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(54) **NICKEL-BASED ALLOY**

(71) Applicant: **ROLLS-ROYCE PLC**, London (GB)

(72) Inventor: **Mark Christopher HARDY**, Belper (GB)

(73) Assignee: **ROLLS-ROYCE PLC**, London (GB)

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(57) **ABSTRACT**

Adding silicon, in a defined range of weight percentage, to the composition of a known nickel-based alloy improves oxidation, hot corrosion and dwell crack growth resistance without the detrimental effects on the thermal stability of the microstructure and on other material properties that have been found with known alloys. In a particular preferred embodiment the alloy has the following composition (in weight percent): chromium 14.6-15.4%; cobalt 18-19%; molybdenum 4.75-5.25%; aluminium 2.8-3.2 titanium 3.4-3.8%; tantalum 1.8-2.2%; hafnium 0.4-0.6%; carbon 0.020-0.034%; boron 0.005-0.025%; silicon 0.2-0.6%; the remainder being nickel and incidental impurities.

NICKEL-BASED ALLOY

[0001] This invention relates to nickel-based alloys, and particularly (although not exclusively) to nickel-based alloys suitable for use in discs of gas turbine engines.

[0002] Known nickel-based alloys were developed for applications such as blades, nozzle guide vanes and combustor components in gas turbine engines. For such applications, the alloys were designed to have improved oxidation resistance in the temperature range 760-1100° C. Such alloys were typically wrought processed, to produce a polycrystalline microstructure, or investment cast, to produce conventionally cast, directionally solidified or single crystal microstructure.

[0003] The so-called third-generation powder metallurgy alloys, such as ME3, Alloy 10 and LSHR, are nickel alloys developed for disc rotor applications at temperatures up to about 700° C. They are all processed using powder metallurgy techniques.

[0004] To enable high-temperature strength and creep resistance to be optimised and to maintain a stable microstructure during exposure to high temperatures, the chromium content in these alloys is 11-15 wt %, compared with about 20 wt % in previous alloys such as Inconel® 718 and Waspaloy®. However, these alloy compositions are not optimised for certain other mechanical properties, such as oxidation resistance, resistance to hot corrosion damage and resistance to dwell crack growth. All of these properties are particularly important for rotor disc applications, because they can limit component life.

[0005] The inventors have discovered a modification to the composition of the known nickel-based alloy RR1000 that improves oxidation, hot corrosion and dwell crack growth resistance, without the detrimental effects on the thermal stability of the microstructure and on other material properties that have been found with known alloys.

[0006] Accordingly, the invention provides a nickel-based alloy and a component made from such an alloy, as set out in the claims.

[0007] Embodiments of the invention will now be described, by way of example only, so that it can be better understood how it is to be put into effect.

[0008] The inventors have discovered the unexpected result that adding silicon, in a defined range of weight percentage, to the composition of the known nickel-based alloy RR1000 improves oxidation, hot corrosion and dwell crack growth resistance without the detrimental effects on the thermal stability of the microstructure and on other material properties that have been found with known alloys.

[0009] Powder particles of the compositions shown in Table 1 were produced by argon gas atomisation. The particles were screened to a final screen size of 53 μm and filled into a mild steel container. Not isostatic pressing was then used to consolidate the particles.

[0010] The resulting compacts were isothermally forged to produce pancake forgings, and solution heat treated to produce fine-grained (average grain size <10 μm) and coarse-grained (average grain size 20-65 μm) microstructures.

TABLE 1

Alloy	Cr	Co	Mo	Al	Ti	Ta	Hf	C	B	Zr	Si	Ni
RR1000	15	18.5	5	3	3.6	2	0.5	0.027	0.015	0.06	0	rem.
#1	15	18.5	5	3	3.6	2	0.5	0.027	0.015	0.06	0.2	rem.
#2	15	18.5	5	3	3.6	2	0.5	0.027	0.015	0.06	0.5	rem.

[0011] Oxidation damage at temperatures between 700 and 800° C. was evaluated by weight change by thermogravimetric analysis on RR1000 and on the alloys #1 and #2 according to the invention. The test pieces were prepared from forgings having fine- and coarse-grained microstructures.

[0012] Hot corrosion resistance was evaluated by deposit recoat experiments at 700° C. on the three alloys. The test pieces were prepared from forgings having a fine-grained microstructure. In these tests, samples were coated with deposits of 98% Na_2SO_4/2% NaCl in a gas stream of air containing 300 vpm SO_2. Corrosion damage is quantified by dimensional metrology of the samples before and after exposure, to determine the amount of sound metal loss.

[0013] Dwell crack growth resistance was evaluated in laboratory air at 700° C. on 5 mm×5 mm square section, corner notch test pieces. The test pieces were prepared from forgings having a coarse-grained microstructure. Fatigue cycles consisting of a 3600s dwell period at peak load and a stress ratio of 0.1 were used.

[0014] By adding a quantity of silicon between 0.2 and 0.6 wt % to the known RR1000 alloy composition, an unexpected improvement in key material properties has been achieved in temperature ranges that are important for gas turbine rotor disc applications, without the detrimental effects in other properties previously associated with such improvements.

[0015] Further improvements may be achievable with higher levels of silicon, but these are considered to reduce the stability of the microstructure, and promote the precipitation of topological close-packed phases (e.g. sigma) during prolonged exposure to temperatures above about 675° C. Such phases form at grain boundaries and are detrimental to tensile strength and ductility, stress rupture and dwell crack growth resistance.

[0016] It is believed that additions of silicon, as described above, could provide similarly beneficial results in other rotor disc alloys. The results are not dependent on a particular processing method, but can be realised for cast, wrought and powder processed alloys.

[0017] it is believed that the most significant benefits are achieved when silicon is used in combination with reactive elements such as hafnium, zirconium and magnesium that "get" oxygen and sulphur and low levels of sulphur and phosphorous.

1. A nickel-based alloy including between 0.2 wt % and 0.6 wt % silicon to improve oxidation resistance, dwell crack growth resistance and hot corrosion resistance without detrimental effect on other mechanical properties of the alloy.

2. An alloy as claimed in claim **1**, further including at least one of the following:

hafnium <=0.75 wt %;

zirconium <=0.1 wt %;

magnesium <=0.03 wt %;

sulphur <=5 ppm;

phosphorous <10 ppm.

3. An alloy as claimed in claim **1** having the following composition in weight percent:
chromium 14.6-15.4%;
cobalt 18-19%;
molybdenum 4.75-5.25%;
aluminium 2.8-12%;
titanium 3.4-3.8%;
tantalum 1.8-2.2%;
hafnium 0.4-0.6%;
carbon 0.020-0.034%;
boron 0.005-0.025%;
silicon 0.2-0.6%;
the remainder being nickel and incidental impurities.

4. An alloy as claimed in claim **1**, having the following composition in weight percent:
chromium 15%;
cobalt 18.5%;
molybdenum 5%;
aluminium 3%;
titanium 3.6%;
tantalum 2%;
hafnium 0.5%;
carbon 0.027%;
boron 0.015%;
silicon 0.2-0.6%;
the remainder being nickel and incidental impurities.

5. An alloy as claimed in claim **1**, having the following composition in weight percent:
chromium 15%;
cobalt 18.5%;
molybdenum 5%;
aluminium 3%;
titanium 3.6%;
tantalum 2%;
hafnium 0.5%;
carbon 0.027%;
boron 0.015%;
silicon 0.2%;
the remainder being nickel and incidental impurities.

6. An alloy as claimed in claim **1**, having the following composition in weight percent:
chromium 15%;
cobalt 18.5%;
molybdenum 5%;
aluminium 3%;
titanium 3.6%;
tantalum 2%;
hafnium 0.5%;
carbon 0.027%;
boron 0.015%;
silicon 0.5%;
the remainder being nickel and incidental impurities.

7. A component fanned of an alloy as claimed in claim **1**.

8. A component as claimed in claim **7**, the component being a disc for a gas turbine engine.

9-10. (canceled)

11. A component formed of an alloy as claimed in claim **2**.

12. A component formed of an allay as claimed in claim **3**

13. A component fanned of an alloy as claimed in claim **4**.

14. A component formed of an alloy as claimed in claim **5**.

15. A component formed of an alloy as claimed in claim **6**.

16. A component as claimed in claim **11**, the component being a disc for a gas turbine engine.

17. A component as claimed in claim **12**, the component being a disc for a gas turbine engine.

18. A component as claimed in claim **13**, the component being a disc for a gas turbine engine.

19. A component as claimed in claim **14**, the component being a disc for a gas turbine engine.

20. A component as claimed in claim **15**, the component being a disc for a gas turbine engine.

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