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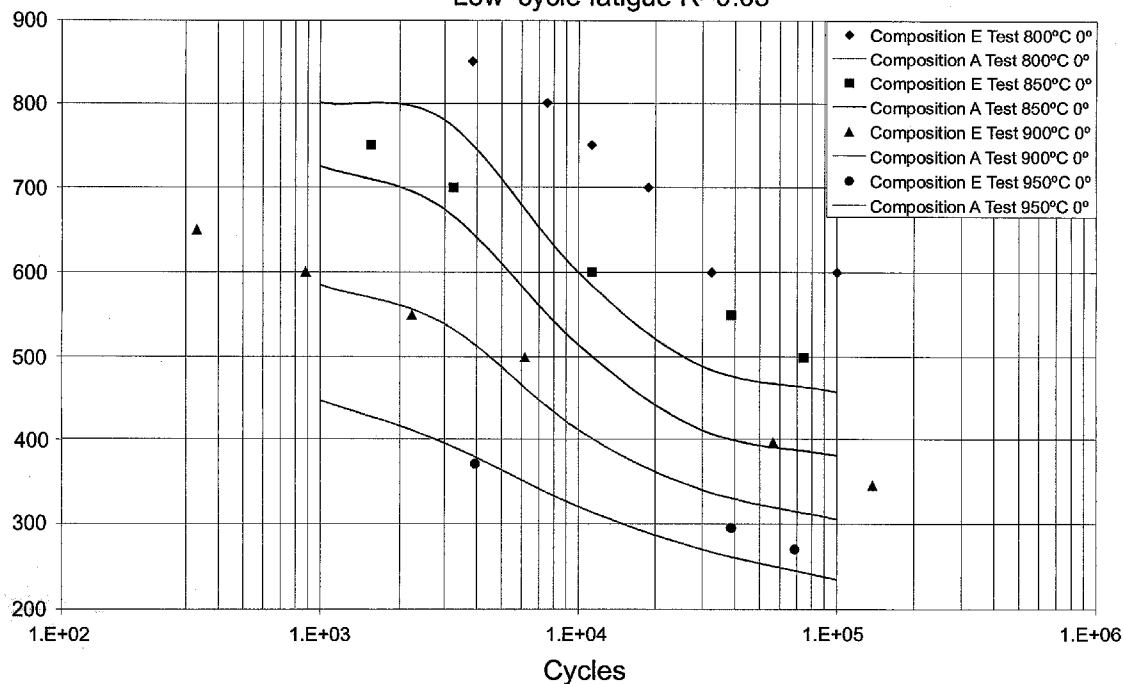
(19) **United States**(12) **Patent Application Publication****Madariaga Rodriguez et al.**(10) **Pub. No.: US 2008/0240972 A1**(43) **Pub. Date: Oct. 2, 2008**(54) **LOW-DENSITY DIRECTIONALLY
SOLIDIFIED SINGLE-CRYSTAL
SUPERALLOYS**(22) Filed: **Nov. 30, 2007**(30) **Foreign Application Priority Data**(75) Inventors: **Inaki Madariaga Rodriguez,**
Leioa (ES); **Inigo Hernandez**
Aguirre, Getxo (ES); **Amaia**
Subinas Rapp, Bilbao (ES); **Koldo**
Estolaza Zamora, San Sebastian
(ES)

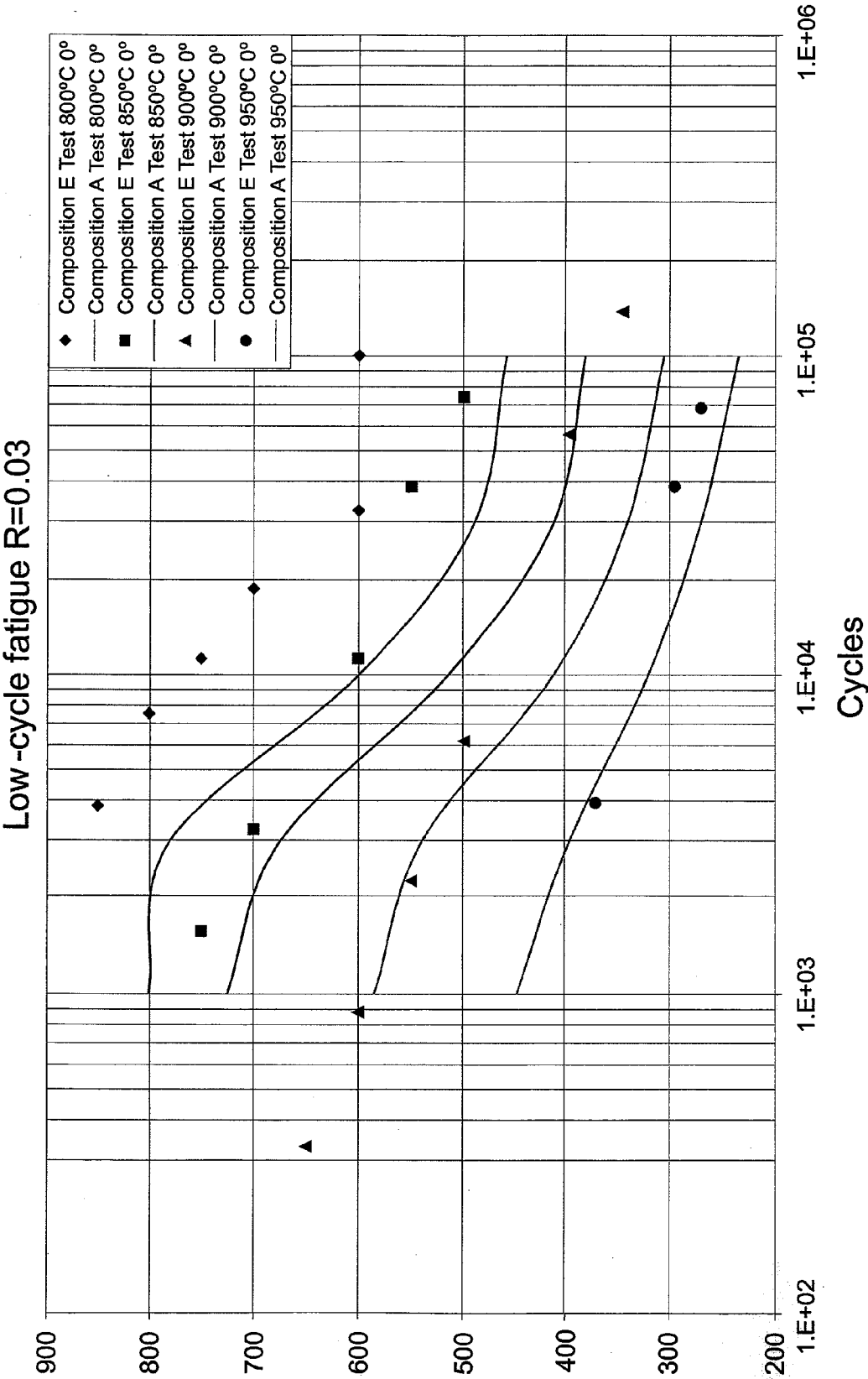
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C22C 19/05 (2006.01)(52) **U.S. Cl.** **420/448; 148/410**(57) **ABSTRACT**

A low-density nickel-base superalloy includes the following elements (percent by weight): 7-13% Chromium, 0-16% Cobalt, 2-5% Titanium, 4.5-7% Aluminium, 0-5% Tantalum, 0-2% Hafnium, 0-3% Tungsten, 0-2% Vanadium, 0-5% Molybdenum, 0.06-0.12% Carbon, 0.01-0.03% Boron, 0.005-0.02% Zirconium, nickel and residual impurities use and to the process for obtaining it. The superalloy has advantageous uses and is obtained by processing.

Correspondence Address:

MERCHANT & GOULD PC**P.O. BOX 2903****MINNEAPOLIS, MN 55402-0903 (US)**(73) Assignee: **INDUSTRIA DE TURBO**
PROPULSOIRES, S.A., Zamudio
(ES)(21) Appl. No.: **11/948,431****Low-cycle fatigue R=0.03**



LOW-DENSITY DIRECTIONALLY SOLIDIFIED SINGLE-CRYSTAL SUPERALLOYS

BACKGROUND OF THE INVENTION

[0001] The present invention relates to nickel-base superalloys used to manufacture gas turbine blades or vanes by means of directional solidification or in the form of single crystals. The present invention particularly relates to low-density alloys which can work under high temperature and high load conditions.

SUMMARY OF THE INVENTION

[0002] Nickel-base superalloys are widely used in the manufacture of components for gas turbines. In the particular field of gas turbines for aircraft, apart from the high requirements from the stress and temperature point of view, it is also important to develop low-density alloys. A precursor of low-density alloys is the In100 alloy (density 7.76 gr/cm³) developed at that beginning of the 60s by The International Nickel Company (INCO) and covered by patent U.S. Pat. No. 3,061, 426. This alloy is still used today to manufacture equiaxed turbine blades although it is admitted that it has low castability and low corrosion resistance.

[0003] In100 has been used as the basis for developing many alloys. Among others, In6212 (density 8.02 gr/cm³) covered by patent U.S. Pat. No. 4,358,318 was also developed by INCO as a low-density material with better corrosion resistance and castability than those of In100 at the expense of a slight increase of density.

[0004] These two equiaxed materials, In100 and In6212, have been used as the basis for developing several single-crystal alloys. In100 was used as a reference for developing the RR2000 alloy, covered by patent GB 2105369A in 1983 whereas In6212 was used as the basis for developing the CMSX-6 alloy, covered by patent U.S. Pat. No. 4,721,540.

[0005] Both single-crystal alloys were developed according to a similar strategy. In both cases, the amount of grain boundary hardening elements such as carbon, boron and zirconium was eliminated to increase the melting point of the alloy. It was thus possible to carry out a solution heat treatment of the hardening gamma prime phase dissolving the microstructure obtained directly after the casting and achieving a fine and homogeneous distribution of precipitates in the subsequent heat treatments.

[0006] There is therefore a need to develop alternative alloys to those used currently.

DESCRIPTION OF THE INVENTION

[0007] The present invention provides a low-density superalloy (7.867 g/cm³) useful for manufacturing components by means of directional solidification or single-crystal components with a relaxed grain structure specification.

[0008] A first aspect of the invention relates to a nickel-base superalloy comprising the following elements (percent by weight):

7-13% Chromium,
0-16% Cobalt,
2-5% Titanium,
4.5-7% Aluminium,
0-5% Tantalum,
0-2% Hafnium,

0-3% Tungsten
0-2% Vanadium
0-5% Molybdenum
0.06-0.12% Carbon,
0.01-0.03% Boron,
0.005-0.02% Zirconium,

[0009] Nickel and residual impurities

[0010] In a particular embodiment the present invention relates to a nickel-base superalloy comprising: 0.07% carbon, 10% chromium, 15% cobalt, 3% molybdenum, 5.5% aluminium, 4% titanium, 1% vanadium, 1.4% hafnium, 0.015% boron and 0.01% zirconium.

[0011] In a particular embodiment the present invention relates to a nickel-base superalloy comprising: 0.07% carbon, 10% chromium, 5% cobalt, 3% molybdenum, 2% tantalum, 4.8% aluminium, 4.7% titanium, 1.4% hafnium, 0.015% boron and 0.01% zirconium.

[0012] A second aspect of the present invention relates to the use of a nickel-base superalloy described above for obtaining a directionally solidified casting or a casting in single-crystal form.

[0013] A third aspect of the present invention relates to a process for obtaining a superalloy as described above, comprising the following steps:

[0014] a) Solution heat treatment at a temperature comprised between 1190-1250° C. for 1 to 5 hours

[0015] b) Intermediate heat treatment at a temperature comprised between 1000-1100° C. for 1 to 5 hours

[0016] c) Precipitation heat treatment at a temperature comprised between 850-900° C. for 1 to 16 hours

[0017] A fourth aspect of the present invention relates to a gas turbine comprising components manufactured with a superalloy as described above, or from alloys obtained by means of a process comprising the following steps:

[0018] a) Solution heat treatment at a temperature comprised between 1190-1250° C. for 1 to 5 hours

[0019] b) intermediate heat treatment at a temperature comprised between 1000-1100° C. for 1 to 5 hours

[0020] c) precipitation heat treatment at a temperature comprised between 850-900° C. for 1 to 16 hours

BRIEF DESCRIPTION OF DRAWINGS

[0021] FIG. 1: Low-cycle fatigue of composition E compared to commercial composition A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] The present invention provides a low-density superalloy useful for manufacturing components by means of directional solidification or single-crystal components with a relaxed grain structure specification. The alloy of the present invention was developed taking two single-crystal alloys, RR2000 and CMSX-6, as a reference.

[0023] The following table shows examples of alloys according to this invention, alloys E to G, inclusive. Alloys A and B are commercial alloys for directional solidification whereas C and D are commercial alloys for manufacturing low-density single-crystal components. The latter alloys are only set forth as a comparison and are not included within the scope of this invention.

Alloy	Co	Cr	Mo	W	Al	Ta	V	Ti	Re	Hf	C	B	Zr
A	9.2	8.1	0.5	9.5	5.6	3.2		0.7		1.4	0.07	0.015	0.007
B	9.3	6	0.5	8.4	5.7	3.4		0.7	3	1.4	0.07	0.015	0.005
C	15	10	3		5.5		1	4					
D	5	10	3		4.8	2		4.7		0.1			
E	15	10	3		5.5		1	4		1.4	0.07	0.015	0.005
F	6	12	3	2	4.5			4.7		1.4	0.07	0.015	0.005
G	5	10	3		4.8	2		4.7		1.4	0.07	0.015	0.005

[0024] Carbon, boron and zirconium were added to the base composition of RR2000 and CMSX-6 but without reaching the high levels of these elements in the compositions In100 or of In6212. The C, B and Zr of the alloy of this invention were maintained at the same levels as other commercial alloys that are usually used for manufacturing directionally solidified components such as alloy A and B of the previous table. The maximum carbon content was limited to 0.12%, the maximum boron content to 0.03% and the maximum zirconium content to 0.02%, while these limits are 0.5%, 0.1% and 0.25% respectively in In100. Hafnium was added to the composition to favor carbide formation in the grain boundary.

[0025] The introduction of these elements involved a reduction in the melting temperature of the alloy. Such that the maximum temperature at which the supersolution heat treatment can be carried out is limited, and therefore it is not possible to reach the high temperatures that are used in the supersolution treatments of single-crystal materials. The gamma prime dissolution that was achieved with the supersolution treatments was thus not as effective as that achieved with the high temperature treatments used in single-crystals. Nevertheless, there are commercial alloys which can be used to manufacture components by means of directional solidification with and without supersolution heat treatment. The absence of supersolution heat treatment gave rise to a drop in the alloy temperature capacity of about 30° C.

[0026] Even with this reduction, the benefit obtained with the low density of the alloy of this invention makes it a suitable option for manufacturing gas turbine blades or vanes.

[0027] The absence of supersolution heat treatment can also give rise to a loss of the resistance to low-cycle fatigue of the alloy with respect to the commercial RR2000 alloy from which it has been developed. However, as can be seen in FIG. 1, composition E of Table 1 has fatigue properties that are greater than those of commercial alloy A.

[0028] The introduction or grain boundary hardening elements allowed the use of this alloy for manufacturing directionally solidified components, which is not possible with most single-crystal alloys. The fact of using an alloy in directional solidification form instead of in single-crystal form gave rise to reduction in the creep rupture of the alloy. Nevertheless, this decrease was considered very small and therefore the alloy of this invention is sufficiently attractive for a wide range of applications.

[0029] Finally, it must be mentioned that the main purpose of this alloy is to offer a low-density alternative to alloys that are currently used in gas turbines. The presence of elements such as C, B, Zr and Hf improved the tolerance of the alloy to the presence of grain boundaries at the expense of a small reduction in properties such as fatigue or creep rupture. But

having been designed from low-density single-crystal alloys, even with this decrease of properties, the alloy of the present invention offers a clear improvement with respect to the alloys that are currently used for manufacturing directionally solidified materials. This benefit will be even greater in the design of advanced gas turbines in which the rotational speed is higher and therefore the centrifugal forces are greater, and the use of a low-density material is a clear advantage.

[0030] Likewise, it must also be mentioned that the use of this material in gas turbines for aircraft involves a clear improvement with respect to current alloys because it can give rise to lighter components and therefore to a lower specific turbine consumption.

1. A nickel-base superalloy comprising the following elements (percent by weight)

7-13% Chromium,
0-16% Cobalt,
2-5% Titanium,
4.5-7% Aluminium,
0-5% Tantalum,
0-2% Hafnium,
0-3% Tungsten
0-2% Vanadium
0-5% Molybdenum
0.06-0.12% Carbon,
0.01-0.03% Boron,
0.005-0.02% Zirconium,
Nickel and residual impurities.

2. A superalloy according to claim 1, comprising: 0.07% carbon, 10% chromium, 15% cobalt, 3% molybdenum, 5.5% aluminium, 4% titanium, 1% vanadium, 1.4% hafnium, 0.015% boron and 0.01% zirconium.

3. A superalloy according to claim 1, comprising: 0.07% carbon, 10% chromium, 5% cobalt, 3% molybdenum, 2% tantalum, 4.8% aluminium, 4.7% titanium, 1.4% hafnium, 0.015% boron and 0.01% zirconium.

4. The use of a nickel-base superalloy according to claim 1 for obtaining a directionally solidified casting or a casting in single-crystal form.

5. A process for obtaining a superalloy described in claim 1 comprising the following steps:

- a) solution heat treatment at a temperature comprised between 1190-1250° C. for 1 to 5 hours
- b) intermediate heat treatment at a temperature comprised between 1000-1100° C. for 1 to 5 hours
- c) precipitation heat treatment at a temperature comprised between 850-900° C. for 1 to 16 hours

6. A gas turbine comprising components manufactured with a superalloy according to claim 1.

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