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TITANIUM BASE ALLOYS

Richard K. Pitler, Menands, N. Y., assignor to Allegheny Ludlum Steel Corporation, Brackenridge, Pa., a corporation of Pennsylvania

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This invention relates to alloys and, in particular, to titanium base alloys.

An object of this invention is to produce a titanium base alloy suitable for use at elevated temperatures of 400° F. to 800° F.

Another object of this invention is to provide a titanium base alloy having a mixture of the alpha and beta phases of titanium and in which the beta phase is stable when the alloy is subjected in use to a temperature within the range of 400° F. to 800° F.

A further object of this invention is to provide a titanium base alloy containing iron, chromium, molybdenum and aluminum.

A more specific object of this invention is to provide an alloy consisting of 1% to 4% iron, 1% to 4% chromium, 1% to 4% molybdenum, 1% to 6% aluminum and the balance titanium with incidental impurities.

Other objects of this invention will become apparent from the following description.

In accordance with this invention the alloy comprises iron, chromium, molybdenum and aluminum alloyed in a titanium base in proper proportions to obtain an alloy having good mechanical properties and which is stable when used at operating temperatures of 400° F. to 800° F. In practice, the components are present in the alloy within the range of 1% to 4% iron, 1% to 4% chromium, 1% to 4% molybdenum, and 1% to 6% aluminum and the balance titanium with not over 0.5% of incidental impurities such as oxygen, nitrogen and carbon. Preferably the impurities are not present in amounts of more than 0.2% of any one of oxygen, nitrogen and carbon. In practice, it has been found desirable to maintain the elements iron, chromium and molybdenum in substantially equal amounts in the alloy of this invention as will be evident from the results given hereinafter.

While the alloying elements utilized in the alloy of this invention are employed in fairly specific ranges as given hereinbefore, the preferred composition range with-

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incidental impurities not exceeding 0.5%. Such alloys are found to have especially good mechanical properties.

The alloy is preferably made from commercially pure titanium, that is the titanium metal commercially available such as is produced from the reaction of chemically pure titanium tetrachloride with magnesium metal and containing not more than 0.25% oxygen, 0.15% nitrogen, and 0.10% carbon present as impurities. In practice the titanium is preferably melted by the electric arc process in a water-cooled copper crucible in an atmosphere such as argon or helium which is non-contaminating to titanium, the alloying elements being added to the melt either as chemically pure components, or where desired, the iron, chromium and molybdenum is added in the form of high purity ferro-alloys of chromium and molybdenum.

The alloy thus formed having the components within the ranges given hereinbefore is found to consist of a mixture of the alpha, low temperature, hexagonal close-packed phase and the beta, high temperature, body-centered cubic crystal structure phase, which mixture is retained over a wide range of temperature. From the results obtained with the alloys of this invention it is believed that the elements iron, chromium and molybdenum within the ranges given tend to go into solution and to stabilize the beta phase whereas the aluminum content tends to stabilize and strengthen the alpha phase. All of the alloying components when present in the ranges given have the effect of increasing the strength of the resulting base alloy when such alloy is subjected in use to temperatures of 400° F. to 800° F. The elements iron, chromium and molybdenum are of particular value in the ranges given of functioning to provide a stable beta phase which will not decompose and embrittle the alloy during long service at elevated temperatures in the range of 400° F. to 800° F.

The alloys produced as described can be readily forged or rolled to sheet, bar or other form from a temperature of 1300° F. to 1800° F. Thereafter they are annealed at a temperature of 1075° F. to 1200° F. and preferably at about 1100° F. for a period of time of up to twenty-four hours to effectively produce a mixture of the alpha and beta phases, the beta phase being completely stable when subjected to reheating as in service at a temperature in the range of 400° F. to 800° F.

As examples of the outstanding mechanical properties of alloys having the composition within the range given hereinbefore, reference may be had to the following table of results obtained on alloys produced and which were forged from a temperature of 1650° F. and then annealed for twenty-four hours at the temperature indicated.

Heat No.	Composition, Percent				Ingot Hardness, Brinell	Anneal. Temp., ° F.	Tensile, p. s. i.	Elong., Percent 1 in.	Red. in Area, Percent
	Fe	Cr	Mo	Al					
K 900-----	1.3	1.4	1.3	1.0	280	1,200	128,500	25	56
K 901-----	1.3	1.4	1.3	3.0	321	1,200	180,000	11	29.6
K 902-----	1.3	1.4	1.3	5.0	330	1,200	156,000	18	46.4
K 899-----	2.0	2.1	1.9	1.0	317	1,200	141,000	22	44.6
K 807-----	2.0	2.1	1.9	3.0	370	1,200	153,000	20	42.2
K 837-----	2.0	2.1	1.9	4.0	375	1,100	179,000	19	51
K 808-----	2.0	2.1	1.9	5.0	415	1,200	190,500	7	11
K 903-----	2.7	2.8	2.5	1.0	291	1,200	159,000	22	41
K 488-----	2.7	2.8	2.5	2.0	330	1,200	147,700	22	48
K 838-----	2.7	2.8	2.5	4.0	351	1,100	191,500	14	28

in the range given is one in which the elements are present in the proportions of 1.2% to 2.7% iron, 1.3% to 2.8% chromium, 1.1% to 2.5% molybdenum, and 3% to 5% aluminum with the balance titanium with the

As examples of other alloys produced within the range given and the exceptional mechanical properties which can be obtained thereon, reference may be had to the following table, each of the alloys listed having been sub-

jected to an annealing treatment at 1100° F. for twenty-four hours after forging.

Heat No.	Composition, Percent				Tensile St., p. s. i.	0.2% Yield St., p. s. i.	Elong., Percent 1 in.	Red. in Area, Percent
	Fe	Cr	Mo	Al				
K 991---	1.3	1.4	1.3	3.0	140,500	140,500	22	50
K 992---	1.3	1.4	1.3	4.0	151,000	148,800	16	45
K 993---	1.3	1.4	1.3	5.0	165,000	164,000	14	17
K 994---	2.0	2.1	1.9	3.0	143,000	138,500	19	43
K 995---	2.0	2.1	1.9	5.0	167,500	167,500	16	47

The mechanical properties of alloys K991 and K995 having the same composition as alloy K901 and K808, respectively, but subjected to the 1100° F. anneal as opposed to the 1200° F. anneal of the latter alloys, demonstrate that while an annealing temperature of 1200° F. is satisfactory, better results can be obtained by annealing at 1100° F.

While the foregoing results of mechanical properties are based on tests at room temperature, the alloys have excellent mechanical properties at elevated temperatures. For example alloy K993 identified hereinbefore had the following mechanical properties when tested at the test temperatures indicated.

Test Temp., ° F.	Tensile St., p. s. i.	Elong., Percent 1 in.	Red. in Area, Percent
500-----	102,000	19	57.4
700-----	97,000	12	30.8
800-----	93,000	22	58.0
900-----	94,500	22	65.0
1000-----	88,800	29	77.0

The alloys of this invention can be readily reproduced by any one skilled in the art and have excellent high temperature strength. This characteristic renders the alloy outstanding for use in jet engines where temperatures in the range of 400° F. to 800° F. are encountered in service. The fact that the beta phase will not decompose and embrittle when the alloy is used at elevated temperatures makes it possible to clearly prolong the life of components formed from the alloy for use at such elevated temperatures thereby greatly increasing the life of jet engines or other apparatus requiring the characteristic of long service at elevated temperatures.

I claim:

1. An alloy consisting of, 1% to 4% iron, 1% to 4% chromium, 1% to 4% molybdenum, 1% to 6% aluminum and the balance titanium with incidental impurities.

2. An alloy consisting of, iron, chromium and molybdenum in substantially equal amounts within the range of 1% to 4% of each element, 1% to 6% aluminum, and the balance titanium with incidental impurities.

3. An alloy consisting of, 1.2% to 2.7% iron, 1.3% to 2.8% chromium, 1.1% to 2.5% molybdenum, 3% to 5% aluminum and the balance titanium with incidental impurities.

4. An alloy having a mixture of alpha and beta phases and in which the beta phase is stable when subjected in use to temperature in the range of 400° F. to 800° F. consisting of, 1% to 4% iron, 1% to 4% chromium, 1% to 4% molybdenum, 1% to 6% aluminum, and the balance titanium with incidental impurities and which has been annealed at a temperature of 1075° F. to 1200° F.

No references cited.