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(54) **ENHANCE DUCTILITY OF GAMMA TITANIUM ALUMINUM ALLOYS BY REDUCING INTERSTITIAL CONTENTS**

(57) A process to increase ductility includes utilizing γ -TiAl alloy as a base alloy and reducing at least one interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

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Description

BACKGROUND

[0001] The present disclosure relates to Enhance ductility of gamma-TiAl alloys.

[0002] Two-phase γ -TiAl alloys are attractive for high temperature structural applications due to their low density, good elevated temperature mechanical properties, and oxidation and burn resistance. This class of material has the potential to withstand the demanding conditions to which aircraft engines, space vehicles, and automotive engines are exposed. Two-phase γ -TiAl alloys in transport technologies may also contribute to a marked reduction in fuel consumption and pollution.

[0003] Recently, a new beta-stabilized γ -TiAl alloy, TNM, has undergone critical evaluation for gas turbine engine applications such as low pressure turbine (LPT) blade applications. The TNM alloy has the chemical composition Ti- (42-44) Al-5 (Nb, Mo)-0.1B (all in at%) with oxygen at about 800 wppm and solidifies through the beta solidification path yielding a fine cast microstructure with low segregation and minor texture.

[0004] Vacuum Arc Melting (VAM) cast microstructure is characterized by predominantly lamellar colonies with small amount of gamma and about 10 volume fraction of b/B2 (co) phase. The strength of as-cast TNM and other conventional cast gamma alloys is too low to fulfill the strength needed for the certain components such as high speed LPT blades. However, in the wrought condition, the TNM alloy can meet the strength goal. The cast structure is commonly broken down by extrusion/and isothermal forging or by isothermal forging alone which is followed by heat treatments to produce microstructures ranging from a duplex microstructure consisting of γ phase and lamellar colonies ($\alpha_2 + \gamma$) to a fully lamellar microstructure with varying amounts of b/B2 (co).

[0005] The high speed LPT blades require a room temperature ductility of about 1.5 -3% and tensile strength of about 130-140 ksi along with creep resistance at about 1400F. Suitable heat treatment of optimum duplex microstructure can fulfill ductility, strength and creep requirements for the high speed LPT blade application. It has been determined that in the wrought condition the maximum use temperature for TNM alloy is 1400F.

SUMMARY

[0006] A process to increase ductility (e.g. of a γ -TiAl alloy) according to one disclosed non-limiting embodiment of the present disclosure can include utilizing γ -TiAl alloy (e.g. an alloy or alloy composition as herein described) as a base alloy; and reducing at least one interstitial of the base alloy to create an alloy compositions (e.g. as described herein) with extremely low interstitials (Eli).

[0007] A further embodiment of the present disclosure may include, reducing the at least one interstitial of the

base alloy to less than about 200 wppm.

[0008] A further embodiment of the present disclosure may include,, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

[0009] A further embodiment of the present disclosure may include,, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing TNM.

[0010] A further embodiment of the present disclosure may include,, wherein the TNM has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

[0011] A further embodiment of the present disclosure may include,, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloys.

[0012] An alloy composition (e.g. produced by the process described herein) according to one disclosed non-limiting embodiment of the present disclosure can include a γ -TiAl alloy with at least one reduced interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

[0013] A further embodiment of the present disclosure may include, wherein the at least one reduced interstitial is less than about 200 wppm.

[0014] A further embodiment of the present disclosure may include,, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

[0015] A further embodiment of the present disclosure may include,, wherein the γ -TiAl alloy is TNM.

[0016] A further embodiment of the present disclosure may include,, wherein the TNM has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

[0017] A further embodiment of the present disclosure may include,, wherein the γ -TiAl alloy includes a cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloy.

[0018] The foregoing features and elements may be combined in various combinations without exclusivity, unless expressly indicated otherwise. These features and elements as well as the operation thereof will become more apparent in light of the following description and the accompanying drawings. It should be understood, however, the following description and drawings are intended to be exemplary in nature and non-limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Various features will become apparent to those skilled in the art from the following detailed description of the disclosed non-limiting embodiments. The drawings that accompany the detailed description can be briefly described as follows:

Figure 1 is a block diagram of a process according to one disclosed non-limiting embodiment to increase ductility in γ -TiAl alloys;

DETAILED DESCRIPTION

[0020] With reference to Figure 1, one disclosed non-

limiting embodiment of a process 100 to increase ductility in γ -TiAl alloys is schematically illustrated. The ductility improvement in γ -TiAl alloys may be effectuated by additions of substitutional solute elements such as chromium, manganese, and vanadium, as well as interstitials such as oxygen, nitrogen and carbon. Generally, ductility in γ -TiAl alloys at room temperature increases with decreasing oxygen content in cast γ -TiAl. For example, a reduction of oxygen from 1500 wppm to 500 wppm leads to a significant improvement in ductility from 0.5% to 1.5% at room temperature.

[0021] Recently, a beta stabilized gamma γ -TiAl alloy, called TNM, has attracted much attention. This alloy has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in %). This alloy solidifies through a beta solidification path which leads to moderate to mild chemical and microstructural segregations. The resultant microstructure consists mainly of lamellar colonies (α_2/γ) with gamma and β /B2 phases located primarily at the colony boundaries.

[0022] Applicant has further identified that cast and Hot Isostatic Pressing (HIP) (HIP'd) TNM γ -TiAl alloys have exhibited a similar trend, in that, by lowering oxygen level from 800 Weight Parts per Million (wppm) to 500 wppm, the room temperature ductility increased from 0.8% for 800 wppm oxygen to 1% for 500 wppm oxygen, along with a 20% increase in tensile strength.

[0023] Ductility improvements, with decreasing oxygen contents in γ -TiAl alloys is not well understood, however, it has been well established that the γ phase has low oxygen solubility, whereas the α_2 phase has high oxygen solubility. It is believed that by lowering the oxygen contents in the γ -TiAl alloys, the gamma and α_2 phases become relatively softer, which thereby leads to increased ductility.

[0024] A γ -TiAl alloy according to one disclosed non-limiting embodiment, utilizes an existing, mature, γ -TiAl alloy (step 110) such as TNM, gamma TiAl, Ti-48Al-2Cr-2Nb, 47 XD alloy, alloy 7, etc., as the base alloys. Next, interstitials such as oxygen, nitrogen and carbon are reduced to a low level (step 120). In one disclosed non-limiting embodiment, the interstitials are reduced to less than about 200 wppm to create new alloy compositions with extremely low interstitials (Eli).

[0025] It is believed that by lowering oxygen to a relatively low level will yield significantly higher room temperature ductility in the cast and HIP'd condition. In addition, when such γ -TiAl alloys with extremely low interstitials are isothermally forged/extruded and heat treated, the γ -TiAl alloy will yield significantly higher room temperature ductility compared to alloys with high interstitial contents.

[0026] At present, only LPT blades are made with gamma TiAl for aircraft engines. High ductility cilities usage in other engine areas such as compressor and turbine rotors. Improvements in ductility of γ -TiAl alloys may further facilitate applications in gas turbine engines through replacement of relatively twice heavier nickel-based superalloys.

[0027] The use of the terms "a," "an," "the," and similar references in the context of description (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or specifically contradicted by context. The modifier "about" used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., it includes the degree of error associated with measurement of the particular quantity). All ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other. It should be appreciated that relative positional terms such as "forward," "aft," "upper," "lower," "above," "below," and the like are with reference to normal operational attitude and should not be considered otherwise limiting.

[0028] Although the different non-limiting embodiments have specific illustrated components, the embodiments of this invention are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments.

[0029] It should be appreciated that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be appreciated that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

[0030] Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present disclosure.

[0031] Preferred embodiments of the present disclosure are as follows:

1. A process to increase ductility, comprising:

utilizing γ -TiAl alloy as a base alloy; and
reducing at least one interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

2. The process as recited in embodiment 1, further comprising reducing the at least one interstitial of the base alloy to less than about 200 wppm.

3. The process as recited in embodiment 1, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

4. The process as recited in embodiment 1, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing TNM.

5. The process as recited in embodiment 4, wherein the TNM has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

6. The process as recited in embodiment 1, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing

cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloys.

7. An alloy composition, comprising:

a γ -TiAl alloy with at least one reduced interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

8. The alloy as recited in embodiment 7, wherein the at least one reduced interstitial is less than about 200 wppm.

9. The alloy as recited in embodiment 7, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

10. The alloy as recited in embodiment 7, wherein the γ -TiAl alloy is TNM.

11. The alloy as recited in embodiment 10, wherein the TNM has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

12. The alloy as recited in embodiment 7, wherein the γ -TiAl alloy includes a cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloy.

[0032] The foregoing description is exemplary rather than defined by the limitations within. Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

Claims

1. A process to increase ductility, comprising:

utilizing γ -TiAl alloy as a base alloy; and
reducing at least one interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

2. The process as recited in claim 1, further comprising reducing the at least one interstitial of the base alloy to less than 200 wppm.

3. The process as recited in claim 1 or claim 2, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

4. The process as recited in any preceding claim, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing TNM.

5. The process as recited in claim 4, wherein the TNM

has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

6. The process as recited in any preceding claim, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloys.

7. An alloy composition, comprising:

a γ -TiAl alloy with at least one reduced interstitial of the base alloy to create an alloy compositions with extremely low interstitials (Eli).

8. The alloy as recited in claim 7, wherein the at least one reduced interstitial is less than 200 wppm.

9. The alloy as recited in claim 7 or claim 8, wherein utilizing γ -TiAl alloy as a base alloy includes utilizing a beta stabilized gamma γ -TiAl alloy

10. The alloy as recited in any one of claims 7 to 9, wherein the γ -TiAl alloy is TNM.

11. The alloy as recited in claim 10, wherein the TNM has a composition of Ti-43.5Al-4Nb-1Mo-0.2B (all in at %).

12. The alloy as recited in any one of claims 7 to 11, wherein the γ -TiAl alloy includes a cast and Hot Isostatic Pressing (HIP'd) TNM γ -TiAl alloy.

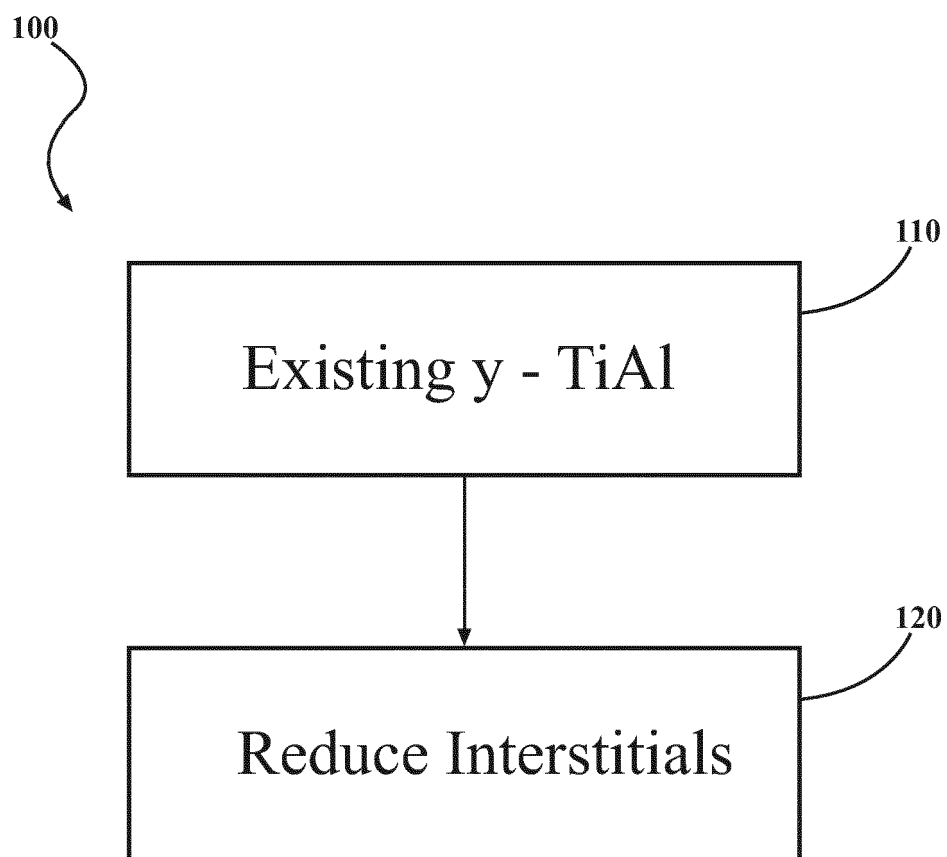


FIG. 1



EUROPEAN SEARCH REPORT

Application Number
EP 17 17 9909

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EPO FORM 1503 03.82 (P04C01)

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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