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[54] **TITANIUM BASE ALLOY**

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[58] **Field of Search** 75/175.5

[56] **References Cited**

UNITED STATES PATENTS

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120,328	12/1958	U.S.S.R.	75/175.5
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[57] **ABSTRACT**

A titanium base alloy comprising by weight, 6.0 to 7.5% of aluminum, 0.5 to 2.0% of zirconium, 0.5 to 2.0% of lead, 1.5 to 2.7% of molybdenum, 0.2 to 1.2% of tungsten, 0.1 to 0.35% of silicon, 0.2 to 0.5% of chromium, 0.05 to 0.1% of rhenium, with the balance being essentially titanium, said alloy exhibiting higher heat resistance and thermal stability at temperatures up to 550°C. than heretofore known.

1 Claim, No Drawings

TITANIUM BASE ALLOY

The present invention relates to the field of nonferrous metallurgy, and more particularly to titanium base alloys.

This invention is broadly applicable to the manufacture of a wide variety of parts which operate at elevated temperatures, for example, blades and compressor drums of modern gas and steam turbines.

Titanium base alloys having improved heat resistance properties exhibit a tendency towards lower thermal stability at elevated temperatures (450°C to 550°C) resulting in an increased brittleness of these alloys. This phenomenon limits the service life of such alloys at high temperatures.

One titanium base alloy known in the prior art is composed essentially of titanium alloyed with 0.25 to 7.5% of aluminum, 2 to 23% of tin, 0.5 to 10% lead 0.5 to 20% of zirconium, 0.25 to 20% of molybdenum and chromium, 0.5 to 15% of tungsten, 0.25 to 2% of silicon and a number of other possible additions, all proportions given by weight percent (cf. West German Auslegeschrift No. 1,082,418, cl. 40*b*, 15/**00, 1960**).

However this prior art alloy does not exhibit sufficient level of heat resistance and thermal stability at temperatures of 500° to 550°C.

The object of the present invention is to eliminate the afore-mentioned disadvantages.

Another object of the invention is to provide a titanium base alloy having a higher level of heat resistance and thermal stability.

These and other objects and aims are attained in a titanium base alloy comprising aluminium, zirconium, lead, molybdenum, tungsten, silicon, chromium by having, in addition to these components, a rhenium component, all components being taken within the following proportional limits given in terms of weight percent: 6.0 to 7.5% of aluminum, 0.5 to 2.0% of zirconium, 0.5 to 2.0% of lead, 1.5 to 2.7% of molybdenum, 0.2 to 1.2% of tungsten, 0.1 to 0.35% of silicon, 0.2 to 0.5% of chromium, 0.05 to 0.1% of rhenium and the remainder essentially all titanium.

Owing to this specific ratio of mixed components and the presence of rhenium, the present titanium base alloy shows, in comparison to known titanium base alloys a higher level of heat resistance and thermal stability at a temperature of 500°C during the service life of more than 2000 hours.

In this invention, rhenium is added to titanium base alloys having the above-described specific ratio of specific components, since it has been discovered that additional alloying of titanium base alloys of such composition by rhenium is quite beneficial for obtaining higher heat resistance levels and finer structures of such alloys than heretofore obtainable, and thus for modifying the alloy, thereby considerably improving the weld structure of parts welded of elements made of the present alloys.

Our tests have proved that rhenium should be preferably added in the proportional limit of 0.05 to 0.1 weight percent. When smaller quantities of rhenium are added, its positive effect practically disappears, and if rhenium is taken in amounts greater than 0.1 weight percent, the ductility, at room temperature, and thermal stability, of the alloy deteriorate.

Furthermore, with respect to the alloy briefly described above it has been found that aluminum increases its heat resistance. It is recognized that aluminum stabilizes the alpha phase, and that the alloys that are composed essentially of a single alpha phase retain their heat resistance properties at higher temperatures than double-phase alpha-beta alloys. Thus, a single-phase alloy is very suitable for making parts which are further welded, since heating and cooling of parts made of such alloys during welding and subsequent heat treatment do not increase their brittleness.

Lead compounded with other components in the limits stated above improves the heat resistance of titanium without deterioration of its ductility.

The maximum strengthening effect due to addition of zirconium to the alloy without any serious increase in the specific weight of said alloy is achieved when the zirconium content is 0.5 to 2.0 weight percent. Both elements, zirconium and lead, stabilize the alpha phase.

Molybdenum, on the other hand stabilizes the beta phase. The purpose of the molybdenum addition is to intensify the strengthening effect taking place due to alloying of the alpha solid solution as well as to create a certain small amount of the beta phase that is required for carrying out possible heat treatments and for improving the technological ductility. Therefore, the molybdenum content should preferably be not more than 2.7 weight percent and not less than 1.5 weight percent. Using a molybdenum content in excess of 2.7 weight percent is not beneficial, since higher amounts of remanent beta phase lead to poor resistance to creep, thermal stability and weldability of the alloy.

Small amounts of chromium of 0.2 to 0.5 weight percent, of silicon of 0.2 to 0.35 weight percent, and of tungsten of 0.2 to 1.2 weight percent provide for higher resistance to creep and heat resistance of the inventive alloy. Thus, the titanium base alloy according to this invention is characterized by comprising: 6.0 to 7.5% of aluminum, 0.5 to 2.0% of zirconium, 0.5 to 2.0% of lead, 1.5 to 2.7% of molybdenum, 0.2 to 1.2% of tungsten, 0.1 to 0.35% of silicon, 0.2 to 0.5% of chromium, 0.05 to 0.1% of rhenium and the remainder essentially all titanium, all percentages being in terms of weight. Such an alloy is also characterized by its great strength, over long periods of time, and by its resistance to creep at temperatures of 500° to 550°C.

Moreover, the thermal stability of the present alloy has an extended service life of 6000 hours at 500°C.

The alloy of this invention has a specific weight of about 4.5 grams per square centimeter, is satisfactorily deformable in the hot state, and is weldable by electron beam and argon-fluorine welding techniques. The present inventive alloy can be used for producing forged, pressed, rolled and stamped semi-finished products.

Other objects and advantages of the present invention will become apparent upon a reading of the following detailed description of representative, non-limiting examples.

EXAMPLE 1

An alloy composed of 6 weight percent of aluminum, 0.5 weight percent of zirconium, 0.5 weight percent of lead, 1.5 weight percent of molybdenum, 0.2 weight percent of tungsten, 0.1 weight percent of silicon, 0.2 weight percent of chromium, 0.05 weight percent of rhenium, with the rest being essentially all titanium after a double annealing, which consisted of keeping the alloy at 950°C for 1 hour, cooling it in the air, subsequently heating it to 550°C, holding it for 6 hours at

this temperature, and then cooling it in the air, was found to have the following characteristics:

Forged rod, dia. 12 mm

Mechanichal properties	Temperature, °C 20	500
Ulitmate strength, kg/mm²	98	82
Yield strength, kg/mm²	87	62
Percent elongation in 60 mm, %	15	20
Percent area reduction, %	35	56
Long-time strength in 100 hrs, kg/mm²	—	62
0.2% offset creep strength in 100 hrs, kg/mm²	—	32

After storage for 6000 hours at 500°C under non-stress conditions percent elongation was 8% and percent area reduction amounted to 12%.

EXAMPLE 2

In this example, the alloy used was an alloy composed of 7.5 weight percent of aluminum, 2 weight percent of zirconium, 2 weight percent of lead, 2.7 weight percent of molybdenum, 1.2 weight percent of tungsten, 0.6 weight percent of chromium, 0.35 weight percent of silicon, 0.1 weight percent of rhenium, with the rest being essentially all titanium. This alloy was subjected to the following treatment: heating to 950°C, holding for 1 hour at this temperature, cooling in the air and subsequent heating to 550°C and holding, at this temperature for 6 hours. A forged rod having a diameter of 12 mm made of this alloy was found to possess the following characteristics:

Mechanical properties	Temperature, °C 20	500
Ultimate strength, kg/mm²	110	93
Yield strength, kg/mm²	110	80
Percent elongation in 60 mm, %	10	15
Percent area reduction, %	30	39
Long-time strength in 100 hrs, kg/mm²	—	72
0.2% offset creep strength in 100 hrs, kg/mm²	—	40

After storage for 6000 hours at 500°C under non-stress conditions, the percent elongation was 3% and the percent of area reduction amounted to 6%.

EXAMPLE 3

In this example, the alloy used was an alloy composed of 6.7 weight percent of aluminum, 1.6 weight percent of zirconium, 1.9 weight percent of lead, 2.4 weight percent of molybdenum, 0.3 weight percent of chromium, 1.0 weight percent of tungsten, 0.2 weight percent of silicon, 0.05 weight percent of rhenium, with the rest being all titanium. This alloy was subjected to the following heat treatment: heating to 950°C, holding for 1 hour at this temperature, cooling in the air and subsequent heating to 550°C and holding, at this temperature, for 6 hours and cooling in the air.

The mechanical properties of forged rods having a diameter of 12 mm made of this alloy are summarized below:

Mechanical properties	Temperature, °C 20	500
Ultimate strength, kg/mm²	115	80
Yield strength, kg/mm²	105	70
Percent elongation in 60 mm, %	12	17
Percent area reduction, %	32	45
Long-time strength in 100 hrs, kg/mm²	—	70
0.2 offset creep strength in 100 hrs, kg/mm²	—	36

After storage for 6000 hours at 500°C under non-stress conditions, the percent elongation was 6% and the percent of area reduction amounted to 10%.

Although the invention may be variously embodied, it will be evident for those skilled in the art that the present invention is not limited by the examples given above, and that the true essence and scope of the invention are defined in the appended claim.

We claim:

1. A titanium base alloy consisting essentially of, by weight, 6.0 to 7.5% of aluminum, 0.5 to 2.0% of zirconium, 0.5 to 2.0% of lead, 1.5 to 2.7% of molybdenum, 0.2 to 1.2% of tungsten, 0.1 to 0.35% of silicon, 0.2 to 0.5% of chromium, 0.05 to 0.1% of rhenium, and the balance essentially titanium.

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