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(54) **Nickel-chromium-molybdenum-vanadium alloy and turbine component**

(57) A NiCrMoV alloy and a turbine component are disclosed. The NiCrMoV alloy includes at least about 0.06%, at least about 3.40% nickel, between about 0.22% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up

to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up to about 0.012% tin, and up to about 0.015% aluminum and/or is resistant to embrittlement at temperatures above 371°C (700°F).

EP 2 671 959 A1

Description

FIELD OF THE INVENTION

[0001] The present invention is directed to alloys and components comprising alloys. More specifically, the present invention is directed to Nickel-Chromium-Molybdenum-Vanadium (NiCrMoV) alloys.

BACKGROUND OF THE INVENTION

[0002] In general, steam turbine plants can include a high pressure steam turbine, an intermediate pressure steam turbine, and a low pressure steam turbine. Each steam turbine is formed of materials appropriate to withstand operating conditions, pressure, temperature, flow rate, etc., for that particular turbine. Each turbine can include a rotor and a casing jacket. The rotor includes a rotatably mounted turbine shaft that includes blades. When heated and pressurized steam flows through the flow space between the casing jacket and the rotor, the turbine shaft is set in rotation as energy is transferred from the steam to the rotor.

[0003] Recently, steam turbine plant designs directed toward a larger capacity and a higher efficiency have been designed that include steam turbines that operate at higher temperatures and/or for longer periods. For example, the low pressure steam turbine can include low pressure rotor forgings that operate for long periods of time at temperatures in excess of 600°F. Alloys of NiCrMoV formed by conventional steel making processes and used at temperatures above 600°F undesirably require special cooling otherwise an undesirable increase in the ductile to brittle transition temperature occurs.

[0004] NiCrMoV alloys capable of handling these high temperatures require extensive steelmaking processing to reduce the content of deleterious impurities, for example, having manganese at a concentration of less than about 0.06% and phosphorus at a concentration of less than about 0.005%. These alloys are referred to as superclean. These superclean alloys can incur a high manufacturing cost and/or are not capable of being produced by conventional steel making processes.

[0005] An alloy and turbine component having an alloy that do not suffer from one or more of the above drawbacks would be desirable in the art.

BRIEF DESCRIPTION OF THE INVENTION

[0006] In an exemplary embodiment, a NiCrMoV alloy includes, by weight, between about 0.06% and about 0.12% manganese, at least about 3.40% nickel, between about 0.24% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up

to about 0.012% tin, and up to about 0.015% aluminum.

[0007] In an exemplary embodiment, a NiCrMoV alloy includes, by weight, between about 0.06% and about 0.12% manganese, at least about 3.40% nickel, between about 0.22% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up to about 0.012% tin, and up to about 0.015% aluminum. The phosphorus is present at a concentration of at least about 0.007%, the sulfur is present at a concentration of at least about 0.006%, the silicon is present at a concentration of at least about 0.05%, or a combination thereof.

[0008] In another exemplary embodiment, a NiCrMoV alloy includes nickel, chromium, molybdenum, vanadium, and manganese, the manganese being at a concentration of, by weight, at least about 0.06%. The NiCrMoV alloy is resistant to embrittlement at temperatures above 371°C (700°F).

[0009] Other features and advantages of the present invention will be apparent from the following more detailed description of the preferred embodiment, by way of example, the principles of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Provided is an exemplary NiCrMoV alloy and turbine component. Embodiments of the present disclosure increase resistance to embrittlement, permit use of NiCrMoV alloys at higher temperatures (for example, in excess of 600°F and especially at 700°F and higher, such as above 725°F or above 750°F), extend the operational use of non-superclean NiCrMoV alloys above 600°F, permit production/fabrication of NiCrMoV alloys that are not superclean alloys without requiring special cooling provisions, limit an increase in the ductile to brittle transition temperature to 60% of what a comparable conventional alloy would experience, reduce costs of production/fabrication (for example, by about 25%), increase operational efficiency of turbine systems, or combinations thereof.

[0011] The NiCrMoV alloy is a portion or all of any suitable component. In one embodiment, the NiCrMoV alloy is in a turbine component, for example, in a power generation system, such as, a steam turbine and/or steam turbine system, a gas turbine and/or gas turbine system, or any other suitable system. In one embodiment, the turbine component is a low pressure rotor of a steam turbine in a steam turbine system.

[0012] The NiCrMoV alloy and/or the turbine component is/are formed by any suitable fabrication process (es). In one embodiment, the fabrication process is a conventional steel-making process and/or is not a superclean process, where the superclean process requires much longer times to refine the steel thereby removing impurities, such as, manganese, sulfur, and/or phosphorus.

[0013] In one embodiment, the turbine component in-

cludes the NiCrMoV alloy and the NiCrMoV alloy has a composition of, by weight, between about 0.06% and about 0.12% manganese, at least about 3.40% nickel, between about 0.24% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up to about 0.012% tin, and up to about 0.015% aluminum. In one embodiment, the phosphorus is present at a concentration of at least about 0.007%, the sulfur is present at a concentration of at least about 0.006%, the silicon is present at a concentration of at least about 0.05%, or a combination thereof. In a further embodiment, the NiCrMoV alloy includes a balance of iron and incidental impurities.

[0014] Additionally or alternatively, in one embodiment, the NiCrMoV alloy includes, by weight, at least about 0.06% manganese, the NiCrMoV alloy being resistant to embrittlement, for example, at temperatures of between about 700°F and about 750°F, between about 700°F and about 725°F, between about 725°F and about 750°F, above about 700°F, above about 725°F, about 700°F, about 725°F, about 750°F, or any suitable combination, sub-combination, range, or sub-range thereof.

[0015] In one embodiment, the NiCrMoV alloy limits the amount of manganese permitting the NiCrMoV alloy to be resistant to embrittlement and retain sufficient manganese to combine with the deleterious sulfur impurity. Suitable amounts of manganese include, by weight, between about 0.06% and about 0.09% manganese, between about 0.09% and about 0.12%, between about 0.08% and about 0.10%, about 0.06%, about 0.08%, about 0.10%, about 0.12%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0016] In one embodiment, the phosphorus is present in the NiCrMoV alloy at a concentration of, by weight, between about 0.010% and about 0.012%, between about 0.007% and about 0.010%, between about 0.008% and about 0.011%, about 0.007%, about 0.008%, about 0.009%, about 0.010%, about 0.011%, about 0.012%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0017] In one embodiment, the sulfur is present in the NiCrMoV alloy at a concentration of, by weight, about 0.006%, about 0.007%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0018] In one embodiment, the silicon is present in the NiCrMoV alloy at a concentration of, by weight, between about 0.05% and about 0.08%, between about 0.08% and about 0.10%, between about 0.07% and about 0.08%, about 0.05%, about 0.07%, about 0.08%, about 0.10%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0019] In one embodiment, the carbon is present in the NiCrMoV alloy at a concentration of, by weight, between about 0.22% and about 0.30%, between about 0.24% and about 0.26%, between about 0.22% and about

0.26%, between about 0.22% and about 0.24%, between about 0.24% and about 0.26%, between about 0.26% and about 0.30%, between about 0.28% and about 0.30%, up to about 0.30%, about 0.22%, about 0.24%, about 0.26%, about 0.28%, about 0.30%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0020] In one embodiment, the molybdenum is present in the NiCrMoV alloy at a concentration of, by weight, between about 0.35% and about 0.50%, between about 0.35% and about 0.40%, between about 0.45% and about 0.50%, between about 0.45% and about 0.60%, between about 0.50% and about 0.60%, between about 0.55% and about 0.60%, about 0.35%, about 0.40%, about 0.45%, about 0.50%, about 0.55%, about 0.60%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0021] In one embodiment, the vanadium is present in the NiCrMoV alloy at a concentration of, by weight, between about 0.10% and about 0.15%, between about 0.05% and about 0.10%, between about 0.09% and about 0.13%, between about 0.10% and about 0.12%, about 0.05%, about 0.07%, about 0.08%, about 0.09%, about 0.10%, about 0.11%, about 0.12%, about 0.13%, about 0.14%, about 0.15%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0022] In one embodiment, the chromium is present in the NiCrMoV alloy at a concentration of, by weight, between about 1.70% and about 2.00%, between about 1.50% and about 1.80%, between about 1.80% and about 2.00%, between about 1.70% and about 1.80%, between about 1.50% and about 1.70%, between about 1.50% and about 1.60%, about 1.50%, about 1.70%, about 1.80%, about 2.00%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0023] In one embodiment, the nickel is present in the NiCrMoV alloy at a concentration of, by weight, between about 3.40% and about 3.80%, between about 3.40% and about 3.70%, between about 3.40% and about 3.60%, between about 3.70% and about 4.00%, between about 3.80% and about 4.00%, between about 3.90% and about 4.00%, between about 3.70% and about 3.80%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0024] In one embodiment, the NiCrMoV alloy includes a concentration of, by weight, up to about 0.012% tin, up to about 0.010% tin, up to about 0.005% tin, between about 0.001% and about 0.012% tin, between about 0.008% and about 0.012% tin, between about 0.001% and about 0.010% tin, between about 0.008% and about 0.010% tin, about 0.001% tin, about 0.005% tin, about 0.010% tin, about 0.012% tin, or any suitable combination, sub-combination, range, or sub-range thereof.

[0025] In one embodiment, the NiCrMoV alloy includes a concentration of, by weight, up to about 0.015% aluminum, up to about 0.010% aluminum, up to about 0.005% aluminum, between about 0.001% and about 0.015% aluminum, between about 0.008% and about 0.015%

aluminum, between about 0.012% and about 0.015% aluminum, between about 0.001% and about 0.010% aluminum, between about 0.008% and about 0.010% aluminum, about 0.001% aluminum, about 0.005% aluminum, about 0.010% aluminum, about 0.015% aluminum, or any suitable combination, sub-combination, range, or sub-range thereof.

[0026] In one embodiment, the NiCrMoV alloy includes a concentration of, by weight, up to about 0.002% antimony, up to about 0.001% antimony, about 0.002% antimony, or about 0.001% antimony, or any suitable combination, sub-combination, range, or sub-range thereof.

[0027] In one embodiment, the NiCrMoV alloy includes up to about 0.008% arsenic, up to about 0.006% arsenic, up to about 0.004% arsenic, up to about 0.002% arsenic, between about 0.001% and about 0.008% arsenic, between about 0.003% and about 0.008% arsenic, between about 0.005% and about 0.008% arsenic, between about 0.007% and about 0.008% arsenic, between about 0.003% and about 0.006% arsenic, between about 0.002% and about 0.007% arsenic, or any suitable combination, sub-combination, range, or sub-range thereof.

[0028] In one embodiment, the NiCrMoV alloy includes oxygen, as either dissolved oxygen or in oxides, at a concentration of, by weight, up to about 0.0075%, up to about 0.0050%, up to about 0.0030%, up to about 0.0010%, between about 0.0010% and about 0.0075%, between about 0.0030% and about 0.0075%, between about 0.0010% and about 0.0030%, about 0.0010%, about 0.0030%, about 0.0075%, or any suitable combination, sub-combination, range, or sub-range thereof.

[0029] In one embodiment, the NiCrMoV alloy is substantially devoid of certain impurities and/or trace elements. For example, in one embodiment, the NiCrMoV alloy is substantially devoid of or completely devoid of tungsten, cobalt, and/or niobium. Alternatively, in one embodiment, the NiCrMoV alloy includes trace amounts or more of tungsten, cobalt, and/or niobium.

[0030] While the invention has been described with reference to a preferred embodiment, 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. A NiCrMoV alloy, comprising, by weight:

between about 0.06% and about 0.12% manga-

nese, at least about 3.40% nickel; between about 0.24% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up to about 0.012% tin, and up to about 0.015% aluminum.

2. The NiCrMoV alloy of claim 1, further comprising a balance of iron and incidental impurities.

3. The NiCrMoV alloy of claim 1 or claim 2, wherein the phosphorus is present at a concentration of at least about 0.007%, the sulfur is present at a concentration of at least about 0.006%, the silicon is present at a concentration of at least about 0.05%, or a combination thereof.

4. The NiCrMoV alloy of any preceding claim, wherein the phosphorus is present at a concentration of at least about 0.007%.

5. The NiCrMoV alloy of any preceding claim, wherein the sulfur is present at a concentration of at least about 0.006%.

6. The NiCrMoV alloy of any preceding claim, wherein the silicon is present at a concentration of at least about 0.05%.

7. The NiCrMoV alloy of any preceding claim, wherein the manganese is present at a concentration of, by weight, at least about 0.06%.

8. The NiCrMoV alloy of any preceding claim, wherein the molybdenum is present at a concentration of, by weight, at least about 0.35%.

9. The NiCrMoV alloy of any preceding claim, wherein the vanadium is present at a concentration of, by weight, at least about 0.05%.

10. The NiCrMoV alloy of any preceding claim, wherein the chromium is present at a concentration of, by weight, at least about 1.50%.

11. The NiCrMoV alloy of any preceding claim, wherein the nickel is present at a concentration of, by weight, up to about 4.00% nickel.

12. The NiCrMoV alloy of any preceding claim, wherein the NiCrMoV alloy is resistant to embrittlement at temperatures above 700°F.

13. The NiCrMoV alloy of any preceding claim, wherein oxygen is present at a concentration, by weight, of

up to about 0.0075%.

14. A turbine component including the alloy of any preceding claim.

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15. A NiCrMoV alloy, comprising, by weight:

between about 0.06% and about 0.12% manganese, at least about 3.40% nickel; between about 0.22% and about 0.30% carbon, up to about 0.60% molybdenum, up to about 0.15% vanadium, up to about 2.00% chromium, up to about 0.012% phosphorus, up to about 0.007% sulfur, up to about 0.10% silicon, up to about 0.002% antimony, up to about 0.008% arsenic, up to about 0.012% tin, and up to about 0.015% aluminum;

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wherein the phosphorus is present at a concentration of at least about 0.007%, the sulfur is present at a concentration of at least about 0.006%, the silicon is present at a concentration of at least about 0.05%, or a combination thereof.

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 0181

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H02 34724 A (TOSHIBA CORP) 5 February 1990 (1990-02-05)	1-14	INV. C22C38/00 F01D5/06 C22C38/44 C22C38/46
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 August 2013	Examiner Nikolaou, Ioannis
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			

2

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 13 17 0181

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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