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(54) THIXOFORMING METHOD FOR TITANIUM-COBALT ALLOY

THIXOFORMINGVERFAHREN FÜR TITAN-KOBALT-LEGIERUNG

PROCÉDÉ DE THIXOFORMAGE ASSOCIÉ POUR ALLIAGE TITANE-COBALT

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Description

FIELD

- 5 **[0001]** This application relates to titanium alloys and, more particularly, to thixoforming of titanium alloys in a method for manufacturing a metallic article.

BACKGROUND

- 10 **[0002]** Titanium alloys offer high tensile strength over a broad temperature range, yet are relatively light weight. Furthermore, titanium alloys are resistant to corrosion. Therefore, titanium alloys are used in various demanding applications, such as aircraft components, medical devices and the like.

- [0003]** Plastic forming of titanium alloys is a costly process. The tooling required for plastic forming of titanium alloys must be capable of withstanding heavy loads during deformation. Therefore, the tooling for plastic forming of titanium alloys is expensive to manufacture and difficult to maintain due to high wear rates. Furthermore, it can be difficult to obtain complex geometries when plastic forming titanium alloys. Therefore, substantial additional machining is often required to achieve the desired shape of the final product, thereby further increasing costs.

- [0004]** Casting is a common alternative for obtaining titanium alloy products having more complex shapes. However, casting of titanium alloys is complicated by the high melting temperatures of titanium alloys, as well as the excessive reactivity of molten titanium alloys with mold materials and ambient oxygen.

- 20 **[0005]** Accordingly, titanium alloys are some of the most difficult metals to be processed in a cost-effective manner. Therefore, those skilled in the art continue with research and development efforts in the field of titanium alloys.

- [0006]** Hautaniemi et al.: "Air passivation of Ti-Cu, Ti-Co and Ti-Al alloys for dental applications", Applied Surface Science, vol. 72, no. 1, (1993-09-01), pages 95 to 102, relates to oxidation of various air-passivated titanium alloys (Ti-zoCu, Ti-20Co and Ti-10Al) for dental applications, which was studied by SEM/EDX, XRD and XPS. Titanium appeared at tetravalent TiO₂ in all alloys studied. In Ti-zoCu alloy copper existed mainly as Cu₂O. No indication of a thin Cu(OH)₂ saturation layer was seen after passivation for several weeks as it was seen for elemental copper. The hydroxide Co(OH)₂ was observed on the surface of Ti-zoCo. The same passivation product was obtained for elemental cobalt. In Ti-10Al alloy aluminum appear as trivalent Al³⁺ ions. A relatively high amount of aluminum was seen in the surface oxide layer whereas only small amounts of copper and cobalt were observed.

- [0007]** AlHilfi et al.: "Corrosion characterization of medical alloys modified by forming titanium nanotubes via anodic oxidation and annealing process", Materials Technology: Advanced Performance Materials, vol. 28, no. 6, (2013-11-18), pages 297 to 304, relates to three medical alloys Ti-6Al-4V, Ti-10Co and Ti-zoCo, which were treated to form Ti nanotubes (TNTs) by anodic oxidation process. The average diameter of TNTs for Ti-6Al-4V and Ti-10Co was 35 and 100 nm respectively. Owing to the α and β phases of Ti-6Al-4V alloy, TNTs had different morphologies. Porous and dendrite structures were formed on the surface of Ti-zoCo alloy. X-ray diffraction (XRD) patterns, optical micrograph images and scanning electron microscope images were used to analyse the produced structures. The XRD profiles of the treated Ti-6Al-4V alloys illustrate the amorphous, anatase and rutile structures of as anodized, annealed samples respectively. The TNTs over β phase areas dissolved after anodic process from the surfaces of Ti-6Al-4V and Ti-10Co alloys. Rutile phase was the dominant phase in all XRD patterns of all annealed alloys at high temperatures. The effects of anodizing process and annealing treatment on the corrosion parameters of the use alloy surfaces inside the simulated body fluid are studied. The annealing process is said to enhance the corrosion parameters for all samples due to the formation of a thick oxide layer.

- [0008]** Tzimas et al.: "Materials Selection for Semisolid Processing", Materials and Manufacturing Processes, vol. 14, no. 2, (1999-01-05), pages 217 to 230, relates to the mechanical behavior of alloys in the semisolid state, which are said to be very sensitive to the volume fraction of the solid. It is said that in the paper, a simple criterion for processability in the semisolid range is introduced, based on the sensitivity of the volume fraction of solid with respect to minor temperature variations. In addition, it is proposed that the processability in the semisolid state can be enhanced using microsegregated material.

- 50 **[0009]** Yim et al.: "Semi-Solid Processing of Magnesium Alloys", Materials Transactions, vol. 44, no. 2., (2003-01-01), pages 558 to 561, relates to the effects of various thermo-mechanical treatments on the change in viscosity of the semi-solid AZ91D magnesium alloys by using a concentric cylinder type viscometer. The effects of gate velocity and thickness on mold filling behavior of the semi-solid AZ91D alloys were also investigated by using a high-speed camera and the results were compared with those obtained from computer simulations. From these results and microstructure examination, a processing map for high pressure die casting of the semi-solid AZ91D alloy was constructed in order to produce sound castings.

- [0010]** US 6,311,759 in accordance with its abstract states "A process for producing a shaped metallic article includes the steps of melting a metal alloy, reducing the temperature of the molten metal to the liquidus temperature, casting the

molten metal at the liquidus temperature into a mould and solidifying the molten metal to obtain a feedstock material. The feedstock material is subsequently heated to a temperature between the liquidus and solidus temperatures to produce a selfsupporting thixotropic material which is then formed to the desired shape. Casting the feedstock material from a melt at substantially the liquidus temperature produces a microstructure that is especially suitable for subsequent forming of the thixotropic material and this allows use of slower forming speeds and lower forming pressure during the forming step".

SUMMARY

[0011] According to the invention, there is provided a method as defined in claim 1.

[0012] In one embodiment, the disclosed titanium alloy consists of 13 to 27 percent by weight cobalt and the balance titanium.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a phase diagram of a titanium-cobalt alloy;

Figs. 2A and 2B are plots of liquid fraction versus temperature for four example titanium alloys generated assuming equilibrium (Fig. 2A) and Scheil (Fig. 2B) conditions;

Fig. 3A, 3B, 3C and 3D are photographic images depicting the microstructures versus time (when maintained at 1060 °C) for four example titanium alloys, specifically Ti-17.5Co (Fig. 3A), Ti-18.5Co (Fig. 3B), Ti-19.5Co (Fig. 3C) and Ti-20.5Co (Fig. 3D);

Fig. 4 is a flow diagram depicting one embodiment of the disclosed method for manufacturing a metallic article;

Fig. 5 is a flow diagram of an aircraft manufacturing and service methodology; and

Fig. 6 is a block diagram of an aircraft.

DETAILED DESCRIPTION

[0014] Disclosed is a titanium-cobalt alloy. When the compositional limits of the cobalt addition in the disclosed titanium-cobalt alloy are controlled as disclosed herein, the resulting titanium-cobalt alloy may be particularly well-suited for use in the manufacture of metallic articles by way of thixoforming.

[0015] Without being limited to any particular theory, it is believed that the disclosed titanium-cobalt alloys are well-suited for use in the manufacture of metallic articles by way of thixoforming because the disclosed titanium-cobalt alloys have a relatively broad solidification range. As used herein, "solidification range" refers to the difference (ΔT) between the *solidus* temperature and the *liquidus* temperature of the titanium-cobalt alloy, and is highly dependent upon alloy composition. The solidification range of the disclosed titanium-cobalt alloys is at least 100 °C. As an example, the solidification range of the disclosed titanium-cobalt alloys may be at least 150 °C. As another example, the solidification range of the disclosed titanium-cobalt alloys may be at least 200 °C. As another example, the solidification range of the disclosed titanium-cobalt alloys may be at least 250 °C. As another example, the solidification range of the disclosed titanium-cobalt alloys may be at least 300 °C.

[0016] The disclosed titanium-cobalt alloys become thixoformable when heated to a temperature between the *solidus* temperature and the *liquidus* temperature of the titanium-cobalt alloy. However, the advantages of thixoforming are limited when the liquid fraction of the titanium-cobalt alloy is too high (processing becomes similar to casting) or too low (processing becomes similar to plastic metal forming). Therefore, it may be advantageous to thixoform when the liquid fraction of the titanium-cobalt alloy is between 30 percent and 50 percent.

[0017] Without being limited to any particular theory, it is further believed that the disclosed titanium-cobalt alloys are well-suited for use in the manufacture of metallic articles by way of thixoforming because the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at temperatures significantly below traditional titanium alloy casting temperatures. In one expression, the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at a temperature less than 1,200 °C. In another expression, the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at a temperature less than 1,150 °C. In another expression, the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at a temperature less

than 1,100 °C. In another expression, the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at a temperature less than 1,050 °C. In yet another expression, the disclosed titanium-cobalt alloys achieve a liquid fraction between 30 percent and 50 percent at a temperature of 1,025 °C.

[0018] In one embodiment, disclosed is a titanium-cobalt alloy having the composition shown in Table 1.

TABLE 1

Element	Range (wt%)
Co	5 - 27
Ti	Balance

[0019] Thus, the disclosed titanium-cobalt alloy may consist of titanium (Ti) and cobalt (Co).

[0020] Those skilled in the art will appreciate that various impurities, which do not substantially affect the physical properties of the disclosed titanium-cobalt alloy, may also be present, and the presence of such impurities will not result in a departure from the scope of the present disclosure. The impurities content of the disclosed titanium-cobalt alloy are controlled as shown in Table 2.

TABLE 2

Impurity	Maximum (wt%)
O	0.25
N	0.03
Other Elements, Each	0.10
Other Elements, Total	0.30

[0021] Without being limited to any particular theory, it is believed that the cobalt addition slightly increases hardness of the as-cast and forged alloy, and contributes to the thixoformability of the disclosed titanium-cobalt alloy.

[0022] As shown in Table 1, the compositional limits of the cobalt addition to the disclosed titanium-cobalt alloy range from 5 percent by weight to 27 percent by weight. In one variation, the compositional limits of the cobalt addition range from 10 percent by weight to 27 percent by weight. In another variation, the compositional limits of the cobalt addition range from 13 percent by weight to 27 percent by weight. In another variation, the compositional limits of the cobalt addition range from 15 percent by weight to 25 percent by weight. In another variation, the compositional limits of the cobalt addition range from 17 percent by weight to 23 percent by weight. In yet another variation, the compositional limits of the cobalt addition range from 17 percent by weight to 21 percent by weight.

Example 1

(Ti-13-27Co)

[0023] One general, non-limiting example of the disclosed titanium-cobalt alloy has the composition shown in Table 3.

TABLE 3

Element	Concentration (wt%)
Co	13 - 27
Ti	Balance

[0024] Referring to the phase diagram of Fig. 1, specifically to the cross-hatched region of Fig. 1, the disclosed Ti-13-27Co alloy has a relatively low solidus temperature (around 1,015 °C) and a relatively broad solidification range. Therefore, the disclosed Ti-13-27Co alloy is well-suited for thixoforming.

Example 2

(Ti-17.5Co)

[0025] One specific, non-limiting example of the disclosed titanium-cobalt alloy has the following nominal composition: Ti-17.5Co and the measured composition shown in Table 4.

TABLE 4

Element	Concentration (wt%)
Ti	Balance
Co	17.6 ± 0.2
O	0.157 ± 0.010
N	0.007 ± 0.001

[0026] PANDAT™ software (version 2014 2.0) from CompuTherm LLC of Middleton, Wisconsin, was used to generate liquid fraction versus temperature data for the disclosed Ti-17.5Co alloy, assuming both equilibrium conditions and Scheil conditions. The results are shown in Figs. 2A (equilibrium conditions) and 2B (Scheil conditions). Based on the data from Fig. 2A (equilibrium conditions), the disclosed Ti-17.5Co alloy has a *solidus* temperature of 1,015 °C and a *liquidus* temperature of 1,350 °C, with a solidification range of 335 °C.

[0027] Referring to Fig. 3A, the disclosed Ti-17.5Co alloy was heated to 1,060 °C—a temperature between the *solidus* and *liquidus* temperatures (i.e., a thixoforming temperature)—and micrographs were taken at 0 seconds, 60 seconds, 300 seconds and 600 seconds. The micrographs show how the disclosed Ti-17.5Co alloy has a globular microstructure at 1,060 °C that becomes increasingly globular over time. Therefore, the disclosed Ti-17.5Co alloy is particularly well-suited for thixoforming.

Example 3

(Ti-18.5Co)

[0028] Another specific, non-limiting example of the disclosed titanium-cobalt alloy has the following nominal composition: Ti-18.5Co and the measured composition shown in Table 5.

TABLE 5

Element	Concentration (wt%)
Ti	Balance
Co	18.9 ± 0.2
O	0.154 ± 0.012
N	0.010 ± 0.007

[0029] PANDAT™ software (version 2014 2.0) was used to generate liquid fraction versus temperature data for the disclosed Ti-18.5Co alloy, assuming both equilibrium conditions and Scheil conditions. The results are shown in Figs. 2A (equilibrium conditions) and 2B (Scheil conditions). Based on the data from Fig. 2A (equilibrium conditions), the disclosed Ti-18.5Co alloy has a *solidus* temperature of 1,015 °C and a *liquidus* temperature of 1,321 °C, with a solidification range of 306 °C.

[0030] Referring to Fig. 3B, the disclosed Ti-18.5Co alloy was heated to 1,060 °C—a temperature between the *solidus* and *liquidus* temperatures (i.e., a thixoforming temperature)—and micrographs were taken at 0 seconds, 60 seconds, 300 seconds and 600 seconds. The micrographs show how the disclosed Ti-18.5Co alloy has a globular microstructure at 1,060 °C that becomes increasingly globular over time. Therefore, the disclosed Ti-18.5Co alloy is particularly well-suited for thixoforming.

Example 4

(Ti-19.5Co)

[0031] Another specific, non-limiting example of the disclosed titanium-cobalt alloy has the following nominal composition:

Ti-19.5Co

and the measured composition shown in Table 6.

TABLE 6

Element	Concentration (wt%)
Ti	Balance
Co	19.6 ± 0.2
O	0.147 ± 0.003
N	0.007 ± 0.002

[0032] PANDAT™ software (version 2014 2.0) was used to generate liquid fraction versus temperature data for the disclosed Ti-19.5Co alloy, assuming both equilibrium conditions and Scheil conditions. The results are shown in Figs. 2A (equilibrium conditions) and 2B (Scheil conditions). Based on the data from Fig. 2A (equilibrium conditions), the disclosed Ti-19.5Co alloy has a *solidus* temperature of 1,015 °C and a *liquidus* temperature of 1,291 °C, with a solidification range of 276 °C.

[0033] Referring to Fig. 3C, the disclosed Ti-19.5Co alloy was heated to 1,060 °C—a temperature between the *solidus* and *liquidus* temperatures (i.e., a thixoforming temperature)—and micrographs were taken at 0 seconds, 60 seconds, 300 seconds and 600 seconds. The micrographs show how the disclosed Ti-19.5Co alloy has a globular microstructure at 1,060 °C that becomes increasingly globular over time. Therefore, the disclosed Ti-19.5Co alloy is particularly well-suited for thixoforming.

Example 5

(Ti-20.5Co)

[0034] Another specific, non-limiting example of the disclosed titanium-cobalt alloy has the following nominal composition:

Ti-20.5Co

and the measured composition shown in Table 7.

TABLE 7

Element	Concentration (wt%)
Ti	Balance
Co	20.5 ± 0.3
O	0.143 ± 0.004
N	0.006 ± 0.001

[0035] PANDAT™ software (version 2014 2.0) was used to generate liquid fraction versus temperature data for the disclosed Ti-20.5Co alloy, assuming both equilibrium conditions and Scheil conditions. The results are shown in Figs. 2A (equilibrium conditions) and 2B (Scheil conditions). Based on the data from Fig. 2A (equilibrium conditions), the disclosed Ti-20.5Co alloy has a *solidus* temperature of 1,015 °C and a *liquidus* temperature of 1,259 °C, with a solidification range of 244 °C.

[0036] Referring to Fig. 3D, the disclosed Ti-20.5Co alloy was heated to 1,060 °C—a temperature between the *solidus* and *liquidus* temperatures (i.e., a thixoforming temperature)—and micrographs were taken at 0 seconds, 60 seconds, 300 seconds and 600 seconds. The micrographs show how the disclosed Ti-20.5Co alloy has a globular microstructure at 1,060 °C that becomes increasingly globular over time. Therefore, the disclosed Ti-20.5Co alloy is particularly well-

suited for thixoforming.

[0037] Accordingly, disclosed are titanium-cobalt alloys that are well-suited for thixoforming. Also, disclosed are methods for manufacturing a metallic article, particularly a titanium alloy article, by way of thixoforming.

[0038] Referring now to Fig. 4, one embodiment of the disclosed method for manufacturing a metallic article, generally designated 10, begins at Block 12 with the selection of a titanium alloy for use as a starting material. The selection of a titanium alloy (Block 12) includes selecting a titanium-cobalt alloy having the composition shown in Table 1, above. Optionally, the titanium-cobalt alloy has one or more of the impurities shown in Table 2, above.

[0039] As is disclosed herein, the solidification range is one consideration during selection (Block 12) of a titanium alloy. Selection of a titanium alloy (Block 12) includes selecting a titanium-cobalt alloy having a solidification range of at least 100 °C. For example, the solidification range may be at least 150 °C, or at least 200 °C or at least 250 °C, or at least 300 °C.

[0040] As is also disclosed herein, the temperature at which a liquid fraction between 30 percent and 50 percent is achieved may be another consideration during selection (Block 12) of a titanium alloy. For example, selection of a titanium alloy (Block 12) may include selecting a titanium-cobalt alloy that achieves a liquid fraction between 30 percent and 50 percent at a temperature less than 1,200 °C, such as a temperature less than 1,150 °C, or a temperature less than 1,100 °C, or a temperature less than 1,050 °C.

[0041] At Block 14, a mass of the titanium alloy is heated to a thixoforming temperature (i.e., a temperature between the *solidus* and *liquidus* temperatures of the titanium alloy). In one particular implementation, the mass of the titanium alloy is heated to a particular thixoforming temperature, and the particular thixoforming temperature may be selected to achieve a desired liquid fraction in the mass of the titanium alloy. As one example, the desired liquid fraction may be 10 percent to 70 percent. As another example, the desired liquid fraction may be 20 percent to 60 percent. As yet example, the desired liquid fraction may be 30 percent to 50 percent.

[0042] At Block 16, the mass of the titanium alloy is maintained at the thixoforming temperature for a predetermined minimum amount of time prior to proceeding to the next step (Block 18). The predetermined minimum amount of time is 600 seconds.

[0043] At Block 18, the mass of the titanium alloy is formed into a metallic article while the mass is at the thixoforming temperature. Various forming techniques may be used, such as, without limitation, casting and molding.

[0044] Accordingly, the disclosed titanium-cobalt alloy and associated thixoforming method may facilitate the manufacture of net shape (or near net shape) titanium alloy articles at temperatures that are significantly lower than traditional titanium casting temperatures, and without the need for the complex/expensive tooling typically associated with plastic forming of titanium alloys. Therefore, the disclosed titanium-cobalt alloy and associated thixoforming method have the potential to significantly reduce the cost of manufacturing titanium alloy articles.

[0045] Examples of the disclosure may be described in the context of an aircraft manufacturing and service method 100, as shown in Fig. 5, and an aircraft 102, as shown in Fig. 6. During pre-production, the aircraft manufacturing and service method 100 includes specification and design 104 of the aircraft 102 and material procurement 106. During production, component/subassembly manufacturing 108 and system integration no of the aircraft 102 takes place. Thereafter, the aircraft 102 goes through certification and delivery 112 in order to be placed in service 114. While in service by a customer, the aircraft 102 is scheduled for routine maintenance and service 116, which may also include modification, reconfiguration, refurbishment and the like.

[0046] Each of the processes of method 100 may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

[0047] As shown in Fig. 6, the aircraft 102 produced by example method 100 includes an airframe 118 with a plurality of systems 120 and an interior 122. Examples of the plurality of systems 120 includes one or more of a propulsion system 124, an electrical system 126, a hydraulic system 128, and an environmental system 130. Any number of other systems may be included.

[0048] The disclosed titanium-cobalt alloy and associated thixoforming method may be employed during any one or more of the stages of the aircraft manufacturing and service method 100. As one example, components or subassemblies corresponding to component/subassembly manufacturing 108, system integration 110, and or maintenance and service 116 are fabricated or manufactured using the disclosed titanium-cobalt alloy and associated thixoforming method. As another example, the airframe 118 is constructed using the disclosed titanium-cobalt alloy and associated thixoforming method. Also, one or more apparatus examples, method examples, or a combination thereof may be utilized during component/subassembly manufacturing 108 and/or system integration 110, for example, by substantially expediting assembly of or reducing the cost of an aircraft 102, such as the airframe 118 and/or the interior 122. Similarly, one or more of system examples, method examples, or a combination thereof may be utilized while the aircraft 102 is in service, for example and without limitation, to maintenance and service 116.

[0049] The disclosed titanium-cobalt alloy and associated thixoforming method is described in the context of an aircraft; however, one of ordinary skill in the art will readily recognize that the disclosed titanium-cobalt alloy and associated thixoforming method may be utilized for a variety of applications. For example, the disclosed titanium-cobalt alloy and associated thixoforming method may be implemented in various types of vehicle including, for example, helicopters, passenger ships, automobiles, marine products (boat, motors, etc.) and the like. Various non-vehicle applications, such as medical applications, are also contemplated.

[0050] Although various embodiments of the disclosed titanium-cobalt alloy and associated thixoforming method have been shown and described, modifications may occur to those skilled in the art upon reading the specification. The present application includes such modifications and is limited only by the scope of the claims.

Claims

1. A method for manufacturing a metallic article comprising:

heating a mass of titanium alloy to a thixoforming temperature, said thixoforming temperature being between a *solidus* temperature of said titanium alloy and a *liquidus* temperature of said titanium alloy, said titanium alloy comprising 5 to 27 percent by weight cobalt, optionally one or more of the following impurities:

Impurity	Maximum (wt%)
Oxygen	0.25
Nitrogen	0.03
Other elements, each	0.10
Other elements, total	0.30

and balance titanium,

wherein a difference between said *solidus* temperature and said *liquidus* temperature of said titanium alloy is at least 100 °C; and

forming said mass into said metallic article while said mass is at said thixoforming temperature, further comprising maintaining said mass at said thixoforming temperature for at least 600 seconds prior to said forming said mass into said metallic article.

2. The method of Claim 1 further comprising selecting said titanium alloy such that a difference between said *solidus* temperature and said *liquidus* temperature is at least 200 °C.
3. The method of Claim 2 further comprising selecting said titanium alloy such that a difference between said *solidus* temperature and said *liquidus* temperature is at least 250 °C.
4. The method of any one of Claims 1-3 further comprising selecting said titanium alloy to have a liquid fraction between 30 percent and 50 percent at a temperature less than 1,200 °C.
5. The method of any one of Claims 1-3 further comprising selecting said titanium alloy to have a liquid fraction between 30 percent and 50 percent at a temperature less than 1,100 °C.
6. The method of any one of Claims 1-5 wherein said cobalt is present in said titanium alloy at 10 to 27 percent by weight.
7. The method of Claim 6 wherein said cobalt is present in said titanium alloy at 13 to 27 percent by weight.
8. The method of Claim 7 wherein said cobalt is present at 15 to 25 percent by weight.
9. The method of Claim 8 wherein said cobalt is present in said titanium alloy at 17 to 23 percent by weight.
10. The method of Claim 9 wherein said cobalt is present in said titanium alloy at 17 to 21 percent by weight.

11. The method of any one of Claims 1-10 wherein said titanium alloy consists of said cobalt and said titanium.
12. The method of Claim 1 wherein said forming said mass into said metallic article while said mass is at said thixoforming temperature comprises one of casting and molding.

Patentansprüche

1. Verfahren zum Herstellen eines metallischen Artikels, das aufweist:

Erhitzen einer Titanlegierungsmasse auf eine Thixoformungstemperatur, wobei die Thixoformungstemperatur zwischen einer Solidustemperatur der Titanlegierung und einer Liquidustemperatur der Titanlegierung liegt, wobei die Titanlegierung 5 bis 27 Gewichtsprozent Kobalt enthält, optional einen oder mehrere der folgenden Fremdstoffe:

Fremdstoff	Maximum (Gew.-%)
Sauerstoff	0,25
Stickstoff	0,03
Andere Elemente, jeweils	0,10
Andere Elemente, gesamt	0,30

und den Rest Titan,
wobei eine Differenz zwischen der Solidustemperatur und der Liquidustemperatur der Titanlegierung wenigstens 100°C beträgt; und
Ausbilden der Masse zu dem metallischen Artikel, während sich die Masse auf der Thixoformungstemperatur befindet, des Weiteren aufweisend das Halten der Masse auf der Thixoformungstemperatur für wenigstens 600 Sekunden vor dem Ausbilden der Masse zu dem metallischen Artikel.

2. Verfahren nach Anspruch 1, das des Weiteren das Auswählen der Titanlegierung derart aufweist, dass eine Differenz zwischen der Solidustemperatur und der Liquidustemperatur wenigstens 200°C beträgt.
3. Verfahren nach Anspruch 2, das des Weiteren das Auswählen der Titanlegierung derart aufweist, dass eine Differenz zwischen der Solidustemperatur und der Liquidustemperatur wenigstens 250°C beträgt.
4. Verfahren nach einem der Ansprüche 1 bis 3, das des Weiteren das Auswählen der Titanlegierung aufweist, um einen Flüssiganteil zwischen 30 Prozent und 50 Prozent bei einer Temperatur von weniger als 1.200°C zu haben.
5. Verfahren nach einem der Ansprüche 1 bis 3, das des Weiteren das Auswählen der Titanlegierung aufweist, um einen Flüssiganteil zwischen 30 Prozent und 50 Prozent bei einer Temperatur von weniger als 1.100°C zu haben.
6. Verfahren nach einem der Ansprüche 1 bis 5, wobei das Kobalt in der Titanlegierung mit 10 bis 27 Gewichtsprozent vorliegt.
7. Verfahren nach Anspruch 6, wobei das Kobalt in der Titanlegierung mit 13 bis 27 Gewichtsprozent vorliegt.
8. Verfahren nach Anspruch 7, wobei das Kobalt mit 15 bis 25 Gewichtsprozent vorliegt.
9. Verfahren nach Anspruch 8, wobei das Kobalt in der Titanlegierung mit 17 bis 23 Gewichtsprozent vorliegt.
10. Verfahren nach Anspruch 9, wobei das Kobalt in der Titanlegierung mit 17 bis 21 Gewichtsprozent vorliegt.
11. Verfahren nach einem der Ansprüche 1 bis 10, wobei die Titanlegierung aus dem Kobalt und dem Titan besteht.
12. Verfahren nach Anspruch 1, wobei das Ausbilden der Masse zu dem metallischen Artikel, während sich die Masse auf der Thixoformungstemperatur befindet, eines aufweist von Gießen und Formen.

Revendications

1. Procédé destiné à fabriquer un article métallique, comprenant :

le chauffage d'une masse d'alliage de titane à une température de thixoformage, ladite température de thixoformage étant comprise entre une température de *solidus* dudit alliage de titane et une température de *liquidus* dudit alliage de titane, ledit alliage de titane comprenant 5 à 27 % en poids de cobalt, en option une ou plusieurs des impuretés suivantes :

Impureté	Maximum (% en poids)
Oxygène	0,25
Azote	0,03
Autres éléments, chacun	0,10
Autres éléments, total	0,30

et le solde en titane,

dans lequel une différence entre ladite température de *solidus* et ladite température de *liquidus* dudit alliage de titane est au moins de 100 °C ; et

la formation de ladite masse dans ledit article métallique pendant que ladite masse est à ladite température de thixoformage, comprenant en outre le maintien de ladite masse à ladite température de thixoformage pendant au moins 600 secondes avant ladite formation de ladite masse dans ledit article métallique.

2. Procédé selon la revendication 1, comprenant en outre la sélection dudit alliage de titane de telle sorte qu'une différence entre ladite température de *solidus* et ladite température de *liquidus* est au moins de 200 °C.
3. Procédé selon la revendication 2, comprenant en outre la sélection dudit alliage de titane de telle sorte qu'une différence entre ladite température de *solidus* et ladite température de *liquidus* est au moins de 250 °C.
4. Procédé selon une quelconque des revendications 1 à 3, comprenant en outre la sélection dudit alliage de titane pour avoir une fraction liquide entre 30 % et 50 % à une température inférieure à 1 200 °C.
5. Procédé selon une quelconque des revendications 1 à 3, comprenant en outre la sélection dudit alliage de titane pour avoir une fraction liquide entre 30 % et 50 % à une température inférieure à 1 100 °C.
6. Procédé selon une quelconque des revendications 1 à 5, dans lequel ledit cobalt est présent dans ledit alliage de titane pour 10 à 27 % en poids.
7. Procédé selon la revendication 6, dans lequel ledit cobalt est présent dans ledit alliage de titane pour 13 à 27 % en poids.
8. Procédé selon la revendication 7, dans lequel ledit cobalt est présent pour 15 à 25 % en poids.
9. Procédé selon la revendication 8, dans lequel ledit cobalt est présent dans ledit alliage de titane pour 17 à 23 % en poids.
10. Procédé selon la revendication 9, dans lequel ledit cobalt est présent dans ledit alliage de titane pour 17 à 21 % en poids.
11. Procédé selon une quelconque des revendications 1 à 10, dans lequel ledit alliage de titane consiste en ledit cobalt et ledit titane.
12. Procédé selon la revendication 1, dans lequel ladite formation de ladite masse dans ledit article métallique pendant que ladite masse est à ladite température de thixoformage comprend une action de coulage et de moulage.

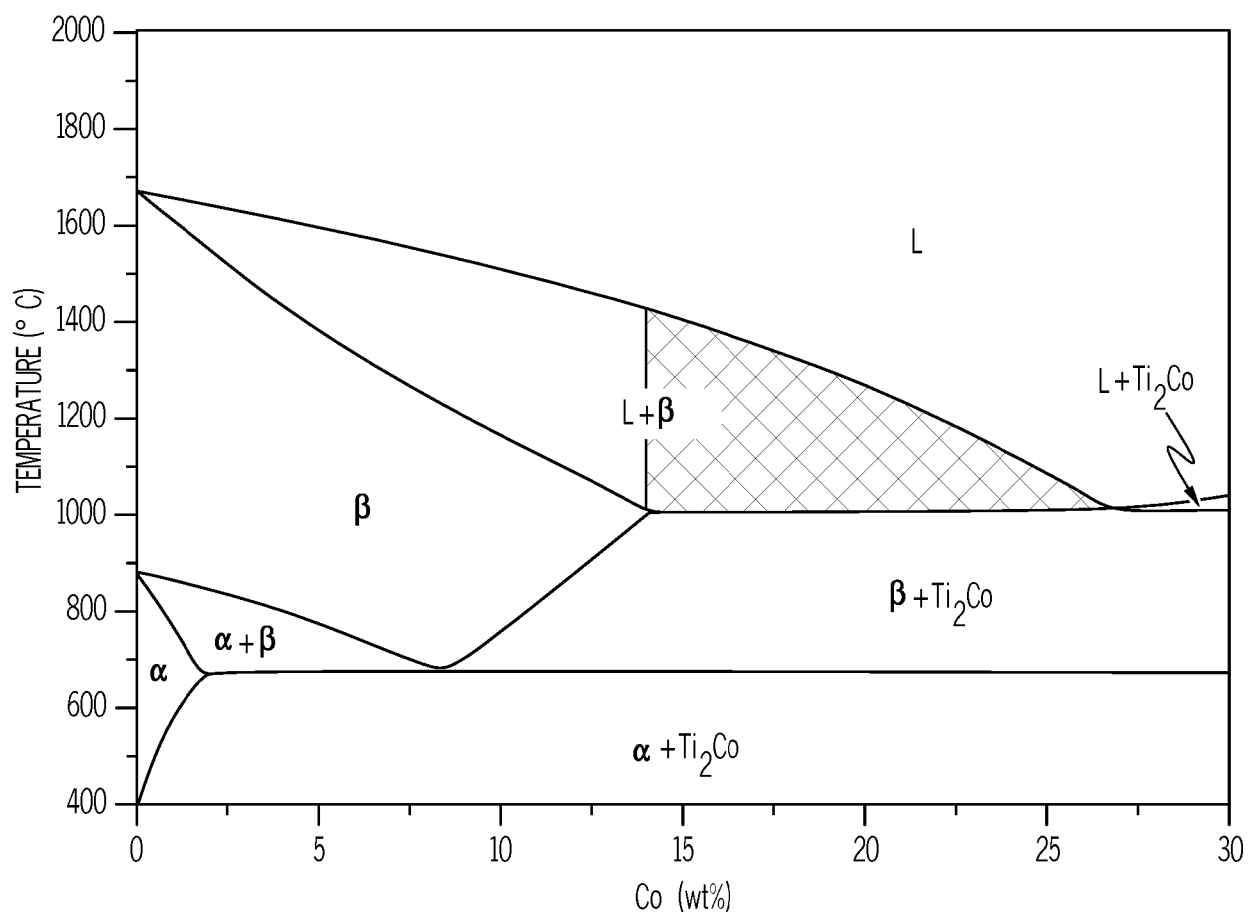


FIG. 1

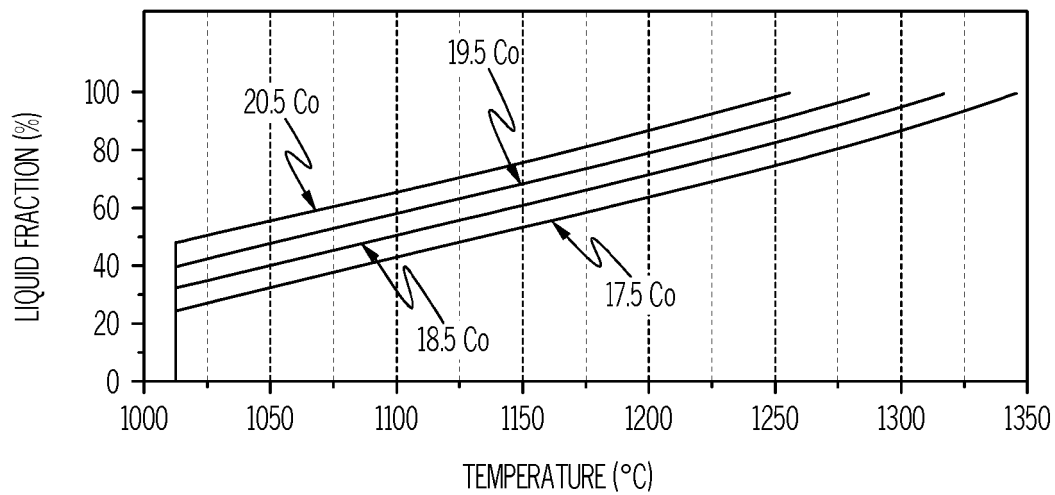


FIG. 2A

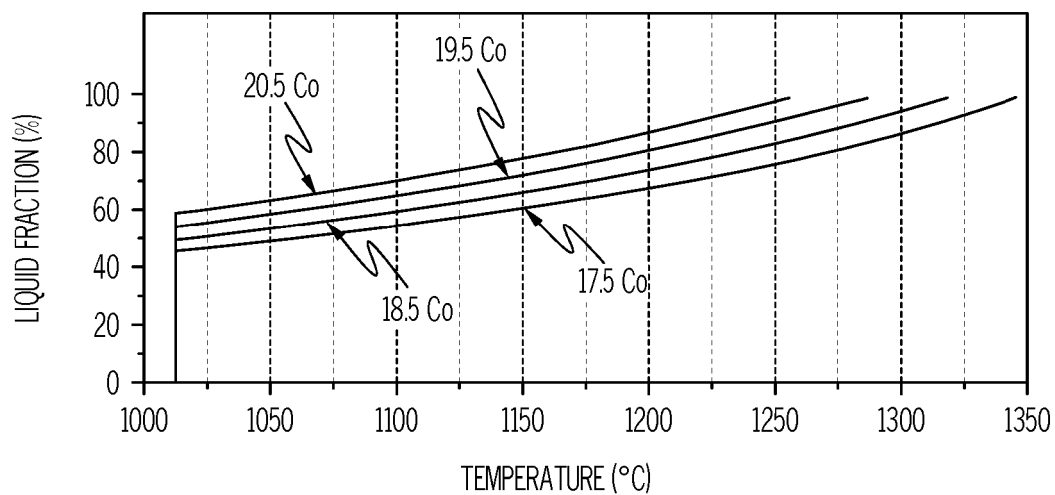


FIG. 2B

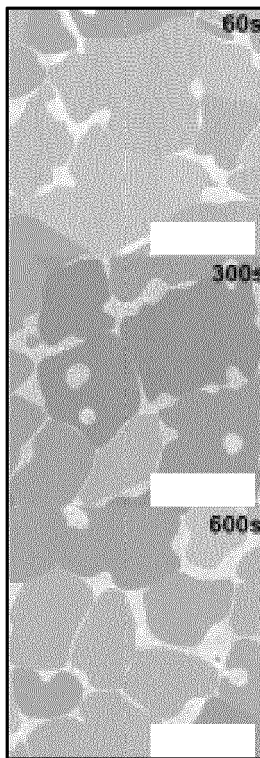


FIG. 3A

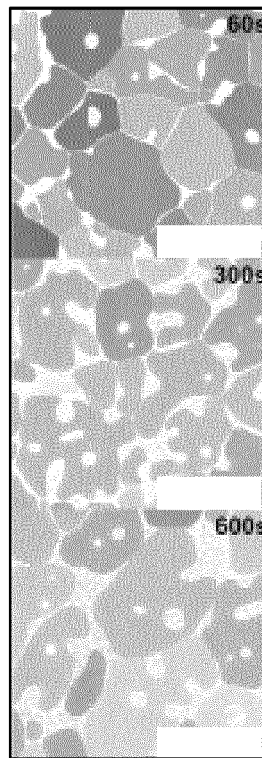


FIG. 3B

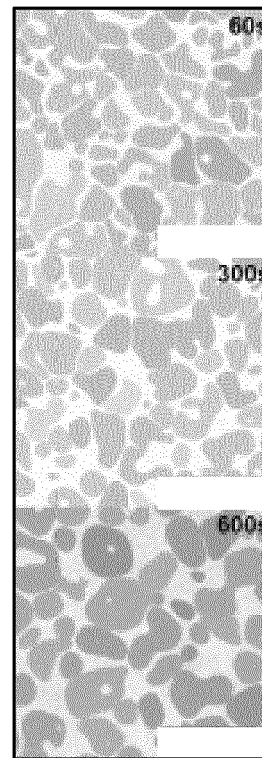


FIG. 3C

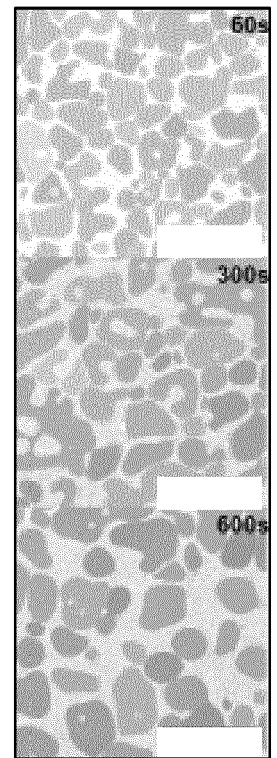


FIG. 3D

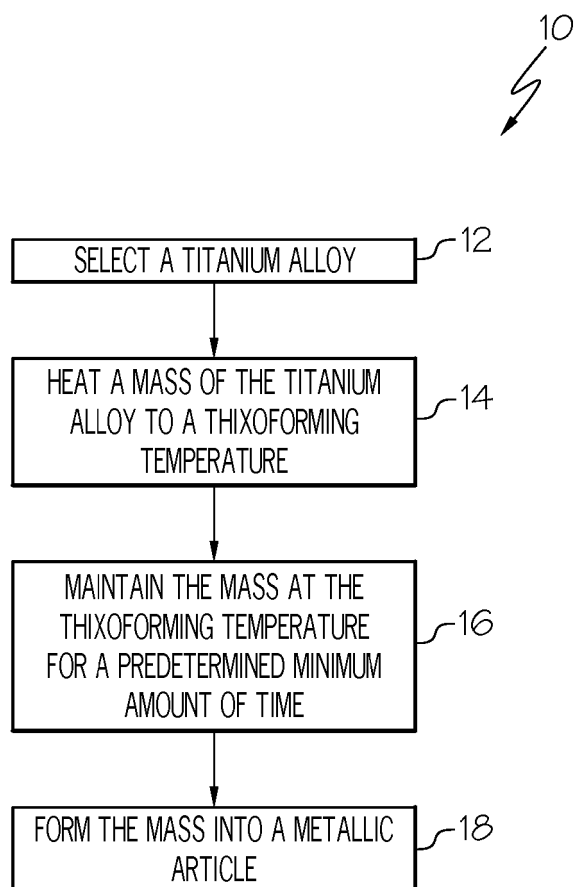


FIG. 4

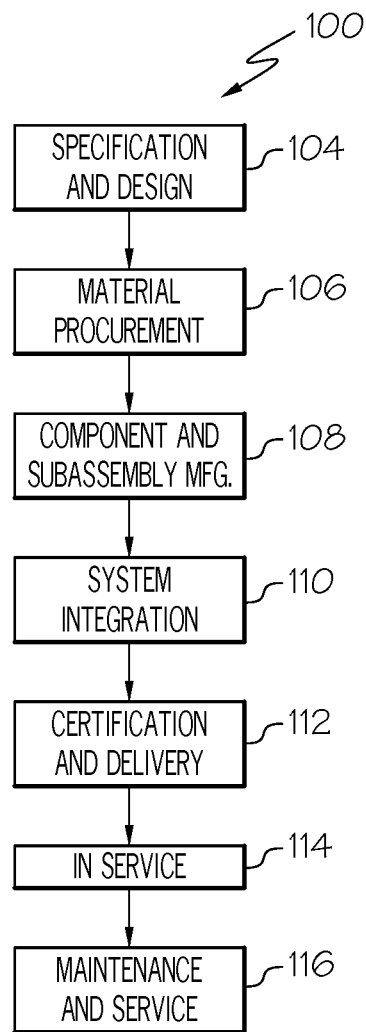


FIG. 5

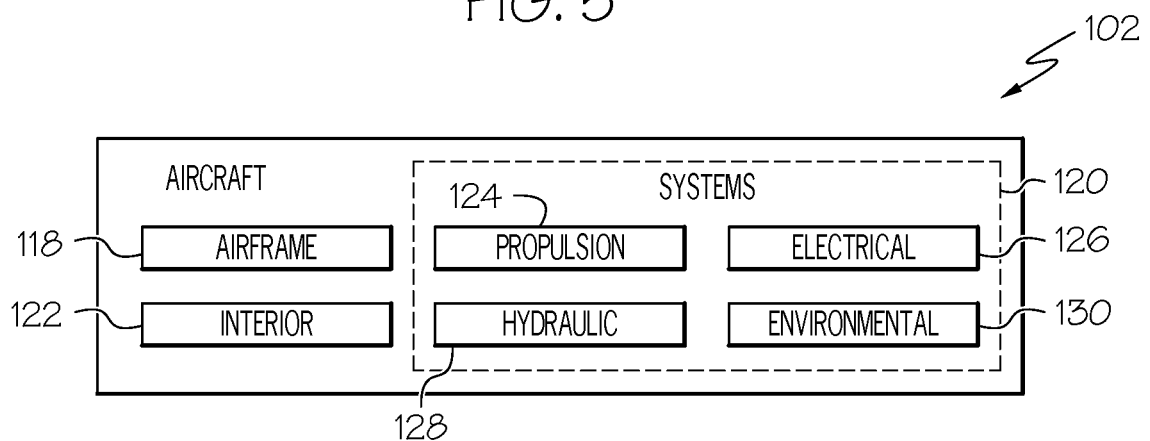


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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