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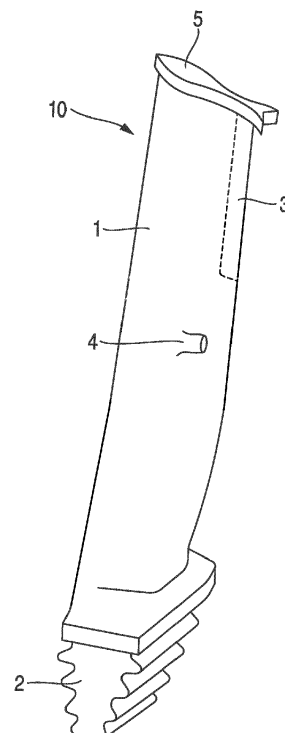
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(54) **Precipitation hardening martensitic stainless steel and long blade for steam turbine using the same**

(57) A precipitation hardening martensitic stainless steel is provided with excellent mechanical property and corrosion resistance and contains, by mass, 0.1% or less of C; 0.1% or less of N; 10.0% ~ 15.0% of Cr; 10.0% ~ 15.0% of Ni; 0.5% ~ 2.5% of Mo; 1.0% ~ 3.0% of Al; 1.0% or less of Si; 1.0% or less of Mn, and the rest is Fe and inevitable impurities. A steam turbine long blade (10) is made of the precipitation hardening martensitic stainless steel.

FIG.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a precipitation hardening martensitic stainless steel having excellent texture stability, mechanical properties, and corrosion-resistance; and also a long blade for a steam turbine using the same.

[0002] Recently, in terms of energy saving (e.g., the conservation of fossil fuel) and the prevention of global warming (e.g., the suppression of CO₂ gas production), it has been demanded to improve the efficiency of a thermal power plant (e.g., efficiency improvement in a steam turbine). One of the effective measures for improving the efficiency of the steam turbine is to increase the size of a steam turbine long blade. In addition, an increase in the size of the steam turbine long blade is also expected to have secondary effects such as shortening a facility construction period, and reducing the resulting cost by decreasing the number of casings.

[0003] A long blade material having both excellent mechanical properties and corrosion-resistance is required to improve the reliability of the steam turbine. A precipitation hardening martensitic stainless steel has a large amount of Cr and a small amount of C and thus has excellent corrosion-resistance. However, a balance between strength and toughness thereof is poor (refer to, e.g., JP-A-2005-194626).

SUMMARY OF THE INVENTION

[0004] An object of the invention is to provide precipitation hardening martensitic stainless steel having excellent mechanical properties and corrosion-resistance.

[0005] The precipitation hardening martensitic stainless steel of the present invention contains, by mass, 0.1% or less of C; 0.1% or less of N; 10.0% ~15.0% of Cr; 10.0%~15.0% of Ni; 0.5%~2.5% of Mo; 1.0%~3.0% of Al, 1.0% or less of Si; 1.0% or less of Mn, and the rest is Fe and inevitable impurities.

[0006] According to the present invention, it is possible to provide precipitation hardening martensitic stainless steel having excellent texture stability, mechanical properties, and corrosion-resistance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a perspective view schematically illustrating an example of a steam turbine long blade of the present invention;

FIG. 2 is a schematic view illustrating an example of a low-pressure stage rotor of the present invention;

FIG. 3 is a schematic view illustrating an example of a low-pressure stage turbine of the present invention; and

FIG. 4 is a schematic view illustrating an example of a power plant of the present invention;

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0008] Hereinafter, the function and amount of the constituent elements contained in precipitation hardening martensitic stainless steel according to the present invention will be described.

[0009] In the following description, the amount of constituent elements is represented by mass ratio (%).

[0010] Carbon (C) forms a Cr carbide, and there are problems that toughness is reduced due to excessive precipitation of carbides and corrosion resistance deteriorates due to reduction in a Cr concentration near a grain boundary. Further, C remarkably reduces an end point of the martensitic transformation temperature. Consequently, the amount of C needs to be suppressed. The amount of C may be preferably 0.1% or less, and more preferably 0.05% or less.

[0011] Nitrogen (N) forms TiN and AlN to reduce fatigue strength, and also adversely affects toughness. For this purpose, the amount of N added needs to be suppressed. The amount may be preferably 0.1% or less, and more preferably 0.05% or less.

[0012] Chromium (Cr) is an element that forms a passive film on the surface and thus contributes to an improvement in the corrosion-resistance. The lower limit of addition is set to 10.0% so that the corrosion resistance may be sufficiently secured. On the other hand, when Cr is excessively added, a harmful phase is precipitated and the mechanical property remarkably deteriorates, and therefore, the upper limit thereof is set to 15.0%. From above, the amount of Cr added needs to be set to 10.0 to 15.0%. The amount may be preferably 11.0 - 14.0%, and particularly preferably 12.0 - 13.0%.

[0013] Nickel (Ni) is an element that suppresses a formation of δ ferrite and also contributes to an improvement in the strength through the precipitation hardening of Ni-Al compounds. Moreover, Ni also improves hardenability and toughness. To sufficiently achieve effects described above, the lower limit of addition needs to be set to 10.0%. On the other hand, when the amount added is more than 15.0%, a harmful phase is precipitated. As a result, an intended mechanical

property is not obtained. Judging from the above points, the amount of Ni added needs to be set to 10.0 ~ 15.0%. The amount may be more preferably 11.0 ~ 14.0%, and particularly preferably 12.0 ~ 13.0%.

[0014] Molybdenum (Mo) is an element that improves corrosion resistance. To obtain the intended corrosion resistance, the amount of Mo added of at least 0.5% is needed. On the other hand, when the amount of Mo added is more than 2.5%, a formation of a harmful phase is assisted and conversely the properties deteriorate. Judging from the above points, the amount of Mo added needs to be set to 0.5 - 2.5%. The amount may be more preferably 1.0 ~ 2.0%, and particularly preferably 1.25 ~ 1.75%.

[0015] Aluminum (Al) is an element that forms a Ni-Al compound and contributes to precipitation hardening. To sufficiently exert precipitation hardening, the amount of Al added of at least 1.0% or more is needed. When the amount of Al added is more than 3.0%, the mechanical property is reduced due to the excessive precipitation of the Ni-Al compounds and the formation of harmful phases. Judging from the above points, the amount of Al added needs to be set to 1.0 ~ 3.0%. The amount may be more preferably 1.5 ~ 2.5%, and particularly preferably 1.75 - 2.25%.

[0016] Silicon (Si) is a deoxidizing agent, and the amount of Si added may be preferably set to 1.0% or less. When the amount is more than 1.0%, there arises a problem that δ ferrite is precipitated. The amount of Si added may be more preferably 0.5% or less, and may be particularly preferably 0.25% or less. It is possible to omit the addition of Si by applying carbon vacuum deoxidization and electro slag remelting. In that case, no addition of Si is preferable.

[0017] Manganese (Mn) is added as a deoxidizing agent and a desulfurizing agent. When the amount of Mn added is more than 1.0%, harmful phases are excessively formed and necessary strength is not obtained. Therefore, the amount of Mn added needs to be set to 1.0% or less. When a solution is dissolved by using a method of vacuum induced melting or vacuum arc remelting, Mn need not be added. The amount of Mn added may be more preferably 0.5% or less, and particularly preferably 0.25% or less.

[0018] As another element, tungsten (W) exerts an effect of improving the corrosion resistance as well as Mo. W further improves this effect through the addition in combination with Mo. In this case, to prevent harmful phases from being precipitated, the sum of the amount of Mo and W added needs to be the same as the amount of Mo added alone.

[0019] Further, niobium (Nb) is an element that forms carbides and contributes to an improvement in the strength; however, deteriorates productivity. For this purpose, in the case of adding Nb, the amount of Nb added needs to be set to 1.0% or less. Alternatively, it is possible to substitute tantalum (Ta) for Nb. In the case of adding Nb and Ta in combination, the sum of the amount of Nb and Ta added needs to be the same as the amount of Nb added alone. Though addition of these elements is not indispensable, this leads to more significant precipitation hardening.

[0020] Inevitable impurities in the present invention are components originally contained in the raw materials or incorporated during production and so on, and refer to components that are unintentionally added. Inevitable impurities include P, S, Sb, Sn, and As, and at least one of them may be contained in the precipitation hardening martensitic stainless steel of the present invention.

[0021] Since reduction in P and S makes it possible to improve toughness without impairing tensile strength, it is preferable that they are minimized. In terms of improving the toughness, it is preferable that P is set to be 0.5% or less and S is set to be 0.5% or less. It is particularly preferable that P is set to be 0.1% or less and S is set to be 0.1% or less.

[0022] The reduction in As, Sb, and Sn makes it possible to improve toughness. For this purpose, it is preferable that the above elements are minimized, and it is preferable that As, Sb, and Sn are set to be 0.1% or less, respectively. It is particularly preferable that As, Sb, and Sn are set to be 0.05% or less, respectively.

[0023] Next, the heat treatment of the present invention will be described.

[0024] In the present invention, it is necessary to perform a solution treatment in which heating and maintenance at 800 to 1050°C, preferably at 850 to 1000°C are followed by rapid cooling. The solution treatment in the present invention refers to a heat treatment for both dissolving components relating to the formation of precipitates such as Al and Ni into the texture and obtaining a martensite texture at the same time. The martensite texture is a kind of matrix of steel and is a texture excellent in the balance between strength and toughness. After the solution treatment, it is necessary to perform an aging treatment of maintenance of heating at 450 to 650°C and thereby gradual cooling. The aging treatment of the present invention refers to a heat treatment to obtain excellent strength by finely precipitating Ni-Al compounds and so on in the texture, performed after the solution treatment.

[0025] Further, when residual austenite is expected to be reduced, a sub-zero treatment may be performed. In the sub-zero treatment, it is necessary to keep the residual austenite for at least four hours or more at -70°C or less and raise it up to room temperature in the atmosphere by using organic solvents such as dry ice and isopentane.

[0026] The application of the alloy of the present invention to steam turbine long blades will be described. Works such as machining and straightening can be performed after the aging treatment. However, when the above works are performed immediately after the solution treatment in which Ni-Al compounds are not yet precipitated, a high working efficiency is expected because of good workability.

[0027] In the steam turbine long blade to which the alloy of the present invention is applied, stellite plates of a Co-based alloy may be joined to a front end portion of the blade by TIG welding. This is a measure to protect the steam turbine long blade from erosion damaging the blade by the high-speed collision of condensed steam. Other techniques

for the installation of stellite plates include silver soldering, plasma transfer arc, and laser build-up welding. Other measures to protect the steam turbine long blade from erosion include modification of the surface with a titanium nitride coating, etc. It is also possible to achieve erosion resistance by repeating more than once heat treatments of heating the surface of the front end portion of the blade to the Ac3 transformation temperature or higher and then cooling it to room temperature by air cooling to a grain size number 6 or finer, followed by the aging treatment of the entire blade to increase only the surface hardness of the front end portion of the blade. Since the alloy of the present invention has a certain degree of erosion resistance, the above measure against erosion may be omitted under conditions that the erosion is not severe.

FIG. 1 illustrates the steam turbine long blade (10) to which the alloy of the present invention is applied. The long blade includes a blade profile portion (1) that receives steam, a blade root portion (2) that implants the blade into a rotor, a stub (4) for integrating with an adjacent blade by screwing, and a continuous cover (5). The blade root portion of the steam turbine long blade is an axial entry type having an inverted Christmas-tree shape. The blade joins a stellite plate as an example of an erosion shield (3). Other techniques for the installation of stellite plates include silver soldering, plasma transfer arc, and laser build-up welding. It is also possible to modify the surface with a titanium nitride coating, etc. Since the alloy of the present invention has a certain degree of erosion resistance, the above measure against erosion may be omitted under conditions that the erosion is not severe.

FIG. 2 illustrates a low-pressure stage rotor (20) to which the long blade of the present invention is applied. This low-pressure stage rotor has a double-flow structure, and long blades are symmetrically placed in a long-blade implantation portion (21) over several stages. The above-described long blade is placed in the final stage.

FIG. 3 illustrates a low-pressure stage steam turbine (30) to which the low-pressure stage rotor of the present invention is applied. A steam turbine long blade (31) rotates by receiving steam guided by a nozzle (32). The rotor is supported by a bearing (33).

FIG. 4 illustrates a power plant (40) to which the low-pressure stage steam turbine of the present invention is applied. High-temperature and high-pressure steam produced in a boiler (41) works in a high-pressure stage turbine (42), and is then reheated in the boiler. The reheated steam works in a medium-pressure stage turbine (43) and then works in a low-pressure stage turbine (44). The work produced in the steam turbine is converted into electricity by a power generator (45). The steam coming out from the low-pressure stage turbine is guided to a condenser (46).

[0028] Hereinafter, examples will be described.

EXAMPLES

[Example 1]

(Preparation of Sample)

[0029] Test samples were prepared to evaluate a relationship between the chemical composition of the precipitation hardening martensitic stainless steel of the present invention, tensile strength thereof, 0.02% yield strength, Charpy impact absorption energy, pitting potential, and micro-texture. Table 1 illustrates a chemical composition of each test sample.

[0030] First, raw materials were melted by using a high-frequency vacuum melting furnace (5.0×10^{-3} Pa or less, 1600°C or higher) to obtain compositions listed in Table 1. The obtained ingot was hot-forged by using a press forging machine and a hammer forging machine, and formed into a square bar having a width×thickness×length of 100 mm×30 mm×1000 mm. Next, the square bar was cut and processed to a width×thickness×length of 50 mm×30 mm×120 mm, thereby giving stainless steel starting materials.

[0031] Next, the stainless steel starting materials were subjected to various heat treatments by using a box electric furnace. Alloys 1 to 13 of the invention were maintained at 925°C for 1 hour as a solution heat treatment, followed by rapid water cooling of immersing in room-temperature water. Subsequently, the alloys were maintained at an arbitrary temperature of 450 to 650°C for 2 hours as an aging heat treatment, followed by air cooling for removing them to room-temperature air.

[0032] Evaluation tests for tensile strength, Charpy impact absorption energy, pitting potential, and micro-texture observation were performed to respective samples obtained above. The following summarizes each evaluation test.

(Test Method)

[0033] A test piece (distance between evaluation points: 30 mm, outer diameter: 6 mm) was prepared from each of the samples obtained above and subjected to a tensile test at room temperature in accordance with JIS Z 2241. The

determination criteria of tensile strength and 0.02% yield strength are as follows. A tensile strength and 0.02% yield strength of 1500 MPa or more and 1000 MPa or more, respectively, were rated as "acceptable", while those of less than these values were rated as "unacceptable". Further, an elongation and drawing of 10% or more and 30% or more, respectively, were rated as "acceptable", while those of less than these values were rated as "unacceptable".

[0034] For the measurement of Charpy impact absorption energy, a test piece having a 2-mm V notch was prepared from each of the samples obtained above and subjected to a Charpy impact test at room temperature in accordance with JIS Z 2242. The determination criteria of Charpy impact absorption energy are as follows. A Charpy impact absorption energy of 20 J or more was rated as "acceptable", while that of less than this value was rated as "unacceptable".

[0035] For the evaluation of pitting potential, a plate-like test piece (15 mm in length, 15 mm in width, and 3 mm in thickness) was prepared from each of the samples obtained above, and coated with an insulator so that an area of a measurement surface becomes equal to 1.0 cm². The evaluation was performed under the following conditions: test solution: 3.0% NaCl solution, temperature of the solution: 30°C, sweep rate: 20 mV/min. The determination criteria of pitting potential are as follows. A pitting potential of 150 mV or more was rated as "acceptable", while that of less than this value was rated as "unacceptable."

[0036] The determination criteria of micro-texture are as follows. Those having a martensite texture in which the amounts of δ ferrite and residual austenite precipitated are 1.0% or less and 10% or less in an area ratio, respectively, were rated as "acceptable". Others were rated as "unacceptable". The amount of δ ferrite precipitated was measured in accordance with a point counting method described in JIS G 0555. The amount of residual austenite precipitated was measured by X-ray diffraction.

(Test Results)

[0037] In alloys 1 to 13 of the invention, mechanical properties of tensile strength, 0.02% yield strength, elongation, drawing, and impact absorption energy were also rated as "acceptable". Also for pitting potential, preferable results were obtained. In addition, the δ ferrite phase and residual austenite in the metal texture were within a target range, and they were thus confirmed to have a martensite texture.

[0038] In any of the comparative alloys 1 to 12, all aimed values of the respective properties were not satisfied. In the comparative alloys 1 to 8, effects on principal components such as Cr, Ni, Mo, and Al were studied. Among them, the comparative alloy 5 is a sample in which the amount of Al added is high, and in which tensile strength and 0.02% yield strength were high; however, elongation, drawing, and impact absorption energy were remarkably lower than their aimed values. The reason is considered that the amount of a reinforcing phase precipitated is excessive. On the other hand, in the comparative alloy 6, the amount of Al added is low, and tensile strength and 0.02% yield strength were lower than their aimed values. Further, a large amount of residual austenite was precipitated in the texture. Further, in the comparative alloys 9 to 12, effects on impurity elements were studied. The comparative alloy 9 is a sample in which the amount of C added is high, and its tensile strength, 0.02% yield strength, elongation, and impact absorption energy were lower than their aimed values. Further, pitting potential was also lower than its aimed value. The reason is considered that a Cr concentration near a grain boundary is reduced through the formation of Cr carbides and corrosion resistance is deteriorated. In addition, a large amount of residual austenite was precipitated in the texture. The comparative alloy 12 is a sample in which the amount of N added is high, and its elongation, drawing, and impact absorption energy were lower than their aimed values. Further, a large amount of residual austenite was precipitated in the texture.

[Table 1]

classification	No	Chemical component (mass%)											
		Cr	Ni	Al	Mo	W	Nb	Ta	C	Si	Mn	N	Fe
Alloy of the invention	Alloy of the invention 1	12,26	12,06	2,02	2,03	—	—	—	—	—	—	—	Rest
	Alloy of the invention 2	14,88	12,16	1,96	2,11	—	—	—	—	—	—	—	
	Alloy of the invention 3	10,22	12,21	1,91	2,10	—	—	—	—	—	—	—	
	Alloy of the invention 4	12,31	14,91	2,04	2,06	—	—	—	—	—	—	—	
	Alloy of the invention 5	12,25	10,11	2,03	2,07	—	—	—	—	—	—	—	
	Alloy of the invention 6	12,21	12,24	2,93	1,93	—	—	—	—	—	—	—	
	Alloy of the invention 7	12,22	12,29	1,03	1,92	—	—	—	—	—	—	—	
	Alloy of the invention 8	12,34	12,19	2,05	2,44	—	—	—	—	—	—	—	
	Alloy of the invention 9	12,20	12,17	2,08	0,56	—	—	—	—	—	—	—	
	Alloy of the invention 10	12,29	12,15	2,03	1,05	0,96	—	—	—	—	—	—	
	Alloy of the invention 11	12,33	12,16	2,01	2,04	—	0,53	—	—	—	—	—	
	Alloy of the invention 12	12,33	12,13	2,00	2,08	—	—	0,49	—	—	—	—	
	Alloy of the invention 13	12,23	12,14	1,98	2,09	—	0,259	0,246	—	—	—	—	
Comparative alloy	Comparative alloy 1	15,51	12,16	2,03	2,07	—	—	—	—	—	—	—	
	Comparative alloy 2	9,46	12,11	2,03	2,04	—	—	—	—	—	—	—	
	Comparative alloy 3	12,31	15,59	1,98	2,11	—	—	—	—	—	—	—	
	Comparative alloy 4	12,32	9,56	1,98	2,05	—	—	—	—	—	—	—	
	Comparative alloy 5	12,22	12,21	3,45	2,13	—	—	—	—	—	—	—	
	Comparative alloy 6	12,25	12,28	0,53	2,03	—	—	—	—	—	—	—	
	Comparative alloy 7	12,19	12,30	1,99	3,06	—	—	—	—	—	—	—	
	Comparative alloy 8	12,35	12,13	1,94	0,26	—	—	—	—	—	—	—	
	Comparative alloy 9	12,38	12,16	2,03	1,89	—	—	—	0,13	—	—	—	
	Comparative alloy 10	12,28	12,22	2,05	2,06	—	—	—	—	1,03	—	—	
	Comparative alloy 11	12,23	12,39	2,07	2,00	—	—	—	—	—	1,11	—	
	Comparative alloy 12	12,29	12,16	2,08	2,11	—	—	—	—	—	—	0,12	

[Table 2]

Classification	No.	Test item						
		Tensile strength	0.02% yield strength	Elongation	Drawing	Impact absorption energy	Pitting potential	Micro-texture
Alloy of the invention	Alloy of the invention 1	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 2	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 3	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 4	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 5	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 6	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 7	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 8	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 9	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 10	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 11	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 12	✓	✓	✓	✓	✓	✓	✓
	Alloy of the invention 13	✓	✓	✓	✓	✓	✓	✓
Comparative alloy	Comparative alloy 1	×	×	×	✓	×	✓	×
	Comparative alloy 2	✓	×	✓	✓	✓	×	×
	Comparative alloy 3	✓	×	✓	✓	✓	✓	×
	Comparative alloy 4	×	×	×	✓	×	✓	×
	Comparative alloy 5	✓	✓	×	×	×	✓	✓
	Comparative alloy 6	×	×	✓	✓	✓	✓	✓
	Comparative alloy 7	×	×	×	✓	×	✓	×
	Comparative alloy 8	✓	✓	×	✓	×	×	×
	Comparative alloy 9	✓	✓	×	×	✓	×	×
	Comparative alloy 10	×	×	×	✓	×	✓	×
	Comparative alloy 11	✓	×	✓	✓	✓	✓	×
	Comparative alloy 12	✓	✓	×	×	×	✓	×

✓:Acceptable ×:Unacceptable

[Example 2]

[0039] The following describes the steam turbine long blade to which the alloy of the present invention is applied. In this embodiment, by using Alloy 1 illustrated in Table 1 of materials of the present invention, an axial-entry-type steam turbine long blade having a blade length of 48 inch was produced. As a method for producing the long blade, vacuum carbon deoxidation was first performed in a high vacuum state of 5.0×10^{-3} Pa or less to deoxidize molten steel by a chemical reaction of $C+O \rightarrow CO$. Subsequently, the steel was formed into an electrode bar by extend forging. Electroslag remelting was thus performed to give a high-grade steel ingot by self-dissolving the electrode bar by Joule heat generated upon the application of current at the time when this electrode bar was immersed in molten slag, and then coagulating it in a water-cooled die. Next, the steel ingot was hot-forged, and then press-forged by using a 48-inch blade die. After that, as a solution treatment, the resulting product was heated and maintained at 925°C for 2.0 hours, followed by forced cooling of rapid cooling by using a fan. Then, the product was formed into a predetermined shape through a cutting step and then, as an aging treatment, heated and maintained at 525°C for 4.0 hours, followed by air cooling. As the final finishing, the curve was eliminated and the surface was polished, thereby giving a 48-inch long blade.

[0040] Test pieces were collected from the front end, center, and root portions of the steam turbine long blade obtained by the above steps, respectively, and subjected to evaluation tests in the same manner as in Example 1. A direction of the collected test pieces is the direction of the length of the blade.

[0041] The micro-texture of each portion was a uniform martensite texture. Neither residual austenite nor δ ferrite was

observed. In addition, regardless of the positions where the test pieces were collected, aimed values of the desired tensile strength, 0.02% yield strength, impact absorption energy, and pitting potential were achieved.

[0042] The precipitation hardening martensitic stainless steel of the present invention has excellent mechanical properties and corrosion-resistance, and thus can be applied to the steam turbine long blade. In addition, it can also be applied to a blade for a gas turbine compressor, and so on.

Claims

1. A precipitation hardening martensitic stainless steel comprising, by mass, 0.1% or less of C; 0.1% or less of N; 10.0% ~ 15.0% of Cr; 10.0% ~ 15.0% of Ni; 0.5% ~ 2.5% of Mo; 1.0% ~ 3.0% of Al; 1.0% or less of Si; 1.0% or less of Mn, and the rest is Fe and inevitable impurities.
2. The precipitation hardening martensitic stainless steel according to claim 1, further comprising at least one member selected from Nb and Ta in an amount of 1.0% or less by mass.
3. The precipitation hardening martensitic stainless steel according to claim 1 or claim 2, further comprising W, a total amount of Mo and W being the same as an amount of Mo added alone.
4. The precipitation hardening martensitic stainless steel according to any one of claims 1~3, wherein the inevitable impurities are at least one member selected from P, S, Sb, Sn, and As.
5. The precipitation hardening martensitic stainless steel according to any one of claims 1~4, wherein a temperature range of a solution treatment is 800 to 1050°C and a temperature range of an aging treatment is 450 to 650°C.
6. A steam turbine long blade (10) using the precipitation hardening martensitic stainless steel of any one of claims 1~5.
7. The steam turbine long blade (10) according to claim 6, wherein a stellite plate made of a Co-based alloy is joined to a front end portion of the blade (10).
8. A turbine rotor (20) comprising the steam turbine long blade (10) of claim 7.
9. A steam turbine (30) comprising the turbine rotor (20) of claim 8.

FIG.1

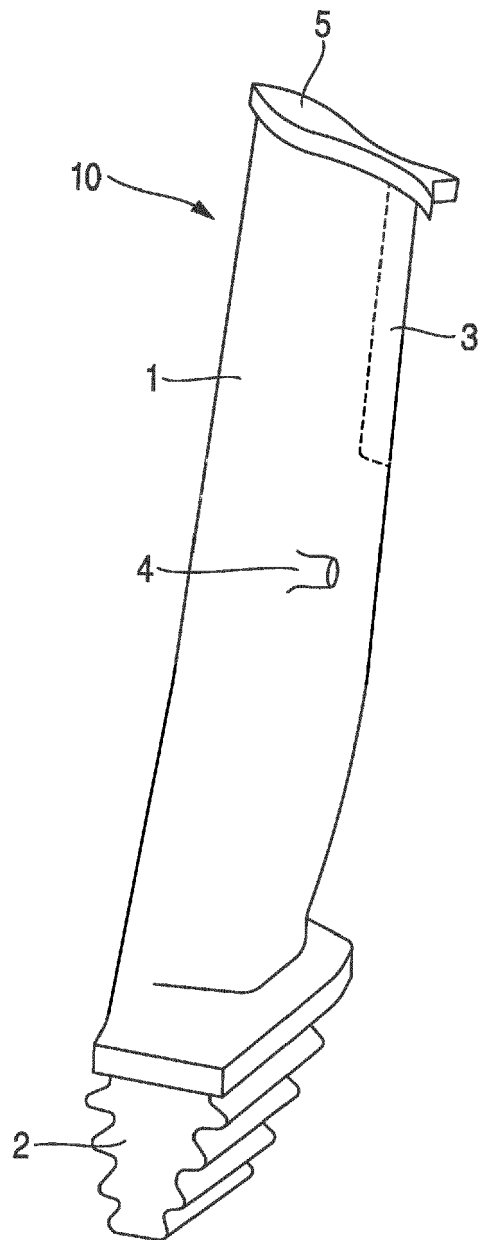


FIG.2

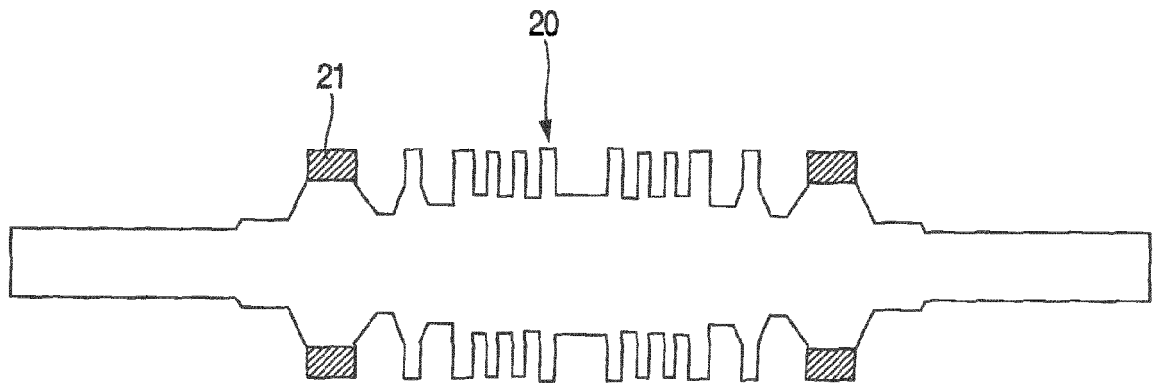


FIG.3

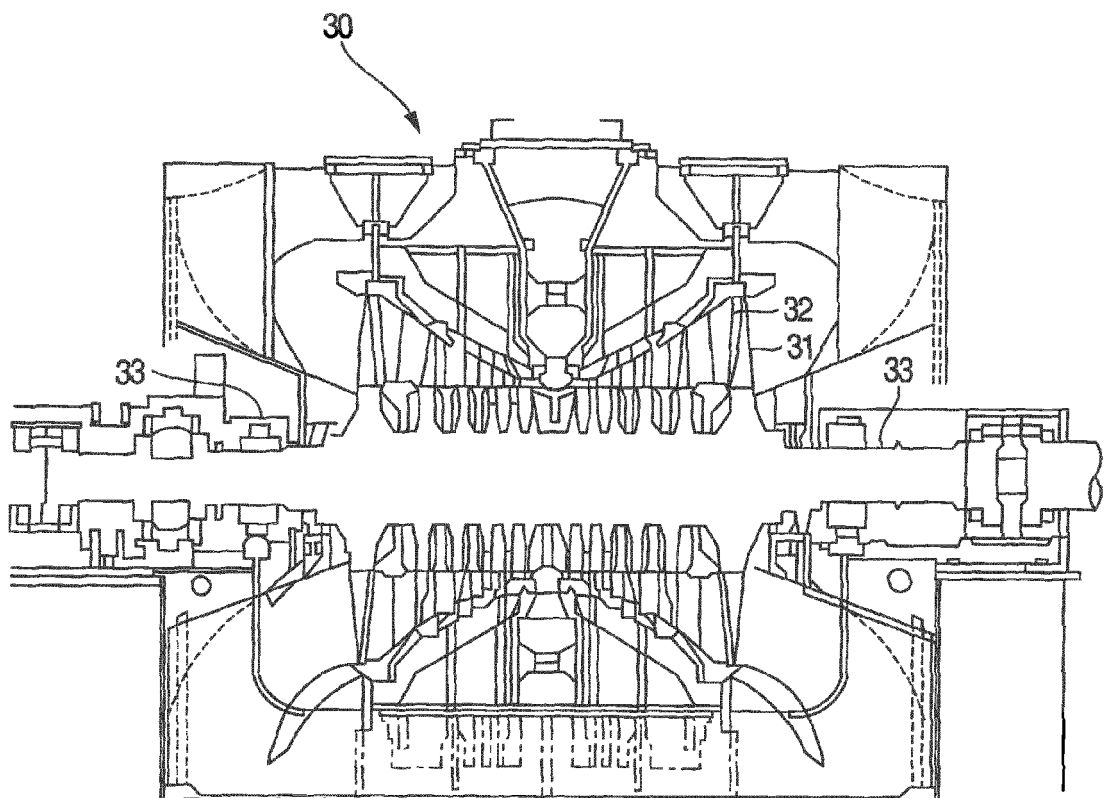
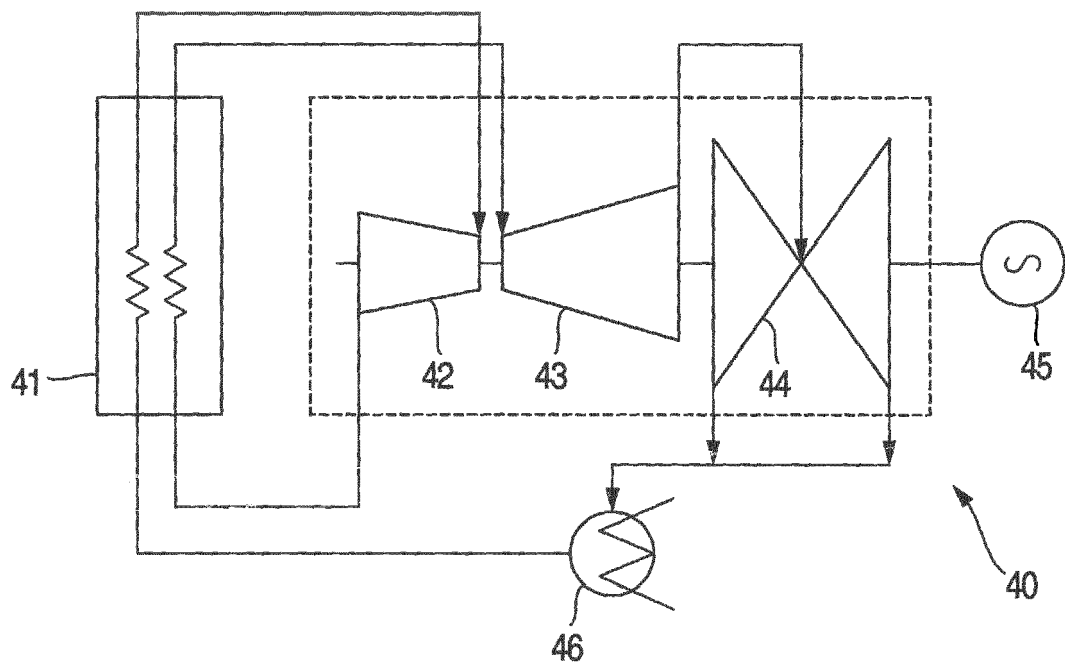


FIG.4



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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