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(54) Article and method for forming article

(57) An article and a method for forming the article are disclosed. The article includes an equiaxed grain structure and a composition (RNX). The composition includes, by weight percent, about 6.0% to about 9.0% aluminum, up to about 0.5% titanium, about 2.5% to about 4.5% tantalum, about 10.0% to about 12.5% chromium, about 5.0% to about 10.0% cobalt, about 0.30% to about 0.80% molybdenum, about 2.0% to about 5.0% tungsten, up to about 1.0% silicon, about 0.35% to about 0.60% hafnium, about 0.005% to about 0.010% boron, about 0.06% to about 0.10% carbon, up to about 0.02% zirconium, up to about 0.1% lanthanum, up to about 0.03% yttrium, and balance nickel and incidental impurities. Rhenium, if present, is a trace element. The method for forming the article includes providing the composition having up to about 0.01 % rhenium and forming the article.

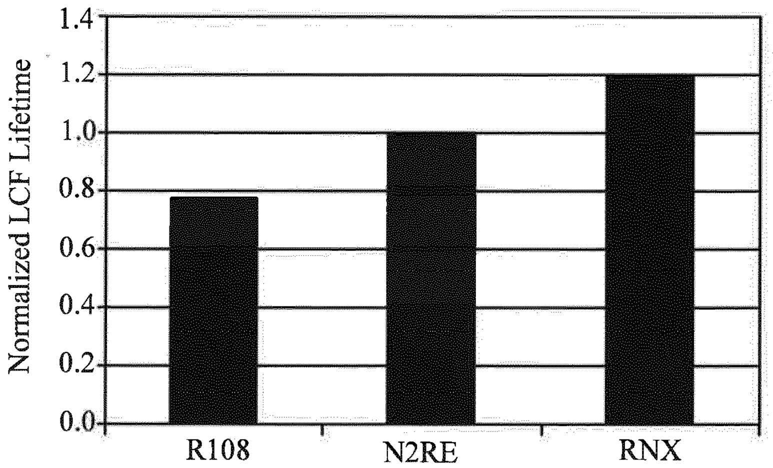


FIG. 2

EP 2 913 417 A1

Description

FIELD OF THE INVENTION

[0001] The present invention is directed to an article and a method for forming an article. More specifically, the present invention is directed to an article and a method for forming an article including an equiaxed grain structure and a composition.

BACKGROUND OF THE INVENTION

[0002] Hot gas path components of gas turbines and aviation engines, particularly turbine blades, vanes, nozzles, seals and stationary shrouds, operate at elevated temperatures, often in excess of 2,000 °F. The superalloy compositions used to form hot gas path components are often single-crystal compositions incorporating significant amounts of rhenium (Re) due to the elevated temperatures and other operating conditions components are exposed to in the first stage. Such superalloy compositions typically contain one to three percent, by weight, rhenium (Re), and some may incorporate up to six percent, by weight, rhenium (Re).

[0003] One such single-crystal, rhenium (Re)-containing superalloy composition is referred to herein as "N2Re." N2Re includes, by weight percent, 6.0% to 9.0% aluminum (Al), up to 0.5% titanium (Ti), 4.0% to 6.0% tantalum (Ta), 12.5% to 15.0% chromium (Cr), 3.0% to 10.0% cobalt (Co), up to 0.25% molybdenum (Mo), 2.0% to 5.0% tungsten (W), up to 1.0% silicon (Si), up to 0.2% hafnium (Hf), 1.0% to 3.0% rhenium (Re), and balance nickel (Ni) and incidental impurities. N2Re may also include up to 0.01% boron (B), up to 0.07% carbon (C), up to 0.03% zirconium (Zr), and up to 0.1% lanthanum (La). One example of a composition that falls within the ranges of N2Re may include the alloy commercially unavailable under the trade name "René N2" (available from General Electric Company).

[0004] An alternate superalloy composition which is not a single-crystal and does not include rhenium (Re) is referred to herein as "R108." R108 includes, by weight percent, 5.25% to 5.75% Aluminum (Al), 0.6% to 0.9% Titanium (Ti), 2.8% to 3.3% Tantalum (Ta), 8.0% to 8.7% Chromium (Cr), 9.0% to 10.0% Cobalt (Co), 0.4% to 0.6% Molybdenum (Mo), 9.3% to 9.7% Tungsten (W), up to 0.12% Silicon (Si), 1.3% to 1.7% Hafnium (Hf), 0.01% to 0.02% Boron (B), up to 0.1% Carbon (C), 0.005% to 0.02% Zirconium (Zr), up to 0.2% Iron (Fe), up to 0.1% Manganese (Mn), up to 0.1% Copper (Cu), up to 0.01% Phosphorous (P), up to 0.004% Sulfur (S), up to 0.1% Niobium (Nb), and balance of nickel (Ni) and incidental impurities. One example of a composition that falls within the ranges of R108 may include the alloy commercially unavailable under the trade name "René 108." Under testing conditions of 2,000 °F in a burner rig, an article formed from R108 forms an unstable oxide scale on the surface due to the low content of chromium.

[0005] R108 and N2Re have comparable high temperature mechanical properties, but R108 has significantly inferior hot corrosion resistance and oxidation resistance in comparison with N2Re. As a result, R108 is unsuitable for making first stage hot gas path components for either heavy duty gas turbine or aviation engines.

[0006] Single-crystal superalloys incorporating rhenium (Re), such as René N5, René N6 and René N2 may provide highly desirable properties for gas turbine or aviation engine applications, including good strength, ductility, creep lifetime, low-cycle fatigue lifetime, oxidation resistance and hot corrosion resistance under gas turbine or aviation engine operating conditions. However, rhenium (Re) is among the most expensive of metals and the processing of single-crystal parts is typically time-consuming and costly, making rhenium (Re)-containing single-crystal superalloys economically undesirable.

[0007] Articles and methods having improvements in the process and/or the properties of the components formed would be desirable in the art.

BRIEF DESCRIPTION OF THE INVENTION

[0008] In one embodiment, an article includes an equiaxed grain structure and a composition, wherein the composition includes, by weight percent, about 6.0% to about 9.0% aluminum (Al), up to about 0.5% titanium (Ti), about 2.5% to about 4.5% tantalum (Ta), about 10.0% to about 12.5% chromium (Cr), about 5.0% to about 10.0% cobalt (Co), about 0.30% to about 0.80% molybdenum (Mo), about 2.0% to about 5.0% tungsten (W), up to about 1.0% silicon (Si), about 0.35% to about 0.60% hafnium (Hf), about 0.005% to about 0.010% boron (B), about 0.06% to about 0.10% carbon (C), up to about 0.02% zirconium (Zr), up to about 0.1% lanthanum (La), up to about 0.03% yttrium (Y), and balance nickel (Ni) and incidental impurities, and wherein rhenium (Re), if present, is a trace element. The terms "includes" and "comprising" encompass the more restrictive term "consisting of'.

[0009] In another embodiment, a method for forming an article includes providing a composition and forming the article. The composition includes, by weight percent, about 6.0% to about 9.0% aluminum (Al), up to about 0.5% titanium (Ti), about 2.5% to about 4.5% tantalum (Ta), about 10.0% to about 12.5% chromium (Cr), about 5.0% to about 10.0% cobalt (Co), about 0.30% to about 0.80% molybdenum (Mo), about 2.0% to about 5.0% tungsten (W), up to about 1.0% silicon (Si), about 0.35% to about 0.60% hafnium (Hf), about 0.005% to about 0.010% boron (B), about 0.06% to about 0.10% carbon (C), up to about 0.02% zirconium (Zr), up to about 0.1% lanthanum (La), up to about 0.03% yttrium (Y), up to about 0.01% rhenium (Re), and balance nickel (Ni) and incidental impurities. The article includes an equiaxed grain structure.

[0010] Other features and advantages of the present invention will be apparent from the following more detailed description, taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is an article cast from RNX including fine dimples of complex geometry, according to an embodiment of the disclosure.

FIG. 2 compares the low-cycle fatigue lifetime of articles formed from N2Re, R108 and RNX.

FIG. 3 compares the creep lifetime of articles formed from N2Re, R108 and RNX.

FIG. 4 compares the oxidation layer depth of articles made from R108 and RNX.

FIG. 5 is a micrograph of a section from an article formed from RNX following burner rig testing, according to an embodiment of the disclosure.

FIG. 6 is a micrograph of a section from a corresponding article formed from R108 following burner rig testing.

[0012] Wherever possible, the same reference numbers will be used throughout the drawings to represent the same parts.

DETAILED DESCRIPTION OF THE INVENTION

[0013] Provided are an article and a method for forming an article. Embodiments of the present disclosure, in comparison to methods and articles not using one or more of the features disclosed herein, increase corrosion resistance, increase oxidation resistance, lengthen low-cycle fatigue lifetime, increase creep lifetime, improve castability, increase phase stability at elevated temperatures, decrease cost, or a combination thereof. Embodiments of the present disclosure enable the fabrication of hot gas path components of gas turbines and aviation engines with rhenium (Re)-free nicked-based superalloys having at least as advantageous properties at elevated temperatures as rhenium (Re)-containing nicked-based superalloys, as well as having an equiaxed grain structure.

[0014] In one embodiment, an article includes an equiaxed grain structure and a composition. The composition includes, by weight percent, about 6.0% to about 9.0% aluminum (Al), up to about 0.5% titanium (Ti), about 2.5% to about 4.5% tantalum (Ta), about 10.0% to about 12.5% chromium (Cr), about 5.0% to about 10.0% cobalt (Co), about 0.30% to about 0.80% molybdenum (Mo), about 2.0% to about 5.0% tungsten (W), up to about 1.0% silicon (Si), about 0.35% to about 0.60% hafnium (Hf), about 0.005% to about 0.010% boron (B), about 0.06% to about 0.10% carbon (C), up to about 0.02% zirconium (Zr), up to about 0.1% lanthanum (La), up to about 0.03% yttrium (Y), and balance nickel (Ni) and incidental impurities. The composition is devoid of rhenium (Re) or includes rhenium (Re) as a trace element. In a further embodiment, rhenium (Re) is present in an amount of less than about 0.01%, by weight, of the composition.

[0015] In one embodiment the about 2.5% to about 4.5% tantalum (Ta) in the composition is completely or partially replaced by niobium (Nb) on a 1:1 molar basis. This substitution does not have any material effect on the castability or service properties of the article, but reduces the cost of the composition.

[0016] In a further embodiment, the composition includes, by weight percent: about 6.2% to about 6.5% aluminum (Al), up to about 0.04% titanium (Ti), about 3.9% to about 4.3% tantalum (Ta), about 12.0% to about 12.5% chromium (Cr), about 7.0% to about 8.0% cobalt (Co), about 0.40% to about 0.75% molybdenum (Mo), about 4.7% to about 5.1% tungsten (W), about 0.08% to about 0.12% silicon (Si), about 0.47% to about 0.53% hafnium (Hf), about 0.005% to about 0.010% boron (B), about 0.06% to about 0.10% carbon (C), up to about 0.02% zirconium (Zr), up to about 0.1% lanthanum (La), up to about 0.03% yttrium (Y), up to about 0.01% rhenium (Re), and balance nickel (Ni) and incidental impurities.

[0017] In one embodiment, the article is a hot gas path component of a gas turbine or an aviation engine, and wherein the hot gas path component is subjected to temperatures of at least about 2,000 °F. In a further embodiment, the hot gas path component is selected from the group consisting of a blade, a vane, a nozzle, a seal and a stationary shroud.

[0018] In one embodiment, the method for forming the article includes providing the composition and forming the article from the composition. In a further embodiment, forming the article from the composition includes any suitable technique, including, but not limited to, casting, powder metallurgy and three-dimensional additive machining. In another embodiment, casting includes precision investment casting with variable pressure control.

[0019] As used herein, "precision investment casting with variable pressure control" means a casting process described as follows. An ingot is heated by induction coils in a melting chamber to surface re-melting under a surface re-melting pressure. An inert gas is introduced into the melting chamber until a casting pressure is reached. The temperature is adjusted until a melt temperature is reached. When the ingot is fully converted into a melt, the melt is poured into a mold cavity under the inert gas at the casting pressure. The inert gas is maintained at the casting pressure until an article being cast solidifies. Other steps in a typical industrial casting process, such as pattern making, mold preparation and post-pour solidification, remain unchanged in precision investment casting with variable pressure control.

[0020] In one embodiment, wherein the ingot is formed of the composition, the precision investment casting with variable pressure control includes a surface re-melting pressure of 10^{-3} atmospheres and an inert gas casting pressure of about 10^{-2} atmospheres to about 10^{-1} atmospheres. In a further embodiment, the inert gas is argon (Ar).

[0021] In one embodiment, precision investment casting with variable pressure control minimizes the loss of chromium (Cr) during melting and casting. The operation of a hot gas path component of a gas turbine or an aviation engine at a temperature of at least about 2,000 °F typically requires a chromium (Cr) content, by weight, of at least about 12.0% in order to maintain hot corrosion resistance and oxidation resistance.

[0022] In one embodiment, the composition is highly castable. As used herein, "highly castable" indicates that during casting of the composition into the article there is no lack of feeding on any fine structural features, such as surface enhancement dimples or thin ribs, solidification shrinkage is within acceptable parameters, and the article is essentially free of mold/metal or core/metal reactions. In a further embodiment, the composition provides sufficiently high internal integrity such that the composition may be cast into a hot gas path component of a gas turbine or an aviation engine subjected to temperatures of at least about 2,000 °F without requiring the use of hot isostatic pressing. Hot isostatic pressing is widely used in order to close the solidification shrinkage porosities inside a cast article and to improve the mechanical properties to meet requirements of a hot gas path component of a gas turbine or an aviation engine subjected to temperatures of at least about 2,000 °F. Eliminating a processing step of subjecting a cast article to hot isostatic pressing reduces the cost of producing the cast article.

[0023] In one embodiment, the surface of an article formed from the composition according to the present disclosure forms a stable aluminum oxide-rich scale hot under operating conditions for the hot gas path of a gas turbine or an aviation engine. In a further embodiment, the stable aluminum oxide-rich scale retards the diffusion of reactive species in the oxidative environment and improves the oxidation and hot corrosion capabilities of the composition according to the present disclosure.

EXAMPLES

[0024] In one embodiment (referred to herein as "RNX"), the composition according to the present disclosure includes, by weight percent, 6.25% aluminum (Al), 4.0% tantalum (Ta), 12.5% chromium (Cr), 7.5% cobalt (Co), 0.5% molybdenum (Mo), 5.0% tungsten (W), 0.5% hafnium (Hf), 0.0075% Boron (B), 0.08% carbon (C), and balance nickel (Ni) and incidental impurities.

[0025] In one embodiment, the high castability of the composition relative to R108 is exemplified by the comparison that an article formed from RNX according to the present disclosure undergoes 50% less solidification shrinkage during casting than does a corresponding article formed from R108.

[0026] Referring to FIG. 1, in one embodiment, the high castability of the composition is demonstrated by an article formed from RNX according to the present disclosure by precision investment casting with variable pressure control, wherein the article is a hot gas path component of a gas turbine, specifically a 48-pound nozzle. The nozzle includes a plurality of very small dimples having complicated geometry, wherein the nozzle includes more than about 400 dimples per square inch on a curved internal surface. The dimples are formed with a high degree of precision suitable for use under operating conditions.

[0027] In one embodiment, the tensile properties, including yield strength, ultimate strength and ductility, of an article formed from RNX according to the present disclosure are at least comparable to the tensile properties of a corresponding article formed from N2Re.

[0028] Referring to FIG. 2, in one embodiment, an article formed from RNX according to the present disclosure has a low-cycle fatigue lifetime about 20% greater, alternatively about 18% to about 22% greater, than a corresponding low-cycle fatigue lifetime exhibited by a corresponding article formed from N2Re, and about 54% greater, alternatively about 50% to about 58% greater, than a corresponding low-cycle fatigue lifetime exhibited by a corresponding article formed from R108, under testing conditions of 1,800 °F and 0.6% strain with two minutes of hold time.

[0029] Referring to FIG. 3, in one embodiment, an article formed from RNX according to the present disclosure has a creep lifetime about 2.3 times greater, alternatively about 2.0 to about 2.6 times greater, than a corresponding creep lifetime exhibited by a corresponding article formed from N2Re, and about 28% greater, alternatively about 25% to about 31% greater, than a corresponding creep lifetime exhibited by a corresponding article formed from R108, under testing conditions of 1,800 °F and 20 ksi.

[0030] In one embodiment, an article formed from RNX according to the present disclosure has an oxidation resistance about the same as a corresponding oxidation resistance exhibited by a corresponding article formed from N2Re, and about 3 times greater, alternately about 2.7 to about 3.3 times greater, than a corresponding oxidation resistance exhibited by a corresponding article formed from R108.

[0031] In one embodiment, an article formed from RNX according to the present disclosure has a hot corrosion resistance about the same as a corresponding hot corrosion resistance exhibited by a corresponding article formed from N2Re, and about 2 times greater, alternately about 1.8 to about 3.2 times greater, than a corresponding hot corrosion resistance exhibited by a corresponding article formed from R108.

[0032] Referring to FIG. 4, a comparison is shown of the oxidation layer depth for an article formed from RNX according to the present disclosure and a corresponding article formed from R108 under testing conditions of 2,000 °F for up to 4,000 hours in a burner rig.

[0033] Referring to FIGS. 5 and 6, in one embodiment, following testing in a burner rig at 2,000 °F for 4,000 hours, an article formed from RNX according to the present disclosure (FIG. 5) includes a composition depletion depth 502, and a corresponding article formed from R108 (FIG. 6) having an equiaxed grain structure includes an R108 depletion depth 602. The article formed from RNX undergoes surface depletion at about one-half the rate, alternatively about one-quarter to about three-quarters, of the corresponding article formed from R108. As used herein, "depletion" means the disappearance of a coherent strengthening phase gamma prime (γ').

[0034] In a further embodiment, the chemical formula for γ' is $Ni_3(Al,Ti,Ta)$. Without being bound by theory, it is believed that oxidation of Al and Ti destroys γ' and causes the formation of a depletion zone. In the depletion zone, the RNX includes a weakened matrix resulting in a significantly reduced load-bearing capability. The significantly reduced load-bearing capability may lead to premature failures when an article is subjected to operating conditions. Therefore, narrowed depletion zone for an article formed from RNX according to the present disclosure represents a remarkable improvement as compared to a corresponding articled formed from R108 when the article is a hot gas path component of a gas turbine or an aviation engine.

[0035] Both the oxidation layer depth and the pitting depth are reduced in the article formed from RNX as compared to the corresponding article formed from R108. Without being bound by theory, it is believed that hafnium (Hf) is highly reactive with oxygen, and the higher concentration of hafnium (Hf) in R108 as compared to RNX (approximately 3-fold higher) promotes hafnium (Hf) segregation during solidification of an article in a casting process, which results in more severe pitting in articles formed from alloys with higher concentrations of hafnium (Hf) (such as R108) as compared to RNX.

[0036] While the invention has been described with reference to one or more embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. An article comprising an equiaxed grain structure and a composition, wherein the composition comprises, by weight percent:

about 6.0% to about 9.0% aluminum (Al);
up to about 0.5% titanium (Ti);
about 2.5% to about 4.5% tantalum (Ta);
about 10.0% to about 12.5% chromium (Cr);
about 5.0% to about 10.0% cobalt (Co);
about 0.30% to about 0.80% molybdenum (Mo);
about 2.0% to about 5.0% tungsten (W);
up to about 1.0% silicon (Si);
about 0.35% to about 0.60% hafnium (Hf);
about 0.005% to about 0.010% boron (B);
about 0.06% to about 0.10% carbon (C);
up to about 0.02% zirconium (Zr);
up to about 0.1% lanthanum (La);
up to about 0.03% yttrium (Y); and
balance nickel (Ni) and incidental impurities, and wherein rhenium (Re), if present, is a trace element.

2. The article of claim 1, wherein the trace element rhenium (Re) is present in an amount of less than about 0.01%, by weight, of the composition.

3. The article of claim 1 or claim 2, wherein the about 2.5% to about 4.5% tantalum (Ta) is replaced completely or partially by niobium (Nb) on a 1:1 molar basis.

4. The article of any preceding claim, wherein the composition further comprises, by weight percent:

about 6.2% to about 6.5% aluminum (Al);
up to about 0.04% titanium (Ti);
about 3.9% to about 4.3% tantalum (Ta);
about 12.0% to about 12.5% chromium (Cr);
about 7.0% to about 8.0% cobalt (Co);
about 0.40% to about 0.75% molybdenum (Mo);
about 4.7% to about 5.1% tungsten (W);
about 0.08% to about 0.12% silicon (Si);
about 0.47% to about 0.53% hafnium (Hf);
about 0.005% to about 0.010% boron (B);
about 0.06% to about 0.10% carbon (C);
up to about 0.02% zirconium (Zr);
up to about 0.1% lanthanum (La);
up to about 0.03% yttrium (Y);
up to about 0.01% rhenium (Re); and
balance nickel (Ni); and incidental impurities.

5. The article of any preceding claim, wherein the article is a hot gas path component of a gas turbine or an aviation engine, and wherein the hot gas path component is subjected to temperatures of at least about 1093° C (2,000° F).

6. The article of claim 5, wherein the hot gas path component is selected from the group consisting of a blade, a vane, a seal and a stationary shroud.

7. The article of any preceding claim, wherein the composition of the article has an oxidation resistance, the oxidation resistance being about 2 to about 4 times greater than a corresponding oxidation resistance exhibited by a corresponding composition of R108; and/or
the composition of the article has a low-cycle fatigue lifetime, the low-cycle fatigue lifetime being about 18% to about 22% greater than a corresponding low-cycle fatigue lifetime exhibited by a corresponding composition of N2Re; and/or
the composition of the article has a creep lifetime, the creep lifetime being about 2.0 to about 2.5 times greater than a corresponding creep lifetime exhibited by a corresponding composition of N2Re; and/or
the composition of the article has a hot corrosion resistance, the hot corrosion resistance being about 1.5 to about 2.5 times greater than a corresponding hot corrosion resistance exhibited by a corresponding composition of R108.

8. A method for forming an article, comprising:

providing a composition comprising, by weight percent:

about 6.0% to about 9.0% aluminum (Al);
up to about 0.5% titanium (Ti);
about 2.5% to about 4.5% tantalum (Ta);
about 10.0% to about 12.5% chromium (Cr);
about 5.0% to about 10.0% cobalt (Co);
about 0.30% to about 0.80% molybdenum (Mo);
about 2.0% to about 5.0% tungsten (W);
up to about 1.0% silicon (Si);
about 0.35% to about 0.60% hafnium (Hf);
about 0.005% to about 0.010% boron (B);
about 0.06% to about 0.10% carbon (C);
up to about 0.02% zirconium (Zr);
up to about 0.1% lanthanum (La);
up to about 0.03% yttrium (Y);
up to about 0.01% rhenium (Re); and
balance nickel (Ni) and incidental impurities; and
forming the article, wherein the article comprises an equiaxed grain structure.

9. The method of claim 8, wherein the about 2.5% to about 4.5% tantalum (Ta) is replaced completely or partially by niobium (Nb) on a 1:1 molar basis.

10. The method of claim 8 or claim 9, wherein the composition further comprises, by weight percent:

about 6.2% to about 6.5% aluminum (Al);
up to about 0.04% titanium (Ti);
about 3.9% to about 4.3% tantalum (Ta);
about 12.0% to about 12.5% chromium (Cr);
about 7.0% to about 8.0% cobalt (Co);
about 0.40% to about 0.75% molybdenum (Mo);
about 4.7% to about 5.1 % tungsten (W);
about 0.08% to about 0.12% silicon (Si);
about 0.47% to about 0.53% hafnium (Hf);
about 0.005% to about 0.010% boron (B);
about 0.06% to about 0.10% carbon (C);
up to about 0.02% zirconium (Zr);
up to about 0.1% lanthanum (La);
up to about 0.03% yttrium (Y);
up to about 0.01% rhenium (Re); and
balance nickel (Ni); and incidental impurities.

11. The method of any one of claims 8 to 10, wherein the article is a hot gas path component of a gas turbine or an aviation engine, and wherein the hot gas path component is subjected to temperatures of at least about 1093° C (2,000° F).

12. The method of claim 11, wherein the hot gas path component is selected from the group consisting of a blade, a vane, a nozzle, a seal and a stationary shroud.

13. The method of any one of claims 8 to 11, wherein forming the article comprises casting, powder metallurgy or three-dimensional additive machining.

14. The method of claim 13, wherein casting comprises precision investment casting with variable pressure control.

15. The method of claim 14, wherein precision investment casting with variable pressure control comprises:

a surface re-melting pressure of 10^{-3} atmospheres; and
an inert gas casting pressure of about 10^{-2} atmospheres to about 10^{-1} atmospheres.

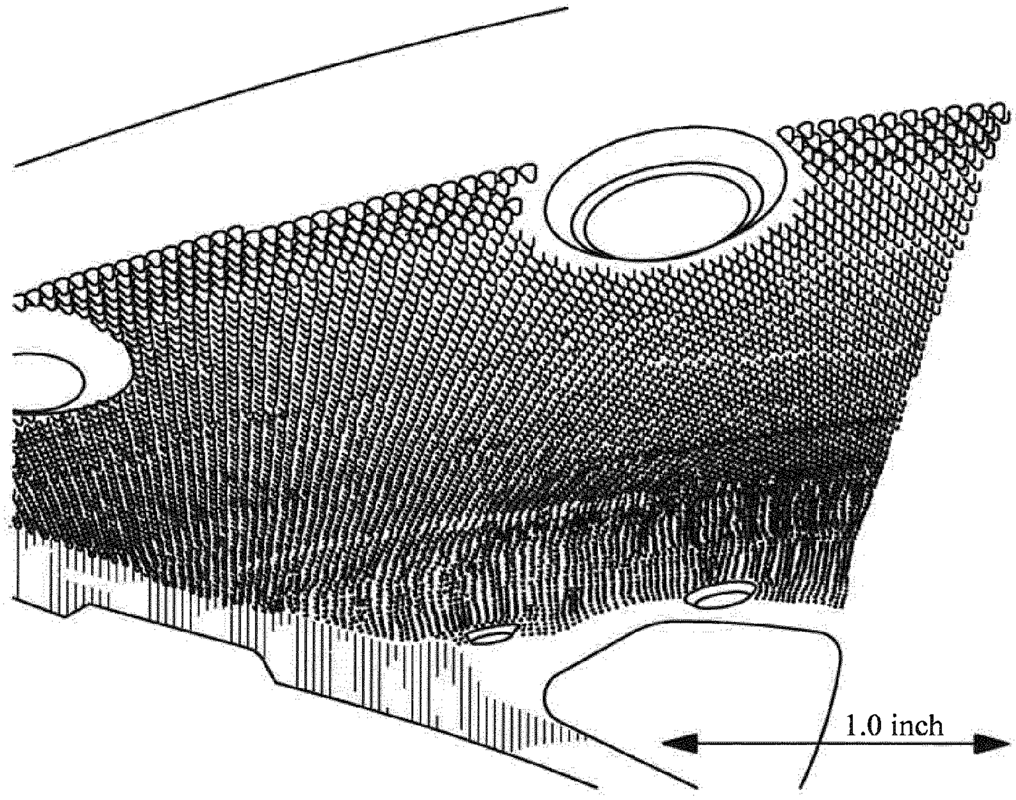

1.0 inch

FIG. 1

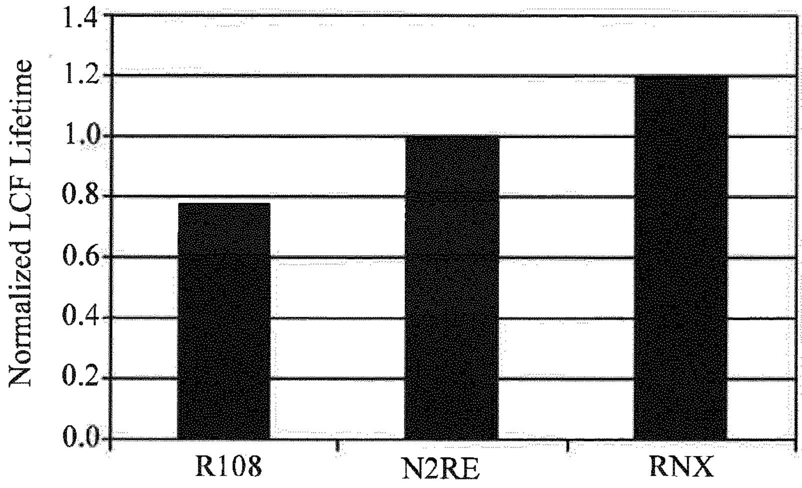
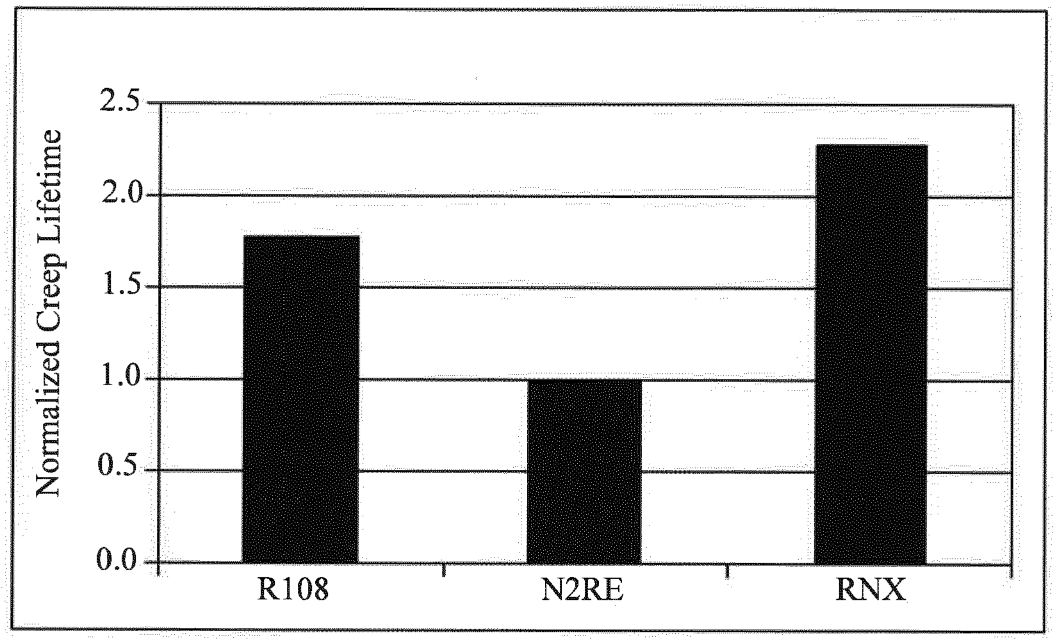

Normalized LCF Lifetime
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
R108
N2RE
RNX

FIG. 2


Normalized Creep Lifetime
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2.0
1.5
1.0
0.5
0.0
R108
N2RE
RNX

FIG. 3

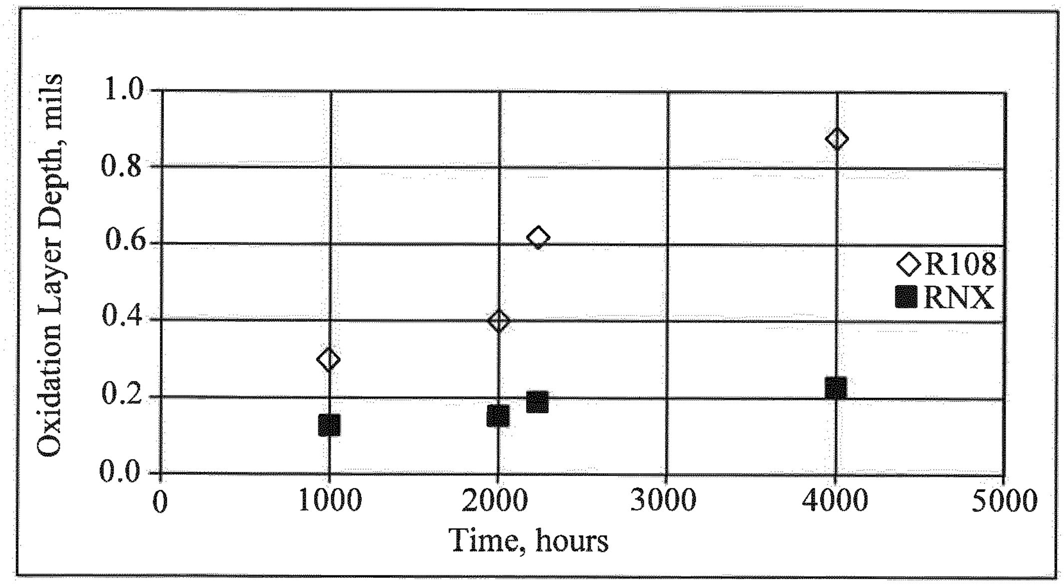
Oxidation Layer Depth, mils
1.0
0.8
0.6
0.4
0.2
0.0
0
1000
2000
3000
4000
5000
Time, hours
R108
RNX

FIG. 4

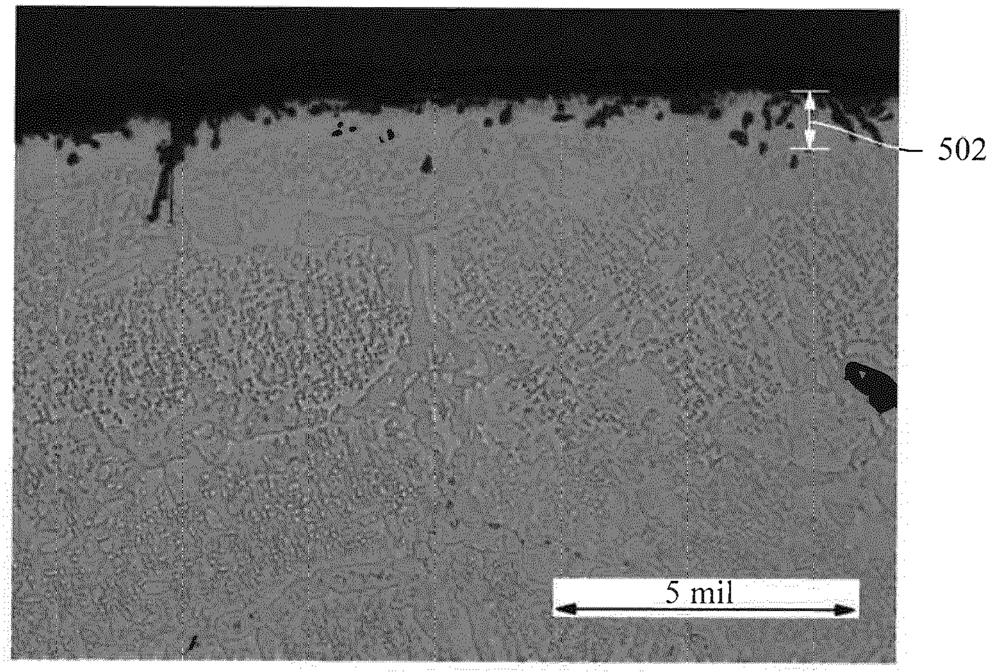

FIG. 5

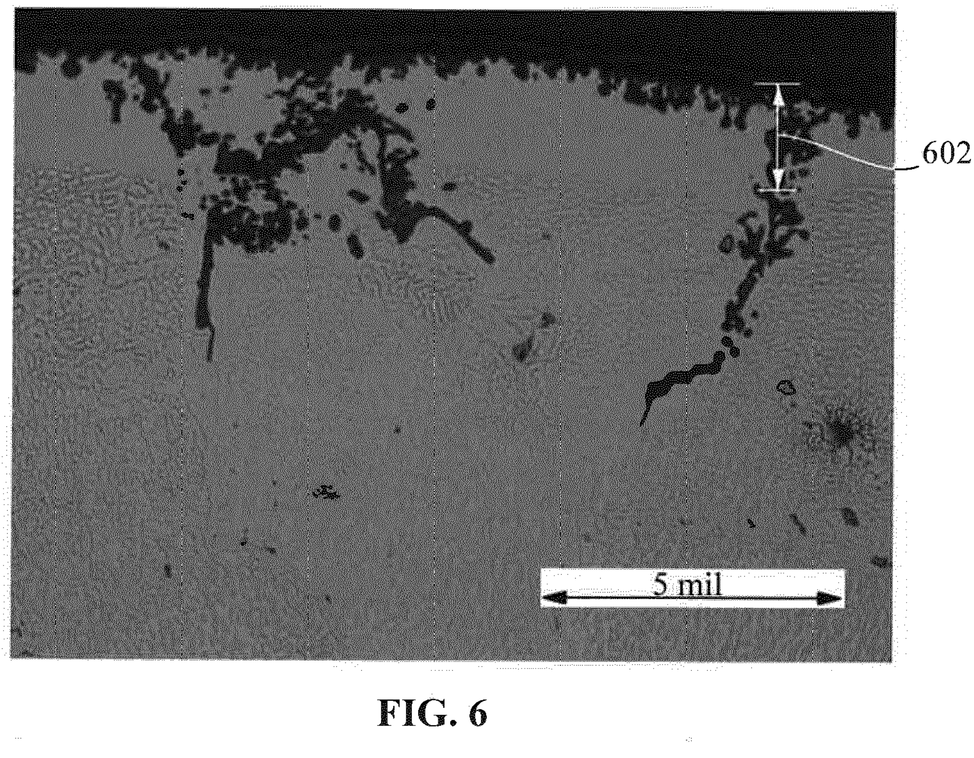

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 15 15 6338

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
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