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TITANIUM BASE ALLOYS

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12 Claims. (Cl. 75—177)

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This invention pertains to new and improved titanium base alloys having ternary or higher metal alloying additions of iron and two or more of the elements chromium, molybdenum and manganese, with oxygen and nitrogen within maximum limits.

Alloys of the type here being considered are suitable for structural purposes and particularly, where impact resistance, tensile strength, good ductility and corrosion resistance are needed, as in aircraft and somewhat special purpose usages.

It has been an object of the present invention to provide titanium base alloys for such a need and particularly, alloys that may be produced with relative ease and economy.

Another object has been to provide improved titanium base alloys having good combinations of tensile, impact and ductility properties.

A further object has been to devise titanium base alloys of a ternary and higher metal alloying content that may be heat treated in a like manner to produce a structure containing a matrix of retained beta phase.

These and other objects will be apparent to those skilled in the art from the following description of the alloys and their characteristics.

The alloys of the present invention are characterized by their good ductility and impact resistance at tensile strengths of about 125,000 plus to 130,000 p. s. i. and over. They provide good combinations of tensile, impact and ductility properties and may be relatively easily and economically produced by employing ferro-alloy additions.

In these alloys, the iron-plus-alloying metal content should be less than 10%, but not less than about 5%, with an optimum total of from 6 to 9%. That is, from the standpoint of metal alloying contents herein set forth, the above specified ranges apply to the total iron-plus-chromium-plus-molybdenum, the total iron-plus-chromium-plus-manganese, the total iron-plus-molybdenum-plus-manganese, and the total iron-plus-chromium- plus -molybdenum-plus-manganese contents.

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The heat treatment of these alloys involves working above and within their alpha-beta phase range of about 1800° to 1000° F., followed by annealing in the lower portion of the alpha-beta region from about 900° to 1400° F. to produce a structure of alpha islands in a matrix of retained beta that has good tensile and impact properties. This desirable structure may also be obtained by cooling rapidly from the upper portion of or over the alpha beta range, about 1400° to 1800° F., and reheating to a lower portion of this range, about 900° to 1400° F.

To provide and maintain good impact properties, the oxygen and nitrogen gas contents should be kept within the maximums specified. The microstructures of all these alloys are similar.

In making alloying additions to the melts, for best results, ferro-manganese, ferro-chromium, and ferro-molybdenum are used. By way of example, the titanium may be supplied in the form of a sponge containing about .10% iron, about .10% oxygen and about .05% nitrogen.

The compositions of these alloys, indicated as A, B, C and D, are represented by the following Tables I, II, III and IV and their properties are illustrated, respectively, by Tables IA, IIA, IIIA and IVA.

TABLE I

Alloy A

General Range	Optimum Range
Fe—1.0-4.0% Cr—1.0-6.0% Mo—1.0-5.0% O—0.30% max. N—0.30% max.	Fe—2.0-3.5% Cr—2.0-5.0% Mo—1.5-4.5% O—0.20% max. N—0.15% max.

TABLE IA

Property data for iron-chromium molybdenum alloys forged from 1700° F., annealed at 1300° F.

Heat No.	Composition					Tensile Strength, p. s. i.	Percent El.	Percent R. A.	V-notch Charpy Impact (Ft.-lb.)
	Percent Fe	Percent Cr	Percent Mo	Percent O_2	Percent N_2				
K-482	2.0	2.8	1.2	0.1	0.05	125,300	15.5	42.8	26.0
K-511	2.1	2.1	1.8	0.1	0.05	127,500	13.0	45.2	42.0
K-483	2.2	1.4	2.4	0.1	0.05	140,300	16.5	51.0	18.0
K-501	2.9	2.1	3.0	0.1	0.05	144,100	14.0	43.4	26.0
K-480	2.8	2.8	2.4	0.1	0.05	162,200	12.0	24.0	18.0
K-489	2.8	2.8	2.4	0.2	0.05	152,100	15.0	21.2	12.0
K-490	2.8	2.8	2.4	0.1	0.15	162,200	13.0	30.8	14.5
K-498	2.7	3.5	1.8	0.1	0.05	153,300	15.0	39.9	25.0
K-502	3.3	5.3	1.5	0.1	0.05	156,000	15.5	39.9	18.0
K-481	3.5	3.5	3.0	0.1	0.05	155,300	14.0	35.5	10.0
K-487	3.8	1.8	4.5	0.1	0.05	162,800	12.5	36.1	22.0

TABLE II

Alloy B

General Range	Optimum Range
Fe—1.0–3.0% Cr—1.0–6.0% Mn—1.0–5.0% O—0.30% max. N—0.30% max.	Fe—1.5–2.5% Cr—2.0–4.0% Mn—2.0–4.5% O—0.20% max. N—0.15% max.

TABLE IIA

Property data for iron-chromium-manganese alloys forged from 1700° F., annealed at 1300° F.

Heat No.	Composition					Tensile Strength, p. s. i.	Percent El.	Percent R. A.	V-notch Charpy Impact (Ft.-lb.)
	Percent Fe	Percent Cr	Percent Mn	Percent O_2	Percent N_2				
K-564	1.4	2.1	2.5	0.1	0.05	151,000	24.0	35.5	26.5
K-556	1.7	2.1	4.2	0.1	0.05	196,000	8.0	13.3	10.0
K-555	1.8	2.8	3.4	0.1	0.05	186,000	10.0	19.8	8.0
K-560	1.8	2.8	3.4	0.3	0.05	192,000	5.0	4.2	7.0
K-561	1.8	2.8	3.4	0.1	0.25	181,000	10.0	15.5	7.0
K-523	2.3	3.5	4.2	0.1	0.05	163,800	11.0	26.1	6.0

TABLE III

Alloy C

General Range	Optimum Range
Fe—1.0–4.0% Mo—1.0–5.0% Mn—1.0–6.0% O—0.30% max. N—0.30% max.	Fe—1.5–3.0% Mo—1.5–4.0% Mn—2.0–4.5% O—0.20% max. N—0.15% max.

TABLE IIIA

Property data for iron-molybdenum-manganese alloys forged from 1700° F., annealed at 1300° F.

Heat No.	Composition					Tensile Strength, p. s. i.	Percent El.	Percent R. A.	V-notch Charpy Impact (Ft.-lb.)
	Percent Fe	Percent Mo	Percent Mn	Percent O_2	Percent N_2				
K-569	1.7	1.8	2.5	0.1	0.05	146,500	21.0	37.3	20.0
K-550	2.0	1.8	4.2	0.1	0.05	182,000	10.0	19.0	10.0
K-548	2.2	2.4	3.4	0.1	0.05	173,500	13.0	25.5	10.0
K-551	2.2	2.4	3.4	0.3	0.05	158,000	12.0	11.6	7.0
K-552	2.2	2.4	3.4	0.1	0.25	183,000	6.0	13.3	5.5
K-549	2.5	3.0	2.5	0.1	0.05	162,000	18.0	36.1	16.5

TABLE IV

Alloy D

General Range	Optimum Range
Fe—1.0–4.0% Cr—0.5–5.0% Mo—0.5–5.0% Mn—0.5–6.0% O—0.30% Max. N—0.30% Max.	Fe—1.5–3.5% Cr—1.5–3.5% Mo—1.0–3.0% Mn—1.5–3.5% O—0.20% Max. N—.15% Max.

TABLE IVA

Property data for iron-chromium-molybdenum-manganese alloys forged from 1700° F., annealed at 1300° F.

Heat No.	Composition						Tensile Strength, p. s. i.	Percent El.	Percent R. A.	V-notch Charpy Impact (Ft. lb.)
	Percent Fe	Percent Cr	Percent Mo	Percent Mn	Percent O_2	Percent N_2				
K-565	1.7	1.4	1.2	1.7	0.10	0.05	159,000	24.0	49.3	24.0
K-562	1.7	1.4	1.2	1.7	0.30	0.05	149,000	10.0	5.5	20.0
K-563	1.7	1.4	1.2	1.7	0.10	0.25	153,000	15.0	19.0	13.0
K-553	2.1	1.8	1.5	2.1	0.10	0.05	184,000	12.0	13.3	11.0
K-557	2.3	2.8	1.2	1.7	0.10	0.05	186,800	12.0	32.8	
K-559	2.3	1.4	2.4	1.7	0.10	0.05	182,000	10.0	26.7	6.0
K-568	2.6	2.1	1.8	2.5	0.10	0.05	195,500	8.0	21.8	10.0
K-524	2.9	3.5	1.5	2.0	0.10	0.05	162,000	14.0	35.5	6.0

It will be noted from alloy D of Table IV that the element chromium is best employed within a slightly lower range than in alloys A and B, and that the elements manganese and molybdenum are best employed in slightly higher minimum amounts in alloys A, B and C. It will also be noted that the maximum ranges of iron and manganese of alloy B are slightly lower than of alloy C for best results.

What I claim is as follows:

1. An improved titanium base alloy which contains about 1 to 4% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, and at least two metals within the ranges specified from the group consisting of: chromium about .5 to 6%, manganese about .5 to 6%, and molybdenum about .5 to 5%; the iron-plus-alloying metal content being less than 10% but not less than about 5%; the alloy being characterized by its good ductility and impact strength with relatively high tensile strength.

2. An improved titanium base alloy as defined in claim 1 as heat treated by working above and within its alpha-beta phase range of about 1800° to 1000° F., followed by annealing in a lower portion of its alpha-beta region of about 900° to 1400° F., and wherein its structure has alpha islands in a matrix of retained beta.

3. An improved titanium base alloy as defined

in claim 1 as treated by rapidly cooling it from an upper portion to slightly above its alpha-beta phase range of about 1400° to 1800° F., followed by reheating to the lower portion of such range, about 900° to 1400° F., and wherein its structure has alpha islands in a matrix of retained beta.

4. An improved titanium base alloy which contains about 1 to 4% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, at least two metals within the ranges specified from the group consisting of: chromium about .5 to 5%, manganese about .5 to 6%, and molybdenum about .5 to 5%, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

5. An improved titanium base alloy which contains about 1 to 4% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, about 1 to 6% chromium, about 1 to 5% molybdenum, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

6. An improved titanium base alloy which contains about 2 to 3.5% iron, up to about .20% maximum oxygen and about .15% maximum nitrogen, about 2 to 5% chromium, about 1.5 to 4.5% molybdenum, the iron-plus-alloying metal contact being less than 10% but not less than 5%, and the balance titanium with incidental impurities.

7. An improved titanium base alloy which contains about 1 to 3% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, about 1 to 6% of chromium, about 1 to 5% manganese, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

8. An improved titanium base alloy which contains about 1.5 to 2.5% iron, up to about .20% maximum oxygen and about .15% maximum nitrogen, about 2 to 4% chromium, about 2 to 4.5% manganese, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

9. An improved titanium base alloy which contains about 1 to 4% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, about 1 to 5% molybdenum, about 1 to 6% manganese, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

10. An improved titanium base alloy which contains about 1.5 to 3% iron, up to about .20% maximum oxygen and about .15% maximum nitrogen, about 1.5 to 4% molybdenum, about 2 to 4.5% manganese, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

11. An improved titanium base alloy which contains about 1 to 4% iron, up to about .30% maximum of each of the gases oxygen and nitrogen, about .5 to 5% chromium, about .5 to 5% molybdenum, about .5 to 6% manganese, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

12. An improved titanium base alloy which contains about 1.5 to 3.5% iron, up to about .20% maximum oxygen and about .15% maximum nitrogen, about 1.5 to 3.5% each of chromium and manganese, about 1 to 3% molybdenum, the iron-plus-alloying metal content being less than 10% but not less than about 5%, and the balance titanium with incidental impurities.

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No references cited.