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(54) Titre : PROCEDE DE FABRICATION D'ATTACHES A PARTIR DE TITANE OU D'ALLIAGE DE TITANE

(54) Title: PROCESS FOR MANUFACTURE OF FASTENERS FROM TITANIUM OR A TITANIUM ALLOY

(57) **Abrégé/Abstract:**

A process for making parts from a titanium alloy includes preparing an intermediate form of an alpha-beta titanium alloy that contains not more than 0.0124% hydrogen. The intermediate form is solution heat treated under conditions of temperature and time selected to produce a desired level of strength when the alloy is subsequently age hardened. The intermediate form is heated to an elevated starting temperature of about 1600°F (871 °C) and then mechanically worked from the starting temperature to a lower finishing temperature that is not below about 800°F (427°C), to provide a desired part or a preform for a desired part. The next step is age hardening the as-formed part or preform under conditions of temperature and time that are selected to produce the desired level of strength. The disclosed process avoids the problems associated with solution heat treating the part or preform after the mechanical working step.

ABSTRACT

A process for making parts from a titanium alloy includes preparing an intermediate form of an alpha-beta titanium alloy that contains not more than 0.0124% hydrogen. The intermediate form is solution heat treated under conditions of temperature and time selected to produce a desired level of strength when the alloy is subsequently age hardened. The intermediate form is heated to an elevated starting temperature of about 1600°F (871°C) and then mechanically worked from the starting temperature to a lower finishing temperature that is not below about 800°F (427°C), to provide a desired part or a preform for a desired part. The next step is age hardening the as-formed part or preform under conditions of temperature and time that are selected to produce the desired level of strength. The disclosed process avoids the problems associated with solution heat treating the part or preform after the mechanical working step.

PROCESS FOR MANUFACTURE OF FASTENERS FROM TITANIUM OR A TITANIUM ALLOY

Field of the Invention

[0001] This invention relates to processes for making fasteners and other parts from titanium or a titanium alloy, and in particular to a process in which a titanium or titanium alloy part is solution heat treated before being thermomechanically formed.

Background of the Invention

[0002] The titanium alloy Ti-6Al-4V has been used to make high strength fasteners, such as bolts and screws. The alloy is supplied in bar, rod, or wire form depending on the type and size of fastener to be made. Hitherto, the bar, rod, or wire has been supplied to the consumer in the annealed condition. The consumer forms the fasteners by such techniques as forging, heading, or extrusion, or a combination of those techniques. The fastener blanks are usually formed at an elevated temperature starting from about 649°C, but usually not below about 427°C. The fastener blanks are then cleaned by immersion in a molten salt bath, which is followed with acid etching.

[0003] The fastener blanks are next heat treated to achieve a desired strength level. The known heat treatment is a two-stage treatment. In the first stage, the parts are solution treated, typically in an inert atmosphere, at about 899 to 968°C for about 1 hour and then water quenched. In the second stage of the heat treatment, the parts are precipitation hardened by an aging treatment at about 427 to 566°C for 2 to 8 hours and then cooled in an inert gas or in a vacuum. Hitherto, the aging step has been performed directly after the solution-treating step.

[0004] The solution treatment is the most problematic step in the heat treatment cycle because during solution treatment contamination of the fasteners must be prevented. Titanium and its alloys are very reactive, especially at elevated temperatures such as those typically used for solution treatment. Any foreign material which comes into contact with the titanium or titanium alloy during solution heat treatment will result in contamination of the material. Common sources of foreign material in the

solution treating process are contaminants in the furnace atmosphere or residual processing materials such as lubricants on the surfaces of the titanium blanks. In order to avoid the problems associated with the presence of such contaminants, special furnace atmospheres must be maintained and the fasteners must be thoroughly cleaned before they are placed in the heat treating furnace. Cleaning of the fasteners presents another problem because it involves the use of aggressive chemicals which pose environmental hazards and disposal concerns. Additionally, the cleaning operation can change the chemistry of the fasteners, such as by adding hydrogen, and can alter the dimensions of the fastener by dissolving metal from the blank. These problems make the cleaning step unreliable, time consuming, and costly.

[0005] The known solution treating operations are also troublesome because the process often results in the final parts being unacceptable. In some cases the parts become contaminated with impurities because of less than desirable furnace atmospheres or residual lubricants on the parts. In other cases the parts have poor mechanical properties because of inadequate quenching. Moreover, parts can become distorted or they may stick together during solution treatment, or they may become bent or develop flat spots. It is also a fact that solution heat treating equipment is expensive and costly to operate for parts manufacturers. Elimination of the need to solution treat the headed fastener blanks, along with the associated relaxation of cleaning requirements, would permit significant improvements in the efficiency of the manufacturing process and greater uniformity of product quality.

[0006] Fasteners are also manufactured by direct machining of solution treated titanium alloy bar. The machined fasteners are then age hardened. However, that process does not involve a forging operation. Therefore, it is not susceptible to the problems discussed above.

[0007] Beta titanium alloys, such as Ti 3-8-6-4-4 and others, are supplied in the solution treated condition for forming into fasteners. The fasteners are then aged to achieve the desired properties. However, there are significant metallurgical differences

between the beta alloys and the other known titanium alloys such as alpha, near-alpha, an alpha-beta alloys.

Summary of the Invention

[0008] In accordance with the present invention a process of making parts from titanium and titanium alloy wire, rod, or bar is provided. Here and throughout the remainder of this specification the term titanium means unalloyed titanium as well as alpha, near-alpha, and alpha-beta titanium alloys. The process includes the step of preparing an intermediate form of titanium. The intermediate form is solution treated under conditions of temperature and time that are sufficient to produce a desired level of strength when the alloy is subsequently age hardened. The solution treated material is then formed into a desired part or component, such as a fastener or a preform for a fastener. The forming step is conducted with the alloy at an elevated temperature and the as-formed part is rapidly cooled from the finish temperature. Subsequent to the forming step, the part is age hardened to achieve the desired level of strength and hardness.

Detailed Description

[0009] In a preferred embodiment of the process according to the present invention, an intermediate form of a titanium alloy, preferably Ti-6Al-4V, is prepared by any known method. Preferred intermediate forms include wire, rod, and bar. The Ti-6Al-4V alloy is a known titanium alloy that contains about 6 weight percent (%) aluminum, about 4 % vanadium, and the balance is titanium and usual impurities. The impurities present in the alloy are restricted such that the alloy contains not more than about 0.10% carbon, not more than about 0.05% nitrogen, not more than about 0.0125% hydrogen, and not more than about 0.20% oxygen. In the preferred titanium alloy used in this process, the oxygen is preferably limited to about 0.14-0.17%. The method by which the intermediate form is made is not critical and any of the known methods for making titanium alloy wire, rod, or bar may be used.

[0010] The intermediate form of the titanium alloy is then solution treated at about 899-968°C for a time of at least about 1 minute up to about 2 hours, and then water quenched. Preferably, the intermediate form is heated at the solution temperature for about 1 hour. Prior to forming a desired product from the intermediate form, the intermediate form may be coated with a lubricant. The preferred lubricant is a dry film lubricant, which consists of graphite and molybdenum disulfide. Other lubricants that are known to those skilled in the art for similar purposes may also be suitable.

[0011] The lubricated wire, rod, or bar is then subjected to thermomechanical working to form the desired part. The preferred forming operation is forging, and heading is particularly preferred for making small parts from wire or rod. For some applications extruding techniques can be used in connection with the preparation of parts by this process. Prior to forming, the intermediate form is cut to a starting size, heated to an elevated starting temperature, and then mechanically worked to the desired size and shape. The elevated starting temperature for the thermomechanical forming is selected to be as close to the solution treating temperature as practicable. A lower forming temperature can be used for applications where adequate lubrication, extended die life, or dimensional control of the part or preform is important. Preferably, the parts are formed from a starting temperature of about 871°C, but preferably not below about 704°C or 649°C. Lower finishing temperatures may be used under appropriate circumstances. However, it is expected that the finishing temperature would, in any event, not be below about 427°C. The as-formed parts are rapidly cooled from the finishing temperature, preferably by water quenching.

[0012] The as-formed parts are then age hardened, preferably in a vacuum heat treating furnace. The parts may also be aged in an inert atmosphere such as argon or helium. It is also expected that the parts can be aged in air. When the parts are aged in a vacuum furnace, it may be preferable to clean the parts to prevent their being contaminated in the heat treating furnace. Such cleaning is accomplished by first immersing the parts in a molten salt bath and then acid etching. Aging is conducted at

a temperature of about 427 to 566°C for about 2 to 8 hours, followed by cooling in inert gas or in a vacuum.

[0013] The heat-treated parts are then ground or machined as necessary to final dimension and shape.

[0014] It will be recognized by those skilled in the art that changes or modifications may be made to the above-described embodiment without departing from the broad inventive concept of the invention. It should therefore be understood that this invention is not limited to the particular embodiment described herein, but is intended to include all changes and modifications that are within the scope and spirit of the invention as set forth in the following claims.

WHAT IS CLAIMED IS:

1. A process for making parts from a titanium alloy comprising the steps of:
preparing an intermediate form of an alpha-beta titanium alloy, wherein said alpha-beta titanium alloy contains not more than 0.0124% hydrogen; then
solution heat treating the intermediate form under conditions of temperature and time that are selected to produce a desired level of strength when the alpha-beta titanium alloy is subsequently age hardened; then
reheating the intermediate form to an elevated starting temperature of about 1600°F (871°C);
mechanically working the reheated intermediate form from the elevated starting temperature to a lower finishing temperature not below about 800°F (427°C) to provide a desired part or a preform for a desired part; and then
age hardening the as-formed part or preform under conditions of temperature and time that are selected to produce the desired level of strength in said part or preform.
2. The process as set forth in Claim 1 wherein the alpha-beta titanium alloy comprises about 6% aluminum, about 4% vanadium, and the balance titanium and usual impurities.
3. The process as set forth in Claim 1 wherein the step of preparing the intermediate form comprises the step of forming the alpha-beta titanium alloy into an elongated form selected from the group consisting of wire, rod, and bar.
4. The process as set forth in Claim 1 which comprises the step of cutting the intermediate form into pieces having a substantially uniform length after the solution heat treating step and before the mechanical working step.
5. The process as set forth in Claim 4 comprising the step of rapidly cooling the part from the finishing temperature after said mechanical working step.
6. The process as set forth in Claim 1 wherein the step of preparing the intermediate form of the alpha-beta titanium alloy comprises the step of preparing the

alpha-beta titanium alloy such that it contains not more than about 0.10% carbon, not more than about 0.05% nitrogen, and not more than about 0.20% oxygen.

7. The process as set forth in Claim 6 wherein the step of preparing the alpha-beta titanium alloy comprises the step of controlling the melting of the titanium alloy such that it contains not more than about 0.17% oxygen.

8. The process as set forth in Claim 1, wherein the step of solution treating the intermediate form comprises the step of heating the intermediate form at a temperature of about 1650-1775°F (899-968°C) for at least about 1 minute up to about 2 hours, and then quenching the intermediate form.

9. The process as set forth in Claim 1 wherein the age-hardening step comprises the steps of heating the as-formed part or preform to a temperature of at least about 800°F (427°C) to not greater than about 1050°F (566°C), holding the part or preform at said temperature for about 2 to 8 hours, and then cooling the part from said temperature.

10. The process as set forth in Claim 1 wherein the mechanical working step is performed from the starting temperature to a finishing temperature not below about 1200°F (649°C).

11. The process as set forth in Claim 1 wherein the mechanical working step is performed from the starting temperature to a finishing temperature not below about 1300°F (704°C).

12. A process for making parts from a titanium alloy comprising the steps of:
 preparing an intermediate form of an alpha-beta titanium alloy; then
 solution heat treating the intermediate form at a temperature of about 1650-1775°F (899-968°C) for at least about 1 minute up to about 2 hours; then
 reheating the intermediate form to an elevated starting temperature of about 1600°F (871°C);
 mechanically working the reheated intermediate form from the starting temperature to a lower finishing temperature to provide a desired part or a preform for a

desired part; and then,

age hardening the as-formed part or preform under conditions of temperature and time that are selected to produced a desired level of strength in the part or preform.

13. The process as set forth in Claim 12 which comprises the step of cutting the intermediate form into pieces having a substantially uniform length after the solution heat treating step and before the reheating step.

14. The process as set forth in Claim 12 wherein the mechanical working step is performed from the starting temperature to a finishing temperature not below about 800°F (427°C).

15. The process as set forth in Claim 12 wherein the mechanical working step is performed from a starting temperature to a finishing temperature not below about 1200°F (649°C).

16. The process as set forth in Claim 12 wherein the mechanical working step is performed from a starting temperature to a finishing temperature not below about 1300°F (704°C).

17. The process as set forth in Claim 12 wherein the age-hardening step comprises the steps of heating the as-formed part or preform to a temperature of about 800-1050°F (427-566°C), holding the part or preform at said temperature for about 2 to 8 hours, and then cooling the part from said temperature.