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(54) **IMPROVEMENTS RELATING TO COMPONENTS MANUFACTURED FROM METAL ALLOYS**

(57) A component, such as a nickel alloy turbine disc, is disclosed. The component has a composition gradient through the component and comprises a first region having a first metal alloy composition and comprising a gamma prime phase; and a second region having a second metal alloy composition and comprising a gamma prime phase. The gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition; and the average grain size of the first metal alloy composition is larger than the average grain size of the second metal alloy composition. A method of manufacturing such a component from metal alloy powders is also disclosed.

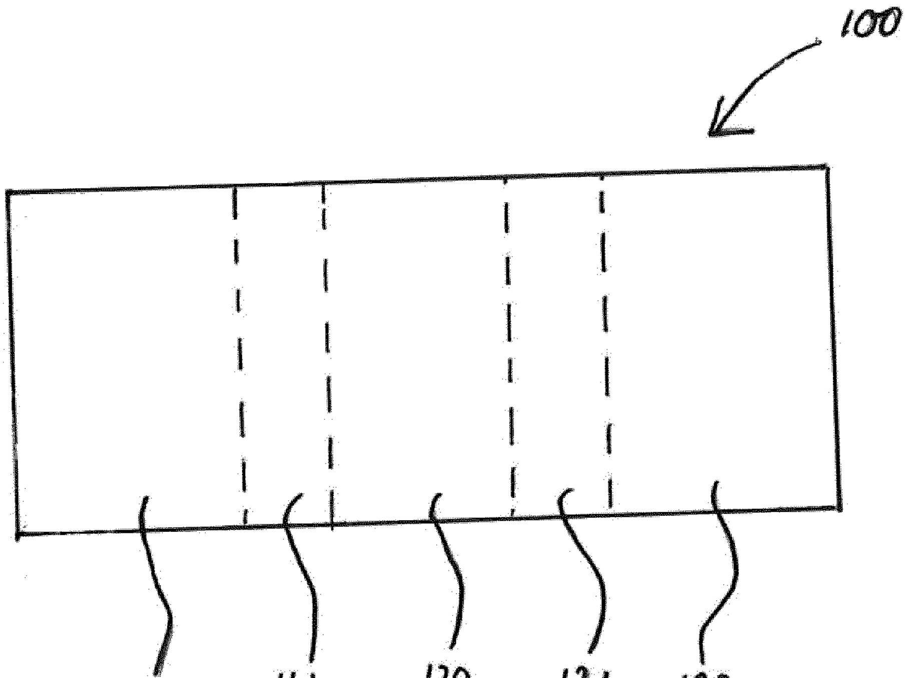

Figure 1

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Description

[0001] The present disclosure relates to components manufactured from metal alloys and to a method of manufacturing such components from metal alloy powders.

[0002] In particular the disclosure is concerned with components, for example turbine discs, having a composition gradient across at least one dimension of the component and different grain sizes in different regions of the component.

Background

[0003] Turbine discs used in the turbine end of gas turbines may be typically made of the nickel alloys IN718 or Nimonic 80. IN718 is typically prone to stress assisted grain boundary oxidation also called "SAGBO" which limits its use to temperatures of less than 550 °C. Such turbine discs may suffer from an intergranular type brittle mode of cracking caused by the SAGBO effect.

[0004] Different regions of a turbine disc ideally require different mechanical properties. For example, the rim region of the disc which is in contact with the turbine blades is typically at a higher temperature than the hub of the disc, in use. This is because the turbine blades are exposed to the high temperature combustion gases and subsequently the high temperature turbine blades heat up the rim region of the disc. The higher temperature at the rim region means that the rim region should ideally have better creep resistance. This may be achieved with a coarse grain size of the nickel alloy. The hub of the disc would not require as high a creep resistance as the rim but would require higher low cycle fatigue resistance due to the centrifugal loading experienced by the hub. Higher low cycle fatigue resistance at the hub may be achieved with a fine grain size of the nickel alloy.

[0005] Hence a metal alloy component, such as a turbine disc, having more favourable grain sizes at the appropriate regions of the component, for example at the rim and hub regions of a turbine disc, and therefore providing better mechanical properties at said regions, is highly desirable.

[0006] US patent 6,660,110 B1 provides a dual heat treatment process for producing a component comprising different grain sizes in different regions. A dual heat treatment process may be more complicated and costly than a single temperature heat treatment process.

[0007] US patent 7,895,874 B2 provides a multistep forging method for obtaining a component comprising different grain sizes in different regions. A multistep forging method may be more complicated and costly than a single step forming process followed by heat treatment.

Summary

[0008] According to the present disclosure there is provided a component and a method of manufacturing components as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

[0009] The inventors have analysed a turbine disc made of IN718 by a standard method of hot die forging. It was observed that the grain size distribution in the disc was the opposite to the ideal distribution described above, namely that the rim region (grain size in the range of ASTM 11-12) had a finer grain size than the hub region (grain size in the range of ASTM 10-10.5). This grain size distribution is not considered to provide the ideal creep resistance at the rim region or the ideal low cycle fatigue resistance at the hub region.

[0010] The reason for this difference in grain size distribution may be due to the hot die forging of these turbine discs which allows greater recrystallization of grains at the outer edge of the forged disc due to the higher temperature at the rim region compared to the hub region.

[0011] It may therefore be an aim of the present invention to provide a component, such as a turbine disc, having more favourable grain sizes at the appropriate regions of the component, for example at the rim and hub regions of a turbine disc, and therefore providing better mechanical properties at said regions.

[0012] According to a first aspect of the present invention, there is provided a component comprising:

a first region having a first metal alloy composition and comprising a first gamma prime phase; and

a second region having a second metal alloy composition and comprising a second gamma prime phase;

wherein the gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition; and

wherein the average grain size of the first metal alloy composition in the first region is larger than the average grain size of the second metal alloy composition in the second region.

[0013] The component of this first aspect may be considered to have a composition gradient across at least one dimension, between the first region and the second region.

[0014] A composition gradient is typically considered to be a variance in composition across a component, for example the metal alloy composition of the component may vary in one or more constituents of the metal alloy along the component.

[0015] Suitably the composition gradient is a gradual change in composition from the first region to the second region of the component. Such a composition gradient may be distinct from a step change in composition between different regions in components formed from metal alloys of the prior art.

[0016] Suitably the first metal alloy composition and the second metal alloy composition are similar and vary in the amount of one or more elements or compounds, suitably metallic elements, present in the compositions.

[0017] Suitably the first metal alloy composition and the second metal alloy composition are 80 % similar, suitably 85 % similar, suitably 90 % similar, suitably 95 % similar.

[0018] Suitably the different metal alloy compositions at different regions of the component, for example the first and second metal alloy compositions, are mixed with the adjacent metal alloy composition at an interface region.

[0019] The inventors have found that providing the component of this first aspect allows the different metal alloy compositions at different regions of the component, for example the first and second metal alloy compositions, to mix in this way at interface regions to provide a more gradual change in composition and properties from one region to the adjacent region than is possible in prior art components. This may also provide a stronger bond between adjacent regions than is possible in prior art components.

[0020] Suitably the component has a composition gradient along the length of the component.

[0021] Suitably the first metal alloy composition and the second metal alloy composition comprise respective gamma and gamma prime phases and therefore an associated gamma prime solvus temperature at which the gamma prime phase is soluble in the gamma phase. The gamma prime solvus temperature may be measured by standard techniques such as differential thermal analysis (DTA).

[0022] The gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition. Suitably the gamma prime solvus temperature of the second metal alloy composition is 15 °C higher than the gamma prime solvus temperature of the first metal alloy composition, suitably 20 °C higher, suitably 25 °C higher, suitably 30 °C higher.

[0023] Suitably the average grain size of the metal alloy compositions are measured according to the methods of ASTM E112-12 "Standard Test Methods for Determining Average Grain Size".

[0024] The average grain size of the first metal alloy composition in the first region is larger than the average grain size of the second metal alloy composition in the second region.

[0025] Suitably the average grain size of the first metal alloy composition is a coarse grain size according to ASTM 9, suitably in the range of ASTM 2 to 9.

[0026] Suitably the average grain size of the second metal alloy composition is a fine grain size according to ASTM 10-13.

[0027] The inventors have found that the component according to this first aspect has average grain sizes of the metal alloy compositions at different regions on the component, for example at the first and second regions, which may provide different mechanical properties at said regions which may be more beneficial to the function of the component than a similar component not having the composition gradient, grain size distribution and gamma prime solvus temperature relationship defined in this first aspect. Advantageously, this grain size distribution can be obtained by using a single heat treatment process on the entire component, suitably at a single temperature, said temperature being higher than the gamma prime solvus temperature of the first metal alloy composition and lower than the gamma prime solvus temperature of the second metal alloy composition. Such a single heat treatment step at a single temperature may provide significant improvements in the efficiency of a manufacturing process used to produce the component.

[0028] Suitably the first metal alloy composition is enriched in an element or a compound which decreases the gamma prime solvus temperature of the first metal alloy composition, compared to the second metal alloy composition.

[0029] Suitably the first metal alloy composition is enriched in a metallic element which decreases the gamma prime solvus temperature of the first metal alloy composition, compared to the second metal alloy composition.

[0030] By enriched we mean that the first metal alloy composition comprises more of the element or compound than the second metal alloy composition. Therefore in order to accommodate an increased amount of said element or compound, the amount of one or more other elements or compounds of the first metal alloy composition are lower than in the second metal alloy composition. By enriched we mean to include embodiments wherein the first metal alloy composition comprises an element or a compound which decreases the gamma prime solvus temperature of the first metal alloy composition, which is not present in the second metal alloy composition.

[0031] Suitably the metallic element which decreases the gamma prime solvus temperature of the first metal alloy composition is cobalt and/or chromium.

[0032] Suitably the metallic element which decreases the gamma prime solvus temperature of the first metal alloy composition is cobalt.

[0033] Suitably the first metal alloy composition comprises at least 3.0 wt% cobalt, suitably at least 4.0 wt%, suitably at least 5.0 wt%, suitably at least 6.0 wt%.

[0034] Suitably the first metal alloy composition comprises up to 11 wt% cobalt, suitably up to 10 wt%, suitably up to 9.0 wt%, suitably up to 8.0 wt%.

[0035] Suitably the first metal alloy composition comprises from 4.0 to 10 wt% cobalt, suitably from 4.0 to 9.0 wt%, suitably from 5.0 to 8.0 wt%, suitably from 6.0 to 8.0 wt%.

[0036] Suitably the first metal alloy composition comprises at least 10 wt% chromium, suitably at least 12 wt%, suitably at least 14 wt%, suitably at least 16 wt%.

[0037] Suitably the first metal alloy composition comprises up to 24 wt% chromium, suitably up to 22 wt%, suitably up to 20 wt%, suitably up to 18 wt%.

[0038] Suitably the first metal alloy composition comprises from 11 to 23 wt% chromium, suitably from 13 to 21 wt%, suitably from 15 to 19 wt%, suitably from 15 to 18 wt%.

[0039] Suitably the first and second metal alloy compositions comprise aluminium and titanium. The ratio of aluminium to titanium in the metal alloy compositions may be associated with the creep resistance of the respective regions of the component. A higher ratio of aluminium to titanium may provide an improved creep resistance. Therefore the first metal alloy composition may be enriched in titanium compared to the second metal alloy composition to provide a higher ratio of aluminium to titanium in the first metal alloy composition compared to the second metal alloy composition, in order to provide an improved creep resistance in the first region compared to the second region.

[0040] Suitably the first metal alloy composition comprises at least 2.0 wt% aluminium, suitably at least 2.5 wt%, suitably at least 3.0 wt%, suitably at least 3.5 wt%.

[0041] Suitably the first metal alloy composition comprises up to 5.5 wt% aluminium, suitably up to 5.0 wt%, suitably up to 4.5 wt%, suitably up to 4.0 wt%.

[0042] Suitably the first metal alloy composition comprises from 2.8 to 5.0 wt % aluminium, suitably from 2.8 to 4.4 wt %, suitably from 3.0 to 4.2 wt %, suitably from 3.0 to 4.0 wt%.

[0043] Suitably the first metal alloy composition comprises at least 0.8 wt% titanium, suitably at least 1.0 wt%, suitably at least 1.2 wt%, suitably at least 1.4 wt%.

[0044] Suitably the first metal alloy composition comprises up to 2.2 wt% titanium, suitably up to 2.0 wt%, suitably up to 1.8 wt%, suitably up to 1.6 wt%.

[0045] Suitably the first metal alloy composition comprises from 0.7 to 2.3 wt % titanium, suitably from 0.9 to 2.1 wt %, suitably from 1.0 to 1.9 wt %, suitably from 1.0 to 1.7 wt%.

[0046] Suitably the first metal alloy composition comprises a ratio of aluminium to titanium of from 0.8 to 1.6, suitably from 1.0 to 1.4, suitably approximately 1.2.

[0047] Alternatively or additionally, the first metal alloy composition may be enriched in boron compared to the second metal alloy composition to provide an improved creep resistance in the first region compared to the second region.

[0048] Suitably the second metal alloy composition comprises at least 0.5 wt% cobalt, suitably at least 1.0 wt%, suitably at least 1.5 wt%, suitably approximately 2.0 wt% cobalt.

[0049] Suitably the second metal alloy composition comprises up to 3.0 wt% cobalt, suitably up to 2.5 wt%, suitably up to 2.0 wt%.

[0050] Suitably the second metal alloy composition comprises at least 10 wt% chromium, suitably at least 11 wt%, suitably at least 12 wt%, suitably at least 13 wt%.

[0051] Suitably the second metal alloy composition comprises up to 17 wt% chromium, suitably up to 16 wt%, suitably up to 15 wt%, suitably up to 14 wt%.

[0052] Suitably the second metal alloy composition comprises from 10 to 15 wt% chromium, suitably from 10 to 16 wt%, suitably from 12 to 16 wt%, suitably from 12 to 15 wt%.

[0053] Suitably the second metal alloy composition may be enriched in one or more of niobium, tungsten and molybdenum, compared to the first metal alloy composition, which may provide an improved strength in the second region compared to the first region.

[0054] Suitably the second metal alloy composition comprises at least 0.1 wt% niobium, suitably at least 0.2 wt%, suitably at least 0.5 wt%.

[0055] Suitably the second metal alloy composition comprises up to 2.0 wt% niobium, suitably up to 1.5 wt%, suitably up to 1.0 wt%.

[0056] Suitably the second metal alloy composition comprises at least 2.0 wt% tungsten, suitably at least 3.0 wt%, suitably at least 4.0 wt%.

[0057] Suitably the second metal alloy composition comprises up to 6.0 wt% tungsten, suitably up to 5.0 wt%, suitably up to 4.5 wt%.

[0058] Suitably the second metal alloy composition comprises from 3.0 to 6.0 wt% tungsten, suitably from 3.0 to 5.0 wt%, suitably from 4.0 to 6.0 wt%, suitably from 4.0 to 5.0 wt%.

[0059] The second metal alloy composition may comprise molybdenum, suitably from 0.5 to 2.5 wt%, suitably from 1.0 to 2.0 wt%.

[0060] Suitably the second metal alloy composition comprises a ratio of aluminium to titanium of from 0.4 to 0.8, suitably from 0.5 to 0.7, suitably from 0.6 to 0.7.

[0061] Suitably the component of this first aspect comprises an intermediate region having an intermediate metal alloy composition wherein the intermediate metal alloy composition in the intermediate region has a gamma prime solvus temperature higher than the gamma prime solvus temperature of the first metal alloy composition in the first region and lower than the gamma prime solvus temperature of the second metal alloy composition in the second region.

[0062] Suitably the intermediate metal alloy composition comprises the element or compound which decreases the gamma prime solvus temperature of the first metal alloy composition in the first region compared to the second metal alloy composition in the second region, in an amount between the amount of said element or compound in the first metal alloy composition and the amount of said element or compound in the second metal alloy composition.

[0063] Suitably the intermediate metal alloy composition is 85 % similar to first and second metal alloy compositions, suitably 90 % similar, suitably 95 % similar.

[0064] In embodiments wherein the component comprises an intermediate region, suitably the intermediate region is arranged between the first and second regions of the component.

[0065] Suitably the intermediate metal alloy composition comprises at least 1.0 wt% cobalt, suitably at least 2.0 wt%, suitably at least 3.0 wt%.

[0066] Suitably the intermediate metal alloy composition comprises up to 6.0 wt% cobalt, suitably up to 5.0 wt%, suitably up to 4.0 wt%.

[0067] Suitably the intermediate metal alloy composition comprises from 2.0 to 5.0 wt% cobalt, suitably from 3.0 to 5.0 wt%, suitably from 3.0 to 4.0 wt%.

[0068] Suitably the intermediate metal alloy composition comprises at least 16 wt% chromium, suitably at least 17 wt%, suitably at least 18 wt%.

[0069] Suitably the intermediate metal alloy composition comprises up to 22 wt% chromium, suitably up to 21 wt%, suitably up to 20 wt%.

[0070] Suitably the intermediate metal alloy composition comprises from 16 to 22 wt% chromium, suitably from 17 to 21 wt%, suitably from 18 to 20 wt%.

[0071] Suitably the intermediate metal alloy composition comprises at least 2.0 wt% aluminium, suitably at least 2.5 wt%, suitably at least 3.0 wt%.

[0072] Suitably the intermediate metal alloy composition comprises up to 5.5 wt% aluminium, suitably up to 5.0 wt%, suitably up to 4.5 wt%, suitably up to 4.0 wt%.

[0073] Suitably the intermediate metal alloy composition comprises from 2.8 to 5.0 wt % aluminium, suitably from 2.8 to 4.4 wt %, suitably from 3.0 to 4.2 wt %, suitably from 3.0 to 4.0 wt%.

[0074] Suitably the intermediate metal alloy composition comprises at least 0.8 wt% titanium, suitably at least 1.0 wt%, suitably at least 1.2 wt%, suitably at least 1.4 wt%.

[0075] Suitably the intermediate metal alloy composition comprises up to 2.8 wt% titanium, suitably up to 2.6 wt%, suitably up to 2.4 wt%, suitably up to 2.2 wt%.

[0076] Suitably the intermediate metal alloy composition comprises from 1.2 to 2.5 wt % titanium, suitably from 1.3 to 2.4 wt %, suitably from 1.4 to 2.3 wt %, suitably from 1.5 to 2.2 wt%.

[0077] Suitably the component comprises a fourth region having a fourth metal alloy composition; wherein the fourth metal alloy composition is enriched in an element or compound which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component.

[0078] Suitably the component comprises a fourth region having a fourth metal alloy composition; wherein the fourth metal alloy composition is enriched in a metallic element which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component.

[0079] Suitably the metallic element which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component is tungsten and/or niobium and/or molybdenum.

[0080] Suitably the metallic element which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component is tungsten.

[0081] Suitably the fourth metal alloy composition comprises at least 2.0 wt% tungsten, suitably at least 2.5 wt%, suitably at least 3.0 wt%.

[0082] Suitably the fourth metal alloy composition comprises up to 5.0 wt% tungsten, suitably up to 4.5 wt%, suitably up to 4.0 wt%.

[0083] Suitably the fourth metal alloy composition comprises from 2.0 to 5.0 wt% tungsten, suitably from 2.0 to 4.0 wt%, suitably from 3.0 to 4.0 wt%.

[0084] Suitably the fourth metal alloy composition comprises at least 10 wt% chromium, suitably at least 12 wt%, suitably at least 14 wt%, suitably at least 16 wt%.

[0085] Suitably the fourth metal alloy composition comprises up to 24 wt% chromium, suitably up to 22 wt%, suitably up to 20 wt%, suitably up to 18 wt%.

[0086] Suitably the fourth metal alloy composition comprises from 11 to 23 wt% chromium, suitably from 13 to 21 wt%, suitably from 15 to 19 wt%, suitably from 15 to 18 wt%.

[0087] Suitably the fourth metal alloy composition comprises at least 0.5 wt% cobalt, suitably at least 1.0 wt%, suitably at least 1.5 wt%, suitably approximately 2.0 wt% cobalt.

[0088] Suitably the fourth metal alloy composition comprises up to 3.0 wt% cobalt, suitably up to 2.5 wt%, suitably up to 2.0 wt%.

[0089] Suitably the fourth metal alloy composition comprises a ratio of aluminium to titanium of from 0.4 to 0.8, suitably from 0.5 to 0.7, suitably from 0.6 to 0.7.

[0090] Suitably the first, second, the optional intermediate and the optional fourth metal alloy compositions are based on a base metal alloy with the amounts of at least one element or compound varying in each of the first, second, the optional intermediate and the optional fourth metal alloy compositions compared to each other.

[0091] In some embodiments, the amounts of at least one element or compound vary in each of the first, second, the optional intermediate and the optional fourth metal alloy compositions compared to the base metal alloy composition.

[0092] Suitably the base metal alloy composition is a commercially available metal alloy composition. One of the first, second, the optional intermediate and the optional fourth metal alloy compositions may have the same composition as the base metal alloy composition.

[0093] Suitably the component is formed of nickel alloys. Suitably the first, second, the optional intermediate, the optional fourth and the optional base metal alloy compositions are nickel alloy compositions.

[0094] Suitably the component is a turbine disc wherein the first region is a rim region of the turbine disc and the second region is a hub region of the turbine disc.

[0095] Suitably the turbine disc comprises the fourth region and the fourth region of the turbine disc is in contact with the hub region and arranged between the hub region and the rim region.

[0096] Suitably the composition gradient across at least one dimension is radially through the turbine disc.

[0097] According to a second aspect of the present invention, there is provided a method of manufacturing a component from metal alloy powders, the method comprising the steps of:

a) providing a first metal alloy powder and a second metal alloy powder;

b) arranging the first metal alloy powder to provide a first region of the component having a first metal alloy composition and arranging the second metal alloy powder to provide a second region of the component having a second metal alloy composition;

c) after step b), processing the first metal alloy powder and the second metal alloy powder to provide the component comprising the first region and the second region, wherein the second metal alloy composition has a higher gamma prime solvus temperature than the first metal alloy composition;

d) after step c), heat treating the component at a temperature between the gamma prime solvus temperature of the first metal alloy composition and the gamma prime solvus temperature of the second metal alloy composition, to provide a larger average grain size in the first metal alloy composition than in the second metal alloy composition.

[0098] The component manufactured by the method of this second aspect may have any of the suitable features or advantages described in relation to the component of the first aspect.

[0099] The first and second metal alloy powders used in the method of this second aspect may have any of the suitable features or advantages described in relation to the first and second metal alloy compositions of the first aspect.

[0100] Suitably the first metal alloy powder is provided by enriching a base metal alloy in a metallic element which decreases the gamma prime solvus temperature of the first metal alloy powder.

[0101] Suitably the component is formed of nickel alloys and the first and second metal alloy powders are nickel alloy powders.

[0102] Suitably step c) involves processing the first metal alloy powder and the second metal alloy powder using hot isostatic pressing.

[0103] In some embodiments, step b) of the method of this second aspect involves providing a hollow canister for use in a process of hot isostatic pressing, the canister having a first section and a second section, the first section having a greater strength than the second section, the first section corresponding to the first region in the component and the second section corresponding to the second region in the component; wherein the first metal alloy powder is added to the first section of the canister and the second metal alloy powder is added to the second section of the canister. In said embodiments step c) involves subjecting the canister comprising the first and second metal alloy powders to a hot isostatic pressing process to form the component inside the canister; wherein the pressure exerted on the metal alloy powders inside the canister by the hot isostatic pressing process is greater at the second section of the canister than at the first section of the canister.

[0104] The canister comprises first and second sections, the first section having a greater strength than the second section. The first and second sections of the canister, along with any other section or sections present, are joined together to form a contiguous canister comprising a contiguous cavity into which metal alloy powders can be added to undergo the hot isostatic pressing procedure. Suitably there is no barrier within the cavity of the canister between the first and second sections. The first and second sections of the canister may be distinguished from each other by the use of different materials to form the first and second sections.

[0105] The first section of the canister has a higher strength than the second section. This may be additionally or alternatively defined as the first section of the canister having a higher resistance to pressure exerted on the canister, for example during hot isostatic pressing, than the second section. Therefore the second section of the canister may exert a higher pressure on the second metal alloy powder contained within the second section than the first section of the canister exerts on first metal alloy powder contained within the first section, when the canister is subjected to a constant uniform pressure across its extent from an external source, for example during hot isostatic pressing.

[0106] The method may therefore allow the first region and the second region of the component to be produced by hot isostatic pressing at different pressures which are more appropriate for favourable mechanical property development than in known methods wherein the first and second regions are formed at the same pressure. The method may therefore provide a component having better mechanical properties in at least one of the first region and the second region than a similar component formed from a method of the prior art using a canister having the same strength in each section.

[0107] The strength of the first and second sections of the canister can be measured by standard techniques using samples of the materials used to make the sections of the canister, for example as described in ASTM E8/E8M-16 A "Standard Test Methods for Tension Testing of Metallic Materials".

[0108] The stated difference in strength of the first and second sections is intended to result from an intentional design choice in the materials or construction of the first and second sections and is not intended to cover the relatively small variance in strength which may arise from the shape of the canister necessitated by the desired shape of the component to be formed within the canister. Suitably the difference in strength between the first section and the second section is at least 40 MPa, suitably at least 50 MPa, suitably at least 60 MPa or at least 75 MPa, for example at least 100 MPa.

[0109] Suitably the method of this first aspect comprises a step, after step c), of removing the component from then canister.

[0110] Suitably the canister comprises a third section having a strength lower than the first section and greater than the second section, and optionally wherein the canister comprises a fourth section having a strength lower than the first and third sections and greater than the second section.

[0111] Suitably the component is a turbine disc and the first section of the canister provides a rim section of the turbine disc and the second section of the canister provides a hub section of the turbine disc.

[0112] Suitably step c) involves subjecting the canister to the same conditions of temperature and pressure throughout the canister.

[0113] Suitably step c) involves subjecting the canister to a pressure of at least 80 MPa, suitably at least 100 MPa, suitably at least 120 MPa.

[0114] Suitably step c) involves subjecting the canister to a pressure of up to 200 MPa, suitably up to 175 MPa, suitably up to 150 MPa.

[0115] Suitably step c) involves subjecting the canister to a temperature of at least 700 °C, suitably at least 750 °C, suitably at least 800 °C, suitably at least 850 °C.

[0116] Suitably step c) involves subjecting the canister to a temperature of up to 1,100 °C, suitably up to 1,000 °C, suitably up to 950 °C, suitably up to 900 °C.

[0117] Suitably the strength of the first and second sections, and optionally the third and fourth sections, of the canister are matched to the ideal pressure during hot isostatic pressing of the metal alloy powders in the first and second, and optionally third and fourth, sections of the canister.

[0118] Suitably by ideal pressure we mean a pressure which, when applied to the metal alloy powder in question, at a particular temperature, provides improved (suitably optimised) mechanical properties in the corresponding regions of the component after hot isostatic pressing.

Brief Description of the Drawings

[0119] Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a schematic of a component (100) according to the first aspect of the present invention;

Figure 2 shows a radial cross section of a turbine disc (200) according to the first aspect of the present invention; and

Figure 3 shows a schematic of the method according to the second aspect of the present invention.

Detailed Description

[0120] Figure 1 shows a component (100) which comprises a first region (110) having a first metal alloy composition and comprising a gamma prime phase, and a second region (120) having a second metal alloy composition and comprising a gamma prime phase. The component (100) also comprises an intermediate region (130) having an intermediate metal alloy composition arranged between the first and second regions of the component. The first, second and intermediate metal alloy compositions are different to each other and provide a composition gradient through the component (100) from the first region (110), through the intermediate region (130) and to the second region (120). The component also comprises a first interface region (111) between the first region (110) and the intermediate region (130), and a second interface region (121) between the intermediate region (130) and the second region (120). The interface regions have a composition which is a mixture of the metal alloy compositions of the adjacent regions. For example, the first interface region (111) has a composition which is a mixture of the first metal alloy composition and the intermediate metal alloy composition and the second interface region (121) has a composition which is a mixture of the intermediate metal alloy composition and the second metal alloy composition. The interface regions provide a gradual change in composition and properties from one region to the adjacent region, and may provide an improved strength at said interface compared to components which have radically different metal alloy compositions adjacent to each other and/or which may not be mixed to form said interface regions.

[0121] The gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition, and the intermediate metal alloy composition has a gamma prime solvus temperature higher than the gamma prime solvus temperature of the first metal alloy composition and lower than the gamma prime solvus temperature of the second metal alloy composition.

[0122] The average grain size of the first metal alloy composition in the first region is larger than the average grain size of the second metal alloy composition in the second region. The average grain size of the intermediate metal alloy composition in the intermediate region may be larger than the average grain size of the second metal alloy composition in the second region and smaller than the average grain size of the first metal alloy composition in the first region.

[0123] In embodiments wherein the component is formed of nickel alloys, suitably of nickel super-alloys, the first, second and intermediate compositions may be based on the following base alloy composition, Nimonic 80:

Table 1: Base metal alloy composition - Nimonic 80

chromium	18-21 wt%
titanium	1.8-2.7 wt%
aluminium	1.0-1.8 wt%
iron	3.0 max wt%
cobalt	2.0 max wt%
manganese	1.0 max wt%
nickel	Balance

[0124] The first metal alloy composition may comprise a relatively high amount of cobalt and/or chromium, compared to the second and/or intermediate metal alloy composition. Said increased amount of cobalt and/or chromium may decrease the gamma prime solvus temperature of the first metal alloy composition relative to the second and/or intermediate metal alloy compositions. Said increased amount of cobalt and/or chromium may also decrease the gamma prime solvus temperature of the first metal alloy composition relative to the base metal alloy composition.

[0125] The first metal alloy composition may comprise a relatively high ratio of aluminium to titanium, compared to the second and/or intermediate metal alloy composition. Said increased ratio of aluminium to titanium may increase the creep resistance of the first metal alloy composition relative to the second and/or intermediate metal alloy compositions. Said increased ratio of aluminium to titanium may increase the creep resistance of the first metal alloy composition relative to the base metal alloy composition.

[0126] The first metal alloy composition may be as follows:

Table 2: First metal alloy composition

chromium	15-18 wt%
titanium	1.0-1.7 wt%
aluminium	3.0- 4.0 wt%
iron	3.0 max wt%
cobalt	8.0 max wt%
manganese	1.0 max wt%
nickel	Balance

[0127] The second metal alloy composition may comprise a relatively low amount of cobalt and/or chromium, compared to the first and/or intermediate metal alloy composition. Said decreased amount of cobalt and/or chromium may increase the gamma prime solvus temperature of the first metal alloy composition relative to the first and/or intermediate metal alloy compositions. The amount of cobalt and/or chromium in the second metal alloy composition may be approximate to the amount of cobalt and/or chromium in the base metal alloy composition.

[0128] The second metal alloy composition may comprise a relatively high amount of tungsten and/or niobium and/or molybdenum, compared to the first and/or intermediate metal alloy compositions. Said increased amount of tungsten and/or niobium and/or molybdenum may increase the strength of the second metal alloy composition relative to the first and/or intermediate metal alloy compositions. Said increased amount of tungsten and/or niobium and/or molybdenum may increase the strength of the second metal alloy composition relative to the base metal alloy composition.

[0129] The second metal alloy composition may be as follows:

Table 3: Second metal alloy composition

chromium	12-15 wt%
titanium	1.8-2.7 wt%
aluminium	1.0- 1.8 wt%
iron	3.0 max wt%
cobalt	2.0 max wt%
niobium	1.0 max wt%
tungsten	4-5 max wt%
nickel	Balance

[0130] In some embodiments, the intermediate metal alloy composition may have the composition of the base metal alloy composition. In some embodiments, the intermediate metal alloy composition may be a mixture of the first and second metal alloy compositions, for example a 1:1 mixture of the first and second metal alloy compositions.

[0131] Figure 2 shows a radial cross section of a nickel alloy turbine disc (200) comprising a first region (210) having a first metal alloy composition and comprising a gamma prime phase and a second region (220) having a second metal alloy composition and comprising a gamma prime phase. The turbine disc (200) also comprises an intermediate region (230) having an intermediate metal alloy composition arranged between the first and second regions of the component. The turbine disc (200) also comprises a fourth region (240) having a fourth metal alloy composition arranged between the first and intermediate regions of the component.

[0132] The first, second and intermediate metal alloy compositions are as described in relation to the component (100) shown in Figure 1. The fourth metal alloy composition is different to each of the first, second and fourth metal alloy compositions.

[0133] The first, second, fourth and intermediate metal alloy compositions provide a composition gradient radially through the turbine disc (200) from the first region (210), through the intermediate region (230), through the fourth region (240) and to the second region (220).

[0134] The turbine disc also comprises first interface region (211) between the first region (210) and the intermediate region (230), second interface region (221) between the second region (220) and the fourth region (240) and fourth interface region (231) between the fourth region (240) and the intermediate region (230). The interface regions have a composition which is a mixture of the metal alloy compositions of the adjacent regions, as described in relation to the component (100) of Figure 1. The interface regions provide a gradual change in composition and properties from one region to the adjacent region, and may provide an improved strength at said interface compared to components which have radically different metal alloy compositions adjacent to each other.

[0135] The first region (210) of the turbine disc (200) is a rim region of the turbine disc and may have the composition described in relation to the first metal alloy composition of the component (100) of Figure 1.

[0136] The second region (220) of the turbine disc (200) is a hub region of the turbine disc and may have the composition described in relation to the second metal alloy composition of the component (100) of Figure 1.

[0137] The average grain size of the first metal alloy composition in the rim region is larger than the average grain size of the second metal alloy composition in the hub region. The rim region having the coarser grain size may have an improved creep resistance compared to the hub and/or intermediate regions and compared to rim regions in prior art turbine discs referred to above. The hub region having the finer grain size may have an improved strength compared to the rim and/or intermediate regions and compared to hub regions in prior art turbine discs referred to above. Turbine disc (200) may therefore have optimised mechanical properties for the rim and hub regions, unlike the some of the prior art turbine discs referred to above.

[0138] The intermediate region (230) of the turbine disc (200) may have the intermediate metal alloy composition shown below:

Table 4: Intermediate metal alloy composition

chromium	18-20 wt%
titanium	1.5-2.2 wt%
aluminium	3.0- 4.0 wt%
iron	3.0 max wt%
cobalt	4.0 max wt%
manganese	1.0 max wt%
nickel	Balance

[0139] The fourth region (240) of the turbine disc (200) may be a region of the turbine disc (200) which is prone to quench cracking, for example a region adjacent to the hub region (220). The fourth metal alloy composition of the fourth region (240) may have a relatively low ratio of aluminium to titanium, compared to the first and/or second and/or intermediate metal alloy composition. Said decreased ratio of aluminium to titanium may increase the quench cracking resistance of the fourth metal alloy composition relative to the first and/or second and/or intermediate metal alloy compositions. Said decreased ratio of aluminium to titanium may increase the quench cracking resistance of the fourth metal alloy composition relative to the base metal alloy composition.

[0140] The fourth metal alloy composition may comprise a relatively high amount of tungsten and/or niobium and/or molybdenum, compared to the first and/or intermediate metal alloy compositions. Said increased amount of tungsten and/or niobium and/or molybdenum may increase the strength of the fourth metal alloy composition relative to the first and/or intermediate metal alloy compositions. Said increased amount of tungsten and/or niobium and/or molybdenum may increase the strength of the second metal alloy composition relative to the base metal alloy composition. The amount of tungsten and/or niobium and/or molybdenum in the fourth metal alloy composition may be lower than the amount of tungsten and/or niobium and/or molybdenum in the second metal alloy composition of the hub region (220). This may provide a strength intermediate between the hub region (220) and the intermediate region (230), which may provide a more gradual change in composition and properties between the hub region (220) and the intermediate region (230) than would otherwise be possible, and may provide an improved bond between the hub region (220), the intermediate region (230) and the fourth region (240) and compared to known similar components.

[0141] The fourth metal alloy composition may be as follows:

Table 5: Fourth metal alloy composition at regions prone to quench cracking

chromium	15-18 wt%
titanium	1.8-2.7 wt%
aluminium	1.0- 1.8 wt%
iron	3.0 max wt%
cobalt	2.0 max wt%
tungsten	3-4 max wt%
nickel	Balance

[0142] In some embodiments wherein the component is formed of nickel alloys, suitably of nickel super-alloys, the first, second and intermediate compositions may be based on the following base alloy composition, IN718:

Table 6: Base metal alloy composition - IN718

nickel	50-55 wt%
iron	18.95 wt%
chromium	17-21 wt%
molybdenum	2.8-3.3 wt%
carbon	0.08 wt%
aluminium	0.2 -0.8 wt%
titanium	0.65 -1.15 wt%
niobium	4.75 - 5.5 wt%

[0143] The composition of IN718 may be adapted as described above for Nimonic 80 to provide the desired properties in the first, second, intermediate and fourth regions of the component. IN718 is a gamma double prime strengthened alloy. The gamma double prime phase has a reduced microstructural stability which results in the formation of delta phase and leads to the loss of mechanical properties and low component lives when temperatures exceed 600 °C, as typically seen at the rim of a gas turbine disc. Specifically IN718 cannot be used when temperatures at the rim of the disc exceed 600 °C. However adjusting the composition of IN718 as described herein for Nimonic 80 may improve the temperature capability of IN718 moderately.

[0144] The coarsening rate of the gamma double prime phase may be slowed down to improve the thermal stability of the material. For example by having a higher Al/Ti as well as a higher (Al+Ti)/Nb content along with higher Al+Ti+Nb content at the expense of reducing the Ni content, slows down the coarsening behaviour of gamma double prime phase which results in increasing the transformation temperature of gamma double prime to delta phase. The temperature capability of IN718 can therefore be extended by a further 50 °C.

[0145] The Al+Ti+Nb content in the base IN718 alloy is 5.43%. Ticolloy has an Al+Ti+Nb content of 6.75%. Ticolloy has a higher temperature capability than IN718 and could therefore be used as the intermediate metal alloy composition in the intermediate region of the turbine disc.

[0146] Figure 3 shows a schematic (300) of a method according to the second aspect of the present invention of manufacturing a component, such as component (100) of Figure 1 or turbine disc (200) of Figure 2, from metal alloy powders. The method comprises operation (301) of providing a first metal alloy powder and a second metal alloy powder, wherein the second metal alloy has a higher gamma prime solvus temperature than the second metal alloy powder. Operation (301) is followed by operation (302) of arranging the first metal alloy powder to provide a first region of the component and arranging the second metal alloy powder to provide a second region of the component. Operation (302) is followed by operation (303) of processing the first metal alloy powder and the second metal alloy powder to provide the component comprising the first region and the second region. Operation (303) is followed by operation (304) of heat treating the component at a temperature between the gamma prime solvus temperature of the first metal alloy powder and the gamma prime solvus temperature of the second metal alloy powder.

[0147] In one embodiment, operation (302) involves providing an open canister and filling the canister with the metal alloy powders, for example from a hopper or hoppers, so that the different metal alloy powders are arranged as discussed above to provide the first and second regions and optionally the intermediate and fourth regions of the component. The adjacent metal alloy powders partially mix as they are added to the open canister to provide interface regions in the component.

[0148] In some embodiments, operation (303) involves processing the first metal alloy powder and the second metal alloy powder by hot isostatic pressing (HPI) to provide the component comprising the first region and the second region. The HIP process may involve closing the canister containing the metal alloy powders, degassing and sealing the closed canister and subjecting the canister to hot isostatic pressing (HIP). For example, the Hot isostatic pressing may be carried out at a temperature of 800 to 950 °C and at a pressure of around 100 MPa for 4 hours. The HIP process can also be carried out as a multi-step process by applying a second value of pressure and temperature for a further amount of time to further enhance inter-particle bonding.

[0149] In hot isostatic pressing (HIP) the consolidation of metal alloy powders occurs under conditions of high temperatures and pressures. The metal alloy powders are typically placed into a container known as a "canister" or "can". The canister is then sealed and degassed to ensure all oxygen is removed. The canister and its contents are subsequently placed in vacuum in a Hot isostatic pressing (HIP) chamber. The canister is then subject to elevated temperature and pressure on the outside typically using an inert gas like argon. The inert gas applies pressure on the canister and then subsequently on the enclosed powder at all sides and directions. The pressure and temperature conditions chosen for proper densification and bonding of powder particles during HIP is normally dependent on the alloy being used. Inadequate values of pressure and temperature could lead to poor inter-particle bonding and subsequent issues due to Prior Particle Boundaries (PPBs). PPBs are normally considered to be a weakness in the microstructure of the component formed. By having a gradual transition in the metal alloy composition of a base composition as described in this patent application it may be possible to use single values of pressure and temperature which is optimised for a particular alloy and subsequently attain a sound and defect free component and simultaneously applying a pressure of around 100-150 MPa for around 4 hours.

[0150] After the HIP process, the component may then be removed from the canister by standard methods such as machining or by acid treatment. The component may be then be isothermally forged or extruded, prior to operation (304) of heat treating the component.

[0151] Operation (304) involves subjecting the whole of the component to a single step of heat treatment at a temperature between the gamma prime solvus temperature of the first metal alloy powder and the gamma prime solvus temperature of the second metal alloy powder. This heat treatment step allows the first region to obtain a coarser grain size than the second region (at this super-solvus temperature with respect to the first region) and allows the second region to obtain a finer grain size than the first region (at this sub-solvus temperature with respect to the second region), thereby providing optimised mechanical properties for the first and second regions. For example, the first region having the coarser grain size may have an improved creep resistance compared to the second and/or intermediate regions and compared to similar regions in similar components of the prior art. Also, the second region having the finer grain size may have an improved strength compared to the first and/or intermediate regions and compared to similar regions in similar components of the prior art.

[0152] This method may be used to produce the turbine disc (200) of Figure 2 by providing a turbine disc canister shaped appropriately for the production of the turbine disc (200) and by filing the canister with the first, second, intermediate and fourth metal alloy powders in the appropriate regions of the turbine disc canister to provide the rim (210), hub (220), intermediate (230) and fourth regions (240) of the turbine disc (200) respectively with the partial mixing of the different adjacent metal alloy powders providing the interface regions (211, 221 and 231).

[0153] Following the heat treatment operation (304), the method may therefore provide a turbine disc (200) having an average grain size of the first metal alloy composition in the rim region which is larger than the average grain size of the second metal alloy composition in the hub region. The rim region having the coarser grain size may have an improved creep resistance compared to the hub and/or intermediate regions and compared to rim regions in prior art turbine discs referred to above. The hub region having the finer grain size may have an improved strength compared to the rim and/or intermediate regions and compared to hub regions in prior art turbine discs referred to above. The method of Figure 3 may therefore provide a turbine disc (200) having optimised mechanical properties for the rim and hub regions.

[0154] In summary, the present invention provides a component, such as a nickel alloy turbine disc. The component has a composition gradient through the component and comprises a first region having a first metal alloy composition and comprising a gamma prime phase; and a second region having a second metal alloy composition and comprising a gamma prime phase. The gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition; and the average grain size of the first metal alloy composition is larger than the average grain size of the second metal alloy composition. As a result of these properties and an appropriate manufacturing process, the component may have optimised mechanical properties at specific regions of the component, for example at the rim and hub regions of a turbine disc. A method of manufacturing such a component from metal alloy powders is also disclosed.

[0155] Throughout this specification, the term "comprising" or "comprises" means including the component(s) specified but not to the exclusion of the presence of other components. The term "consisting essentially of" or "consists essentially of" means including the components specified but excluding other components except for materials present as impurities, unavoidable materials present as a result of processes used to provide the components, and components added for a purpose other than achieving the technical effect of the invention. Typically, when referring to compositions, a composition consisting essentially of a set of components will comprise less than 5% by weight, typically less than 3% by weight, more typically less than 1% by weight of non-specified components.

[0156] The term "consisting of" or "consists of" means including the components specified but excluding addition of other components.

[0157] Whenever appropriate, depending upon the context, the use of the term "comprises" or "comprising" may also be taken to encompass or include the meaning "consists essentially of" or "consisting essentially of", and may also be taken to include the meaning "consists of" or "consisting of".

[0158] For the avoidance of doubt, wherein amounts of components in a composition are described in wt%, this means the weight percentage of the specified component in relation to the whole composition referred to. For example, "the first metal alloy composition comprises at least 3.0 wt% cobalt" means that 3.0 wt% of the first metal alloy composition is provided by cobalt.

[0159] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0160] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0161] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0162] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A component comprising:

a first region having a first metal alloy composition and comprising a first gamma prime phase; and
a second region having a second metal alloy composition and comprising a second gamma prime phase;
wherein the gamma prime solvus temperature of the second metal alloy composition is higher than the gamma prime solvus temperature of the first metal alloy composition; and
wherein the average grain size of the first metal alloy composition in the first region is larger than the average grain size of the second metal alloy composition in the second region.

2. The component according to claim 1, wherein the first metal alloy composition is enriched in a metallic element which decreases the gamma prime solvus temperature of the first metal alloy composition, compared to the second metal alloy composition.

3. The component according to claim 2, wherein the metallic element which decreases the gamma prime solvus temperature of the first metal alloy composition is cobalt and/or chromium.

4. The component according to any one of the preceding claims, comprising an intermediate region having an intermediate metal alloy composition; wherein the intermediate metal alloy composition in the intermediate region has a gamma prime solvus temperature higher than the gamma prime solvus temperature of the first metal alloy composition in the first region and lower than the gamma prime solvus temperature of the second metal alloy composition in the second region.

5. The component according to claim 4, wherein the intermediate region is arranged between the first and second regions of the component.

6. The component according to any one of the preceding claims, comprising a fourth region having a fourth metal alloy composition; wherein the fourth metal alloy composition is enriched in a metallic element which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component.

7. The component according to claim 6, wherein the metallic element which increases the quench cracking resistance of the fourth region of the component compared to the first and/or second region of the component is tungsten and/or niobium and/or molybdenum.

8. The component according to any one of the preceding claims, wherein the component is formed of nickel alloys and the first, second, the optional intermediate and the optional fourth metal alloy compositions are nickel alloy compositions.

9. The component according to any one of the preceding claims, wherein the component is a turbine disc; and wherein the first region is a rim region of the turbine disc and the second region is a hub region of the turbine disc.

10. The component according to claim 9, wherein the turbine disc comprises the fourth region of claim 6; and wherein the fourth region of the turbine disc is in contact with the hub region and arranged between the hub region and the rim region.

11. The component according to claim 9 or claim 10, wherein the composition gradient across at least one dimension is radially through the turbine disc.

12. A method of manufacturing a component from metal alloy powders, the method comprising the steps of:

a) providing a first metal alloy powder and a second metal alloy powder;
b) arranging the first metal alloy powder to provide a first region of the component having a first metal alloy composition and arranging the second metal alloy powder to provide a second region of the component having a second metal alloy composition;
c) after step b), processing the first metal alloy powder and the second metal alloy powder to provide the component comprising the first region and the second region, wherein the second metal alloy composition has a higher gamma prime solvus temperature than the first metal alloy composition;
d) after step c), heat treating the component at a temperature between the gamma prime solvus temperature of the first metal alloy composition and the gamma prime solvus temperature of the

second metal alloy composition, to provide a larger average grain size in the first metal alloy composition than in the second metal alloy composition.

13. The method according to claim 12, wherein the first metal alloy powder is provided by enriching a base metal alloy in an metallic element which decreases the gamma prime solvus temperature of the first metal alloy powder.

14. The method according to claim 12 or claim 13, wherein the component is formed of nickel alloys and the first and second metal alloy powders are nickel alloy powders.

15. The method according to any one of claims 12 to 14, wherein step c) involves processing the first metal alloy powder and the second metal alloy powder using hot isostatic pressing.

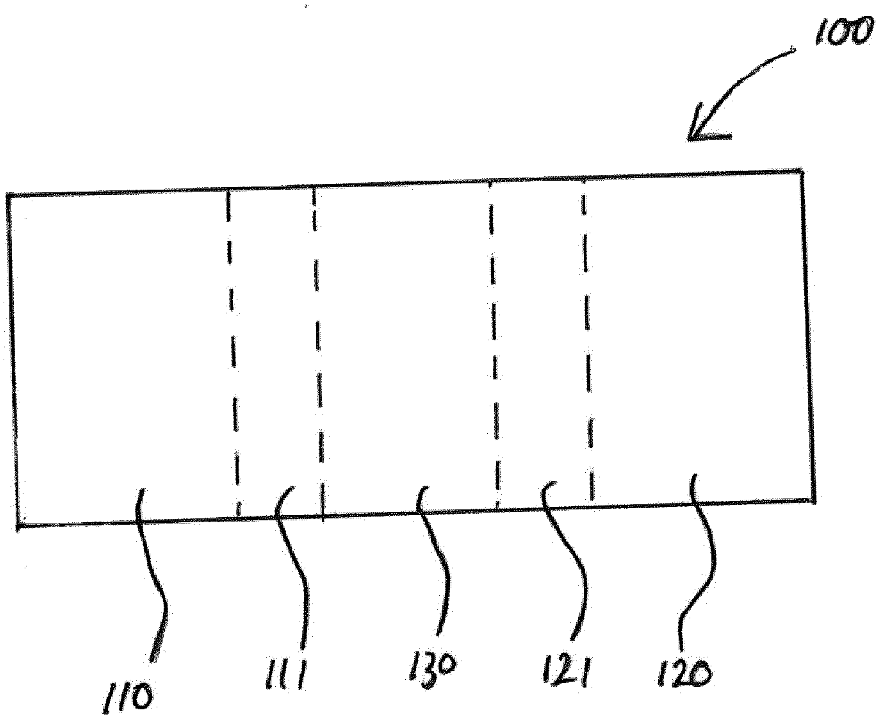

Figure 1

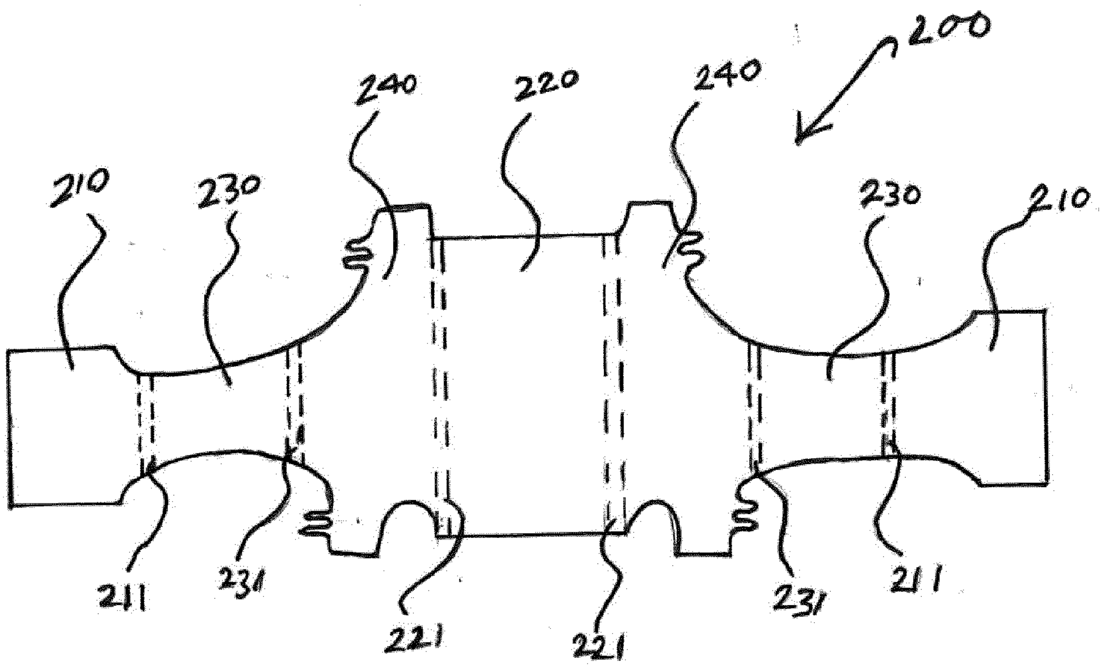

Figure 2

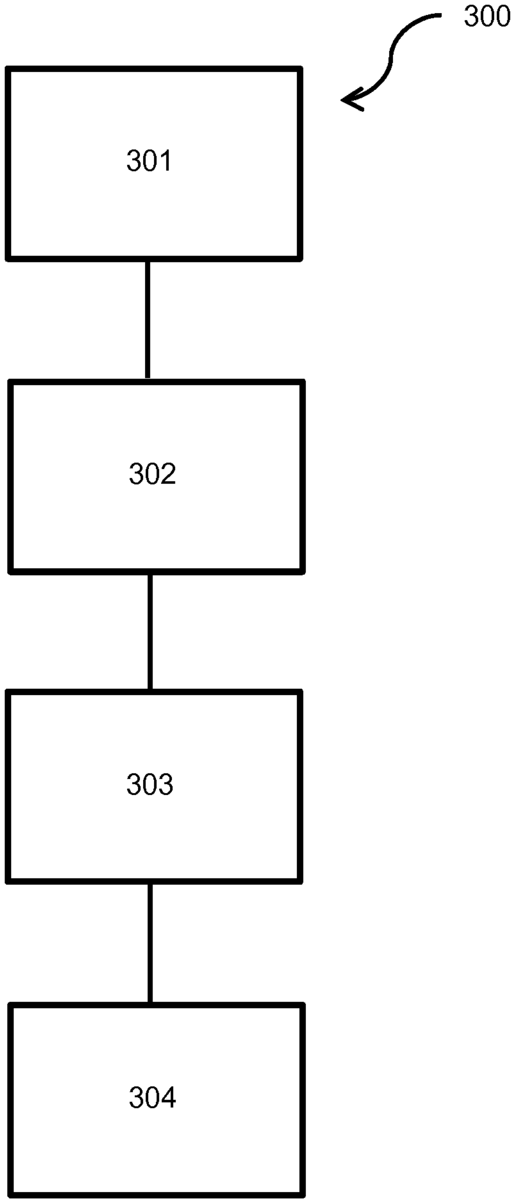

Figure 3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 5350

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
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