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TITANIUM BASE VANADIUM-IRON-ALUMINUM
ALLOYS

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The invention relates to titanium base alloys and more particularly to quaternary titanium base alloys containing vanadium, iron and aluminum. More particularly, the invention relates to a titanium base alloy adapted for rolling into sheet material with good ductility and formability accompanied by high strength in the as-annealed condition.

Finally, the invention relates specifically to a titanium base alloy having at least a 130,000 p. s. i. minimum yield strength as annealed, with good tensile and bend ductility.

Normally an increase in strength of titanium can be obtained by the addition of a strengthener. Iron may be used as a strengthener but it is a strong compound former. Vanadium may be used to retard the formation of the titanium-iron compound. However, vanadium is an expensive alloying element. Nevertheless, vanadium can be obtained at a much lower cost in the form of a master alloy with aluminum. This creates further problems because while aluminum like iron is a strengthener aluminum accelerates the formation of the titanium-iron compound with resulting embrittlement.

We have discovered however, that certain quaternary alloys of vanadium, iron and aluminum can be made with a minimum yield strength as-annealed of as high as 130,000 p. s. i., and with tensile and bend ductility properties comparable to those in other titanium alloys now used which only have a 110,000 p. s. i. minimum yield strength in the as-annealed condition.

One outstanding characteristic of the improved V-Fe-Al titanium alloy of the present invention is that there is no apparent embrittlement resulting from compound formation following heat treatment or heating of any kind.

A further unusual characteristic of the improved alloy of the present invention is the ease with which it may be melted as compared with the melting problems involved in the manufacture of a manganese titanium binary alloy which has comparable ductility, but with which the problem of segregation in melting is ever present.

The improved alloy, in addition to having good tensile and bend ductility in the as-annealed condition with a high minimum yield strength, has excellent formability. Heretofore it has been difficult to obtain such a combination of properties in titanium alloy material.

Accordingly, it is an object of the present invention to provide a new quaternary titanium sheet alloy characterized by a desirable combination of favorable properties including good formability, good tensile and bend ductility in the as-annealed condition, and a 130,000 p. s. i. minimum yield strength as annealed.

Furthermore, it is an object of the present invention to provide a new quaternary titanium sheet alloy in which no apparent embrittlement occurs resulting from compound formation following heat treatment, even though the alloy contains iron and aluminum as strengtheners.

Also it is an object of the present invention to provide a new quaternary titanium alloy which is relatively easy

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to produce without segregation during melting, and which has high strength and good ductility and formability in the as-annealed condition.

In addition, it is an object of the present invention to provide a new quaternary titanium sheet alloy which is lighter in weight or has a lower density than other titanium alloys presently used which have less favorable properties from the standpoint of minimum yield strength, as-annealed, but which other alloys may have comparable tensile and bend ductility properties.

Finally, it is an object of the present invention to provide a new quaternary titanium base sheet alloy containing about 8% vanadium, 3% to 5% iron and 1.5% aluminum.

These and other objects and advantages apparent to those skilled in the art from the following description and claims may be obtained, the stated results achieved, and the described difficulties overcome by the discoveries, principles, compositions and alloys which comprise the present invention, the nature of which is set forth below—illustrative of the best modes in which applicants have contemplated applying the principles—and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

The alloys of the present invention 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, vanadium, iron and aluminum, is 0.02% C, 0.01% N₂, 0.10% O₂ and 0.005% H₂. 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% N₂, 0.15% O₂ and 0.020% to 0.024% H₂.

In other words, presently available sponge having a sponge hardness of 120 BHN is suitable. The sponge hardness may, however, range from, 100 BHN to 150 BHN. In examples given below, titanium sponge having a typical interstitial level of 120 BHN was used.

In practice, the titanium is preferably melted by the electric arc process in a water-cooled copper crucible in an atmosphere such as argon, and the alloying elements are added to the melt either separately or in alloy combinations of vanadium and aluminum, vanadium and iron, or vanadium, iron and aluminum.

In general, the alloys of the present invention comprise about 8% vanadium, from 3% to 5% iron, and 1.5% aluminum, the balance being titanium. More particularly, the preferred alloys of the present invention may have the analyses given in Table I below.

The alloys of the present invention after melting and casting may be processed in the usual manner and forged or rolled to form the desired semi-finished or finished product. For instance, ingots of the improved quaternary alloys may be forged or bloomed to slab form, hot rolled to sheet bar, and the sheet bar may be hot rolled to form finished sheets, say, .020" to .090" thick.

Several examples of the improved alloy of the present invention are as follows:

Table I

Example No.	Heat No.	Nominal or Intended Composition			
		Percent V	Percent Fe	Percent Al	Percent Ti
1.....	DM 454	8	3	1.5	Bal.
2.....	DM 455	8	5	1.5	Bal.

The mechanical properties of sheet fabricated from al-

loys of the present invention as determined by evaluation, are indicated in Table II below:

Table II

Example No.	Heat No.	UTS, p. s. i.	YS, p. s. i. (0.2% Offset)	Elong., Percent in 2"	T _B Bend
1 (avg. 2)-----	DM 454	129,500	122,200	12.9	2.0
2 (avg. 2)-----	DM 455	145,000	137,800	12.1	1.7

The alloys of the present invention are characterized by their good ductility with a minimum as-annealed yield strength of 122,200 p. s. i. and higher with larger amounts of iron, and with freedom from embrittlement resulting from compound formation following heating or heat treatment.

The improved alloy likewise has a relatively low density of about 0.169 pound per cubic inch for the alloy of Example 2 which compares favorably with a higher 0.172 density for the 8% binary manganese alloy which has a lower minimum yield strength in the as-annealed condition and which is more difficult to make because of the segregation problem in melting.

Although the alloys of the present invention have been described particularly as sheet alloys, the use of the same is not limited to the manufacture of sheet material as the desirable properties can be availed of in other kinds of semi-finished or finished titanium alloy products, such as bars.

It is to be understood that in the foregoing tables, where intended composition is indicated, there may be some variation in actual composition determined by chemical analyses. Compositions usually are close to the nominal or intended composition but may vary slightly either way from the intended values, depending upon the ability to control the exact amount of alloying additions made.

The sheet alloys of the present invention accordingly provide quaternary titanium alloys which are relatively easy to make, which may have a 130,000 p. s. i. minimum yield strength or higher, as annealed, with good tensile and bend ductility, which have good forming characteristics, which have relatively low density, and which have a combination of the indicated properties heretofore not obtained in any known prior titanium alloy.

In the foregoing description certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom be-

yond the requirements of the prior art, because such terms are used for descriptive purposes herein and are intended to be broadly construed.

Having now described the invention, the features, discoveries and principles thereof, the characteristics of the new alloys, several examples of preferred embodiments of the new alloys, and the new and useful results obtained; the new and useful compositions, combinations, products, discoveries and principles, and reasonable mechanical equivalents thereof obvious to those skilled in the art are set forth in the appended claims.

We claim:

1. A titanium base alloy consisting of 8% vanadium, 3% to 5% iron, 1.5% aluminum, and the balance titanium with incidental impurities.

2. A titanium base alloy consisting of 8% vanadium, 3% iron, 1.5% aluminum, and the balance titanium with incidental impurities.

3. A titanium base alloy consisting of 8% vanadium, 5% iron, 1.5% aluminum, and the balance titanium with incidental impurities.

4. A titanium base sheet alloy consisting of 8% vanadium, 3% to 5% iron, 1.5% aluminum, the balance titanium with incidental impurities; said alloy having as-annealed a minimum yield strength of 122,200 p. s. i. and elongation in excess of 12%.

5. A titanium base sheet alloy consisting of 8% vanadium, 3% to 5% iron, 1.5% aluminum, the balance titanium with incidental impurities; said alloy having as-annealed a minimum yield strength of 122,200 p. s. i. and being free from embrittlement resulting from compound formation following heat treatment.

6. A titanium base sheet alloy consisting of 8% vanadium, 3% iron, 1.5% aluminum, and the balance titanium with incidental impurities; said alloy having as-annealed a minimum yield strength of 122,200 p. s. i. and elongation of 12.9%.

7. A titanium base sheet alloy consisting of 8% vanadium, 5% iron, 1.5% aluminum, and the balance titanium with incidental impurities; said alloy having as-annealed a minimum yield strength of 137,800 p. s. i. and elongation of 12.1%.

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