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US4746374	Method of producing titanium aluminide metal matrix composite articles US AIR FORCE

Method to produce gamma titanium aluminide articles having improved properties

USH001988

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- **International Patent Classification**
  C22C-014/00 C22C-030/00 C22F-001/04 C22F-001/18
- **US Patent Classification**
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- **Fampat family**
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- **Abstract:**
  (USH001988)
  Methods are presented to produce duplex (DP) microstructures, nearly lamellar (NL) microstructures, and fully TMT lamellar (TMTL) microstructures in gamma titanium aluminide alloy articles. The key step for obtaining a specific type of microstructure is the post-hot work annealing treatment at a temperature in a specific range for the desired microstructure. The annealing temperatures range from Te+100° C. to Talpha-25° C. for duplex (DP) microstructures, from Talpha-25° C. to Talpha-5° C. for nearly lamellar (NL) microstructures, and from Talpha to Talpha+60° C. for fully TMT lamellar (TMTL) microstructures, where Te is the titanium-aluminum eutectoid temperature of the alloy and Talpha is the alpha transus temperature of the alloy. The times required for producing specific microstructures range from 2 min to 15 hours depending on microstructural type, alloy composition, annealing temperature selected, material section size, and desired grain-size. The heating rate to the post-hot work annealing treatment is critical and must be fast enough to avoid compositional segregation (in the two-phase field) and uneven grain growth. Cooling schemes and rates after the annealing treatments are determined according to the microstructural features of interest, and their stability.

Claims
(USH001988)
We claim:
1.
A process for producing duplex microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) annealing the hot worked article at an annealing temperature in the range of Te +100 (degree) C. to T ALPHA -25 (degree) C. for about 10 minutes to 15 hours;
(c) cooling said article from said annealing temperature to a preselected temperature between said annealing temperature and about 700 (degree) C. at a first cooling rate of about 10 (degree) to 1000 (degree) C./min and then cooled at a second rate ranging from said first cooling rate to water quenching to room temperature, and
(d) aging the so cooled article at an aging temperature in the range of 700 (degree) to 1050 (degree) C. for about 1 to 150 hours.
2. The process of claim 1 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
3. The process of claim 2 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
4. A process for producing duplex microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) annealing the hot worked article at an annealing temperature in the range of Te +100 (degree) C. to T ALPHA -25 (degree) C. for about 10 minutes to 15 hours;
(c) cooling said article from said annealing temperature to an aging temperature in the range of 700 (degree) to 1050 (degree) C. at a cooling rate of about 5 (degree) to 1000 (degree) C./min;
and
(d) aging the so cooled article at said aging temperature for about 1 to 150 hours.
5. The process of claim 4 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
6. The process of claim 5 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
7. A process for producing nearly-lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) annealing the hot worked article at an annealing temperature in the range of T ALPHA -1 (degree) C. to T ALPHA -25 (degree) C. for about 0.5 to 10 hours;
(c) cooling said article from said annealing temperature to a preselected temperature between said annealing temperature and about 700 (degree) C. at a first cooling rate of about 5 (degree) to 1000 (degree) C./min and then cooled at a second rate ranging from said first cooling rate to water quenching to room temperature;
and
(d) aging the so cooled article at an aging temperature in the range of 700 (degree) to 1050 (degree) C. for about 1 to 150 hours.
8. The process of claim 7 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
9. The process of claim 8 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
10. A process for producing nearly-lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) annealing the hot worked article at an annealing temperature in the range of T ALPHA -1 (degree) C. to T ALPHA -25 (degree) C. for about 0.5 to 10 hours;
(c) cooling said article from said annealing temperature to an aging temperature in the range of 700 (degree) to 1050 (degree) C. at a cooling rate of about 5 (degree) to 1000 (degree) C./min;
and
(d) aging the so cooled article at said aging temperature for about 1 to 150 hours.
11. The process of claim 10 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
12. The process of claim 11 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
13. A process for producing fully TMT lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) pre-annealing the hot worked article at a temperature in the range of T ALPHA -12 C. to T ALPHA -100 (degree) C. for about 1 minute to 2 hours;
(c) heating the pre-annealed article to annealing temperature at a rate greater then 20 (degree) C./min;
(d) annealing the hot worked article at an annealing temperature in the range of T ALPHA to T ALPHA +60 (degree) C. for about 1 minute to 10 hours;
(e) cooling said article from said annealing temperature to a preselected temperature between said annealing temperature and about 700 (degree) C. at a first cooling rate of about 5 (degree) to 1000 (degree) C./min and then cooled at a second rate ranging from said first cooling rate to water quenching to room temperature;
and
(f) aging the cooled article at an aging temperature in the range of 700 (degree) to 1050 (degree) C. for about 1 to 150 hours.

14. The process of claim 13 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
15. The process of claim 14 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
16. A process for producing fully TMT lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) pre-annealing the hot worked article at a temperature in the range of T ALPHA -1 (degree) C. to T ALPHA -100 (degree) C. for about 1 minute to 2 hours;
(c) heating the pre-annealed article to annealing temperature at a rate greater than 20 (degree) C./min;
(d) annealing the hot worked article at an annealing temperature in the range of T ALPHA to T ALPHA +60 (degree) C. for about 1 minute to 10 hours;
(e) cooling said article from said annealing temperature to an aging temperature in the range of 700 (degree) to 1050 (degree) C. at a cooling rate of about 5 (degree) to 1000 (degree) C./min;
and
(f) aging the cooled article at said aging temperature for about 1 to 150 hours.
17. The process of claim 16 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
18. The process of claim 17 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
19. A process for producing fully lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) heating the said article to annealing temperature at a rate greater than 20 (degree) C./min;
(c) annealing the hot worked article at an annealing temperature in the range of T ALPHA to T ALPHA +60 (degree) C. for about 1 minute to 10 hours;
(d) cooling said article from said annealing temperature to a preselected temperature between said annealing temperature and about 700 (degree) C. at a first cooling rate of about 5 (degree) to 1000 (degree) C./min and then cooled at a second rate ranging from said first cooling rate to water quenching to room temperature;
and
(e) aging the cooled article at an aging temperature in the range of 700 (degree) to 1050 (degree) C. for about 1 to 150 hours.
20. The process of claim 19 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
21. The process of claim 20 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.
22. A process for producing fully lamellar microstructure in an article of gamma titanium aluminide alloy containing 0.05 to 1.0 atomic percent boron, which comprises the steps of:
(a) hot working the article;
(b) heating the said article to annealing temperature at a rate greater than 20 (degree) C./min;
(c) annealing the hot worked article at an annealing temperature in the range of T ALPHA to T ALPHA +60 (degree) C. for about 1 minute to 10 hours;
(d) cooling said article from said annealing temperature to an aging temperature in the range of 700 (degree) to 1050 (degree) C. at a cooling rate of about 5 (degree) to 1000 (degree) C./min;
and
(e) aging the cooled article at said aging temperature for about 1 to 150 hours.
23. The process of claim 22 wherein said alloy has the composition Ti-(45.0-49)Al-(0-3)X-(0-6)Y-(0.05-1.0)B wherein X is Cr, Mn, V or any combination thereof, and Y is Nb, Ta, W, Mo, Zr, Hf, or any combination thereof.
24. The process of claim 23 wherein said alloy has the composition Ti-(46-47.5)Al-(1-3)Cr-(2-4)Nb-(0-0.3)W-(0.1-0.5)B.

Method for heat treating titanium aluminide alloys
USH001659

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- **International Patent Classification**
  C22F-001/18
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USH1659	H	1997-07-01	[USH001659]

- **Abstract:**
  (USH001659)
  A heat treatment method for producing moderate alpha grain size (50-250 mu m) fully lamellar, microstructures in thin cross section near- gamma titanium aluminide alloy products is described, wherein a wrought, fine y grain starting microstructure is heated at a temperature high in the two-phase alpha + gamma phase field and 30-60 DEG C. below the alpha transus temperature to produce a structure of small equiaxed alpha grains (about 25 mu m dim) and fine gamma phase grains, which is then briefly heated to a temperature in the single-phase alpha field in order to complete dissolution of remnant gamma grains and to minimize growth of alpha grains. The material is then cooled to transform the microstructure to fully lamellar alpha 2+ gamma .

Claims

(USH001659)

We claim:

1.

A method for heat treating titanium aluminide ahoy, comprising the steps of:

(a) providing titanium aluminide alloy material having a recrystallized microstructure of gamma phase grains in a matrix of alpha-2 phase or lamellar alpha-2 plus gamma phase;

(b) heating said material at a temperature 30 to 60 centigrade degrees below the alpha transus temperature of said alloy whereby a microstructure having equiaxed alpha phase grains surrounded by fine gamma phase grains is produced within said alloy;

(c) thereafter heating said alloy at a temperature 20 to 50 centigrade degrees above the alpha transus temperature of said alloy to dissolve said fine gamma phase grains to produce in said alloy substantially single phase equiaxed alpha grain structure of grain size in the range of 50 to 250 MU m;

and

(d) thereafter cooling said alloy to transform the microstructure of said alloy to fully lamellar alpha-2 plus gamma phase.

2. The method of claim 1 wherein said alloy has a composition in the ranges Ti-(42-49)A1-(0-10)X, where X is one or more alloying elements selected from the group consisting of chromium, manganese, vanadium, niobium, tantalum, tungsten, molybdenum, silicon, boron, and zirconium.

3. The method of claim 1 wherein said alloy is an alpha-beta titanium alloy.

4. A method for heat treating titanium aluminide alloy, comprising the steps of:

(a) providing titanium aluminide alloy;

(b) hot working said material to produce therein a recrystallized microstructure of gamma phase grains in a matrix of alpha-2 phase or lamellar alpha 2 plus gamma phase;

(c) thereafter heating said alloy at a temperature 30 to 60 centigrade degrees below the alpha transus temperature of said alloy whereby a microstructure having equiaxed alpha phase grains surrounded by fine gamma phase grains is produced within said alloy;

(d) thereafter heating said alloy at a temperature 20 to 50 centigrade degrees above the alpha transus temperature of said alloy to dissolve said fine gamma phase grains to produce in said alloy a substantially single phase equiaxed alpha grain structure of grain size in the range of 50 to 250 MU m;

and

(e) thereafter cooling said alloy to transform the microstructure of said alloy to fully lamellar alpha-2 plus gamma phase.

5. The method of claim 4 wherein said alloy has a composition in the ranges Ti-(42-49(A1-(0-10)X, where X is one or more alloying elements selected from the group consisting of chromium, manganese, vanadium, niobium, tantalum, tungsten, molybdenum, silicon, boron, and zirconium.

6. The method of claim 4 wherein said alloy is previously cast or previously cast and hot isostatically pressed.

7. The method of claim 4 wherein said alloy is an alpha-beta titanium alloy.

Method to produce gamma titanium aluminide articles having improved properties

US5558729

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- **International Patent Classification**
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- **US Patent Classification**
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  1996US-08652679 1996-05-28

- **Fampat family**

US5558729	A	1996-09-24	[US5558729]
US5746846	A	1998-05-05	[US5746846]

- **Abstract:**
  (US5558729)
  Gamma titanium aluminide alloys having the composition Ti-(45.5-47.5)Al-(0-3.0)X-(1-5)Y-(0.05-1.0)W, where X is Cr, Mn or any combination thereof, and Y is Nb, Ta or any combination thereof (at %), are treated to provide specific microstructures. To obtain duplex microstructures, the annealing temperature (Ta) range is the eutectoid temperature (Te)+100 DEG C. to the alpha transus temperature (T alpha)-30 DEG C.; to obtain nearly lamellar microstructures, the annealing temperature range is T alpha -20 DEG C. to T alpha -1 DEG C.; to obtain fully lamellar microstructures, the annealing temperature range is T alpha to T alpha +50 DEG C. The times required for producing these microstructures range from 0.25 to 15 hours, depending on the desired microstructure, alloy composition, annealing temperature selected, material section size and grain size desired. The cooling schemes and rates after annealing depend mainly on the microstructure type and stability; for duplex and nearly lamellar microstructures, the initial cooling rate is 5 DEG to 1000 DEG C./min, while for fully lamellar microstructure, the initial cooling rate is 5 DEG to 100 DEG C./min. The article can be cooled at the initial rate directly to the aging temperature; alternatively, the article can be cooled at the initial rate down to a temperature between room temperature and the annealing temperature, then cooled to room temperature at a cooling rate between the initial rate and water quenching, after which the article is aged. Following annealing, the article is aged at a temperature in the range of 700 DEG C. to 1050 DEG C. for about 4 to 150 hours.

Claims

(US5558729)

We claim:

1.

A method to produce duplex microstructure in an article of tungsten-containing gamma titanium aluminide alloy, which comprises the steps of (a) hot working the article, (b) annealing the so hot worked article at an annealing temperature in the range of Te +100 (degree) C. to T ALPHA -30 (degree) C. for about 1 to 15 hours, (c) cooling said article from said annealing temperature to a preselected temperature between said annealing temperature and about 700 (degree) C. at a first cooling rate of about 5 (degree) to 1000 (degree) C./min, (d) increasing the cooling rate to a second rate ranging from said first cooling rate to water quenching, and cooling said article from said preselected temperature to room temperature, and (e) aging the so cooled article at an aging temperature in the range of 700 (degree) to 1050 (degree) C. for about 2 to 150 hours.

2. The method of claim 1 wherein said alloy has the composition Ti--(45.5-47.5)Al--(0-3.0)X--(1-5)Y--(0.05-1.0)W, where X is Cr, Mn or any combination thereof, and Y is Nb, Ta or any combination thereof.

3. The method of claim 2 wherein said alloy has the composition Ti--(46-47)Al--(1.5-3.0)Cr--(2-3.5)Nb--(0.1-0.3)W.

Method to refine the microstructure of .alpha.-2 titanium aluminide-based cast and ingot metallurgy articles

US5447582

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- **International Patent Classification**
  C22F-001/18
- **US Patent Classification**
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- **Priority Details**
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- **Fampat family**

US5447582	A	1995-09-05	[US5447582]

- **Abstract:**
  (US5447582)
  The microstructure of alpha-2 and orthorhombic titanium aluminide alloy cast and ingot metallurgy articles is refined by: (a) hydrogenating the article at a temperature at or slightly below the beta -transus temperature of the alloy; (b) cooling the article, under a positive partial pressure of hydrogen, to a temperature about 20 to 40 percent below the beta -transus; and (c) dehydrogenating the article.

Claims
(US5447582)
We claim:
1.
A method for refining the microstructure of titanium aluminide alloy cast and ingot metallurgy articles which comprises the steps of:
(a) hydrogenating said titanium aluminide alloy cast or ingot metallurgy article at a temperature at or slightly below the BETA -transus temperature of the alloy;
(b) cooling the article, under a positive partial pressure of hydrogen, to a temperature about 20 to 40 percent below the BETA -transus;
and
(c) dehydrogenating the article;
- wherein said alloy contains about 20-30 atomic percent aluminum, about 70-80 atomic percent titanium, and about 1-25 atomic percent of at least one beta stabilizer selected from the group consisting of Nb, Mo and V;
- and wherein the time period of steps (a) and (b) is about 16 to 24 hours.
2. The method of claim 1 wherein said alloy further contains about 0.1-5 atomic percent of at least one other beta stabilizer selected from the group consisting of Mn, Cr, and W.
3. The method of claim 1 wherein said alloy is Ti--24Al--11Nb.
4. The method of claim 1 wherein said dehydrogenation step (c) comprises heating said article at about 650 (degree) to 760 (degree) C., under vacuum, for about 12 to 48 hours.
5. The method of claim 2 wherein said alloy is Ti--25Al--10Nb--3V--1Mn.
6. The method of claim 5 wherein said article is held at or near said BETA -transus temperature for about 8 to 12 hours, then cooled to about 20 to 40 percent below the BETA -transus and held for about 8 to 12 hours, then dehydrogenated.
7. The method of claim 5 wherein said article is held at or near said BETA -transus temperature for about 2 hours, cooled to about 10 percent below said BETA -transus temperature and held for about 4 hours, cooled to about 25 percent below said BETA -transus temperature and held for about 6 hours, cooled to about 35 percent below said BETA -transus temperature and held for about 6 hours, then dehydrogenated.

Method to produce hot-worked gamma titanium aluminide articles US5424027

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- **International Patent Classification**
  C22C-001/04 C22F-001/18
- **US Patent Classification**
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  1993US-08161620 1993-12-06
- **Fampat family**

US5424027	A	1995-06-13	[US5424027]

- **Abstract:**
  (US5424027)
  A method for producing hot worked gamma titanium aluminide alloy articles which comprises the steps of: (a) providing a prealloyed gamma titanium aluminide alloy powder; (b) filling a suitable die or mold with the powder; (c) hot isostatic press (HIP) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature below the alpha-two+gamma eutectoid temperature of the alloy to produce a preform; (d) hot working the preform at a temperature at or below the alpha-two+gamma eutectoid temperature of the alloy; and (e) optionally, heat treating the hot worked article. By hot working the preform at or below the alpha-two+gamma eutectoid temperature, the fine, uniform, isotropic microstructure of the preform is maintained, allowing a large metal flow and good shape definition with no edge cracking.

Claims

(US5424027)

I claim:

1. A method for producing hot worked gamma titanium aluminide alloy articles which comprises the steps of:

(a) providing a prealloyed gamma titanium aluminide alloy powder;

(b) filling a suitable die or mold with the powder;

(c) hot isostatic press (HIP) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature below the alpha-two+gamma eutectoid temperature of the alloy to produce a preform;

and

(d) hot working the preform at a temperature at or below the alpha-two+gamma eutectoid temperature of the alloy.

2. The method of claim 1 further comprising the step of heat treating the hot worked article.

3. The method of claim 1 wherein the preform is hot worked by isothermal forging at about 1100 (degree) C.

4. The method of claim 2 wherein said heat treating step consists of heating the article at 1290 (degree) C. for 3 hours.

5. The method of claim 2 wherein said heat treating step consists of heating the article at 1350 (degree) C. for 1 hour.

6. The method of claim 2 wherein said heat treating step consists of heating the article at 1400 (degree) C. for 30 minutes.

Method to produce gamma titanium aluminide articles having improved properties

US5226985

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- **International Patent Classification**
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- **US Patent Classification**
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- **CPC Code**
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- **Priority Details**
  1992US-07823737 1992-01-22
- **Fampat family**
  US5226985 A 1993-07-13 [US5226985]

- **Abstract:**
  (US5226985)
  A first method for producing articles of gamma titanium alumide alloy having improved properties comprises the steps of: (a) shaping the article at a temperature between the titanium-aluminum eutectoid temperature of the alloy and the alpha-transus temperature of the alloy, and (b) aging the thus-shaped article at a temperature between about 750 (degree) and 1050 (degree) C. for about 4 to 150 hours. Shaping is preferably carried out at a temperature about 0 (degree) to 50 (degree) C. below the alpha-transus temperature. A second method for producing articles of gamma titanium aluminide alloy having improved properties comprises the steps of: (a) shaping the article at a temperature in the approximate range of about 130 (degree) C. below the titanium-aluminum eutectoid temperature of the alloy to about 20 (degree) C. below the alpha-transus temperature of the alloy; (b) heat treating the thus-shaped article at about the alpha-transus temperature of the alloy for about 15 to 120 minutes; and (c) aging the thus-heat treated article at a temperature between about 750 (degree) and 1050 (degree) C. for about 4 to 300 hours.

Claims

(US5226985)

We claim:

1.

A method for producing articles of gamma titanium aluminide alloy having improved properties which comprises the steps of:

(a) shaping said article at a temperature in the approximate range of about 130 (degree) C. below the titanium-aluminum eutectoid temperature of said alloy to about 20 (degree) C. below the alpha-transus temperature of said alloy;

(b) heat treating the thus-shaped article at about the alpha-transus temperature of said alloy for about 15 to 120 minutes;

(c) cooling the heat-treated article at a rate of about 30 (degree) to 500 (degree) C. per minute;

and

(d) aging the article at a temperature between about 750 (degree) and 1050 (degree) C. for about 4 to 300 hours.

2. The method of claim 1 wherein said article is shaped by extrusion at a temperature in the approximate range of 130 (degree) C. below said titanium-aluminum eutectoid to about 20 (degree) C. below said alpha-transus.

3. The method of claim 1 wherein said article is shaped by isothermal forging at a temperature in the approximate range of 130 (degree) C. below said titanium-aluminum eutectoid to about 100 (degree) C. above said eutectoid.

4. The method of claim 1 wherein said article is shaped by hot die forging at a temperature in the approximate range of 130 (degree) C. below said titanium-aluminum eutectoid to about 20 (degree) C. below said alpha-transus.

5. The method of claim 1 wherein said heat treatment step (b) is carried out at a temperature about 5 (degree) below to 20 (degree) C. above said alpha-transus.

6. A method for producing extruded articles of gamma titanium aluminide alloy having improved properties which comprises the steps of:

(a) extruding said article at a temperature in the approximate range of 0 (degree) to 20 (degree) C. below the alpha-transus temperature of said alloy, at an extrusion ratio of about 4:1 to 16:1 and an extrusion rate of about 1-2 cm/second, and

(b) aging the thus-extruded article at a temperature between about 750 (degree) and 1050 (degree) C. for about 4 to 300 hours.

Method to produce improved property titanium aluminide articles US5098650

- **Patent Assignee**
  US AIR FORCE
- **Inventor**
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- **International Patent Classification**
  C22C-001/04
- **US Patent Classification**
  PCLO=419048000 PCLX=419023000 PCLX=419049000 PCLX=419051000
- **CPC Code**
  C22C-001/04/16 C22C-001/04/58;
- **Publication Information**
  US5098650 A 1992-03-24 [US5098650]
- **Priority Details**
  1991US-07747160 1991-08-16
- **Fampat family**
  US5098650 A 1992-03-24 [US5098650]

- **Abstract:**
(US5098650)
A method for producing titamium alloy articles having a desired microstructure which comprises the steps of: (a) providing a prealloyed gamma titanium aluminide alloy powder; (b) filling a suitable die or mold with the powder; (c) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature of about 70 to 95 percent of the alpha-2+gamma eutectoid temperature of the alloy, in degrees C.

Claims

(US5098650)

We claim:

1.

A method for producing titanium alloy articles having a desired microstructure which comprises the steps of:

(a) providing prealloyed gamma titanium aluminide alloy powder;

(b) filling a suitable die or mold with the powder;

(c) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature of about 70 to 95 percent of the alpha-two+gamma eutectoid temperature of the alloy, in degrees C.

2. The method of claim 1 wherein said titanium aluminide alloy comprises about 0.1-5 atomic percent of at least one beta stabilizer element selected from the group consisting of Nb, Mo, Mn, Cr, W and V.

3. The method of claim 2 wherein said alloy is Ti-48Al-lNb.

4. The method of claim 2 wherein said alloy is Ti-48Al-2Nb-2Cr.

5. The method of claim 2 wherein said alloy is Ti-48Al-lNb-lV.

6. The method of claim 2 wherein said alloy is Ti-48Al-3Nb-2Cr-lMn.

Method for producing very fine microstructures in titanium aluminide alloy powder compacts

US5098484

- **Patent Assignee**
  US AIR FORCE
- **Inventor**
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  APGAR LESLIE S
- **International Patent Classification**
  C22C-001/04
- **US Patent Classification**
  PCLO=419029000 PCLX=419031000 PCLX=419048000
- **CPC Code**
  C22C-001/04/58
- **Publication Information**
  US5098484 A 1992-03-24 [US5098484]
- **Priority Details**
  1991US-07648464 1991-01-30

- **Fampat family**

US5098484	A	1992-03-24	[US5098484]

- **Abstract:**
  (US5098484)
  A method of producing titanium alloy articles having a desired microstructure which comprises the steps of: (a) providing a prealloyed titanium alloy powder; (b) filling a suitable die or mold with the powder; (c) hot isostatic press (HIP) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature of about 60 to 80 percent of the beta transus temperature of the alloy, in degrees C. In another embodiment of the invention, the prealloyed titanium aluminide alloy powder is hydrogenated to about 0.1 to 1.0 wt. % prior to die filling and consolidation. The compacted article is vacuum annealed to remove hydrogen from the article after removal of the die material.

Claims

(US5098484)

We claim:

1.

A method for producing titanium alloy articles having a desired microstructure which comprises the steps of:

(a) providing prealloyed alpha-2 titanium aluminide powder containing about 20-30 atomic percent aluminum, about 70-80 atomic percent titanium and about 1-25 atomic percent of at least one beta stabilizer selected from the group consisting of Nb, Mo and V;

(b) filling a suitable die or mold with the powder;

and

(c) consolidating the powder in the filled mold at a pressure of 30 Ksi or greater and at a temperature of about 60 to 80 percent of the beta transus temperature of the alloy, in degrees C.

2. The method of claim 1 further comprising the step of:

(d) annealing the resulting consolidated article to alter its microstructure.

3. The method of claim 1 further comprising the steps of hydrogenating said powder to about 0.1 to 1.0 wt % hydrogen prior to said consolidation step (c) and removing hydrogen from said article following consolidation.

4. The method of claim 1 wherein said beta stabilizer element is Nb.

5. The method of claim 3 wherein said consolidation temperature is about 70 to 80 percent of said beta transus temperature.

6. The method of claim 4 wherein the quantity of Nb is about 10-11 atomic percent.

7. The method of claim 6 wherein said alloy is Ti-24Al-11Nb.

8. The method of claim 6 wherein said alloy is Ti-25Al-10Nb-3Mo-1V.

Method to manufacture titanium aluminide matrix composites
US5104460

- **Patent Assignee**
  US AIR FORCE
- **Inventor**
  SMITH JR PAUL R
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  REVELOS WILLIAM C
- **International Patent Classification**
  C22C-049/11
- **US Patent Classification**
  PCLO=148527000 PCLX=148407000 PCLX=148516000 PCLX=148564000 PCLX=420129000 PCLX=428608000 PCLX=428614000 PCLX=428629000 PCLX=428660000
- **CPC Code**
  B22F-2999/00; C22C-049/11; Y10T-428/12444; Y10T-428/12486; Y10T-428/1259; Y10T-428/12806
- **Publication Information**
  US5104460 A 1992-04-14 [US5104460]
- **Priority Details**
  1990US-07628955 1990-12-17
- **Fampat family**

US5104460	A	1992-04-14	[US5104460]

- **Abstract:**
  (US5104460)
  A method for fabricating a composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, titanium boride-coated silicon carbide and silicon-coated silicon carbide, embedded in an alpha-2 titanium aluminide metal matrix, which comprises the steps of modifying the desired filamentary material with at least one beta stabilizer, providing a beta-stabilized Ti3 Al foil, fabricating a preform consisting of alternating layers of foil and a plurality of at least one of the beta stabilizer-coated filamentary materials, and applying heat and pressure to consolidate the preform. The composite structure fabricated using the method of this invention is characterized by its lack of a denuded zone and absence of fabrication cracking.

Claims

(US5104460)

We claim:

1.

A method for manufacturing a composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, titanium boride-coated silicon carbide and silicon-coated silicon carbide, embedded in a beta stabilized Ti_3Al matrix, which comprises the steps of providing a beta stabilized Ti_3Al foil containing a quantity of beta stabilizer approximately equal to the desired quantity of beta stabilizer in the matrix portion of said composite structure, modifying said filamentary material to contain at least about 30% of said desired quantity of said beta stabilizer, fabricating a preform consisting of alternating layers of foil and a plurality of at least one of said filamentary materials, and applying heat and pressure to consolidate the preform.

2. The method of claim 1 wherein said beta stabilizer is Nb.

3. The method of claim 1 wherein said filamentary material is modified to contain about 30 to 50% beta stabilizer.

Method to fabricate titanium aluminide matrix composites
US5118025

- **Patent Assignee**
  US AIR FORCE
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- **International Patent Classification**
  C22C-047/20 C22C-049/11 C22C-049/12
- **US Patent Classification**
  PCLO=228121000 PCLX=148527000 PCLX=228190000
  PCLX=228208000 PCLX=228262710
- **CPC Code**
  C22C-047/20; C22C-049/11; C22C-049/12
- **Publication Information**
  US5118025 A 1992-06-02 [US5118025]
- **Priority Details**
  1990US-07628951 1990-12-17

- **Fampat family**

US5118025	A	1992-06-02	[US5118025]

- **Abstract:**
  (US5118025)
  A method for fabricating a titanium aluminide composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, titanium boride-coated silicon carbide and silicon-coated silicon carbide, embedded in an alpha-2 titanium aluminide metal matrix, which comprises the steps of providing a beta-stabilized Ti3 Al foil containing a sacrificial quantity of beta stabilizer element in excess of the desired quantity of beta stabilizer, fabricating a preform consisting of alternating layers of foil and a plurality of at least one of the aforementioned filamentary materials, and applying heat and pressure to consolidate the preform. In another embodiment of the invention, the beta-stabilized Ti3 Al foil is coated on at least one side with a thin layer of sacrificial beta stabilizer. The composite structure fabricated using the method of this invention is characterized by its lack of a denuded zone and absence of fabrication cracking.

Claims

(US5118025)

We claim:

1.

A method for fabricating a composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron and silicon-coated silicon carbide, embedded in a beta stabilized Ti3 Al matrix, which compises the steps of providing a beta stabilized Ti3 Al foil containing a desired quantity of beta stabilizer, coating at least one side of said foil with a sacrificial quantity of beta stabilizer, fabricating a preform consisting of alternating layers of foil and a plurality of at least one of said filamentary materials, and applying heat and pressure to consolidate the preform.

2. The method of claim 1 wherein said coating has a thickness such as to provide about 30 to 50% additional beta stabilizer.

3. The method of claim 1 wherein said beta stabilizer is Nb.

4. The method of claim 3 wherein said foil has the composition Ti-25Al-11Nb and wherein said foil is coated with about 30 to 50% additional Nb.

Method and titanium aluminide matrix composite
US5030277

- **Patent Assignee**
  US AIR FORCE
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- **International Patent Classification**
  C22C-049/04
- **US Patent Classification**
  PCLO=075229000 PCLX=075236000 PCLX=075238000 PCLX=075244000 PCLX=419012000 PCLX=419017000 PCLX=419024000 PCLX=419035000 PCLX=419036000 PCLX=419037000 PCLX=419048000
- **CPC Code**
  C22C-049/04
- **Publication Information**
  US5030277 A 1991-07-09 [US5030277]
- **Priority Details**
  1990US-07628956 1990-12-17
- **Fampat family**
  US5030277 A 1991-07-09 [US5030277]

- **Abstract:**
  (US5030277)
  A method for fabricating a titanium aluminide composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, titanium boride-coated silicon carbide and silicon-coated silicon carbide, embedded in an alpha-2 titanium aluminide metal matrix, which comprises the steps of providing a first beta-stabilized Ti3 Al powder containing a desired quantity of beta stabilizer, providing a second beta-stabilized Ti3 Al powder containing a sacrificial quantity of beta stabilizer in excess of the desired quantity of beta stabilizer, coating the filamentary material with the second powder, fabricating a preform consisting of the thus-coated filamentary materials surrounded by the first powder, and applying heat and pressure to consolidate the preform. The composite structure fabricated using the method of this invention is characterized by its lack of a denuded zone and absence of fabrication cracking.

Claims

(US5030277)

We claim:

1.

A method for producing a composite structure consisting of a filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, titanium boride-coated silicon carbide and silicon-coated silicon carbide, embedded in a beta stabilized Ti_3Al matrix, which comprises the steps of providing a first beta-stabilized Ti_3Al powder containing a desired quantity of beta stabilizer, providing a second beta-stabilized Ti_3Al powder containing a sacrificial quantity of beta stabilizer in excess of the desired quantity of beta stabilizer, coating said filamentary material with said second powder, fabricating a preform consisting of the thus-coated filamentary materials surrounded by said first powder, and applying heat and pressure to consolidate the preform.

2. The method of claim 1 wherein said second powder is coated onto said filamentary material using a fugitive binder.

3. The method of claim 2 wherein said fugitive binder is a thermoplastic binder.

4. The method of claim 1 wherein said beta stabilizer is Nb.

5. The method of claim 4 wherein the amount of said beta stabilizer in said first powder is about 10-11 atomic percent.

6. The method of claim 5 wherein the amount of said beta stabilizer in said second powder is about 17-18 atomic percent.

7. A product produced according to the method of claim 1.

Low temperature hydrogenation of gamma titanium aluminide
US5067988

- **Patent Assignee**
  US AIR FORCE
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- **International Patent Classification**
  C22F-001/02
- **US Patent Classification**
  PCLO=419031000 PCLX=148513000 PCLX=148514000 PCLX=428614000
- **CPC Code**
  C22F-001/02; Y10T-428/12486
- **Publication Information**
  US5067988 A 1991-11-26 [US5067988]
- **Priority Details**
  1990US-07474197 1990-02-02
- **Fampat family**

US5067988	A	1991-11-26	[US5067988]

- **Abstract:**
  (US5067988)
  A method for refining the microstructure and enhancing the processability of titanium aluminum alloys containing about 45 to 55 atomic percent aluminum which comprises the steps of: (a) rapidly solidifying a titanium aluminum alloy containing about 45 to 55 atomic percent aluminum to provide a rapidly solidified material having at least one dimension not greater than about 100 micrometers; (b) diffusing hydrogen into the resulting rapidly solidified material at a temperature in the approximate range of 400 (degree) to 780 (degree) C., and; (c) diffusing hydrogen out of the hydrogenated solid material.

Claims

(US5067988)

We claim:

5.

A method for producing a molded article from gamma titanium-aluminum alloys which comprises the steps of:

(a) rapidly solidifying said alloy to provide a rapidly solidified material having at least one dimension not greater than about 100 micrometers;

(b) diffusing hydrogen into the resulting rapidly solidified material at a temperature in the approximate range of 400 (degree) to 780 (degree) C.;

(c) diffusing hydrogen out of the hydrogenated solid material, and;

(d) consolidating said solid material in a suitable mold at a temperature of about 0 (degree) to 250 (degree) C. below the beta transus temperature of said alloy at a pressure of about 5 to 45 ksi to produce said article.

1. A method for refining the microstructure and enhancing the processability of gamma titanium-aluminum alloys which comprises the steps of:

(a) rapidly solidifying said alloy to provide a rapidly solidified material having at least one dimension not greater than about 100 micrometers;

(b) diffusing hydrogen into the resulting rapidly solidified material at a temperature in the approximate range of 400 (degree) to 780 (degree) C., and;

(c) diffusing hydrogen out of the hydrogenated solid material.

2. The method of claim 1 further comprising the step of heat treating the hydrogenated solid material prior to diffusing hydrogen out of said material.

3. The method of claim 1 wherein said alloy is Ti-35Al.

4. The method of claim 1 wherein said alloy is Ti-34Al-1.3V-0.52C.

6. The method of claim 5 further comprising the step of heat treating the hydrogenated solid material prior to diffusing hydrogen out of said material.

7. The method of claim 5 wherein said alloy is Ti-35Al.

8. The method of claim 5 wherein said alloy is Ti-34Al-1.3V-0.52C.

9. A method for producing a molded article from gamma titanium-aluminum alloys which comprises the steps of:

(a) rapidly solidifying said alloy to provide a rapidly solidified material having at least one dimension not greater than about 100 micrometers;

(b) diffusing hydrogen into the resulting rapidly solidified material at a temperature in the approximate range of 400 (degree) to 780 (degree) C.;

(c) consolidating said solid material in a suitable mold at a temperature of about 0 (degree) to 250 (degree) C. below the beta transus temperature of said alloy at a pressure of about 5 to 45 ksi to produce said article, and;

(d) diffusing hydrogen out of said article.

10. The method of claim 9 further comprising the step of heat treating the hydrogenated solid article prior to diffusing hydrogen out of said article.

11. The method of claim 9 wherein said alloy is Ti-35Al.

12. The method of claim 9 wherein said alloy is Ti-34Al-1.3V-0.52C.

High temperature hydrogenation of gamma titanium aluminide
US5015305

• **Patent Assignee** **US AIR FORCE** • **Inventor** FROES FRANCIS H SHONG SIMON D • **International Patent Classification** C22C-001/00 • **US Patent Classification** PCLO=148670000 PCLX=029527500 • **CPC Code** C22C-001/00; Y10T-029/49988	• **Publication Information** US5015305 A 1991-05-14 [US5015305] • **Priority Details** 1990US-07474196 1990-02-02
• **Fampat family** US5015305 A 1991-05-14 [US5015305]	

- **Abstract:**
  (US5015305)
  A method for refining the microstructure and enhancing the processability of titanium aluminum alloys containing about 45 to 55 atomic percent aluminum which comprises the steps of: (a) rapidly solidifying a titanium aluminum alloy containing about 45 to 55 atomic percent aluminum in a hydrogen-containing atmosphere to provide a hydrogenated, rapidly solidified material having at least one dimension not greater than about 100 micrometers, and; (b) diffusing hydrogen out of the hydrogenated solid material.

Claims

(US5015305)

We claim:

1.

A method for refining the microstructure and enhancing the processability of titanium aluminum alloys containing about 45 to 55 atomic percent aluminum which comprises the steps of:

(a) rapidly solidifying a titanium aluminum alloy containing about 45 to 55 atomic percent aluminum in a hydrogen-containing atmosphere to provide a hydrogenated, rapidly solidified material having at least one dimension not greater than about 100 micrometers, and;

(b) diffusing hydrogen out of the hydrogenated solid material.

2. The method of claim 1 further comprising the step of heat treating the hydrogenated solid material prior to diffusing hydrogen out of said material.

3. The method of claim 1 wherein said alloy is Ti-35Al.

4. The method of claim 1 wherein said alloy is Ti-34Al-1.3V-0.52C.

5. A method for producing a molded article from titanium-aluminum alloys containing about 45 to 55 atomic percent aluminum which comprises the steps of:

(a) rapidly solidifying a titanium aluminum alloy containing about 45 to 55 atomic percent aluminum in a hydrogen-containing atmosphere to provide a hydrogenated, rapidly solidified material having at least one dimension not greater than about 100 micrometers;

(b) diffusing hydrogen out of the hydrogenated solid material, and;

(c) consolidating said solid material in a suitable mold at a temperature of about 0 (degree) to 250 (degree) C. below the beta transus temperature of said alloy at a pressure of about 5 to 45 ksi to produce said article.

6. The method of claim 5 further comprising the step of heat treating the hydrogenated solid material prior to diffusing hydrogen out of said material.

7. The method of claim 5 wherein said alloy is Ti-35Al.

8. The method of claim 5 wherein said alloy is Ti-34Al-1.3V-0.52C.

9. A method for producing a molded article from titanium-aluminum alloys containing about 45 to 55 atomic percent aluminum which comprises the steps of:

(a) rapidly solidifying a titanium aluminum alloy containing about 45 to 55 atomic percent aluminum in a hydrogen-containing atmosphere to provide a hydrogenated, rapidly solidified material having at least one dimension not greater than about 100 micrometers;

(b) consolidating said hydrogenated, solid material in a suitable mold at a temperature of about 0 (degree) to 250 (degree) C. below the beta transus temperature of said alloy at a pressure of about 5 to 45 ksi to produce said article, and;

(c) diffusing hydrogen out of said article.

10. The method of claim 9 further comprising the step of heat treating the hydrogenated solid article prior to diffusing hydrogen out of said article.

11. The method of claim 9 wherein said alloy is Ti-35Al.

12. The method of claim 9 wherein said alloy is Ti-34Al-1.3V-0.52C.

Method for producing titanium aluminide foil
US4917858

• **Patent Assignee** **US AIR FORCE** • **Inventor** EYLON DANIEL FROES FRANCIS H • **International Patent Classification** B22F-003/18 C22C-001/04 • **US Patent Classification** PCLO=419028000 PCLX=075245000 PCLX=419029000 PCLX=419043000 PCLX=419046000 • **CPC Code** B22F-003/18; C22C-001/04/58	• **Publication Information** **US4917858 A 1990-04-17 [US4917858]** • **Priority Details** 1989US-07387925 1989-08-01
• **Fampat family** **US4917858** A 1990-04-17 [US4917858]	

• **Abstract:**
(US4917858)
A method for producing foil of titanium aluminide is described which comprises providing a preselected quantity of blended powder of chloride free commercially pure elemental titanium, aluminum and other alloying metal(s) in preselected proportions, rolling the blended powder into a green foil, sintering the green foil, and thereafter pressing the sintered foil to full density.

Claims

(US4917858)

We claim:

1.

A method for producing a titanium aluminide alloy foil comprising the steps of:

(a) providing a preselected quantity of blended elemental powder including substantially chloride free unalloyed titanium and aluminum in preselected proportions;

(b) rolling said powder to predetermined thickness to form a foil of a titanium-aluminum alloy in said preselected proportions of elemental powder;

(c) sintering said foil;

and

hot pressing said foil to densify said foil to substantially 100% theoretical density of said alloy.

2. The method of claim 1 wherein said blended elemental powder further comprises an alloying element selected from the group consisting of niobium, molybdenum, vanadium, chromium, manganese, erbium and yttrium.

3. The method of claim 1 wherein said preselected proportions are selected to form Ti_3Al in said alloy.

4. The method of claim 1 wherein said preselected proportions are selected to form TiAl in said alloy.

5. The method of claim 3 wherein said rolling step is performed at about room temperature to 700 (degree) C.

6. The method of claim 4 wherein said rolling step is performed at about room temperature to 700 (degree) C.

7. The method of claim 3 wherein said sintering step is performed at about 500 (degree) to 1200 (degree) C.

8. The method of claim 4 wherein said sintering step is performed at about 500 (degree) to 1300 (degree) C.

9. The method of claim 3 wherein said hot pressing step is performed at about 1100 (degree) C.

10. The method of claim 4 wherein said hot pressing step is performed at about 1150 (degree) C.

11. The method of claim 1 wherein said hot pressing step is performed at about 5 to 120 ksi.

Method of producing titanium aluminide metal matrix composite articles
US4746374

- **Patent Assignee**
  US AIR FORCE
- **Inventor**
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  EYLON DANIEL
- **International Patent Classification**
  C22C-047/20
- **US Patent Classification**
  PCLO=228190000 PCLX=228124100 PCLX=228262710 PCLX=428614000
- **CPC Code**
  C22C-047/20; Y10T-428/12486
- **Publication Information**
  US4746374 A 1988-05-24 [US4746374]
- **Priority Details**
  1987US-07013817 1987-02-12
- **Fampat family**
  US4746374 A 1988-05-24 [US4746374]

- **Abstract:**
  (US4746374)
  A method for fabricating an improved titanium alloy composite consisting of at least one high strength/high stiffness filament or fiber embedded in a titanium-aluminum base alloy matrix which comprises the steps of providing a rapidly-solidified foil made of the titanium-aluminum base alloy, fabricating a preform consisting of alternating layers of the rapidly-solidified foil and the filamentary material, and applying heat and pressure to consolidate the preform, wherein consolidation is carried out at a temperature below the beta-transus temperature of the alloy.

Claims

(US4746374)

We claim:

1.

A method for fabricating a titanium alloy composite consisting of at least one filamentary material selected from the group consisting of silicon carbide, silicon carbide-coated boron, boron carbide-coated boron, and silicon-coated silicon carbide, and a titanium-aluminum base alloy containing about 10 to 50 atomic percent aluminum and about 80 to 50 atomic percent titanium which comprises the steps of:

(a) providing rapidly-solidified foils, having an average beta grain size of about 2 to 20 microns, of said alloy;

(b) fabricating a preform consisting of alternating layers of at least one of said filamentary materials and said foil;

and

(c) applying heat at a level of about 0 (degree) to 250 (degree) C. below the beta transus temperature of said alloy and applying a pressure of about 5 to 40 ksi for about 0.25 to 24 hours, to consoliate said preform.

2. The method of claim 1 wherein the quantity of filamentary materials in said composite is about 25 to 45 volume percent.

3. The method of claim 1 wherein said alloy is Ti-14Al-22Nb.

4. The method of claim 1 wherein said alloy is Ti-36Al.

5. The method of claim 1 wherein said alloy is Ti-15.8Al.

6. The method of claim 1 wherein said alloy is Ti-14.3Al-19.7Nb.

7. The method of claim 1 wherein said alloy is Ti-15Al-10.3Nb.

8. The method of claim 1 wherein said alloy is Ti-15.4Al-5.3Nb.

9. The method of claim 1 wherein said alloy is Ti-31.5Al.

10. The method of claim 1 wherein said alloy is Ti-14.6Al-10Nb-4W.

11. The method of claim 1 wherein said alloy is Ti-6.6Al-15.6Mo.