Alloy	Heat treatment	0.1 Y.S. (p.s.i.)	0.2% Y.S. (p.s.i.)	Tensile strength (p.s.i.)	Percent elonga- tion (1")	Percent reduction in area	Impact energy -40°
A1	Ti-6Al-4V	1,750° F.—1hr./WQ, ¹ plus 1,200° F.—1hr./AC ²	139,000	144,000	156,000	16.4	45.3	13.5
A2	do	1,750° F.—1hr./WQ, plus 1,100° F.—1hr./AC	143,500	147,500	159,500	14.1	44.5	15.0
A3	do	1,750° F.—1hr./WQ, plus 900° F.—1hr./AC	143,000	149,000	164,500	13.0	32.5	14.0
A4	do	1,650° F.—2hr./WQ, plus 1,000° F.—1hr./AC	141,500	147,000	162,500	14.1	41.0	12.6
B1	Ti-6Al-6V-2Sn	1,700° F.—1hr./WQ, plus 1,150° F.—1hr./AC	152,500	157,000	170,500	11.5	28.1	8.8
B2	do	1,650° F.—1hr./WQ, plus 1,150° F.—1hr./AC	158,000	163,000	179,500	10.1	24.6	10.1
B3	do	1,600° F.—1hr./WQ, plus 1,100° F.—1hr./AC	153,500	158,000	171,500	10.4	27.2	10.3
B4	do	1,600° F.—1hr./WQ, plus 1,050° F.—1hr./AC	154,000	159,000	178,000	9.4	25.4	10.0

¹ WQ=Water quench. ² AC=Air cool.

strength, toughness and ductility can be obtained by the proper heat treatment of a titanium base alloy having 6% aluminum and 4% vanadium. However, efforts to raise the tensile strength of this alloy above 165,000 p.s.i. by increasing the amount of the interstitial contaminants such as oxygen and nitrogen or by the addition of alpha or beta promoting elements have invariably resulted in an excessive reduction in the ductility, toughness, and impact strength of the resulting alloy. For example, as can be seen by reference to Table I above, while the addition of 2% each of vanadium and tin to the basic Ti-6Al-4V alloy increases the tensile strength by as much as 20,000 p.s.i. or 12½% when alloys A2 and B2 are compared, the elongation in one inch drops almost 30%, the reduction in area falls about 45% and the impact energy at -40° F. is reduced by about 33⅓%.

As shown in Table II, slight increases in the amount of iron and copper together with a very small reduction in the amount of aluminum serve to improve the mechanical properties while slightly reducing the maximum attainable tensile strength. Such improvement is particularly noticeable in regard to the ability of the alloys to absorb impact energy at -40° F. which reaches a maximum of 13.4 ft.-lbs. even though the tensile strength is at the very high value of 197,000 p.s.i.

As shown in Table I, V-notch Charpy impact values at -40° F. of between 12.5-15.0 have heretofore been attained only where the tensile strength values were below 164,500 p.s.i. While tensile strengths of over 165,000 p.s.i. can be attained in some titanium base alloys, such accomplishment is generally accompanied by a substantial decrease in ductility as shown by the elongation

Table II

No.	Alloy	Heat treatment	0.1% Y.S. (p.s.i.)	0.2% Y.S. (p.s.i.)	Tensile strength (p.s.i.)	Percent elonga- tion 1"	Percent reduction in area	V-notch Charpy impact at -40° F. (ft.- lbs.)
C1	Ti-5.5Al-5.5V-2Sn-0.5Fe-0.25Cu	1,725° F.—1 hr./WQ, ¹ plus 1,100° F.—1 hr./AC ²	194,000	200,500	208,000	8.0	30.1	9.0
C2	Ti-5.5Al-5.5V-2Sn-0.5Fe-0.25Cu	1,675° F.—2 hr./WQ, plus 1,000° F.—1 hr./AC	192,500	200,000	208,000	9.4	39.0	8.3
C3	Ti-5.5Al-5.5V-2Sn-0.5Fe-0.25Cu	1,675° F.—2 hr./WQ, plus 1,100° F.—1 hr./AC	181,300	186,000	194,000	11.0	46.6	7.6
C4	Ti-5.5Al-5.5V-2Sn-0.5Fe-0.25Cu	1,625° F.—2 hr./WQ, plus 1,000° F.—1 hr./AC	190,000	193,000	198,500	13.2	54.7	8.8
D1	Ti-5.25Al-5.5V-2Sn-0.9Fe-0.25Cu	1,612° F.—3 hr./WQ, plus 150° F.—1 hr./AC	176,000	179,000	188,000	10.3	43.6	12.1
E1	Ti-5.25Al-5.5V-2Sn-0.9Fe-0.5Cu	1,587° F.—3 hr./WQ, plus 1,050° F.—1 hr./AC	181,000	182,500	188,300	10.0	33.5	13.0
F1	Ti-5.25Al-5.5V-2Sn-0.9Fe-1.0Cu	1,562° F.—3½ hr./WQ, plus 1,050° F.—1 hr./AC	191,000	193,000	197,000	9.2	36.3	13.4
G1	Ti-5.25Al-5.5V-2Sn-1.15Fe-0.25Cu	1,587° F.—3 hr./WQ, plus 1,050° F.—1 hr./AC	178,000	180,000	189,500	9.3	25.8	11.5

¹ WQ=Water quench. ² AC=Air cool.

The present invention is based upon the discovery that the addition of relatively small amounts of iron and copper to the basic Ti-6Al-4V alloy along with 2% Sn and an additional 2% V will provide a substantial increase in tensile strength without the customary large reduc-

values in U.S. Patent No. 2,739,887, dated March 27, 1956. Although U.S. Patent 2,884,323 dated April 28, 1959, which teaches the attainment of very high tensile strengths through the inclusion of over 0.4% oxygen, does not show the expected drop in the values for the elon-

gation and reduction in area, this unusual result does not extend to the ability of the alloy to absorb impact energy which is reduced to 5.5 ft.-lbs. The toughness of titanium base alloys is highly important in ordnance applications wherein unusually high impact forces are frequently encountered.

The compositions of the alloys listed in Tables I and II are nominal percentages measured in terms of weight indicative of the exact analyzed values and are utilized for the sake of brevity.

The sum of the interstitial elements in the alloys of Table II is maintained below 0.25% with oxygen below 0.2%, nitrogen below 0.05% and carbon below 0.1%.

The alloys of Table II were cast as 3¼" diameter ingots weighing approximately 6 lbs. Initial forging was accomplished at a temperature up to 300° F. in excess of the temperature at which a 100% beta structure is stable, commonly referred to as the beta transus. These ingots were forged to a 2" square bar, reheated to 150° F. above the beta transus and thereafter forged to a 1" square. The resulting bar was then reheated to between 50° F.-75° F. below the beta transus temperature and then forged to ½" square. These bars were heat treated as indicated in Table II and were then machined to provide the necessary tensile and Charpy impact specimen.

Accordingly, the complex alloys of the present invention can be heat treated to provide tensile strengths in the vicinity of 200,000 p.s.i. while maintaining good elongation, reduction in area, and impact strength values. At lower tensile strengths which, however, are still above the maximum which can be attained with the well-known Ti-6Al-4V alloy, the ductility values can even be appreciably enhanced by varying the composition of the alloy and the heat treatment thereof to a slight extent.

Although a particular embodiment of the invention has been described in detail herein, it is evident that many variations may be devised within the spirit and scope thereof and the following claims are intended to include such variations.

We claim:

1. A titanium base mixed phase alpha-beta alloy consisting of, by weight, from 5%-6% Al, 5%-6% V, 2% Sn, 0.20-1.5% Fe and 0.10-1.5% Cu and the balance titanium with incidental impurities.

U.S. Office of Technical Services Report PB 131502, November 1956, 100 pages.

2. A titanium base mixed phase alpha-beta alloy consisting of, by weight, from about 5%-6% Al, 5%-6% V, 2% Sn, 0.20-1.5% Fe and 0.10-1.5% Cu and the balance titanium with the sum of oxygen, nitrogen, and carbon below 0.25%, and characterized by a tensile strength in excess of 185,000 p.s.i. with good ductility and toughness.

3. A titanium base mixed phase alpha-beta alloy consisting of, by weight, from about 5%-6% Al, 5%-6% V, 2% Sn, 0.20-1.5% Fe, and 0.10-1.5% Cu and the balance titanium with incidental impurities, said alloy having a tensile strength ranging up to 208,000 p.s.i. with good ductility and excellent impact energy at -40° F. when solution treated at a temperature of about 50° F.-75° F. below the beta transus temperature followed by a water quench and thereafter aged at a temperature of about 1000° F.-1100° F.

4. A titanium base mixed phase alpha-beta alloy consisting of, by weight, from about 5.25% Al, 5.5% V, 2% Sn, 0.9% Fe and 1.0% Cu and the balance titanium with incidental impurities and interstitials below 0.25% characterized by a tensile strength of 197,000 p.s.i., an elongation in one inch of 9.2%, a reduction in area of 36.3% and a V-notch Charpy impact energy values at -40° F. of 13.4 ft.-lbs., when heated to 1562° F. for 3½ hours and water quenched followed by aging for 1 hour at 1050° F. and air cooked therefrom.

References Cited in the file of this patent

UNITED STATES PATENTS

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2,892,705	Jaffee et al.	June 30, 1959
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2,918,367	Crossley et al.	Dec. 22, 1959

OTHER REFERENCES

Kirk et al.: Development of Tough, High-Strength Quaternary Titanium-Base Alloys of the Ti-Al-V-X System, New York University (Watertown Arsenal Labs.),

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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Harold Margolin et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Columns 1 and 2, Table II, under the heading "Heat Treatment" and opposite alloy No. "D1", for "150° F." read - 1,050° F. --; column 4, lines 1 and 2, strike out "U.S. Office of Technical Services Report PB 131502, November 1956, 100 pages."; line 29, for "cooked" read -- cooled --; line 42, after "(Watertown Arsenal Labs.)," insert -- U.S. Office of Technical Services Report PB 131502, November 1956, 100 pages. --.

Signed and sealed this 22nd day of October 1963.

(SEAL)

Attest:

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