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PROCESS FOR INCREASING MECHANICAL PROPERTIES OF TITANIUM ALLOYS HIGH IN ALUMINUM

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention pertains to a heat treating process for titanium-base alloys having at normal temperatures a mixed alpha beta microstructure whereby an ordering reaction is caused to be effected in the alpha phase so as to improve the creep strength of such alloys without decreasing the thermal stability thereof.

Considerable time and money has been expended to solve the long standing problem of how to increase the thermal stability of titanium-aluminum alloys when they are heated to a temperature over 1700° F. either for purposes of fabrication or heat treatment. Since aluminum has the effect of raising the alpha to alpha + beta transus temperature, the alloy system of aluminum and titanium is quite desirable from the standpoint of elevated temperature service, especially in the range from 800° F. to 1200° F. These alloys of the titanium-aluminum system have the requisite high temperature stability; however, they were found not to possess sufficient thermal stability when the aluminum content is greater than six percent to permit them to be commercially fabricated.

Thermal stability is a term used to indicate the ability of the alloy to retain its annealed room temperature tensile ductility usually measured by percent reduction in area after long time exposure to elevated temperature. Little loss in tensile reduction in area could be regarded as a sign of good thermal stability.

Therefore, this invention is applicable to titanium alloys containing aluminum as the primary alloying element along with a small percentage of one or more of the beta promotors from the group consisting of molybdenum and vanadium. Since aluminum has the effect of raising the alpha to alpha + beta transus temperature and the alpha + beta to beta transus temperature in a titanium-base alloy, the temperature range over which the alpha phase exists is much broader where aluminum is a component of the alloy. However, since the alpha phase has a "close-packed hexagonal" crystallographic lattice configuration, it exhibits low thermal stability in comparison to the "body centered cubic" crystallographic lattice of the beta phase. It is to overcome the low thermal stability of the "close-packed hexagonal" lattice structure of the alpha phase that small amounts of the beta stabilizers are added to the binary titanium aluminum alloy. Unforunately, the addition of beta stabilizers will cause a reduction of the creep resistance of the alloy.

Under the prior art, the alloys of titanium which contained both aluminum and a beta stabilizer were fabricated by forging them from a temperature in the range between 1750° F. and 2000° F. The step of forging is performed on the cast ingot to break up the "as cast" structure. The forged alloys are then subjected to a solution-anneal at 1650° F. for one hour followed by air cooling and then to a stabilizing-anneal at 1100° F. for 24 hours followed by air cooling. Thereafter the forged alloy is hot rolled to the desired size in any conventional rolling mill. It was found that these titanium alloys

fabricated in this manner possessed a low creep resistance. In order to impart high resistance to creep, at least 6% aluminum was added to the alloy. It was previously known under the art that if aluminum in the alpha phase were distributed so as to interfere with the deformation of the beta to a maximum extent, then the entire structure would have maximum creep resistance. In this connection it should be pointed out that the distribution designed to resist creep is quite different from that designed to resist slip. For creep resistance, a high aluminum content, relatively massive component is required to maintain its shape and through being bonded to the beta component, to resist change in shape of the entire structure. In the case of creep, deformation is by way of a fluid-like drift of the mass by individual atom movements (diffusion), whereby massive barriers are most effective. However, in the case of slip the strains and irregularities produced by a much finer and more uniform distribution, is most effective in preventing the cataclysmic and complex sliding along plane surfaces.

The problem with these high aluminum content (over 6%) alloys was that severe embrittlement was found in them. This was attributed to the precipitation of a new phase in the alpha after the alloy was subjected to prolonged exposure to temperature over 1000° F.

An object of this invention is to improve the heat treatment of alloys containing at least 6% aluminum wherein the creep resistance of such alloys is markedly improved without much loss in thermal stability.

Another object of this invention is to provide an improved method for the heat treatment of titanium alloys of the "alpha" or "near-alpha" type wherein the alloys possess good hot creep properties and also good room temperature properties.

Yet another object of this invention is to provide a method for heat treating titanium alloys high in aluminum content which method produces an ordering reaction in the alpha phase of this type alloy thereby eliminating the problem of its becoming embrittled after exposure to temperatures above 1200° F.

The foregoing and still further objects of the invention may be seen from the following description.

In carrying out one form of the invention a titanium alloy comprising by weight 8% of aluminum, 1% of molybdenum and 1% of vanadium was used by the inventor to demonstrate the effects of his improved treatment.

Ti-8A1-Mo-1V was designed and developed by Titanium Metals Corporation of America for applications where good strength is required at temperatures up to 1000° F. The alloy derives its good elevated temperature strength from its high alpha stabilizing alloy content of 8% of aluminum. Through the addition of small percentages of the beta stabilizers, molybdenum and vanadium, it was possible to produce a titanium alloy high in aluminum content without appreciable loss in fabricability and room temperature tensile ductility.

This alloy was forged into bars which were $^{5}/_{64}$" in diameter and 24 inches long. The bars were rolled from 1900° F., reforged from 1850° F., and duplex-annealed. Duplex-annealing consisted of a solution anneal at 1650° F. for one hour, air cooled, followed by a stabilizing-anneal at 1100° F. for twenty-four hours followed by air-cooling.

In working with this alloy, I found that it showed poor thermal stability after exposure at 950° F. for 500 hours. The tensile elongation being reduced from 21.5% to 11.0% and reduction in area, from 30.5% to 12.5%. However, if the treatment were continued at this temperature for at least a 1000 hours, the alloy recovered a signifiicant amount of its lost tensile ductility whereby

it could be considered as having good thermal stability. The tensile elongation was 14.0% and the reduction in area was 18.2%.

The significance of this discovery is that the potential of the Ti-8Al-1Mo-1V can be greatly increased by application of a heating of the alloy at 950° F. for at least 1000 hours. The essence of this additional heating treatment resides in heating of this alloy to critical temperatures for critical periods of time. At first it was believed that the unusual changes in the mechanical behavior of the alloy was due to precipitation of a new phase in the alpha region; however, metallographic examination of the thermally exposed alloy failed to reveal any such new phase. Moreover, an ordering reaction was found to take place in the alpha phase of the alloy. An ordering reaction is characterized by what is called a "critical temperature of ordering." This represents a temperature slightly below which the disordered phase shows rapid ordering. This characteristic temperature appears to persist in the other titanium alloys containing aluminum as the primary alloying element and seems not to depart much from 950° F.±25° F. The fact that such commercial alpha-beta titanium alloys are presently used with heat treatments specifying heat treating temperatures well above 950° F. indicates that the much higher potential available in these alloys from an ordered alpha phase is only realized in a small part. If the heat treating temperature is higher than the "critical ordering temperature," then the alpha will remain disordered as long range ordering will not proceed; if the heat treating temperature is lower than 950° F., the ordering process would take too long a time to be practical since diffusion will then be very sluggish.

Stress would serve to accelerate the ordering process so that any processing techniques introducing stress into the alloy would be beneficial to the heat treatment in that it would increase the heat treating response thereby reducing the heat treating time. It was found that when

a stress of 47,500 lbs. was placed upon the alloy results equivalent to the cold worked conditions were obtained.

The fact that ordering was found in the Ti-8Al-1Mo-1V alloy indicates that other alpha-beta titanium alloys containing similar or larger quantities of aluminum will show similar behavior. The inventor has discovered that ordered alpha exists in the composition range from 6.0% aluminum to about 25.0% aluminum by weight.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A heating treatment for improving the elevated temperature creep strength of a high alpha phase alloy consisting essentially of 6–25 weight percent of aluminum, 1 weight percent of molybdenum and 1 weight percent of vanadium with the balance of the alloy being essentially titanium, which comprises the step of exposing the alloy to a temperature of 950° F. for at least 1000 hours whereby an ordering of the alpha phase is effected in the alloy.

2. A heating treatment according to claim 1 further including the step of subjecting the alloy to a stress of 47,500 lbs.

3. An alloy made according to the method of claim 1 and possessing an improved resistance to creep property at elevated temperatures.

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