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2,740,711

IRON CHROMIUM MOLYBDENUM TITANIUM BASE ALLOY

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This invention relates to a new and improved titanium
base alloy having ternary metal alloying additions of iron,
chromium and molybdenum, and wherein oxygen and
nitrogen are maintained within maximum limits.

This application is a continuation-in-part of our co-
pending application No. 118,723 of September 29, 1949
entitled "Titanium Alloys."

It has been an object of our present invention to pro-
duce a relatively inexpensive titanium alloy having a
stabilized all beta phase structure;

Another object is to provide an improved titanium base
alloy which may make use of ferro alloys as additional
agents in the melt;

A further object has been to produce titanium base
alloys which are substantially free of intermetallic com-
pounds and their resultant harmful effects;

These and many other objects of our invention will
appear to those skilled in the art from the following de-
scription.

The alloying content of our alloy is critical and par-
ticularly, from the standpoint of a retained beta body-
centered cubic form of lattice structure which is character-
istic of titanium metal when heated above about 1625° F.
The alloy here being considered saves scarce and strategic
elements and is suitable for structural purposes, such as
in airplanes, where the service temperature does not go
above about 400° F. and a good ductility is needed with
a high tensile strength.

Unalloyed titanium normally exists in a hexagonal,
closely-packed, crystalline structure at room temperature
and transforms on heating to above about 1625° F. to a
body-centered cubic lattice crystalline structure. The
present invention deals with alloying additions stabiliz-
ing and completely retaining the high temperature beta
structure of titanium, so that it is fully available at room
temperature without the presence of alpha phase titanium.
In this manner, we have been able to produce an alloy
having an excellent ductility with a good tensile strength,
impact, and other properties.

Reheating an alloy of the present invention within a
range of about 500° to 1100° F. after its solution heat
treatment will result in a decomposition of the retained
beta phase, a resultant precipitation of the alpha phase,
and serious loss of ductility. The alloy is, however, very
useful in service at room temperature up to about 400°
F. due to its combination of high strength and good
ductility. Also, it is capable of being cold worked and
annealed, thus facilitating the processing of sheet and
strip products.

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In carrying out our invention, we employ a titanium
base alloy of the following composition:

Table 1

General Range	Optimum Range
Mo=1.5 to 10%	Mo=2.5 to 6.5%
Cr=1.5 to 11%	Cr=2.5 to 6.5%
Fe=3.0 to 8%	Fe=3.5 to 6.0%
O ₂ = .20% max.	O ₂ = .20% max.
N ₂ = .10% max.	N ₂ = .10% max.

In the above alloys, the remainder is titanium with in-
cidental impurities or substantially all titanium and the
alloying element contents are critical in their specified
ranges. The metal alloying elements are also critical in
their total content (molybdenum + iron + chromium)
in that such total should be above about 11.00% and be-
low about 20%; the optimum range being about 13 to
16%.

We have found that the three metal elements in com-
bination all tend to stabilize the beta phase of titanium.
Further, the use of these metal elements within the
ranges specified produces an alloy which is more stable
than one made from one of the elements alone and pro-
duces an alloy that is free from the harmful effects due to
the presence of intermetallic compounds that are present
in binary iron-titanium and chromium-titanium alloying
systems. The metal alloying elements, as an optimum,
are introduced at one time to the melt and as ferro alloy-
additions. The latter type of additions are more readily
soluble in the melt and are less scarce and strategic than
the single elements, themselves. The total content of the
metal alloying elements is highly critical and particularly
so from the standpoint of the retention of the beta phase
of titanium.

Heat treatment consists of a solution treatment in the
range of about 1200° to 1500° F., followed by air cool-
ing. This treatment provides an all beta-phase structure
having the required ductility and tensile properties. The
alloys may be hot worked within a range of about 1200
to 1700° F. and may also be cold worked at room tem-
perature to produce a resultant increase of tensile strength
and decrease in ductility. Titanium of commercial
purity may be used in making the alloys, but it is im-
portant to maintain the oxygen and nitrogen gaseous
alloying elements within the previously specified maxi-
mum amounts to obtain requisite properties.

The following is indicative of the properties of alloys
of our alloy invention after they have been solution
treated in the manner previously explained. Melt No.
K669 which has a total metal alloying content of 11%,
illustrates the importance of the lower critical total metal
alloying content. Melt K662 which has a molybdenum
content that is well below the critical minimum of 1.5%
required and is thus not an alloy of our invention, illus-

trates the importance of the individual contents of the metal alloying elements:

Table II

Heat No.	Composition					Tensile Strength, lbs./sq. in.	El. Per-cent	R. A., Per-cent	Ingot Hardness, BHN
	Using Ferro Additions		Based On Individual Elements						
	FeCr, Per-cent	FeMo, Per-cent	Fe, Per-cent	Cr, Per-cent	Mo, Per-cent				
K642	10	10	6.7	7.0	6.3	173,000	11	19	332
K645	9	3	3.8	6.3	1.9	167,000			332
K662	10	2	3.75	7.0	1.25	167,000	1	1.6	311
K663	2	10	4.25	1.4	6.35	156,000	19	48.7	321
K664	4	8	4.15	2.8	5.05	158,500	12	48	305
K665	8	4	3.9	5.6	2.5	158,500	14	47	316
K666	3	9	4.2	2.1	5.7	165,000	12	34	345
K667	15	3	5.6	10.5	1.9	163,500	22	47	316
K668	3	15	6.45	2.1	9.45	170,500	21	42	311
K669	5.5	5.5	3.65	3.85	3.5	188,000	0	0	332

As a further example, we have chosen three alloys of our invention having a total of 15% (within the optimum range) of metal alloying content:

Table III

Item	Composition			Tensile Strength	Elongation	Reduction of Area
	Fe	Cr	Mo			
1	5.5	3.5	6.0	156,200	22	50
2	5.0	7.0	3.0	152,600	23	53
3	5.25	5.25	4.5	155,200	23	43

In the above Table III, the alloys were tested as one half inch square bars annealed 1400° F. for one half hour and air cooled.

The result of reheating the alloys of Table III after a solution heat treatment is indicated as follows:

Table IV

Item	Fe	Cr	Mo	Rockwell "C" Hardness After Indicated Heat Treatment				
				1,500° F., 45 min. Water Quench	+600° F., 6 hrs.	+700° F., 6 hrs.	+700° F., 24 hrs.	+600° F., 24 hrs.
1	5.5	3.5	6.0	34.5	38.5			45.0
2	5.0	7.0	3.0	35.0	36.0			44.5
3	5.25	5.25	4.5	36.0		44.0	48.0	

What we claim is:

1. A titanium base alloy composition having an all beta-phase structure as solution treated at a temperature of about 1200° or 1500° F., followed by air cooling, which structure is wholly stable at room temperature, and which alloy composition consists of oxygen in the amount up to about .20% maximum, nitrogen in the

amount up to about .10% maximum, about 1.5 to 10% molybdenum, about 1.5 to 11% chromium, about 3 to

8% iron, and the remainder titanium with incidental impurities; the total metal alloying content of molybdenum, chromium and iron being highly critical within the range of about 11 to 20%.

2. A titanium base alloy as defined in claim 1 wherein the total metal alloying content is within a range of about 13 to 16%.

3. A titanium alloy composition having an all beta-phase structure as solution treated at a temperature within a range of 1200° to 1500° F., followed by air cooling, which structure is wholly stable at room temperature, and which alloy composition consists of oxygen in the amount up to about .20% maximum, nitrogen in the amount up to about 11% maximum, about 2.5 to 6.5% each of molybdenum and chromium, about 3.5 to 6% iron, the molybdenum plus chromium plus iron content being within a highly critical range of above about 11% and below about 20%, and the remainder titanium with incidental impurities.

4. An improved titanium base alloy as defined in claim 11 wherein the total molybdenum plus chromium plus iron content is within a range of about 13 to 16%.

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