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2,880,089

TITANIUM BASE ALLOYS

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No Drawing. Application December 13, 1957
Serial No. 702,533

2 Claims. (Cl. 75—175.5)

This invention pertains to titanium-base alloys containing aluminum and manganese as essential constituents.

This application is a continuation-in-part of my applications Serial No. 131,044, filed December 3, 1949, now Patent No. 2,675,309, dated April 13, 1954, and Serial No. 385,720, filed October 12, 1953, now abandoned.

The alloys of the invention may contain from about 0.5 to 40% aluminum together with about 0.5 to 20% manganese. Where the manganese content is on the high side of its range, the aluminum content is preferably on the low side of its range, and vice versa, for the best combination of properties.

The alloys containing about 0.5 to 13% aluminum and about 0.5 to 13% manganese, are characterized by high tensile strength combined with adequate ductility for fabrication purposes, i.e., forging, extruding, rolling, drawing, etc., provided the manganese content is on the high side of its range when the aluminum content is on the low side of its range and vice versa.

The alloys containing aluminum and/or manganese contents above about 13%, tend to become increasingly brittle with increase in total alloy content, but are usable in cast form, being characterized in general by high hardness.

As is known, pure titanium metal has at normal or atmospheric temperatures a close-packed hexagonal or all-alpha microstructure which transforms at about 885° C. and above to a body-centered cubic or all-beta microstructure. Aluminum alloyed with titanium tends to stabilize the alpha phase, whereas manganese tends to promote retention and stabilization of the beta phase at normal or atmospheric temperatures. The alloys of the invention are accordingly characterized in general by a mixed alpha-beta microstructure at room temperature, which may contain in addition, eutectoid decomposition products depending on the heat treatment, since manganese is a beta-promoter of the sluggishly reactive eutectoid type.

In my patent aforesaid I have described ternary titanium-aluminum-manganese alloys containing about 1 to 7% each of aluminum and manganese, which are strong and ductile. My further investigations have established,

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as shown in my copending application Serial No. 385,720 above mentioned, that strong and ductile ternary alloys of titanium, aluminum and manganese are also obtained over the range of from more than 7% up to about 13% aluminum with about 0.5 to 13% manganese and also over the range of more than 7% manganese with about 0.5 to 13% aluminum.

I have further discovered, also as shown in my application Serial No. 385,720 aforesaid, that titanium-aluminum-manganese base alloys containing about 0.5 to 13% each of aluminum and manganese may be further strengthened with retention of adequate ductility for fabrication by additions of beta promoters other than manganese, such as Mo, V, Nb, Ta, Zr, Cr, W, Fe, Co, Ni, Cu, Be and Si. The beta promoters Mo, V, Nb, Ta and Zr are beta-isomorphous with titanium and hence may be added to the base Ti-Al-Mn alloy in large amounts ranging up to 40 or 50% with increasing effect on room temperature beta stabilization. The same is true to a lesser degree of the sluggishly eutectoid beta promoters Cr, Fe and W, with respect to which chromium and tungsten are effective up to about 20% for either or both, while iron is effective up to about 7% without unduly embrittling the resulting alloy. Cobalt, nickel and copper transform more or less rapidly into eutectoid decomposition products which tend to produce embrittlement, and hence are subject to lower tolerances, i. e., up to about 5% each or in aggregate. The lower effective limit for these additions is about 0.5% for all except Ni, Co, Cu, the lower effective limit for the latter being about 0.25%. The upper effective limit for Si and Be to avoid undue embrittlement is about 2-3%, and the lower effective limit about 0.1%.

The alloys of this invention are susceptible to embrittlement by an excess of carbon, oxygen and/or nitrogen. While the quantities of carbon, oxygen and nitrogen normally present in high quality commercial titanium can be tolerated, the oxygen and nitrogen content should not exceed about 0.1% each and the carbon content should not exceed about 0.3%.

Mechanical properties of ternary Ti-Al-Mn alloys according to the invention are given below in Table I. In producing the alloys of Table I, titanium metal of high purity, i.e., "iodide" base was employed.

It will be seen from the test results of Table I that alloys of high strength combined with adequate ductility for purposes of fabrication are obtainable over the range extending up to about 13% each of aluminum and manganese, provided that for a high content of one of these elements, the other should be present in correspondingly lower amount.

As regards requisite ductility for fabrication purposes, where the alloys are to be used for sheet material, the minimum bend ductilities may range as high as 20T, and where used in massive form, as in forgings, the percent tensile elongation may range as low as 1 or 2%.

TABLE I
Mechanical properties of Ti-Al-Mn alloys (iodide
titanium base)

Composition, Percent (Balance Titanium)			Condition ¹	Tensile Properties, p.s.i. × 1,000		Percent Elonga- tion in 1"	Percent Reduc- tion in Area	VHN	MBR, T, L ²
Al	Mn	C, O, N		0.2% Offset Yield	Ultimate				
5	7.5	---	R and A 750	131	142	8	23	367	1.1
5	10	---	R and A 750	145	145	2	7	371	0.8
5	12.5	---	R 850, A 900	---	130	0	0	302	0
5	15	---	R 850, A 900	---	80	0	0	343	Br
5	20	---	R 850, Q 1,000	---	---	---	---	405	Br
7.5	2	---	R 980, A 925	124	154	5	13	384	5.4
7.5	5	---	R 980, A 950	141	146	5	16	341	Br
7.5	10	---	R 980, A 1,050	---	101	0	0	366	7.6
7.5	15	---	R 980, A 1,050	---	---	---	---	378	Br
10	2	---	R 980, A 925	129	137	5	5	402	4.7
10	5	---	R 980, A 950	---	136	0	0	364	Br
10	10	---	R 980, A 1,000	---	---	---	---	334	---
12.5	5	---	R 980, A 950	104	107	2	4	337	Br
12.5	10	---	R 980, Q 1,050	---	---	---	---	403	Br
15	5	---	R 980, Q 1,050	---	99	0	0	364	Br
15	10	---	R 980, Q 1,050	---	---	---	---	442	---
20	5	---	AC	---	---	---	---	501	---
20	10	---	AC	---	---	---	---	624	---
30	10	---	AC	---	---	---	---	387	---
35	10	---	AC	---	---	---	---	347	---
37.5	1	---	AC	---	---	---	---	226	---
37	5	---	AC	---	---	---	---	282	---

¹ R=rolled; A=annealed; Q=quenched; numerals represent temperature in °C.; AC=as cast.
² Minimum bend radius, longitudinal.

Table II below gives mechanical properties showing the effect of adding the various other beta promoters to the Ti-Al-Mn base alloy of the invention. As noted in the table, the majority of the analyses were derived from titanium metal of commercial purity as obtained by the magnesium reduction of titanium tetrachloride, one example being derived from "iodide" titanium base metal, as indicated.

It will be seen that the quaternary and higher component alloys of Table II containing at least one beta promoter in addition to manganese are in general characterized by high tensile strengths and excellent bend ductilities.

The alloys of the invention may be made by melt casting in a cold mold furnace employing an arc electrode in an inert atmosphere or by equivalent procedures.

TABLE II
Mechanical properties of Ti-Al-Mn alloys plus other beta
additions

Composition, Percent (Balance Titanium)			Condition ¹	Tensile Properties, p.s.i. X1,000		Percent Elonga- tion in 1"	Percent Reduction in Area	VHN	MBR, T ²	
Al	Mn	Other		0.2% Offset Yield	Ultimate Strength				L	T
(Commercial Purity Ti-Base)										
---	---	---	R and A 850	48	71	21	51	187	0.8	0.8
4	---	---	R and A 850	88	101	19	48	304	1.7	2.6
---	5	---	R 650, A 550	115	136	10	---	290	3.0	---
4	2.5	2.5Mo	R 700, A 700	131	145	12	34	331	2.9	5.3
2	3	3Mo	R 700, A 600	127	152	10	31	333	3.2	4.2
4	4	7.5Mo	R 800, A 700	143	164	6	25	329	1.0	6.3
4	2.5	2Ni	R 700, A 700	110	130	3	9	332	7.8	9
4	2.5	5Ta	R 700, A 700	126	129	8	36	353	2.6	5.8
4	2.5	5V	R 700, A 700	145	150	5	33	355	2.8	3.1
4	2.5	2.5W	R 700, A 700	139	146	13	38	362	2.5	5.7
4	2.5	2Co	R 700, A 700	117	138	12	29	348	1.9	9
4	2.5	5Cb	R 700, A 700	144	148	7	38	355	2.5	5.9
2	3	3Cr	R 700, A 600	123	142	14	37	330	1.5	4.7
4	2.5	2.5Cr	R 700, A 700	138	144	6	33	358	1.8	8
4	4	7.5Cr	R 800, A 700	138	142	11	38	319	0	0
2	2	2Cr, 2Mo	R 700, A 600	137	146	9	25	329	1.2	4.4
4	2.5	1.5Fe	R 700, A 700	143	151	11	31	286	2.6	9
4	4	3Fe	R 815, A 700	154	160	5	24	361	0.9	6
(Iodide Ti-Base)										
5	2.5	2.5Fe	R and A 850	115	131	10	24	343	1.1	---
2	3	3Mo	R 700, A 700	127	152	10	31	---	---	---

¹ R=rolled; A=annealed; Q=quenched; numerals represent temperature in °C.
² Minimum bend radius—longitudinal and transverse.

What is claimed is:

1. A titanium base alloy consisting essentially of about: 0.5 to 13% each of aluminum and manganese and at least one beta promoter selected from the group consisting of 0.5 to 40% of molybdenum, vanadium, columbium, tantalum and zirconium, 0.5 to 20% of chromium and tungsten, 0.5 to 7% iron, 0.5 to 5% of cobalt, nickel and copper, and 0.1 to 3% of silicon and beryllium, characterized in having a tensile strength of at least 100,000 p.s.i. and a minimum bend radius of at least 20T.

2. A titanium base alloy consisting essentially of about: 0.5 to 13% each of aluminum and manganese, the manganese being present on the high side of its range when aluminum is present on the low side of its range and vice versa, said alloy also containing at least one beta promoter selected from the group consisting of 0.5 to 40% of molybdenum, vanadium, columbium, tantalum and zirconium, 0.5 to 20% of chromium and tungsten, 0.5 to 5% iron, 0.5 to 5% of cobalt, nickel and copper, and 0.1 to 3% of silicon and beryllium, characterized in having a tensile strength of at least 100,000 p.s.i. and a minimum bend radius of at least 20T.

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