United States Patent Office

2,819,958

Patented Jan. 14, 1958

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2,819,958

TITANIUM BASE ALLOYS

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No Drawing. Application August 16, 1955 Serial No. 528,819

6 Claims. (Cl. 75—175.5)

The invention relates to titanium-base alloys and more particularly to titanium-base alloys containing aluminum, vanadium, chromium and molybdenum.

The present invention comprises the discovery that the addition to titanium-aluminum alloys of relatively small amounts of vanadium, chromium and molybdenum effects a marked improvement in the properties of such alloys of an aluminum content of 3% to 5%. The alloys show a rare combination of extraordinary strength with adequate ductility.

The use of titanium as a structural material is limited by its relatively low strength and high cost; for which reason it has been found desirable to alloy titanium with such other metals as will increase the strength and preferably effect some reduction in the total cost. Aluminum is a metal well suited to these objectives, being low in weight, relatively low in cost, and having a material strengthening effect on titanium.

However, the amount of aluminum alone that can be added to titanium is limited by its adverse effect on ductility. Binary alloys of titanium with more than 5% of aluminum are too brittle for most structural uses, and such binary alloys containing a lesser amount of aluminum do not possess sufficient strength to be of general utility. Further strengthening of the material without decreasing the ductility is therefore highly desirable.

It is known that tin has been used in a titanium-aluminum alloy together with one or more of the elements vanadium, chromium and molybdenum, but we have found that such an alloy without tin is superior to the same alloy with tin, for both plate and sheet applications, as it produces improved toughness in the plate and improved bend properties in the sheet. Also, it is desirable to eliminate tin from the alloy not only for the reason that it is a strategic element, but because it increases the density of the material, and, because of its relatively low melting point it is difficult to handle in the melt.

It is an object of the invention to provide strong, ductile alloys of titanium.

Another object is to provide titanium alloys which are heat treatable to high strength.

A further object is to provide a titanium, aluminum, vanadium, chromium, molybdenum alloy which is suitable for use in plate or sheet form.

A still further object is to provide such an alloy which maintains satisfactory and good notch toughness in plate form.

Another object of the invention is to provide a titanium alloy which is soft in the as-quenched condition with good bend properties in the sheet form.

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A further object is to provide such a titanium alloy which is age hardenable by following the heat treatment with ageing at 900 to 1100° F.

A still further object is to provide a titanium alloy of this character in which the ductility of the hardened material is very satisfactory and in which the tensile strength approaches 200,000 lbs. per square inch.

Other objects and advantages of the invention will be apparent in view of the following deteailed descriptions thereof.

In general, the invention relates to quinary alloys of titanium, aluminum, vanadium, chromium and molybdenum, comprising from 3 to 5% aluminum, from 1 to 2% vanadium, from a trace to 1% chromium (preferably from .5 to 1%), from a trace to 1% molybdenum (preferably from .5 to 1%), the balance being all titanium.

Titanium, aluminum, vanadium, chromium, molybdenum alloys coming within the above range are heat treatable to high strength and maintain satisfactory and good notch toughness desirable in plate form. The alloy is soft in the as-quenched condition with good bend properties desirable in the sheet form.

This alloy may be heat treated by heating at 1200 to 1700° F. for a half hour and then water quenching. After this treatment the alloy is age hardenable by ageing for two hours between 900 and 1100° F. and air cooling. The ductility of this hardened material is very satisfactory, having approximately 10% elongation with tensile strength approaching 200,000 lbs. per square inch.

The following are examples of titanium, aluminum, vanadium, chromium, molybdenum alloys, coming within the above range, which have been produced, heat treated and evaluated for mechanical properties.

Example 1.—3% aluminum, 1½% vanadium, .5% chromium, .5% molybdenum and the balance essentially all titanium.

Example 2.—4% aluminum, 1½% vanadium, .5% chronium, .5% molybdenum and the balance essentially all titanium.

Example 3.—5% aluminum, 1½% vanadium, .5% chronium, .5% molybdenum and the balance essentially all titanium.

Example 4.—4% aluminum, 2% vanadium, 1% chrominum, 1% molybdenum and the balance essentially all titanium.

These alloys may be prepared from either commercial titanium or high purity titanium. Where prepared from commercial titanium, a typical analysis of the material, in addition to titanium, aluminum, vanadium, chromium and molybdenum, is 0.02% C, 0.01% N_2 0.10% O_2, and 0.005% H_2. However, the invention is not restricted to the use of material having the typical interstitial level indicated, as the level may be of the order of 0.06% C, 0.03% N_2, 0.15% O_2 and 0.017 H_2.

An ingot of the alloys of Example 4 was cast and hot forged into ⅝" rounds, and specimens were cut therefrom and heat treated, and evaluated for mechanical properties of the plate form, as shown in the following Table I.

TABLE I

Heat treating data for 4% Al, *2%* V, *1%* Cr, *1%* Mo, *balance* Ti, *and evaluation for mechanical properties of plate*

Heat treatment	Ultimate Strength	.2% yield strength	percent elong.	Percent area reduc.	Impact, 40° F. (Ft. Lb.)
1,600° F., ½ hr. AC	145,800	112,000	17.2	52.4	19.5
1,600° F., ½ hr. WQ	142 300	101,200	18.0	50.9	19.5
1,600° F., ½ hr. WQ and aged at 1,100° F., 2 hr. AC.[1]	143 800	126,100	13.3	42.4	23.5
	146,100	130,000	14.1	50.1	20.5
1,600° F., ½ hr. WQ and aged at 900° F., 2 hr. AC.[1]	167,500	136,800	9.4	23.7	10 5
	157,800	127,200	10.2	33.7	12
1,300° F., 1 hr. AC (annealed)	132,800	124,600	11.7	47.4	26.5

[1] Two specimens.

An ingot of the alloy of Example 1 was cast, hot forged to sheet bars, hot rolled to 0.040″ sheets, and specimens thereof were heat treated and evaluated for mechanical properties of the sheet form as shown in the following Table II.

TABLE II

Heat treating data for 3% Al, 1½% V, .5% Cr, .5% Mo, balance Ti, *and evaluation for mechanical properties of sheet*

Heat Treatment	Ultimate Strength	.2% yield strength	percent elong.	Bend Test
1,500° F., ½ hr. WQ	110,200	75,600	21.1	3.2 T
Quenched and aged at 900° F., 2 hrs	133,100	99,400	12.5	4.7 T

An ingot of the alloy of Example 2 was cast, hot forged to sheet bars, hot rolled to 0.040″ sheets, and specimens thereof were heat treated and evaluated for mechanical properties of the sheet form as shown on the following Table III.

TABLE III

Heat treating data for 4% Al, *1½%* V, *.5%* Cr, *.5%* Mo, *balance* Ti, *and evaluation for mechanical properties of sheet*

Heat Treatment	Ultimate Strength	.2% yield strength	percent elong.	Bend Test
1,600° F., ½ hr. WQ	123,800	96,400	16.0	6.0 T
Quenched and aged at 900° F., 2 hrs	146,700	121,600	10.9	6.1 T

An ingot of the alloy of Example 3 was cast, hot forged to sheet bars, hot rolled to 0.040″ sheets, and specimens thereof were heat treated and evaluated for mechanical properties of the sheet form as shown on the following Table IV.

TABLE IV

Heat treating data for 5% Al, *1½%* V, *.5%* Cr, *.5%* Mo, *balance* Ti, *and evaluation of mechanical properties of sheet*

Heat Treatment	Ultimate Strength	.2% yield strength	percent elong.	Bend Test
1,600° F., ½ hr. WQ	134,100	94,600	16.4	5.9 T
Quenched and aged at 900° F., 2 hrs	157,700	128,200	10.2	9.0 T

In the same manner an ingot of the alloy of Example 4 was cast, hot forged to sheet bars, hot rolled to 0.040″ sheets, and specimens were heat treated and evaluated for mechanical properties of sheet form as shown in the following Table V.

TABLE V

Heat treating data for 4% Al, *2%* V, *1%* Cr, *1%* Mo, *balance* Ti, *and evaluation of mechanical properties of sheet*

Heat Treatment	Ultimate Strength	.2% yield strength	per-cent elong.	Bend Test
1,600° F., ½ hr. WQ	135,000	95,000	[1] 7.8	2.8 T
Quenched and aged at 900° F., 2 hrs	182,100	150,000	10.2	8.8 T
1,650° F., ½ hr. WQ and aged at 900° F., 2 hrs	195,700	171,000	10.2	Brittle.

[1] The low elongation in the as-quenched condition is due to fracture occurring at the gauge mark. On the basis of the as-quenched properties of the low beta complex the true value should be better than 16% elongation. The good T bend adds to the validity of this analogy.

The alloys of the present invention are characterized by their good ductility and impact resistance at tensile strength of from about 150,000 p. s. i. to nearly 200,000 p. s. i., when heat treated and aged.

These alloys compare very favorably with the ternary alloy 6Al, 4V, balance Ti, which has become generally accepted throughout the titanium industry as a heat-treatable alloy. The successful use of this Al—4V alloy is somewhat limited in use because of its low hardenability, high strengths being limited to sections up to about two inches thick, and because of its poor formability and low heat-treat response in sheet thicknesses, T bends averaging 5–6T at best.

It appears that the Cr and Mo substitution in our complex alloys substantially improve the hardenability and response to heat treatment of the alloys. For comparative purposes, the 6Al—4V alloy was investigated for heat-treat response in sheet form, and it was found that while the as-quenched strengths are somewhat higher for the 6Al—4V alloy than for our Al—V complex alloys, the bend ductility of our complex alloys is superior in the as-quenched condition. Aging the 6Al—4V alloy at 900° F. raises the strength level some 25,000 p. s. i., whereas aging our complex alloys improves the strength some 50,000 p. s. i. The highest aged strength consistent with good ductility is about 160,000 p. s. i. for the 6Al—4V alloy and about 180,000 p. s. i. for our complex alloys.

The 4Al—2V—1Cr—1Mo alloy in plate form should produce improved properties for plate applications, especially armor plate when high impact strength at 130,000 p. s. i. yield is desired. The low beta complex such as 4Al—1.5V—.5Cr—.5Mo alloy offers good ductility and low strength in the solution treated condition.

From the above it is evident that titanium, aluminium, vanadium, chromium, molybdenum alloys produced in accordance with the invention are heat treatable to high strength, and while in the as-quenched condition have good bend properties for sheet form, and are age hardenable so as to produce the best mechanical properties for plate form. The excellent strength and ductility of any of the foregoing alloys render them highly desirable materials for many uses requiring high ratio of strength to weight.

In the foregoing description, certain terms have been used for brevity, clearness and understanding, but no unnecessary limitation are to be implied therefrom beyond the requirements of the prior art, because such words are used for descriptive purposes herein and are intended to be broadly construed.

Having now described the invention or discovery, the use of preferred embodiments thereof, and the advantageous new and useful results obtained thereby, it should be understood that the embodiments described are by way of typical examples only, and that the proportions of the several metals may be varied within the above range without departing from the invention as set forth in the appended claims.

We claim:

1. An alloy consisting of from 3% to 5% aluminum, from 1% to 2% vanadium, from 0.5% to 1% chromium, from 0.5% to 1% molybdenum, balance titanium.
2. An alloy consisting of 3% aluminum, 1½% vanadium, 0.5% chromium, 0.5% molybdenum, balance titanium.
3. An alloy consisting of 4% aluminum, 1½% vanadium, 0.5% chromium, 0.5% molybdenum, balance titanium.
4. An alloy consisting of 5% aluminum, 1½% vanadium, 0.5% chromium, 0.5% molybdenum, balance titanium.
5. An alloy consisting of 4% aluminum, 2% vanadium, 1% chromium, 1% molybdenum, balance titanium.
6. An alloy consisting of from 3% to 5% Al, from 1% to 2% V, from 0.5% to 1% Cr, from 0.5% to 1% Mo, from 0.02% to 0.06% C, from 0.01% to 0.03% N_2, from 0.10% to 0.15% O_2, from 0.005% to 0.017% H_2, balance Ti.

References Cited in the file of this patent

UNITED STATES PATENTS

2,700,607	Methe	Jan. 25, 1955
2,711,960	Methe	June 28, 1955

FOREIGN PATENTS

1,085,628	France	July 28, 1954

OTHER REFERENCES

The Manufacture of Titanium Alloys, Larsen et al., pages 52, 54, 70 and 82. Report #9, Titanium Project Navy Contract No. Noa(s) 51-006-c, P. R. Mallory & Co. Inc., Indianapolis, Ind., January 26, 1952.