United States Patent Office

2,754,205

Patented July 10, 1956

2,754,205

TITANIUM BASE ALLOYS

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No Drawing. Application December 28, 1953, Serial No. 400,745

3 Claims. (Cl. 75—175.5)

This invention pertains to titanium base alloys containing as essential constituents aluminum and zirconium in proportions as specified below.

The use of titanium as a structural material is limited by its relatively low tensile strength and high cost, and it therefore becomes desirable to alloy with titanium such other metals as will increase the strength to acceptable levels, and preferably at the same time effect some reduction in total material cost. Aluminum is a metal well suited to the attainment of these objectives, being low in weight, relatively low in cost, and having a material strengthening effect on titanium. However, the amount of aluminum alone that can be added to titanium is limited by its adverse effect on ductility. Binary alloys of titanium with more than about 8% of aluminum are somewhat brittle, while those containing less than about 5% aluminum are of reduced strength as compared to those containing upwards of 5% aluminum. A further strengthening as well as an increase in the content of relatively inexpensive aluminum that may be employed, is highly desirable.

The present invention comprises the discovery that additions of zirconium to titanium-aluminum alloys, effects a marked improvement in properties, and likewise enables the aluminum content to be increased to as much as about 10%, with material increase in strength, while maintaining adequate ductility for fabrication purposes.

We have found that additions of zirconium in amounts ranging from as low as about 0.5% to as high as about 40%, effectively strengthen titanium-aluminum alloys, containing aluminum over the range of about 0.5 to 10%, without appreciable impairment of the ductility characteristics. A preferred range analysis is about 3.5 to 10% aluminum with about 1 to 20% zirconium, as the alloys throughout this range are extremely strong and ductile. For securing an optimum combination of strength combined with good ductility, the zirconium should be on the high side of its range when the aluminum is on the low side of its range, and vice versa.

The alloys of the invention are further strengthened without undue loss of ductility by controlled and limited additions of the interstitials carbon, oxygen and nitrogen. To this end carbon may be added in amounts up to about 0.3%, and oxygen and nitrogen up to about 0.2% each.

As is known, the metal titanium, in the pure state, is capable of existing in either of two allotropic forms. Below about 885° C. or 1625° F., it assumes a close-packed, hexagonal microstructure known as the alpha phase, while at this temperature and above, it assumes a body centered, cubic structure known as the beta phase.

Certain substitutional alloying additions to the titanium-base metal, among which are included aluminum as well as the interstitials carbon, oxygen and nitrogen, tend to stabilize the alpha phase, and thus may be referred to as "alpha promoters."

Other substitutional alloying elements, when added in progressively increasing quantities, stabilize the beta

phase at progressively lower temperatures, until a mixed alpha-beta or all-beta microstructure is obtained at normal or atmospheric temperatures, or the beta phase undergoes an eutectoid reaction, depending on the character and amount of the beta stabilizers added.

Zirconium forms a continuous series of solid solutions with titanium, since the beta forms of both elements are isomorphous, and since the alpha forms of both elements are likewise isomorphous, it thus forms an alpha-beta isomorphous system with titanium. The addition of zirconium tends to stabilize or promote the beta phase of titanium in that the lowest temperature at which the alloy is entirely beta becomes progressively lower with increasing amounts of zirconium until a point is reached at which this so called "beta transus" temperature starts to increase again with further additions of zirconium. While zirconium thus lowers the transformation temperature of titanium, the alloys eventually revert to the alpha phase at lower temperatures unless other beta promoters are present. However, in view of the fact that zirconium forms an alpha-beta isomorphous system with titanium, where the beta reverts to alpha on cooling, the resulting alloys are characterized by high thermal stability, in that the beta phase stabilized by zirconium does not form eutectoid decomposition products.

Thus the titanium-aluminum-zirconium alloys of the invention are characterized by high strength and ductility combined with high thermal stability.

The alloys of the invention may be prepared by melt-casting in an atmosphere of argon, rolling at a suitable temperature, say 980° C., and annealing under conditions which will effect recrystallization, but not substantial grain growth or re-solution of carbides. A typical but by no means universal annealing treatment comprises soaking at a temperature of about 850° C. for about 3½ hours. The titanium base metal employed should be of acceptable purity, such as "iodide" base titanium as produced, for example, in accordance with Patent No. 1,671,213 to Van Arkel, or the commercial purity product obtained by magnesium reduction of titanium tetrachloride in accordance with the process described in Patent No. 2,205,854 to Kroll.

The properties of selected alloys in accordance with the invention made from "iodide" base titanium, as annealed 3½ hours at 850° C. are given below in the following table.

Table

Composition, Percent (Balance Titanium)			Vickers Hardness	Tensile Properties—p. s. i. × 1,000			
Al	Zr	C		0.2% Offset Yield	Ultimate Strength	Percent Elongation in 1"	Min. Bend Radius, T/L
--	--	--	105	27	43	40	0
5	--	--	268	62	79	17	-------
5	1	--	291	65	78	20	0.7
5	2.5	--	288	71	84	17	0.3
5	5	--	303	83	96	17	1.0
5	10	--	322	92	103	14	1.3
7.5	--	--	361	101	101	20	3.0
7.5	2.5	--	336	99	100	17	1.2
7.5	2.5	0.25	375	127	131	10	0.8
7.5	5	--	349	114	120	22	0.9
7.5	7.5	--	371	113	116	22	0.9
10	--	--	[1] 307	[3]	[3]	[3]	[3]
10	2.5	--	384	121	123	5	Br
[2] 0.5	30	--	309	114	145	5	6.2

[1] As cast hardness.
[2] Rolled 850° C., annealed ¼ hour at 850° C. and quenched. The Ti-0.5Al-30Zr alloy, after aging 48 hours at 400° C. was found to have a minimum bend radius of 2.0 T longitudinal and 3.0 T transverse.
[3] Brittle.

As shown by the data in the table, the alloys according to the invention are quite ductile, having tensile elongations of at least 5% and minimum bend ductilities, in general, under 2. These alloys are quite ductile with

minimum bend ductilities up to 7. Where the alloys are to be used in the form of sheets the minimum bend ductilities may range as high as 20, and where they are to be used in massive form, as in forgings, the percent tensile elongations may range as low as about 2%.

It will be also noted from the data in the table that the alloys according to the invention have tensile strengths at least 10% in excess of that of the unalloyed titanium base metal. The tensile strengths of the zirconium-containing alloys are also substantially higher than for the corresponding binary titanium-aluminum alloys, and are also in general more ductile, particularly as regards bend ductility. Furthermore, brittle binary titanium-aluminum alloys are rendered strong and ductile as shown by the data for the Ti–10 Al analysis.

The alloys of the invention may be welded without appreciable impairment of ductility in the welded as compared to the non-welded portions, by reason, among others, of their thermally stable characteristics above mentioned.

This application is a continuation-in-part of our application Serial No. 209,904, filed February 7, 1951, and now abandoned, and our copending application Serial No. 327,422, filed December 22, 1952.

What is claimed is:

1. An alloy consisting essentially of: about 0.5 to 10% aluminum, about 0.5 to 40% zirconium, aluminum being present on the low side of its range when zirconium is present on the high side of its range and vice versa, up to about 0.3% carbon, up to about 0.2% each of oxygen and nitrogen, and balance substantially titanium characterized in having a minimum bend ductility of no more than 20T, and a tensile strength at least 10% in excess of that of the corresponding titanium-aluminum binary alloy.

2. An alloy consisting of: about 0.5 to 10% aluminum, about 0.5 to 40% zirconium, carbon up to about 0.3%, oxygen and nitrogen up to about 0.2% each, balance titanium.

3. A titanium base alloy consisting essentially of about: 3.5 to 10% aluminum, 0.5 to 40% zirconium, up to 0.3% carbon, up to 0.2% each of the oxygen and nitrogen, characterized in having in the annealed condition, a minimum bend ductility of not over 7 T, a tensile elongation of at least 5% and a tensile strength of at least 80,000 p. s. i.

References Cited in the file of this patent

UNITED STATES PATENTS

1,585,786	Richardson	May 26, 1926
2,370,289	Chandler	Feb. 27, 1945

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OTHER REFERENCES

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