

UNITED STATES PATENT OFFICE

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TITANIUM-BASE ALLOYS

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The present invention relates to new and useful titanium-base alloys. More particularly, it is concerned with and has as its principal object the provision of a new titanium-base alloy possessing optimum strength and ductility characteristics.

The invention is based on the discovery that a titanium-base alloy having good strength and ductility characteristics at both room and elevated temperatures, should contain small but effective amounts of oxygen, iron, copper, manganese and aluminum. It has been found that a very useful level of strength and ductility characteristics can be obtained in such an alloy without the use of large additions of strategically important metals, such as chromium, which have been present in certain of the known titanium-base alloys. The alloys of the present invention are in general characterized by a minimum 0.2% offset yield strength of about 120,000 p. s. i., a minimum room temperature tensile strength of about 140,000 p. s. i., and a minimum elongation of 15%.

In general, the alloys of the present invention consist, by weight, of from 0.1 to 0.5% oxygen, 0.3 to 2% copper, 0.3 to 2% iron, 0.5 to 2% manganese, 0.5 to 2% aluminum, with the balance titanium except for incidental impurities including carbon which do not aggregate more than about 0.1%. Particularly useful alloys for structural purposes at room and elevated temperatures are those containing from about 0.1 to 0.4% oxygen, and from 1 to 2% manganese, in addition to the prescribed amounts of the remaining alloying ingredients. The best combination of yield strength, tensile strength and ductility has been obtained in alloys containing from about 0.1 to 0.3% oxygen, 1 to 1.5% iron, about 1% carbon, 1 to 1.5% manganese, and about 1% aluminum. Preferably the alloying ingredients other than the oxygen should comprise at least 3.5% by weight of the alloy and preferably should be less than about 5%. Some nitrogen may unavoidably be present in the alloys due to the presence thereof in the titanium base metal from which the alloy is prepared.

While any suitable method may be employed in the manufacture of the alloys of this invention, consistently good results have been obtained by arc melting a mixture of the ingredients comprising the alloy. When necessary to obtain the desired oxygen content, titanium oxide may be added. The following table includes compositions and properties of various alloys both within and without the scope of the present invention.

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Alloy No.	O	Fe	Cu	Mn	Al	2% offset yield strength	Tensile strength room temperature	Percent elongation	Percent reduction in area
D9	0.2	1	1	1	1	119,560	140,750	24	45.3
D93	.3	1	1	1	1	146,020	157,850	16	49.4
1	.1	.3	2.0	.3	1.0	103,000	118,000	13	23
2	.2	.3	1.5	.5	1.0	108,000	124,000	11	17
3	.3	.3	1.0	1.0	1.0	125,000	140,000	20	43
4	.4	.3	.5	1.5	1.0	105,000	120,000	22	45
5	.5	.3	.3	2.0	1.0	140,000	146,000	22	46
6	.1	.5	.3	.5	1.0	128,000	136,000	22	48
7	.2	.5	2.0	1.0	1.0	127,000	137,000	12	20
8	.3	.5	1.5	1.5	1.0	106,000	118,000	16	34
9	.4	.5	1.0	2.0	1.0	127,000	138,000	20	46
10	.5	.5	.5	.5	1.0	118,000	135,000	20	42
11	.1	1.0	.5	1.0	1.0	130,000	140,000	20	40
12	.2	1.0	.3	1.5	1.0	127,000	138,000	17	49
13	.3	1.0	2.0	2.0	1.0	142,000	155,000	9	21
14	.4	1.0	1.5	.3	1.0	105,000	116,000	21	45
15	.5	1.0	1.0	.5	1.0	-----	73,000	-----	-----
16	.1	1.5	1.0	1.5	1.0	137,000	147,000	18	36
17	.2	1.5	.5	2.0	1.0	120,000	136,000	14	34
18	.3	1.5	.3	.3	1.0	100,000	118,000	22	48
19	.4	1.5	2.0	.5	1.0	-----	152,000	-----	-----
20	.5	1.5	1.5	1.0	1.0	96,000	114,000	17	28
21	.1	2.0	1.5	2.0	1.0	93,000	116,000	18	40
22	.2	2.0	1.0	.3	1.0	113,000	131,000	16	23
23	.3	2.0	.5	.5	1.0	123,000	137,000	20	48
24	.4	2.0	.3	1.0	1.0	-----	146,000	2	9
25	.5	2.0	2.0	1.5	1.0	-----	163,000	3	8

The test results set forth in the above table were on test bars taken from alloys which had been forged and thereafter heat-treated at about 1300° F. for one hour, followed by air cooling. In general, the alloys are forged at temperatures of from 1300° F. to about 1650° F., within which temperature range the alloy is soft and ductile enough for most forging operations. The use of more elevated temperatures in the presence of an oxidizing atmosphere may result in substantial diffusion of oxygen into the surface, with a detectible increase in hardness of the surface. The alloys can also be hot-rolled within the same temperature range and exhibit the usual machinability characteristics of other known titanium-base alloys.

The optimum tensile strength and ductility characteristics exhibited by the alloys of the present invention make them particularly suitable as wheel and bucket or blade materials for use in the intermediate stages in gas turbine compressors and the like. In such applications, advantage can be taken of their marked reduction in weight as compared with comparable steel parts.

If desired, the formed parts can be surface hardened by diffusion of elements, such as oxygen or nitrogen into the surface, thereby altering the composition and properties of the surface layers.

Alloy D9 is representative of the alloys of the present invention insofar as their properties are concerned. This alloy, which has a room temperature tensile strength in excess of 140,000 p. s. i. exhibits a tensile strength of about 90,000 p. s. i. at 400° F., and 61,000 p. s. i. at 800° F. Its 1000-hour stress rupture value at 400° F. is 95,000 p. s. i., and at 800° F. is 21,000 p. s. i. In the forged and annealed state, the alloys of the present invention ordinarily have a Rockwell-C hardness of at least 30, and usually from 33 to about 38. Maximum hardness can ordinarily be obtained by air cooling the alloy following a heat treatment at a temperature in the neighborhood of 1400° F. to 1800° F. for about one hour. Ordinarily, the hardness values for these alloys will not change or materially vary through exposure to elevated temperature up to about 900° F.

The presence of all of the enumerated elements within the designated ranges appears to be essential to obtain the optimum strength and ductility characteristics, while the iron and aluminum contents of the alloy appear to be the more critical insofar as the tensile properties of the alloy are concerned than the copper and manganese, test results on alloys containing only the oxygen, iron and aluminum in addition to titanium have indicated that desired elongation

or ductility characteristics cannot be obtained without the presence of effective quantities of copper and manganese.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A titanium-base alloy consisting essentially of from 0.1 to 0.5% by weight oxygen, 0.3 to 2% copper, 0.3 to 2% iron, 0.5 to 2% manganese, 0.5 to 2% aluminum, balance substantially all titanium.

2. A titanium-base alloy consisting essentially of from 0.1 to 0.3% oxygen, 1 to 1.5% iron, 1% copper, 1 to 1.5% manganese, about 1% aluminum, balance substantially all titanium.

3. A titanium-base alloy consisting essentially of from 0.2 to 0.3% oxygen, 0.5 to 1% copper, about 1.5% iron, 1 to 2% manganese, about 1% aluminum, balance titanium.

4. A titanium-base alloy consisting essentially of 0.3% oxygen and 1% by weight each of iron, copper, manganese and aluminum, balance titanium.

5. A titanium-base alloy consisting essentially of about 0.1% oxygen, 1.5% iron, 1% copper, 1.5% manganese, and 1% aluminum, balance titanium.

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No references cited.