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(54) **HEAT-RESISTANT STEEL AND GAS TURBINE MADE OF THE SAME**

WARMFESTER STAHL UND DARAUS GEFERTIGTE GASTURINE

ACIER RESISTANT A LA CHALEUR ET TURBINE A GAZ COMPOSEE DE CET ACIER

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Description

The present invention relates to a novel heat-resistant steel and particularly to a novel gas turbine made of said steel.

A Cr-Mo-V steel is currently used in discs for a gas turbine.

In recent years, an improvement in the thermal efficiency of a gas turbine has been desired from the viewpoint of the saving of energy. The most useful means of improving the thermal efficiency of a gas turbine is to increase the temperature and pressure of a gas used. For example, an improvement in the efficiency of about 3% in terms of relative ratio can be expected by raising the gas temperature from 1,100°C to 1,300°C and increasing the pressure ratio from 10 to 15.

However, with an increase in the temperature and the pressure ratio, the conventional Cr-Mo-V steel becomes unsatisfactory from the standpoint of strength. Therefore, a material having higher strength is needed. Creep rupture strength has the greatest influence on high-temperature properties of the material and therefore is a critical requirement with respect to the strength. Austenitic steels, Ni-based alloys, Co-based alloys, and martensitic steels are generally known as structural materials having a creep rupture strength higher than that of Cr-Mo-V steels. However, the Ni-based alloy and Co-based alloy are undesirable from the standpoint of hot workability, machinability, vibration damping property, etc. Further, the austenitic steel is also undesirable not only because its high-temperature strength is not so high at around 400 to 450°C but also from the viewpoint of the entire gas turbine system. On the other hand, the martensitic steel matches other constituent parts and also has a sufficient high-temperature strength. Examples of known martensitic steel include those disclosed in Japanese Patent Laid-Open Nos. 55552/1981, 110661/1983, and 138054/1985 and Japanese Patent Publication No. 279/1971. However, these materials do not necessarily exhibit a high creep rupture strength at 400 to 450°C and further exhibit low toughness after heating at a high temperature for a long period of time, which renders these materials unsuitable for use in turbine discs. This makes it impossible to improve the efficiency of a gas turbine.

US-T-964003 discloses a martensitic stainless steel suitable for components of high-temperature turbine engines containing 0.1-0.2%C, up to 0.9% Mn, up to 0.35% Si, up to 0.025%P, up to 0.025%S, 11-12.5% Cr, 2-3% Ni, 1.5-2%Mo, 0.25-0.4%V, up to 0.05%N, and 0.1-0.25%Nb, the balance being iron impurities.

Also documents JP-A-54 146211 and JP-A-61-51025 are concerned with steel for turbine rotors, said steel comprising 0.05-0.3%C, <0.2%Si, 0.3-1.5%Mn, 9-13%Cr, 0.5-2.0%Mo, 0.1-0.5%V, 1-2.5%Ni, 0.01-0.5% Nb, or 1-2.5%Ta, respectively, 0.01-0.1%N and the balance being Fe plus incidental impurities.

The mere use of a material having a high strength for the purpose of coping with increases in both the temperature and pressure of a gas turbine is insufficient for raising the gas temperature. In general, an increase in the strength brings about a lowering in the toughness.

An object of the present invention is to provide a heat-resistant steel having a combination of a high strength with a high toughness after heating at a high temperature for a long period of time.

Another object of the present invention is to provide a gas turbine having a high thermal efficiency.

The present invention relates to a heat-resistant steel comprising 0.05 to 0.2% by weight of C, less than 0.5% by weight (of Si, 0.1 to 0.40% by weight) of Mn, 8 to 13% by weight of Cr, 1.5 to 3% by weight of Mo, 2 to 3% by weight of Ni, 0.05 to 0.3% by weight of V, 0.02 to 0.2% by weight in total of either or both of Nb and Ta, and 0.02 to 0.1% by weight of N, the Mn to Ni ratio being 0.11 or less, with the balance being Fe and unavoidable impurities as defined in claim 1.

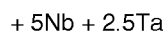
Preferably, the present invention also relates to a heat-resistant steel comprising 0.07 to 0.15% by weight of C, 0.01 to 0.1% by weight of Si, 0.15 to 0.4% by weight of Mn, 11 to 12.5% by weight of Cr, 2.2 to 3.0% by weight of Ni, 1.8 to 2.5% by weight of Mo, 0.04 to 0.08% by weight in total of either or both of Nb and Ta, 0.15 to 0.25% by weight of V, and 0.04 to 0.08% by weight of N, the Mn to Ni ratio being 0.04 to 0.10, with the balance being Fe plus unavoidable impurities and having a wholly tempered martensite structure.

Further, the steel of the present invention may additionally comprise at least one member selected from among: less than 1% by weight of W, less than 0.5% by weight of Co, less than 0.5% by weight of Cu, less than 0.01% by weight of B, less than 0.5% by weight of Ti, less than 0.3% by weight of Al, less than 0.1% by weight of Zr, less than 0.1% by weight of Hf, less than 0.01% by weight of Ca, less than 0.01% by weight of Mg, less than 0.01% by weight of Y, and less than 0.01% by weight of rare earth elements.

In the steel of the present invention, it is desirable for the components to be adjusted so that the Cr equivalent calculated by the following equation is 10 or less and the steel to be substantially free from δ -ferrite phase.

$$\text{Cr equivalent} = -40\text{C} - 2\text{Mn} - 4\text{Ni} - 30\text{N}$$

$$+ 6\text{Si} + \text{Cr} + 4\text{Mo} + 11\text{V}$$



wherein the value with respect to each element is calculated based on the content (% by weight) thereof in the alloy.

The present invention also relates to a disc having in its outer circumferential section a plurality of grooves into which blades are embedded, having a maximum thickness in its central section and having on its outer circumferential side through-holes into which bolts are inserted to connect a plurality of said discs, characterized in that said disc is made of a martensitic steel as defined above. A preferred steel has a creep rupture strength of at least 50 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value of at least 5 kg-m/cm² at 25°C after heating at 500°C for 10³ hr.

A plurality of turbine discs may be connected to each other on the outer circumferential side thereof with bolts through annular spacers. The annular spacer is characterized by being made of a martensitic steel having the above-described properties or a heat-resistant steel having the above-described composition.

In the present invention, there are also provided the following members, each of which is characterized by being made of a martensitic steel having the above-described properties or a heat-resistant steel having the above-described composition:

a cylindrical distance piece through which a turbine disc and a compressor disc are connected to each other with a bolt;

at least either one of a set of bolts for connecting a plurality of turbine discs and a set of bolts for connecting a plurality of compressor discs; and

a compressor disc having in its outer circumferential section a plurality of grooves into which blades are embedded, having such a structure that bolts are inserted into the outer circumferential side thereof to connect a plurality of discs and having a maximum thickness in its central section and a section provided with a through-hole.

The present invention also relates to a gas turbine comprising a turbine stub shaft, a plurality of turbine discs connected to said shaft with a turbine stacking bolt through a spacer interposed between said turbine discs, a turbine bucket embedded into said turbine disc, a distance piece connected to said turbine disc with said turbine stacking bolt, a plurality of compressor discs connected to said distance piece with a compressor stacking bolt, a compressor blade embedded into said compressor disc and a compressor stub shaft formed integrally with a first stage disc of said compressor discs, characterized in that at least said turbine disc is made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value of at least 5 kg-m/cm² at 25°C after heating at 500°C for 10³ hr. The martensitic steel particularly comprises heat-resistant steel having the above-described composition.

The application of the above-described martensitic steel to a gas turbine disc according to the present invention makes it possible to limit the ratio of the thickness (t) of the central portion to the outer diameter (D) to 0.15 to 0.3, thereby enabling a reduction in the weight of the disc. In particular, the limitation of the ratio to 0.18 to 0.22 enables a decrease in the distance between the discs, so that an improvement in the thermal efficiency can be expected.

The reason for the limitation of the components of the present invention to the above-described range will now be described. In order to attain a high tensile strength and a high proof strength, it is necessary that the content of C should be 0.05% at the lowest. However, when the content of C is too high, a metal structure becomes unstable when the steel is exposed to a high temperature for a long period of time, which brings about a decrease in the 10⁵-hr creep rupture strength. Therefore, the content of C should be 0.20% or less. The content of C is preferably 0.07 to 0.15%, more preferably 0.10 to 0.14%.

Si and Mn are added as a deoxidizer and a deoxidizer-desulfurizer, respectively, in melting a steel. They are effective even when used each in a small amount. Since Si is a δ -ferrite forming element, the addition thereof in a large amount causes the formation of δ -ferrite. Therefore, the Si content should be 0.5% by weight or less. When carbon vacuum deoxidation, electroslag melting, or the like is employed, there is no need of adding Si, so that it is preferred to add no Si.

The Si content is particularly preferably 0.2% or less from the viewpoint of embrittlement. Even if no Si is added, Si is contained as an impurity in an amount of 0.01 to 0.1%.

Mn promotes thermal embrittlement of the steel. Therefore, the Mn content should be low. But since Mn is effective as a desulfurizer, the Mn content is 0.1 to 0.4% in order to avoid the thermal embrittlement, more preferably 0.1 to 0.25%. Further, in order to prevent the embrittlement, it is preferred that the total content of Si and Mn be 0.3% or less.

Cr enhances the corrosion resistance and high-temperature strength. However, the addition of Cr in an amount of 13% or more causes the formation of a δ -ferrite structure. When the Cr content is less than 8%, the corrosion resistance and the high-temperature strength are unsatisfactory. For this reason, the Cr content was limited to 8 to 13%. In particular, it is preferred from the viewpoint of strength that the Cr content be 11 to 12.5%.

Mo not only enhances the creep rupture strength by virtue of its solid solution strengthening and precipitation strengthening actions but also has an effect of preventing the embrittlement. When its content is less than 1.5%, no

sufficient improvement in the creep rupture strength can be attained. On the other hand, when its content is more than 3.0%, δ -ferrite tends to be formed. For this reason, the Mo content was limited to 1.5 to 3.0%. In particular, it is preferred that the Mo content be 1.8 to 2.5%. Further, when the Ni content exceeds 2.1%, Mo exhibits such an effect that the higher the Mo content, the higher the creep rupture strength. In particular, this effect is remarkable when the Mo content is 2.0% or above.

V and Nb each exhibit an effect of not only enhancing the high-temperature strength but also improving the toughness through precipitation of carbide. When the V and Nb contents are less than 0.1% and less than 0.02%, respectively, the above-described effect is unsatisfactory, while when the V and Nb contents are more than 0.3% and more than 0.2%, respectively, there is caused a tendency that δ -ferrite is formed and the creep rupture strength is lowered. In particular, it is preferred that the V and Nb contents be 0.15 to 0.25% and 0.04 to 0.08%, respectively. Ta may be added instead of Nb in exactly the same amount as that of Nb. Further, Nb and Ta may be added in combination.

Ni has effects of not only enhancing the toughness after heating at a high temperature for a long period of time but also preventing the formation of δ -ferrite. When its content is less than 2.0%, the above-described effect is unsatisfactory, while when its content is more than 3%, the long-term creep rupture strength is lowered. In particular, the Ni content is preferably 2.2 to 3.0%, more preferably more than 2.5%.

Ni has an effect of preventing the thermal embrittlement. By contrast, Mn has an adverse effect on the prevention of the thermal embrittlement. The present inventors have found that there is a close correlation between these elements. Namely, the present inventors have found that the thermal embrittlement can be remarkably prevented when the Mn to Ni ratio is 0.11 or less. In particular, the ratio is preferably 0.10 or less, more preferably 0.04 to 0.10.

N has effects of improving the creep rupture strength and preventing the formation of δ -ferrite. When its content is less than 0.02%, the above-described effect is unsatisfactory. On the other hand, when its content exceeds 0.1%, the toughness is lowered. In particular, excellent properties can be attained when the N content ranges from 0.04 to 0.08%.

In the heat-resistant steel of the present invention, Co enhances the strength but promotes the embrittlement. Therefore, the Co content should be under 0.5%. As with Mo, W contributes to an increase in the strength and may be contained in an amount of under 1%. The high-temperature strength may be improved by addition of under 0.01% of B, under 0.3% of Al, under 0.5% of Ti, under 0.1% of Zr, under 0.1% of Hf, under 0.01% of Ca, under 0.01% of Mg, under 0.01% of Y, under 0.01% of rare earth elements, and under 0.5% of Cu.

In the heat treatment for the material of the present invention, the material is desirably uniformly heated at a temperature sufficient to cause a complete transformation thereof to austenite, i.e., at 900°C at the lowest and 1150°C at the highest, thereby forming a martensite structure. The material is desirably then quenched at a cooling rate of at least 100°C/hr, heated and held at a temperature of 450 to 600°C (first tempering), and then heated and held at a temperature of 550 to 650°C for second tempering. In carrying out the hardening, it is preferred to stop the quenching at a temperature immediately above the Ms point for the purpose of preventing the occurrence of quenching crack. More particularly, it is preferred to stop the quenching at a temperature of 150°C or above. It is preferred to carry out the hardening by oil hardening or water spray hardening. The first tempering is begun from the temperature at which the quenching is stopped.

One or more of the above-described distance piece, turbine spacer, turbine stacking bolt, compressor stacking bolt, and at least a final stage disc of the compressor discs may be made of a heat-resistant steel having a wholly tempered martensite structure and comprising 0.05 to 0.2% by weight of C, under 0.5% by weight of Si, under 1% by weight of Mn, 8 to 13% by weight of Cr, under 3% by weight of Ni, 1.5 to 3% by weight of Mo, 0.05 to 0.3% by weight of V, 0.02 to 0.2% by weight of Nb, and 0.02 to 0.1% by weight of N with the balance being Fe plus unavoidable impurities. When all of these parts are made of this heat-resistant steel, it is possible to raise the gas temperature to a high level, which contributes to an improvement in the thermal efficiency. Particularly, a highly safe turbine having a high resistance to embrittlement can be realized when at least one of the above-described parts is made of a heat-resistant steel comprising 0.05 to 0.2% by weight of C, under 0.5% by weight of Si, 0.6% by weight or less of Mn, 8 to 13% by weight of Cr, 2 to 3% by weight of Ni, 1.5 to 3% by weight of Mo, 0.05 to 0.3% by weight of V, 0.02 to 0.2% by weight of Nb, and 0.02 to 0.1% by weight of N with the balance being Fe, and unavoidable impurities, the Mn to Ni ratio being 0.11 or less, particularly 0.04 to 0.10, and having a wholly tempered martensite structure.

A martensitic steel having a creep rupture strength of at least 40 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value of at least 5 kg-m/cm² at 20°C is used as a material for these parts. However, in a particularly preferable composition, the steel has a creep rupture strength of at least 50 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value of at least 5 kg-m/cm² at 20°C after heating at 500°C for 10³ hr.

This material may further contain at least one member selected from among 1% or less of W, 0.5% or less of Co, 0.5% or less of Cu, 0.01% or less of B, 0.5% or less of Ti, 0.3% or less of Al, 0.1% or less of Zr, 0.1% or less of Hf, 0.01% or less of Ca, 0.01% or less of Mg, 0.01% or less of Y, and 0.01% or less of rare earth elements.

At least the final stage disc or discs of all stages among the compressor discs may be made of the above-described heat-resistant steel. Alternatively, since the gas temperature is low in a zone from the first stage to the middle stage,

other low-alloy steel may be used for the discs in this zone, and the above-described heat-resistant steel may be used for the discs in a zone from the middle stage to the final stage. For example, for the discs from the first stage on the upstream side of the gas flow to the middle stage, it is possible to use a Ni-Cr-Mo-V steel comprising 0.15 to 0.30% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less of Mn, 1 to 2% by weight of Cr, 2.0 to 4.0% by weight of Ni, 0.5 to 1% by weight of Mo, and 0.05 to 0.2% by weight of V with the balance being Fe and unavoidable impurities and having a tensile strength of at least 80 kg/mm² at room temperature and a V-notch Charpy impact value of at least 20 kg-m/cm² at room temperature, and for the discs from the middle stage except for the final stage, it is possible to use a Cr-Mo-V steel comprising 0.2 to 0.4% by weight of C, 0.1 to 0.5% by weight of Si, 0.5 to 1.5% by weight of Mn, 0.5 to 1.5% by weight of Cr, 0.5% by weight or less of Ni, 1.0 to 2.0% by weight of Mo, and 0.1 to 0.3% by weight of V with the balance being Fe and unavoidable impurities and having a tensile strength of at least 80 kg/mm² at room temperature, an elongation of at least 18% and a reduction of area of at least 50%.

The above-described Cr-Mo-V steel may be used for a compressor shaft and a turbine shaft.

The compressor disc of the present invention has a circular shape and is provided over the entire periphery of the outer portion with a plurality of holes for inserting stacking bolts, and it is preferred that the ratio of the minimum thickness (t) of the compressor disc to the diameter (D) thereof (t/D) be 0.05 to 0.10.

The distance piece of the present invention has a cylindrical shape and is provided on its both ends with flanges for connecting both ends of the distance piece to the compressor disc and the turbine disc, respectively, with bolts and it is preferred that the ratio of the minimum thickness (t) to the maximum inner diameter (D) thereof (t/D) be 0.05 to 0.10.

For the gas turbine of the present invention, it is preferred that the ratio of the spacing (ℓ) between individual gas turbine discs to the diameter (D) of the disc (ℓ/D) be 0.15 to 0.25.

According to an example of the present invention, when a compressor disc assembly has 17 stages, the discs from the first stage to the 12th stage, the discs from the 13th stage to the 16th stage, and the disc of the 17th stage may be made of the above-described Ni-Cr-Mo-V steel, the above-described Cr-Mo-V steel, and the above-described martensitic steel, respectively.

The first-stage disc has higher rigidity than that of the disc subsequent thereto, and the final-stage disc has higher rigidity than that of the disc preceding it. Further, this disc assembly has such a structure that the thickness of the discs is gradually reduced from the first stage towards the final stage to reduce the stress caused by high-speed rotation.

It is preferred that the blade of the compressor be made of a martensitic steel comprising 0.05 to 0.2% of C, 0.5% or less of Si, 1% or less of Mn, and 10 to 13% of Cr and optionally 0.5% or less of Mo and 0.5% or less of Ni with the balance being Fe.

The first stage of the shrouds which are formed in a ring shape and are in sliding contact with the leading end of the turbine blade is made of a cast alloy comprising 0.05 to 0.2% by weight of C, 2% by weight or less of Si, 2% by weight or less of Mn, 17 to 27% by weight of Cr, 5% or less of Co, 5 to 15% by weight of Mo, 10 to 30% by weight of Fe, 5% by weight or less of W, and 0.02% by weight or less of B with the balance being Ni, and unavoidable impurities while the other stages of the shrouds are each made of a cast alloy composed of 0.3 to 0.6% by weight of C, 2% by weight or less of Si, 2% or less of Mn, 20 to 27% by weight of Cr, 20 to 30% by weight of Ni, 0.1 to 0.5% by weight of Nb, and 0.1 to 0.5% by weight of Ti with the balance being Fe and unavoidable impurities. These alloys are formed into a ring-shaped structure with a plurality of blocks.

Among diaphragms for fixing turbine nozzles, the diaphragm for the first-stage turbine nozzle is made of a Cr-Ni steel comprising 0.05% by weight or less of C, 1% by weight or less of Si, 2% by weight or less of Mn, 16 to 22% by weight of Cr, and 8 to 15% by weight of Ni with the balance being Fe and unavoidable impurities, while the diaphragms for the other turbine nozzles are each made of a high C-high Ni cast alloy.

The turbine blade is made of a cast alloy comprising 0.07 to 0.25% by weight of C, 1% by weight or less of Si, 1% by weight or less of Mn, 12 to 20% by weight of Cr, 5 to 15% by weight of Co, 1.0 to 5.0% by weight of Mo, 1.0 to 5.0% by weight of W, 0.005 to 0.03% by weight of B, 2.0 to 7.0% by weight of Ti, and 3.0 to 7.0% by weight of Al and at least one member selected from among 1.5% by weight or less of Nb, 0.01 to 0.5% by weight of Zr, 0.01 to 0.5% by weight of Hf, and 0.01 to 0.5% by weight of V with the balance being Ni and unavoidable impurities and having a structure in which a γ' phase and a γ'' phase are precipitated in an austenite phase matrix. The turbine nozzle is made of a cast alloy comprising 0.20 to 0.60% by weight of C, 2% by weight or less of Si, 2% by weight or less of Mn, 25 to 35% by weight of Cr, 5 to 15% by weight of Ni, 3 to 10% by weight of W, 0.003 to 0.03% by weight of B with the balance being Co and unavoidable impurities and further optionally at least one member selected from among 0.1 to 0.3% by weight of Ti, 0.1 to 0.5% by weight of Nb and 0.1 to 0.3% by weight of Zr, and having a structure in which eutectic carbide and secondary carbide are contained in an austenite phase matrix. These alloys are subjected to an aging treatment subsequent to a solution treatment to form the above-described precipitates, thereby strengthening the alloys.

In order to prevent the turbine blade from being corroded by a high-temperature combustion gas, a diffusion coating made of Al, Cr, or Al + Cr may be applied to the turbine blade. It is preferred that the coating layer have a thickness of 30 to 150 μm and be provided on the blade which are exposed to the gas.

A plurality of combustors are provided around the turbine and each have a dual structure comprising outer and inner cylinders. The inner cylinder is made of 0.05 to 0.2% by weight of C, 2% by weight or less of Si, 2% by weight or less of Mn, 20 to 25% by weight of Cr, 0.5 to 5% by weight of Co, 5 to 15% by weight of Mo, 10 to 30% by weight of Fe, 5% by weight or less of W, and 0.02% by weight or less of B with the balance being Ni and unavoidable impurities. The inner cylinder is manufactured by welding the material in the form of a plate which has been subjected to plastic working to have a thickness of 2 to 5 mm and provided over the whole periphery of the cylinder body with crescent louver holes for supplying air. The material for the inner cylinder is a solution-treated material having a wholly austenite structure.

[Brief Description of Drawings]

Fig. 1 is a cross-sectional view of the rotary section of an example of a gas turbine according to the present invention; Fig. 2 a diagram showing the relationship between the impact value after embrittlement and the Mn to Ni ratio; Fig. 3 a diagram showing the relationship between the impact value after embrittlement and the Mn content; Fig. 4 a diagram showing the relationship between the impact value after embrittlement and the Ni content; Fig. 5 a diagram showing the relationship between the creep rupture strength and the Ni content; Fig. 6 a cross-sectional view of an example of a turbine disc according to the present invention; and Fig. 7 a partial sectional view around the rotary section of an example of a gas turbine according to the present invention.

[Best Mode for Carrying Out the Invention]

Example 1

Samples respectively having the compositions (in % by weight) shown in Table 1 were melted in an amount of 20 kg and heated at 1150°C, followed by forging to prepare experimental materials. These materials were heated at 1150°C for 2 hr and then subjected to air blast cooling. The cooling was stopped when the temperature reached 150°C. Then, a first tempering was conducted by heating the materials from that temperature to 580°C, maintaining the temperature for 2 hr and then subjecting the materials to air cooling. Thereafter, a second cooling was conducted by heating the materials at 605°C for 5 hr and then cooling them in a furnace.

Test pieces for a creep rupture test, a tensile test, and a V-notch Charpy impact test were sampled from the materials after heat treatment and applied to the experiments. The impact test was conducted on an embrittled material prepared by heating at 500°C for 1000 hr a material as heat-treated. This embrittled material corresponds to a material heated at 450°C for 10⁵ hr according to the Larson-Miller parameter.

Table 1

No.	Composition (% by weight)										
	C	Si	Mn	Cr	Ni	Mo	V	Nb	N	Mn/Ni	Fe
1	0.12	0.01	0.24	11.5	2.75	2.0	0.20	0.07	0.05	0.08	Bal.
2	0.12	0.25	0.71	11.5	2.83	1.8	0.32	-	0.03	0.25	"
3	0.10	0.02	0.38	11.8	2.09	2.0	0.29	0.05	0.07	0.18	"
4	0.10	0.09	0.71	12.0	2.41	1.9	0.29	0.04	0.06	0.30	"
5	0.08	0.15	0.82	11.9	1.62	2.5	0.27	0.06	0.07	0.51	"
6	0.09	0.09	0.84	11.8	2.10	2.3	0.35	0.05	0.07	0.40	"
7	0.09	0.05	0.20	11.0	1.71	1.9	0.20	0.05	0.06	0.12	"
8	0.10	0.04	0.15	10.9	2.51	2.4	0.19	0.06	0.06	0.06	"

Table 2

No.	Tensile strength (kg/mm ²)	0.2% Proof stress (kg/mm ²)	Elongation (%)	Reduction of area (%)	450°C Rupture strength (kg/mm ²)	25°C Impact value (kg-m)	
						Before embrittlement	After embrittlement
1	112.8	93.7	20.9	63.8	54.5	9.1	7.6
2	115.1	94.0	19.8	60.0	42.0	8.3	2.7
3	112.0	93.3	19.6	60.1	55.1	8.1	2.9
4	113.5	94.3	19.5	59.9	54.1	7.8	2.3
5	110.7	92.9	19.5	59.7	55.2	6.9	1.7
6	111.7	93.6	19.8	60.2	54.3	6.1	1.9
7	111.5	97.7	22.6	62.3	58.0	6.2	3.5
8	113.9	95.3	24.8	61.1	58.1	8.5	7.0

In Table 1, samples Nos. 1 and 8 are materials according to the present invention, samples Nos. 2 to 7 are com-

parative materials, and sample No. 2 is a material corresponding to M152 steel which is currently used as a material for discs.

The mechanical properties of these samples are shown in Table 2. It has been confirmed that the materials of the present invention (samples Nos. 1 and 8) satisfy the requirements for creep rupture strength at 450°C for 10⁵ hr (> 50 kg/mm²) and V-notch Charpy impact value at 25°C after embrittlement treatment [at least 4 kg-m (5 kg-m/cm²)] of a high-temperature and high-pressure gas turbine disc material. By contrast, the material (sample No. 2) corresponding to M152 which is currently used for gas turbines exhibited a creep rupture strength 42 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value at 25°C after embrittlement treatment of 2.7 kg-m, i.e., could not satisfy the requirements for the mechanical properties of a high-temperature and high-pressure gas turbine disc material. With respect to the mechanical properties of the steels (samples Nos. 3 to 7) having a content of Si + Mn of 0.4 to about 1% and a Mn to Ni ratio of at least 0.12, although the creep rupture strength satisfies the value required for a high-temperature and high-pressure gas turbine material, the V-notch Charpy impact value after embrittlement is 3.5 kg-m or less and does not satisfy the requirement.

Fig. 2 is a diagram showing the relationship between the impact value after embrittlement and the Mn to Ni ratio. As shown in this figure, no significant difference in the effect is observed when the Mn to Ni ratio is 0.12 or more. However, when the ratio is 0.11 or less, the resistance to embrittlement is greatly improved, and the impact value is at least 4 kg-m (5 kg-m/cm²). Further, when the ratio is 0.10 or less, the impact value is as high as 6 kg-m (7.5 kg-m/cm²). Mn is indispensable as a deoxidizer and a desulfurizer, and it is necessary that Mn should be added in an amount of 0.6% or less.

Fig. 3 is a diagram showing the relationship between the impact value after embrittlement and the Mn content. As shown in this figure, when the Ni content is 2.1% or less, no significant effect on the impact value after embrittlement can be attained even by reducing the Mn content, while when the Ni content exceeds 2.1%, a reduction in the Mn content brings about a significant effect. In particular, when the Ni content is 2.4% or more, a remarkable effect can be attained.

Further, when the Mn content is around 0.7%, no improvement in the impact value is attained irrespective of the Ni content. However, when the Mn content is 0.6% or less and the Ni content is at least 2.4%, the lower the Mn content, the higher the impact value.

Fig. 4 is a diagram showing the relationship between the impact value after embrittlement and the Ni content. As shown in this figure, when the Mn content is at least 0.7%, no significant improvement in the resistance to the embrittlement can be attained even by increasing the Ni content, while when the Mn content is less than 0.7%, the resistance to the embrittlement is significantly improved with an increase in the Ni content. In particular, when the Mn content is 0.15 to 0.4% and the Ni content is at least 2.2%, a remarkable improvement can be attained. Specifically, when the Mn content is 2.4% or more, the impact value is 6 kg-m (7.5 kg-m/cm²) or more, and when the Ni content is 2.5% or more, the impact value is 7 kg-m/cm² or more.

Fig. 5 is a diagram showing the relationship between the creep rupture strength at 450°C for 10⁵ hr and the Ni content. As shown in this figure, a Ni content up to about 2.5% has no significant effect on the strength. However, when the Ni content exceeds 3.0%, the creep rupture strength is less than 50 kg/mm², so that no intended strength can be attained. It is noted that the strength is increased with a lowering in the Mn content and the most remarkable strengthening, i.e., the highest strength, can be attained when the Mn content is about 0.15 to 0.25%.

Fig. 6 is a cross-sectional view of a gas turbine disc according to the present invention. The chemical composition (in % by weight) is shown in Table 3.

Table 3

No.	C	Si	Mn	Cr	Ni	Mo	Nb	V	N	Mn/Ni	Fe
9	0.12	0.04	0.20	11.1	2.70	2.05	0.07	0.20	0.05	0.07	Bal.

The melting of the steel material was conducted by carbon vacuum deoxidation. After the completion of the forging, the steel was heated at 1050°C for 2 hr and hardened in an oil of 150°C. Tempering was then conducted by heating the steel from that temperature, maintaining the temperature at 520°C for 5 hr and cooling the steel with air. Thereafter, further tempering was conducted by heating the steel at 590°C for 5 hr and cooling the heated steel in a furnace. After the completion of the heat treatment, the steel was machined into a shape shown in the drawing, and the formed disc had an outer diameter of 1000 mm and a thickness of 200 mm. The diameter of a center hole 11 is 65 mm. Numeral 12 designates a section in which are provided holes into which stacking bolts are inserted, and numeral 13 designates a section in which a turbine blade is embedded.

This disc exhibited excellent properties, i.e., an impact value of 8.0 kg-m (10 kg-m/cm²) after embrittlement under the same conditions as those described above and a creep rupture strength of 55.2 kg/mm² at 450°C for 10⁵ hr.

Example 2

Fig. 1 is a cross-sectional view of the rotary section of an example of a gas turbine in which the above-described disc is used according to the present invention. Numeral 1 designates a turbine stub shaft, numeral 2 a turbine bucket, numeral 3 a turbine stacking bolt, numeral 4 a turbine spacer, numeral 5 a distance piece, numeral 6 a compressor disc, numeral 7 a compressor blade, numeral 8 a compressor stacking bolt, numeral 9 a compressor stub shaft, numeral 10 a turbine disc, and numeral 11 a center hole. In the gas turbine of the present invention, the number of stages of the compressor discs 6 is 17, and the number of stages of the turbine buckets 2 is 2. The number of stages of the turbine buckets 2 may be 3. The steel of the present invention can be applied to both cases.

With respect to the materials shown in Table 4, a large steel having a size corresponding to a real size was prepared by electroslog remelting and then subjected to forging and heat treatment. The forging was conducted at a temperature ranging from 850 to 1150°C, while the heat treatment was conducted under conditions shown in Table 4. The chemical compositions (in % by weight) of the samples are shown in Table 4. With respect to the microstructures of these materials, samples Nos. 6 to 9 each had a wholly tempered martensite structure, and samples Nos. 10 and 11 each had a wholly tempered bainite structure. Sample No. 6 was used for a distance piece and a compressor disc at the final stage. The distance piece had a size of 60 mm in thickness x 500 mm in width x 1000 mm in length, while the compressor disc had a diameter of 1000 mm and a thickness of 180 mm. Sample No. 7 was used for production of a disc having a size of 1000 mm in diameter x 180 mm in thickness, sample No. 8 was used for production of a spacer having a size of 1000 mm in outer diameter x 400 mm in inner diameter x 100 mm in thickness, and sample No. 9 was used for production of a stacking bolt having a size of 40 mm in diameter x 500 mm in length for both of the turbine and the compressor. Sample No. 9 was also used for production of a bolt for connecting the distance piece to the compressor disc. Sample Nos. 10 and 11 were forged into a turbine stub shaft and a compressor stub shaft, respectively, each having a size of 250 mm in diameter x 300 mm in length. Further, the alloy of sample No. 10 was also used for the 13th to 16th stages of the compressor disc 6, while sample No. 11 was used for the first to 12th stages of the compressor disc 6. They were produced so as to have the same size as that of the turbine disc. The test pieces except for sample No. 9 were extracted from the central portion of the samples in a direction perpendicular to the axial (longitudinal) direction thereof. In this example, the test piece was extracted in the longitudinal direction of the sample.

Table 5 shows the results of the tensile strength test at room temperature, the V-notch Charpy impact test at 20°C and the creep rupture strength test. The creep rupture strength at 450°C for 10⁵ hr was determined according to a commonly used method, i.e., Larson-Miller method.

Samples Nos. 6 to 9 (12Cr steel) according to the present invention had a creep rupture strength of at least 51 kg/mm² at 450°C for 10⁵ hr and a V-notch Charpy impact value of 7 kg-m/cm² at 20°C. Therefore, it has been confirmed that samples Nos. 6 to 9 satisfy the requirement for the strength of the material for a high-temperature gas turbine.

Samples Nos. 10 and 11 (low-alloy steel) for the stub shaft exhibited a low creep rupture strength at 450°C but had a tensile strength of 86 kg/mm² or more and a V-notch Charpy impact value of 7 kg-m/cm² or more at 20°C. Therefore, it has been confirmed that these samples satisfy the requirement for the strength of the stub shaft (tensile strength $\geq$ 81 kg/mm²; and a V-notch Charpy impact value at 20°C $\geq$ 5 kg-m/cm²).

The gas turbine of the present invention made of a combination of the above-described materials enables the adoption of a compression ratio of 14.7, a temperature of 350°C or above, a compressor efficiency of 86% or more, a gas temperature of about 1200°C in the inlet of the first-stage nozzle, which brings about a thermal efficiency (LHV) of 32% or more.

Under these conditions, the temperature of both the distance piece and the final-stage compressor disc reaches 450°C at the highest. It is preferred that the thickness of the distance piece and that of the final-stage compressor disc be 25 to 30 mm and 40 to 70 mm, respectively. The turbine and the compressor disc are each provided at its central portion with a through-hole. A compressive residual stress is caused at the through-hole of the turbine disc.

Further, the heat-resistant steel shown in the above-described Table 3 was used for production of the turbine spacer 4, the distance piece 5, and the final stage of the compressor disc 6, and the other parts were produced by using the same steels as those described above, thereby forming a gas turbine of the present invention. This gas turbine enabled the adoption of a compression ratio of 14.7, a temperature of 350°C or above, a compression efficiency of 86% or more, and a gas temperature of 1200°C at the first-stage nozzle inlet. Consequently, it becomes possible to attain not only a thermal efficiency of 32% or more but also, as described above, a high creep rupture strength and a high impact strength after thermal embrittlement, thus realizing the formation of a more reliable gas turbine.

Table 4

Example Kind of steel	Composition (%)										Heat treatment
	C	Si	Mn	Cr	Ni	Mo	V	Nb	N	Fe	
6 (Distance piece)	0.10	0.04	0.70	11.56	1.98	1.98	0.20	0.08	0.06	Bal.	1050°C x 5hOQ 550°C x 15hAC 600°C x 15hAC
7 (Turbine disc)	0.10	0.05	0.65	11.49	1.70	2.04	0.19	0.08	0.06	"	1050°C x 8hOQ 550°C x 20hAC 600°C x 20hAC
8 (Spacer)	0.09	0.07	0.59	11.57	2.31	2.22	0.18	0.09	0.06	"	1050°C x 3hOQ 550°C x 10hAC 600°C x 10hAC
9 (Stacking bolt)	0.10	0.03	0.69	11.94	1.86	2.25	0.21	0.15	0.05	"	1050°C x 1hOQ 550°C x 2hAC 600°C x 2hAC
10 Cr-Mo-V steel	0.26	0.25	0.79	1.09	0.41	1.25	0.23	-	-	"	975°C x 8hWQ 665°C x 25hAC 665°C x 25hAC
11 Ni-Cr-Mo-V steel	0.20	0.21	0.36	1.51	2.78	0.62	0.10	-	-	"	840°C x 8hWQ 635°C x 25hAC 635°C x 25hAC

Table 5

Example Kind of steel	Tensile strength (kg/mm ²)	0.02% Proof stress (kg/mm ²)	Elongation (%)	Reduction of area (%)	Impact value vE ₂₀ (kg-m/cm ²)	10 ⁵ -h Creep rupture strength (kg/mm ²)
						450°C
6	112.0	79.3	19.8	60.1	8.7	51.1
7	111.7	79.5	20.1	59.3	8.3	52.3
8	114.3	81.2	19.5	62.5	7.2	51.3
9	115.7	82.6	22.3	63.4	8.7	52.7
10	86.4	-	26.7	68.8	7.5	35.2
11	86.8	77.1	26.9	69.1	18.2	23

Example 3

Fig. 7 is a partial sectional view of the rotary section of an example of a gas turbine having a gas turbine disc made of the heat-resistant steel according to the present invention. The number of stages of the gas turbine discs 10 in this example are 3. The first stage and the second stage on the upstream side of the gas flow are each provided with a

center hole 11. In this example, each of the turbine discs is made of the heat-resistant steel shown in Table 3. Further, in this example, the heat-resistant steel shown in the above-described Table 3 was used for the final stage of the compressor disc 6 on the downstream side of the gas flow, the distance piece 5, the turbine spacer 4, the turbine stacking bolt 3, and the compressor stacking bolt 8. The alloys shown in Table 6 were used for construction of the other parts, i.e., the turbine blade 2, the turbine nozzle 14, the liner 17 of the combustor 15, the compressor blade 7, the compressor nozzle 16, the diaphragm 18, and the shroud 19. In particular, the turbine nozzle 12 and the turbine blade 2 were made of a casting. The number of stages of the compressor discs in this example was 17, and the discs were arranged in the same manner as that of Example 2. The turbine stub shaft 1 and the compressor stub shaft 9 were each also constructed in the same manner as that of Example 2.

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Table 6

	C	Si	Mn	Cr	Ni	Co	Fe	Mo	B	W	Ti	Others
Turbine blade	0.15	0.11	0.12	15.00	Bal.	9.02	-	3.15	0.015	3.55	4.11	Zr 0.05, Al 5.00
Turbine nozzle	0.43	0.75	0.66	29.16	10.18	Bal.	-	-	0.010	7.11	0.23	Nb 0.21, Zr 0.15
Combustor liner	0.07	0.83	0.75	22.13	Bal.	1.57	18.47	9.12	0.008	0.78	-	-
Compressor blade and nozzle	0.11	0.41	0.61	12.07	0.31	-	Bal.	-	-	-	-	-
Shroud segment (1)	0.08	0.87	0.75	22.16	Bal.	1.89	18.93	9.61	0.005	0.85	-	-
(2)	0.41	0.65	1.00	23.55	25.63	-	Bal.	-	-	-	0.25	Nb 0.33
Diaphragm	0.025	0.81	1.79	19.85	11.00	-	"	-	-	-	-	-

In Table 6, the turbine blade, the turbine nozzle, the shroud segment (1), and the diaphragm were each used at the first stage on the upstream side of the gas flow, while the shroud segment (2) was used at the second stage.

In this example, the final stage of the compressor disc 6 has a ratio (t/D) of the minimum thickness (t) to the outer diameter (D) of 0.08, and the distance piece 5 has a ratio (t/D) of the minimum thickness (t) to maximum inner diameter (D) of 0.04. The ratio (t/D) of the maximum thickness (t) of the central section of the turbine disc to the diameter (D) thereof is 0.19 in the case of the first stage and 0.205 in the case of the second stage, and the ratio (ℓ/D) of the spacing

(ℓ) between the discs to the diameter (D) thereof is 0.21. A spacing is provided between the turbine discs. The turbine disc is provided over the entire periphery with a plurality of holes at equal intervals for inserting the bolts for the purpose of connecting the discs.

The above-described construction enables the adoption of a compression ratio of 14.7, a temperature of 350°C or above, a compression efficiency of 86% or more, a gas temperature of 1200°C at the inlet of the first-stage turbine nozzle, which brings about a thermal efficiency of 32% or more. Further, as described above, a heat-resistant steel which has a high creep rupture strength and is less susceptible to thermal embrittlement can be used for the turbine disc, the distance piece, the spacer, the final stage of the compressor disc, and the stacking bolt. Moreover, since an alloy having an excellent high-temperature strength is used for the turbine blade, an alloy having excellent high-temperature strength and high-temperature ductility is used for the turbine nozzle and an alloy having excellent high-temperature strength and fatigue resistance is used for the combustor liner, it is possible to obtain a more reliable and well-balanced gas turbine.

[Industrial Applicability]

The present invention enables the formation of a heat-resistant steel satisfying the requirements for the creep rupture strength and the impact value after thermal embrittlement of a high-temperature and high-pressure gas turbine disc (a gas temperature of 1200°C or above; and a compression ratio of about 15). The gas turbine comprising this material exhibits an excellent effect of attaining a remarkably high thermal efficiency.

Claims

1. A heat resistant steel consisting of

0.05 to 0.2 wt. % of C,
 less than 0.5 wt. % of Si,
 0.1 to 0.40 wt. % of Mn,
 8 to 13 wt. % of Cr,
 1.5 to 3 wt. % of Mo,
 2 to 3 wt. % of Ni,
 0.05 to 0.3 wt. % of V,
 0.02 to 0.2 wt. % in total of either or both of Nb and Ta,
 0.02 to 0.1 wt. % of N, and optionally one or more of:
 less than 0.5 wt. % of Co
 less than 1 wt. % of W
 less than 0.01 wt. % of B
 less than 0.3 wt. % of Al
 less than 0.5 wt. % of Ti
 less than 0.1 wt. % of Zr
 less than 0.1 wt. % of Hf
 less than 0.01 wt. % of Ca
 less than 0.01 wt. % of Mg
 less than 0.01 wt. % of Y
 less than 0.01 wt. % of rare earth elements
 less than 0.5 wt. % of Cu
 a ratio (Mn/Ni) of Mn to Ni of less than 0.11, and
 the balance Fe and unavoidable impurities.

2. A heat resistant steel according to claim 1 containing

0.07 to 0.15 wt. % of C,
 0.01 to 0.1 wt. % of Si,
 0.15 to 0.4 wt. % of Mn,
 11 to 12.5 wt. % of Cr,
 2.2 to 3.0 wt. % of Ni,
 1.8 to 2.5 wt. % of Mo,
 0.04 to 0.08 wt. % in total of either or both of Nb and Ta,

0.15 to 0.25 wt. % of V,
 0.04 to 0.08 wt. % of N,
 the ratio (Mn/Ni) of Mn to Ni being 0.04 to 0.10, and
 having a wholly tempered martensite structure.

3. A heat resistant steel according to claim 1 or claim 2 having a 450°C, 10⁵-h creep rupture strength of higher than 50 kg/mm² and a 25°C, V-notch Charpy impact value of higher than 5 kg - m/cm² after having been heated at 500°C for 10³ hours.
4. A gas turbine disc having in its outer circumferential portion a plurality of recessed grooves into which blades are embedded, having a maximum thickness in its center and having in its outer circumferential region a plurality of through-holes into which bolts are inserted to connect a plurality of said discs, said disc is made of a martensitic steel according to any one of claims 1 to 3.
5. A gas turbine disc according to claim 4 wherein the ratio (t/D) of the thickness (t) of said disc to the diameter (D) thereof is in the range 0.15 to 0.30.
6. A turbine spacer for a gas turbine for use when a plurality of turbine discs are connected together at their outer circumferential regions by bolts with said spacer or spacers interposed therebetween, said spacer being made of a martensitic steel according to any one of claims 1 to 3.
7. A cylindrical distance piece for a gas turbine used when a plurality of turbine discs and a plurality of compressor discs are connected together through said distance piece by bolts, said distance piece being made of a martensitic steel according to any one of claims 1 to 3.
8. A cylindrical distance piece according to claim 7 wherein the ratio (t/D) of the minimum thickness (t) of said distance piece to the maximum inner diameter (D) thereof is in the range of 0.05 to 0.10.
9. A compressor disc having in its outer circumferential region a plurality of recessed grooves into which blades are embedded, having in its outer circumferential region a plurality of through-holes into which bolts are inserted to connect a plurality of said discs and having in its center and portions provided with said through-holes a maximum thickness, said compressor disc being made of a steel according to any one of claims 1 to 3.
10. A compressor disc according to claim 9 wherein the ratio (t/D) of the thickness (t) of said compressor disc to the diameter (D) thereof is in the range of 0.05 to 0.10.
11. Stacking bolts for a gas turbine which are respectively used to connect a plurality of turbine discs and compressor discs, made of a martensitic steel according to any one of claims 1 to 3.
12. A gas turbine comprising:
 - a turbine stub shaft;
 - a plurality of turbine discs connected to said turbine stub shaft by turbine stacking bolts with a turbine spacer or turbine spacers interposed therebetween;
 - turbine blades embedded into each of said turbine discs;
 - a distance piece connected to said turbine discs by said turbine stacking bolts;
 - a plurality of compressor discs connected to said distance piece by compressor stacking bolts;
 - compressor blades embedded into each of said compressor discs; and
 - a compressor stub shaft integral with the first stage disc of said compressor discs;
 wherein at least said turbine discs are made of a martensitic steel according to any one of claims 1 to 3.
13. A gas turbine according to claim 12 wherein the ratio (l/D) of the gap (l) between said respective turbine discs to the outer diameter (D) thereof is 0.15 to 0.25.
14. A gas turbine according to claim 12 or claim 13, wherein said final stage disc of said compressor discs is more rigid than the preceding stage disc.
15. A gas turbine according to any one of claims 12 to 14 wherein at least one of said turbine stacking bolts, said

distance piece, said turbine spacer, said compressor blades, at least said compressor discs from the final to central stages and said compressor stacking bolts is or are made of a martensitic steel according to any of claims 1 to 3.

5 16. A gas turbine according to any one of claims 12 to 14 wherein at least one said turbine stacking bolts, said distance piece, said turbine spacer, at least said compressor discs from the final to central stages and said compressor stacking bolts is or are made of a martensitic steel, which steel is a steel according to any one of claims 1 to 3.

10 17. A gas turbine according to any one of claims 12 to 16 wherein said turbine stub shaft is made of a Cr-Mo-V steel consisting of

0.2 to 0.4 wt. % of C,
0.5 to 1.5 wt. % of Mn,
0.1 to 0.5 wt. % of Si,
0.5 to 1.5 wt. % of Cr,
15 less than 0.5 wt. % of Ni,
1.0 to 2.0 wt. % of Mo,
0.1 to 0.3 wt. % of V and
the balance Fe and unavoidable impurities.

20 18. A gas turbine according to claim 15 wherein said turbine spacer is made of a heat resistant steel consisting of

0.05 to 0.2 wt. % of C,
less than 0.5 wt. % of Si,
less than 1 wt. % of Mn,
25 8 to 13 wt. % of Cr,
1.5 to 3.0 wt. % of Mo,
less than 3 wt. % of Ni,
0.05 to 0.3 wt. % of V,
0.02 to 0.2 wt. % of Nb,
30 0.02 to 0.1 wt. % of N and
the balance Fe and unavoidable impurities.

35 19. A gas turbine according to claim 15 wherein said turbine stacking bolts are respectively made of a heat resistant steel consisting of

0.05 to 0.2 wt. % of C,
less than 0.5 wt. % of Si,
less than 1 wt. % of Mn,
8 to 13 wt. % of Cr,
40 1.5 to 3.0 wt. % of Mo,
less than 3 wt. % of Ni,
0.05 to 0.3 wt. % of V,
0.02 to 0.2 wt. % of Nb,
0.02 to 0.1 wt. % of N and
45 the balance Fe and unavoidable impurities.

20. A gas turbine according to claim 15 wherein said turbine distance piece is made of a heat resistant steel consisting of

50 0.05 to 0.2 wt. % of C,
less than 0.5 wt. % of Si,
less than 1 wt. % of Mn,
8 to 13 wt. % of Cr,
1.5 to 3.0 wt. % of Mo,
less than 3 wt. % of Ni,
55 0.05 to 0.3 wt. % of V,
0.02 to 0.2 wt. % of Nb,
0.02 to 0.1 wt. % of N and
the balance Fe and unavoidable impurities.

21. A gas turbine according to claim 15 wherein said compressor stacking bolts are respectively made of a heat resistant steel consisting of

0.05 to 0.2 wt. % of C,
less than 0.5 wt. % of Si,
less than 1 wt. % of Mn,
8 to 13 wt. % of Cr,
1.5 to 3.0 wt. % of Mo,
less than 3 wt. % of Ni,
0.05 to 0.3 wt. % of V,
0.02 to 0.2 wt. % of Nb,
0.02 to 0.1 wt. % of N and
the balance Fe and unavoidable impurities.

22. A gas turbine according to claim 15 wherein said compressor blades are respectively made of a martensitic steel consisting of

0.05 to 0.2 wt. % of C,
less than 0.5 wt. % of Si,
less than 1 wt. % of Mn,
10 to 13 wt. % of Cr and
the balance Fe and unavoidable impurities.

23. A gas turbine according to any one of claims 12 to 22, wherein said compressor discs disposed from the first to central stages on the upstream side of a gas flow are respectively made of a Ni-Cr-Mo-V steel consisting of

0.15 to 0.30 wt. % of C,
less than 0.5 wt. % of Si,
less than 0.6 wt. % of Mn,
1 to 2 wt. % of Cr,
2.0 to 4.0 wt. % of Ni,
0.5 to 1.0 wt. % of Mo,
0.05 to 0.2 wt. % of V and
the balance Fe and unavoidable impurities

and wherein said compressor discs disposed from said central stage toward the downstream side except for at least the final stage are respectively made of a Cr-Mo-V steel consisting of

0.2 to 0.4 wt. % of C,
0.1 to 0.5 wt. % of Si,
0.5 to 1.5 wt. % of Mn,
0.5 to 1.5 wt. % of Cr,
less than 0.5 wt. % of Ni,
1.2 to 2.0 wt. % of Mo,
0.1 to 0.3 wt. % of V and
the balance Fe and unavoidable impurities.

24. A gas turbine according to any one of claims 12 to 23, wherein said compressor stub shaft is made of a Cr-Mo-V steel consisting of

0.15 to 0.3 wt. % of C,
less than 0.6 wt. % of Mn,
less than 0.5 wt. % of Si,
2.0 to 4.0 wt. % of Ni,
1 to 2 wt. % of Cr,
0.5 to 1 wt. % of Mo,
0.05 to 0.2 wt. % of V and
the balance Fe and unavoidable impurities.

25. A gas turbine according to claim 12 or claim 13 wherein said steel of said turbine discs has a wholly tempered

martensite structure.

26. A gas turbine according to any one of claims 12 to 15, wherein at least said compressor disc used as a final stage disc on a high-temperature side is made of a martensitic steel according to any one of claims 1 to 3.

27. A gas turbine according to any one of claims 18 to 21, wherein said turbine stacking bolts, said spacer, said turbine discs, said distance piece, said compressor stacking bolts and said compressor disc used as a final stage disc on a high-temperature side are respectively made of a martensitic steel having a 450°C, 10⁵-h creep rupture strength of higher than 50 kg/mm² and a 25°C, V-notch Charpy impact value of higher than 5 kg - m/cm² after having been heated at 500°C for 10³ hours, and having a wholly tempered martensite structure.

28. A gas turbine according to any one of claims 12 to 27, comprising:

said turbine stub shaft;
 said plurality of turbine discs connected to said turbine stub shaft by turbine stacking bolts with said spacer of spacers interposed therebetween;
 said turbine blades embedded into each of said turbine discs;
 a shroud formed in an annular shape for making a sliding contact with the outer circumferential ends of said turbine blades;
 a plurality of combustors each having a turbine nozzle for directing the flow of high-temperature gas toward said turbine blades to cause rotation thereof and a cylindrical body for generating said high-temperature gas;
 said distance piece connected to said turbine discs by said turbine stacking bolts;
 said plurality of compressor discs connected to said distance piece by said compressor stacking bolts;
 said compressor blades embedded into each of said compressor discs; and
 said compressor stub shaft integral with the first stage disc of said compressor discs;
 wherein said shroud is, at its portion corresponding to said first stage turbine blade, made of a Ni-based alloy consisting of
 0.05 to 0.2 wt. % of C,
 less than 2 wt. % of Si,
 less than 2 wt. % of Mn,
 17 to 27 wt. % of Cr,
 less than 5 wt. % of Co,
 5 to 15 wt. % of Mo,
 10 to 30 wt. % of Fe,
 less than 5 wt. % of W,
 less than 0.02 wt. % of B and
 the balance Ni and unavoidable impurities and
 having a wholly austenite structure, and,
 at its portions corresponding to said turbine blades disposed at the remaining stages, made of a Fe-based cast alloy consisting of
 0.3 to 0.6 wt. % of C,
 less than 2 wt. % of Si,
 less than 2 wt. % of Mn,
 20 to 27 wt. % of Cr,
 20 to 30 wt. % of Ni,
 0.1 to 0.5 wt. % of Nb,
 0.1 to 0.5 wt. % of Ti and
 the balance Fe and unavoidable impurities.

29. A gas turbine according to any one of claims 12 to 28, comprising:

said turbine stub shaft;
 said plurality of turbine discs connected to said turbine stub shaft by said turbine stacking bolts with said spacer or spacers interposed therebetween;
 said turbine blades embedded into each of said turbine discs;
 said plurality of combustors each having said turbine nozzle for directing the flow of high-temperature gas toward said turbine blades to cause rotation thereof, having a diagram for fixing said turbine nozzle and having said cylindrical body for generating said high-temperature gas;

said distance piece connected to said turbine discs by said turbine stacking bolts;
 said plurality of compressor discs connected to said distance piece by compressor stacking bolts;
 said compressor blades embedded into each of said compressor discs; and
 said compressor stub shaft integral with the first stage disc of said compressor discs;
 wherein said diaphragm is, at its first stage turbine blade portion for directing the flow of high-temperature gas
 toward said first stage turbine blades, made of a Cr-Ni steel consisting of
 less than 0.05 wt. % of C,
 less than 1 wt. % of Si,
 less than 2 wt. % of Mn,
 16 to 22 wt. % of Cr,
 8 to 15 wt. % of Ni and
 the balance Fe and unavoidable impurities.

30. A gas turbine according to any one of claims 12 to 29 comprising:

said turbine stub shaft;
 said plurality of turbine discs connected to said turbine stub shaft by said turbine stacking bolts with said spacer
 or spacers interposed therebetween;
 said turbine blades embedded into each of said turbine discs;
 said plurality of combustors each having said turbine nozzle for directing the flow of high temperature gas
 toward said turbine blades to cause rotation thereof and said cylindrical body for generating said high-tem-
 perature gas;
 said distance piece connected to said turbine discs by said turbine stacking bolts;
 said plurality of compressor discs connected to said distance piece by said compressor stacking bolts;
 said compressor blades embedded into each of said compressor discs;
 a compressor nozzle for directing air toward said compressor blades; and
 said compressor stub shaft integral with the first stage disc of said compressor discs;
 wherein said compressor nozzle is made of a martensitic steel consisting of
 0.05 to 0.2 wt. % of C,
 less than 0.5 wt. % of Si,
 less than 1 wt. % of Mn,
 10 to 30 wt. % of Cr,
 less than 0.5 wt. % of Ni and
 less than 0.5 wt. % of Mo, and
 the balance Fe and unavoidable impurities;
 said compressor discs which are disposed in a low-temperature range including said first stage are respectively
 made of a Ni-Cr-Mo-V steel consisting of
 0.15 to 0.3 wt. % of C,
 less than 0.5 wt. % of Si,
 less than 0.6 wt. % of Mn,
 1 to 2 wt. % of Cr,
 2 to 4 wt. % of Ni,
 0.5 to 1 wt. % of Mo,
 0.05 to 0.2 wt. % of V and
 the balance Fe and unavoidable impurities; and
 said compressor discs which are disposed at the remaining stages of high-temperature side are respectively
 made of a Cr-Mo-V steel consisting of
 0.2 to 0.4 wt. % of C,
 0.1 to 0.5 wt. % of Si,
 0.5 to 1.5 wt. % of Mn,
 0.5 to 1.5 wt. % of Cr,
 less than 0.5 wt. % of Ni,
 1 to 2 wt. % of Mo,
 0.1 to 0.3 wt. % of V and
 the balance Fe and unavoidable impurities.

31. A gas turbine according to any one of claims 12 to 30, comprising:

said turbine stub shaft;
 said plurality of turbine discs connected to said turbine stub shaft by said turbine stacking bolts with said spacer
 or spacers interposed therebetween;
 said turbine blades embedded into each of said turbine discs;
 5 said plurality of combustors each having said turbine nozzle for directing the flow of high-temperature gas
 toward said turbine blades to cause rotation thereof and said cylindrical body for generating said high-tem-
 perature gas;
 said distance piece connected to said turbine discs by said turbine stacking bolts;
 said plurality of compressor discs connected to said distance piece by said compressor stacking bolts;
 10 said compressor blades embedded into each of said compressor discs; and
 said compressor stub shaft integral with the first stage disc of compressor discs;
 wherein said turbine blades are respectively made of a Ni-based cast alloy consisting of
 0.07 to 0.25 wt. % of C,
 less than 1 wt. % of Si,
 15 less than 1 wt. % of Mn,
 12 to 20 wt. % of Cr,
 5 to 15 wt. % of Co,
 1 to 5 wt. % of Mo,
 1 to 5 wt. % of W,
 20 0.005 to 0.03 wt. % of B,
 2 to 7 wt. % of Ti,
 3 to 7 wt. % of Al,
 at least one element selected from
 25 less than 1.5 wt. % of Nb,
 0.01 to 0.5 wt. % of Zr,
 0.01 to 0.5 wt. % of Hf and
 0.01 to 0.5 wt. % of V, and
 the balance Ni and unavoidable impurities,
 30 and having γ' and γ'' phases;

 said turbine nozzle is made of either a Co-based cast alloy consisting of
 0.20 to 0.6 wt. % of C,
 less than 2 wt. % of Si,
 35 less than 2 wt. % of Mn,
 25 to 35 wt. % of Cr,
 5 to 15 wt. % of Ni,
 3 to 10 wt. % of W,
 0.003 to 0.03 wt. % of B and
 40 the balance Co and unavoidable impurities and
 having an austenite matrix containing therein eutectic carbide and secondary carbide,
 or said Co-based cast alloy further containing, in addition to the above composition at least one element
 selected from
 45 0.1 to 0.3 wt. % of Ti,
 0.1 to 0.5 wt. % of Nb and
 0.1 to 0.3 wt. % of Zr, and
 having an austenite matrix containing therein eutectic carbide and secondary carbide; and
 said combustors are respectively made of a Ni-based alloy consisting of
 50 0.05 to 0.2 wt. % of C,
 less than 2 wt. % of Si,
 less than 2 wt. % of Mn,
 20 to 25 wt. % of Cr,
 0.5 to 5 wt. % of Co,
 5 to 15 wt. % of Mo,
 55 10 to 30 wt. % of Fe,
 less than 5 wt. % of W,
 less than 0.02 wt. % of B and
 the balance Ni and unavoidable impurities, and

having a wholly austenite structure.

Patentansprüche

5

1. Hitzebeständiger Stahl, bestehend aus:

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0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
0,1 bis 0,40 Gew.-% Mn,
8 bis 13 Gew.-% Cr,
1,5 bis 3 Gew.-% Mo,
2 bis 3 Gew.-% Ni,
0,05 bis 0,3 Gew.-% V,
insgesamt 0,02 bis 0,2 Gew.-% Nb und/oder Ta,
0,02 bis 0,1 Gew.-% N,

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und gegebenenfalls einem oder mehreren der folgenden Bestandteile:

20

weniger als 0,5 Gew.-% Co,
weniger als 1 Gew.-% W,
weniger als 0,01 Gew.-% B,
weniger als 0,3 Gew.-% Al,
weniger als 0,5 Gew.-% Ti,
weniger als 0,1 Gew.-% Zr,
weniger als 0,1 Gew.-% Hf,
weniger als 0,01 Gew.-% Ca,
weniger als 0,01 Gew.-% Mg,
weniger als 0,01 Gew.-% Y,
weniger als 0,01 Gew.-% Seltenerd-elemente,
weniger als 0,5 Gew.-% Cu,
einem Verhältnis (Mn/Ni) zwischen Mn und Ni von weniger als 0,11, und aus Fe und unvermeidlichen Verunreinigungen als Rest.

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2. Hitzebeständiger Stahl nach Anspruch 1, umfassend:

40

0,07 bis 0,15 Gew.-% C,
0,01 bis 0,1 Gew.-% Si,
0,15 bis 0,4 Gew.-% Mn,
11 bis 12,5 Gew.-% Cr,
2,2 bis 3,0 Gew.-% Ni,
1,8 bis 2,5 Gew.-% Mo,
insgesamt 0,04 bis 0,08 Gew.-% Nb und/oder Ta,
0,15 bis 0,25 Gew.-% V,
0,04 bis 0,08 Gew.-% N,

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wobei das Verhältnis (Mn/Ni) zwischen Mn und Ni 0,04 bis 0,10 beträgt und der Stahl eine vollständig vergütete Martensit-Struktur aufweist.

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3. Hitzebeständiger Stahl nach Anspruch 1 oder 2 mit einer Zeitstandfestigkeit bei 450°C und 10⁵ h von mehr als 50 kg/mm² und einer Charpy-Spitzkerbschlagzähigkeit bei 25°C von mehr als 5 kg.m/cm² nach Erhitzen auf 500°C über einen Zeitraum von 10³ Stunden.

55

4. Gasturbinenscheibe, die in ihrem äußeren Umfangsabschnitt eine Vielzahl an ausgenommenen Nuten aufweist, in denen Schaufeln eingebettet sind, die in ihrer Mitte eine maximale Dicke besitzt und die in ihrem äußeren Umfangsbereich eine Vielzahl Durchgangslöcher aufweist, in die Bolzen eingesetzt sind, um eine Vielzahl an Scheiben zu verbinden, wobei die Scheibe aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 besteht.

5. Gasturbinenscheibe nach Anspruch 4, worin das Verhältnis (t/D) zwischen der Dicke (t) der Scheibe und ihrem Durchmesser (D) im Bereich von 0,15 bis 0,30 liegt.
- 5 6. Turbinenabstandhalter für eine Gasturbine zur Verwendung, wenn eine Vielzahl an Turbinenscheiben in ihrem äußeren Umfangsbereich durch Bolzen miteinander verbunden sind, wobei der oder mehrere Abstandhalter dazwischen angeordnet ist/sind und der Abstandhalter aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 besteht.
- 10 7. Zylindrisches Distanzstück für eine Gasturbine zur Verwendung, wenn eine Vielzahl an Turbinenscheiben und eine Vielzahl an Kompressorscheiben durch das Distanzstück hindurch durch Bolzen miteinander verbunden werden, wobei das Distanzstück aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 besteht.
- 15 8. Zylindrisches Distanzstück nach Anspruch 7, worin das Verhältnis (t/D) zwischen der minimalen Dicke (t) des Distanzstücks und dessen maximalem Innendurchmesser (D) im Bereich von 0,05 bis 0,10 liegt.
- 20 9. Kompressorscheibe, die in ihrem äußeren Umfangsbereich eine Vielzahl an ausgenommenen Nuten aufweist, in die Schaufeln eingebettet sind, die in ihrem äußeren Umfangsbereich eine Vielzahl Durchgangslöcher besitzt, in die Bolzen eingesetzt sind, um mehrere der Scheiben miteinander zu verbinden, und die in ihrer Mitte und den mit den Durchgangslöchern versehenen Abschnitten eine maximale Dicke aufweist, wobei die Kompressorscheibe aus Stahl nach einem der Ansprüche 1 bis 3 besteht.
- 25 10. Kompressorscheibe nach Anspruch 9, worin das Verhältnis (t/D) zwischen der Dicke (t) der Kompressorscheibe und ihrem Durchmesser (D) im Bereich von 0,05 bis 0,10 liegt.
11. Stapelbolzen für eine Gasturbine, die jeweils zur Verbindung einer Vielzahl an Turbinenscheiben und Kompressorscheiben dienen und aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 bestehen.
12. Gasturbine, umfassend:
30 eine Turbinenflanschswelle;
eine Vielzahl an Turbinenscheiben, die durch Turbinenstapelbolzen mit der Turbinenflanschswelle verbunden sind, wobei ein oder mehrere Turbinenabstandhalter dazwischen angeordnet ist/sind;
in jede der Turbinenscheiben eingebettete Turbinenschaufeln;
ein durch die Turbinenstapelbolzen mit den Turbinenscheiben verbundenes Distanzstück;
35 eine Vielzahl an durch die Kompressorstapelbolzen mit dem Distanzstück verbundene Kompressorscheiben;
in jede der Kompressorscheiben eingebettete Kompressorschaufeln; und
eine einstückig mit der Erststufenscheibe der Kompressorscheiben ausgebildete Kompressorflanschswelle;
worin zumindest die Turbinenscheiben aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 bestehen.
- 40 13. Gasturbine nach Anspruch 12, worin das Verhältnis (l/D) zwischen dem Abstand (l) zwischen den jeweiligen Turbinenscheiben und ihrem Außendurchmesser (D) 0,15 bis 0,25 beträgt.
14. Gasturbine nach Anspruch 12 oder 13, worin die Endstufenscheibe der Kompressorscheiben starrer ist als die Scheibe der vorherigen Stufe.
- 45 15. Gasturbine nach einem der Ansprüche 12 bis 14, worin zumindest einer der Turbinenstapelbolzen, das Distanzstück, der Turbinenabstandhalter, die Kompressorschaufeln, zumindest die Kompressorscheiben von der Endstufe bis hin zu Mittelstufen, sowie die Kompressorstapelbolzen aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 bestehen.
- 50 16. Gasturbine nach einem der Ansprüche 12 bis 14, worin zumindest einer der Turbinenstapelbolzen, das Distanzstück, der Turbinenabstandhalter, zumindest die Kompressorscheiben von der Endstufe bis hin zu Mittelstufen, sowie die Kompressorstapelbolzen aus martensitischem Stahl bestehen, welcher Stahl ein Stahl nach einem der Ansprüche 1 bis 3 ist.
- 55 17. Gasturbine nach einem der Ansprüche 12 bis 16, worin die Turbinenflanschswelle aus Cr-Mo-V-Stahl besteht, umfassend:

- 0,2 bis 0,4 Gew.-% C,
0,5 bis 1,5 Gew.-% Mn,
0,1 bis 0,5 Gew.-% Si,
0,5 bis 1,5 Gew.-% Cr,
5 weniger als 0,5 Gew.-% Ni,
1,0 bis 2,0 Gew.-% Mo,
0,1 bis 0,3 Gew.-% V, sowie
Fe und unvermeidliche Verunreinigungen als Rest.
- 10 **18.** Gasturbine nach Anspruch 15, worin der Turbinenabstandhalter aus hitzebeständigem Stahl besteht, umfassend:
- 0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 1 Gew.-% Mn,
15 8 bis 13 Gew.-% Cr,
1,5 bis 3,0 Gew.-% Mo,
weniger als 3 Gew.-% Ni,
0,05 bis 0,3 Gew.-% V,
0,02 bis 0,2 Gew.-% Nb,
20 0,02 bis 0,1 Gew.-% N, sowie
Fe und unvermeidliche Verunreinigungen als Rest.
- 19.** Gasturbine nach Anspruch 15, worin die Turbinenstapelbolzen jeweils aus hitzebeständigem Stahl bestehen, umfassend:
- 25 0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 1 Gew.-% Mn,
8 bis 13 Gew.-% Cr,
30 1,5 bis 3,0 Gew.-% Mo,
weniger als 3 Gew.-% Ni,
0,05 bis 0,3 Gew.-% V,
0,02 bis 0,2 Gew.-% Nb,
0,02 bis 0,1 Gew.-% N, sowie
35 Fe und unvermeidliche Verunreinigungen als Rest.
- 20.** Gasturbine nach Anspruch 15, worin das Turbinenabstandsstück aus hitzebeständigem Stahl besteht, umfassend:
- 40 0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 1 Gew.-% Mn,
8 bis 13 Gew.-% Cr,
1,5 bis 3,0 Gew.-% Mo,
weniger als 3 Gew.-% Ni,
45 0,05 bis 0,3 Gew.-% V,
0,02 bis 0,2 Gew.-% Nb,
0,02 bis 0,1 Gew.-% N, sowie
Fe und unvermeidliche Verunreinigungen als Rest.
- 50 **21.** Gasturbine nach Anspruch 15, worin die Kompressorstapelbolzen jeweils aus hitzebeständigem Stahl bestehen, umfassend:
- 55 0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 1 Gew.-% Mn,
8 bis 13 Gew.-% Cr,
1,5 bis 3,0 Gew.-% Mo,
weniger als 3 Gew.-% Ni,

0,05 bis 0,3 Gew.-% V,
0,02 bis 0,2 Gew.-% Nb,
0,02 bis 0,1 Gew.-% N, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

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- 22.** Gasturbine nach Anspruch 15, worin die Kompressorschaukeln jeweils aus martensitischem Stahl bestehen, umfassend:

10

0,05 bis 0,2 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 1 Gew.-% Mn,
10 bis 13 Gew.-% Cr, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

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- 23.** Gasturbine nach einem der Ansprüche 12 bis 22, worin die Kompressorscheiben, die auf der stromaufwärtigen Seite eines Gasstroms von der ersten Stufe bis hin zu Mittelstufen angeordnet sind, jeweils aus Ni-Cr-Mo-V-Stahl bestehen, umfassend:

20

0,15 bis 0,30 Gew.-% C,
weniger als 0,5 Gew.-% Si,
weniger als 0,6 Gew.-% Mn,
1 bis 2 Gew.-% Cr,
2,0 bis 4,0 Gew.-% Ni,
0,5 bis 1,0 Gew.-% Mo,
0,05 bis 0,2 Gew.-% V, sowie
Fe und unvermeidliche Verunreinigungen als Rest,

25

und worin die Kompressorscheiben, die von der Mittelstufe hin zur stromabwärtigen Seite mit Ausnahme zumindest der Endstufe angeordnet sind, jeweils aus Cr-Mo-V-Stahl bestehen, umfassend:

30

0,2 bis 0,4 Gew.-% C,
0,1 bis 0,5 Gew.-% Si,
0,5 bis 1,5 Gew.-% Mn,
0,5 bis 1,5 Gew.-% Cr,
weniger als 0,5 Gew.-% Ni,
1,2 bis 2,0 Gew.-% Mo,
0,1 bis 0,3 Gew.-% V, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

35

- 24.** Gasturbine nach einem der Ansprüche 12 bis 23, worin die Kompressorflanschelle aus einem Cr-Mo-V-Stahl besteht, umfassend:

40

0,15 bis 0,3 Gew.-% C,
weniger als 0,6 Gew.-% Mn,
weniger als 0,5 Gew.-% Si,
2,0 bis 4,0 Gew.-% Ni,
1 bis 2 Gew.-% Cr,
0,5 bis 1 Gew.-% Mo,
0,05 bis 0,2 Gew.-% V, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

45

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- 25.** Gasturbine nach Anspruch 12 oder 13, worin der Stahl der Turbinenscheiben eine vollständig vergütete Martensit-Struktur besitzt.

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- 26.** Gasturbine nach einem der Ansprüche 12 bis 15, worin zumindest jene Kompressorscheibe, die als Endstufenscheibe auf einer Hochtemperaturseite eingesetzt wird, aus martensitischem Stahl nach einem der Ansprüche 1 bis 3 besteht.

27. Gasturbine nach einem der Ansprüche 18 bis 21, worin die Turbinenstapelbolzen, der Abstandhalter, die Turbinenscheiben, das Distanzstück, die Kompressorstapelbolzen und jene Kompressorscheibe, die als Endstufenscheibe auf einer Hochtemperaturseite eingesetzt wird, jeweils aus martensitischem Stahl mit einer Zeitstandfestigkeit bei 450°C und 10⁵ h von mehr als 50 kg/mm² und einer Charpy-Spitzkerbschlagzähigkeit bei 25°C von mehr als 5 kg.m/cm² nach Erhitzen auf 500°C über einen Zeitraum von 10³ Stunden bestehen, und eine vollständig vergütete Martensit-Struktur aufweisen.

28. Gasturbine nach einem der Ansprüche 12 bis 27, umfassend:

die Turbinenflanschswelle;
die Vielzahl an durch Turbinenstapelbolzen mit der Turbinenflanschswelle verbundenen Turbinenscheiben, wobei der oder die Abstandhalter dazwischen angeordnet ist/sind;
die in jede der Turbinenscheiben eingebettete Turbinenschaufeln;
eine Abdeckung in Ringform zur Herstellung eines Gleitkontakts zu den äußeren Umfangsenden der Turbinenschaufeln;
eine Vielzahl an Brennern mit jeweils einer Turbinendüse zum Lenken des Hochtemperatur-Gasstroms hin zu den Turbinenschaufeln, um deren Drehung zu bewirken, und einem zylindrischen Körper zum Erzeugen des Hochtemperaturgases;
das durch die Turbinenstapelbolzen mit den Turbinenscheiben verbundene Distanzstück;
die Vielzahl an durch die Kompressorstapelbolzen mit dem Distanzstück verbundenen Kompressorscheiben;
die in jede der Kompressorscheiben eingebetteten Kompressorscheufeln, und
die einstückig mit der Erststufenscheibe der Kompressorscheiben ausgebildete Kompressorflanschswelle;
worin die Abdeckung in jenem Abschnitt, welcher der Erststufen-Turbinenschaufel entspricht, aus einer Legierung auf Ni-Basis besteht, umfassend:

0,05 bis 0,2 Gew.-% C,
weniger als 2 Gew.-% Si,
weniger als 2 Gew.-% Mn,
17 bis 27 Gew.-% Cr,
weniger als 5 Gew.-% Co,
5 bis 15 Gew.-% Mo,
10 bis 30 Gew.-% Fe,
weniger als 5 Gew.-% W,
weniger als 0,02 Gew.-% B, sowie
Ni und unvermeidliche Verunreinigungen als Rest,

und die eine vollständig aus Austenit bestehende Struktur aufweist und in jenen Abschnitten, die den Turbinenschaufeln in den übrigen Stufen entsprechen, aus einer Gußlegierung auf Fe-Basis besteht, umfassend:

0,3 bis 0,6 Gew.-% C,
weniger als 2 Gew.-% Si,
weniger als 2 Gew.-% Mn,
20 bis 27 Gew.-% Cr,
20 bis 30 Gew.-% Ni,
0,1 bis 0,5 Gew.-% Nb,
0,1 bis 0,5 Gew.-% Ti, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

29. Gasturbine nach einem der Ansprüche 12 bis 28, umfassend:

die Turbinenflanschswelle;
die Vielzahl an durch Turbinenstapelbolzen mit der Turbinenflanschswelle verbundenen Turbinenscheiben, wobei der oder die Abstandhalter dazwischen angeordnet ist/sind;
die in jede der Turbinenscheiben eingebetteten Turbinenschaufeln;
die Vielzahl an Brennern mit jeweils der Turbinendüse zum Lenken des Hochtemperatur-Gasstroms hin zu den Turbinenschaufeln, um deren Drehung zu bewirken, mit einer Membran zum Fixieren der Turbinendüse und mit dem zylindrischen Körper zum Erzeugen des Hochtemperaturgases;
das durch die Turbinenstapelbolzen mit den Turbinenscheiben verbundene Distanzstück;

die Vielzahl an durch Kompressorstapelbolzen mit dem Distanzstück verbundenen Kompressorscheiben;
 die in jede der Kompressorscheiben eingebetteten Kompressorschaukeln; und
 die einstückig mit der Erststufenscheibe der Kompressorscheiben ausgebildete Kompressorflanschswelle;
 worin die Membran in ihrem Erststufen-Turbinenschaufelabschnitt zum Lenken des Hochtemperatur-Gas-
 stroms hin zu den Erststufen-Turbinenschaufeln aus einem Cr-Ni-Stahl besteht, umfassend:

weniger als 0,05 Gew.-% C,
 weniger als 1 Gew.-% Si,
 weniger als 2 Gew.-% Mn,
 16 bis 22 Gew.-% Cr,
 8 bis 15 Gew.-% Ni, sowie
 Fe und unvermeidliche Verunreinigungen als Rest.

30. Gasturbine nach einem der Ansprüche 12 bis 29, umfassend:

die Turbinenflanschswelle;
 die Vielzahl an durch Turbinenstapelbolzen mit der Turbinenflanschswelle verbundenen Turbinenscheiben, wo-
 bei der oder die Abstandhalter dazwischen angeordnet ist/sind;
 die in jede der Turbinenscheiben eingebetteten Turbinenschaufeln;
 die Vielzahl an Brennern mit jeweils der Turbinendüse zum Lenken des Hochtemperatur-Gasstroms hin zu
 den Turbinenschaufeln, um deren Drehung zu bewirken, und mit dem zylindrischen Körper zur Erzeugung
 des Hochtemperaturgases;
 das durch die Turbinenstapelbolzen mit den Turbinenscheiben verbundene Distanzstück;
 die Vielzahl an durch die Kompressorstapelbolzen mit dem Distanzstück verbundenen Kompressorscheiben;
 die in jede der Kompressorscheiben eingebetteten Kompressorschaukeln;
 eine Kompressordüse zum Lenken von Luft hin zu den Kompressorschaukeln;
 und die einstückig mit der Erststufenscheibe der Kompressorscheiben ausgebildete Kompressorflanschswelle;
 worin die Kompressordüse aus einem martensitischem Stahl besteht, umfassend:

0,05 bis 0,2 Gew.-% C,
 weniger als 0,5 Gew.-% Si,
 weniger als 1 Gew.-% Mn,
 10 bis 30 Gew.-% Cr,
 weniger als 0,5 Gew.-% Ni und
 weniger als 0,5 Gew.-% Mo, sowie
 Fe und unvermeidliche Verunreinigungen als Rest;

wobei die Kompressorscheiben, die in einem die erste Stufe umfassenden Niedertemperaturbereich angeord-
 net sind, jeweils aus einem Ni-Cr-Mo-V-Stahl bestehen, umfassend:

0,15 bis 0,3 Gew.-% C,
 weniger als 0,5 Gew.-% Si,
 weniger als 0,6 Gew.-% Mn,
 1 bis 2 Gew.-% Cr,
 2 bis 4 Gew.-% Ni,
 0,5 bis 1 Gew.-% Mo,
 0,05 bis 0,2 Gew.-% V, sowie
 Fe und unvermeidliche Verunreinigungen als Rest;

wobei die Kompressorscheiben, die in den übrigen Stufen der Hochtemperaturseite angeordnet sind, jeweils
 aus einem Cr-Mo-V-Stahl bestehen, umfassend:

0,2 bis 0,4 Gew.-% C,
 0,1 bis 0,5 Gew.-% Si,
 0,5 bis 1,5 Gew.-% Mn,
 0,5 bis 1,5 Gew.-% Cr,
 weniger als 0,5 Gew.-% Ni,
 1 bis 2 Gew.-% Mo,

0,1 bis 0,3 Gew.-% V, sowie
Fe und unvermeidliche Verunreinigungen als Rest.

31. Gasturbine nach einem der Ansprüche 12 bis 30, umfassend:

5 die Turbinenflanschswelle;
die Vielzahl an durch die Turbinenstapelbolzen mit der Turbinenflanschswelle verbundenen Turbinenscheiben,
wobei der oder die Abstandhalter dazwischen angeordnet ist/sind;
die in jede der Turbinenscheiben eingebetteten Turbinenschaufeln;
10 die Vielzahl an Brennern jeweils mit der Turbinendüse zum Lenken des Hochtemperatur-Gasstroms hin zu
den Turbinenschaufeln, um deren Drehung zu bewirken, und mit dem zylindrischen Körper zum Erzeugen
des Hochtemperaturgases;
das durch Turbinenstapelbolzen mit den Turbinenschaufeln verbundene Distanzstück;
die Vielzahl an durch die Kompressorstapelbolzen mit dem Distanzstück verbundenen Kompressorscheiben;
15 die in jede der Kompressorscheiben eingebetteten Kompressorschaufeln; und
die einstückig mit der Erststufenscheibe der Kompressorscheiben ausgebildete Kompressorflanschswelle;
worin die Turbinenschaufeln jeweils aus einer Gußlegierung auf Ni-Basis bestehen, umfassend:

20 0,07 bis 0,25 Gew.-% C,
weniger als 1 Gew.-% Si,
weniger als 1 Gew.-% Mn,
12 bis 20 Gew.-% Cr,
5 bis 15 Gew.-% Co,
1 bis 5 Gew.-% Mo,
25 1 bis 5 Gew.-% W,
0,005 bis 0,03 Gew.-% B,
2 bis 7 Gew.-% Ti,
3 bis 7 Gew.-% Al,
zumindest ein Element, ausgewählt aus:
30 weniger als 1,5 Gew.-% Nb,
0,01 bis 0,5 Gew.-% Zr,
0,01 bis 0,5 Gew.-% Hf und
0,01 bis 0,5 Gew.-% V, sowie
Ni und unvermeidliche Verunreinigungen als Rest,
35

und γ' - und γ'' -Phasen aufweisen;
wobei die Turbinendüse entweder aus einer Gußlegierung auf Co-Basis besteht, umfassend:

40 0,20 bis 0,6 Gew.-% C,
weniger als 2 Gew.-% Si,
weniger als 2 Gew.-% Mn,
25 bis 35 Gew.-% Cr,
5 bis 15 Gew.-% Ni,
3 bis 10 Gew.-% W,
45 0,003 bis 0,03 Gew.-% B sowie
Co und unvermeidliche Verunreinigungen als Rest,

und eine Austenit-Matrix aufweist, die eutektisches Carbid und sekundäres Carbid enthält,
oder aus einer Gußlegierung auf Co-Basis, die zusätzlich zur obigen Zusammensetzung zumindest ein Ele-
50 ment umfaßt, ausgewählt aus

0,1 bis 0,3 Gew.-% Ti,
0,1 bis 0,5 Gew.-% Nb und
0,1 bis 0,3 Gew.-% Zr, und
55

eine Austenit-Matrix aufweist, die eutektisches Carbid und sekundäres Carbid enthält; und
worin die Brenner jeweils aus einer Legierung auf Ni-Basis bestehen, umfassend:

0,05 bis 0,2 Gew.-% C,
weniger als 2 Gew.-% Si,
weniger als 2 Gew.-% Mn,
20 bis 25 Gew.-% Cr,
0,5 bis 5 Gew.-% Co,
5 bis 15 Gew.-% Mo,
10 bis 30 Gew.-% Fe,
weniger als 5 Gew.-% W,
weniger als 0,02 Gew.-% B, sowie
Ni und unvermeidliche Verunreinigungen als Rest,

mit einer vollständig aus Austenit bestehenden Struktur.

Revendications

1. Acier résistant à la chaleur consistant de :

0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
0,1 à 0,4 % en poids de Mn,
8 à 13 % en poids de Cr,
1,5 à 3 % en poids de Mo,
2 à 3 % en poids de Ni,
0,05 à 0,3 % en poids de V,
0,02 à 0,2 % en poids au total de l'un ou les deux de
Nb et Ta,
0,02 à 0,1 % en poids de N, et optionnellement un ou plus de :
moins de 0,5 % en poids de Co
moins de 1 % en poids de W
moins de 0,01 % en poids de B
moins de 0,3 % en poids de Al
moins de 0,5 % en poids de Ti
moins de 0,1 % en poids de Zr
moins de 0,1 % en poids de Hf
moins de 0,1 % en poids de Ca
moins de 0,01 % en poids de Mg
moins de 0,01 % en poids de Y
moins de 0,01 % en poids d'éléments de terres rares
moins de 0,5 % en poids de Cu

un rapport (Mn/Ni) de Mn à Ni inférieur à 0,11, et le reste de fer et des impuretés inévitables.

2. Acier résistant à la chaleur selon la revendication 1 contenant

0,07 à 0,15 % en poids de C,
0,01 à 0,1 % en poids de Si,
0,15 à 0,4 % en poids de Mn,
11 à 12,5 % en poids de Cr,
2,2 à 3,0 % en poids de Ni,
1,8 à 2,5 % en poids de Mo,
0,04 à 0,08 % au total de l'un ou des deux de Nb et Ta,
0,15 à 0,25 % en poids de V,
0,04 à 0,08 % en poids de N,

le rapport (Mn/Ni) de Mn à Ni étant de 0,04 à 0,10 et ayant entièrement une structure martensitique trempée.

3. Acier résistant à la chaleur selon la revendication 1 ou la revendication 2 ayant une résistance à la rupture au

fluage de 10^5 -h à 450°C supérieure à 50 kg/mm² et une valeur d'impact Charpy à encoche en V à 25°C supérieure à 5 kg -m/cm² après avoir été chauffé à 500°C pendant 10^3 heures.

4. Disque de turbine à gaz ayant dans sa portion circonférentielle extérieure une pluralité de rainures évidées dans lesquelles des lames sont noyées, ayant une épaisseur maximale à son centre et ayant dans sa région circonférentielle externe une pluralité de trous traversants dans lesquels des boulons sont insérés pour connecter une pluralité desdits disques, ledit disque est fait d'un acier martensitique selon l'une quelconque des revendications 1 à 3.
5. Disque de turbine à gaz selon la revendication 4, dans lequel le rapport (t/D) de l'épaisseur (t) dudit disque au diamètre (D) de celui-ci est dans l'intervalle de 0,15 à 0,30.
6. Espaceur de turbine à gaz pour une turbine à gaz pour utilisation lorsqu'une pluralité de disques de turbine sont connectés ensemble à leurs régions circonférentielles externes par des boulons avec ledit ou lesdits espaceurs interposé(s) entre eux, ledit espaceur étant fait d'un acier martensitique selon l'une quelconque des revendications 1 à 3.
7. Pièce de distance cylindrique pour une turbine à gaz utilisée lorsqu'une pluralité de disques de turbine et une pluralité de disques de compresseur sont connectées ensemble par ladite pièce de distance par des boulons, ladite pièce de distance étant faite d'un acier martensitique selon l'une quelconque des revendications 1 à 3.
8. Pièce de distance cylindrique selon la revendication 7 dans laquelle le rapport (t/D) de l'épaisseur minimale (t) de ladite pièce de distance au diamètre interne maximum (D) de celle-ci est dans l'intervalle de 0,05 à 0,10.
9. Disque de compresseur ayant dans sa région circonférentielle externe une pluralité de rainures évidées dans lesquelles des lames sont noyées, ayant dans sa région circonférentielle externe une pluralité de trous traversants dans lesquels des boulons sont insérés pour connecter une pluralité desdits disques et ayant en son centre et ses portions munies desdits trous traversants une épaisseur maximale, ledit disque de compresseur étant fait d'un acier selon l'une quelconque des revendications 1 à 3.
10. Disque de compresseur selon la revendication 9 dans lequel le rapport (t/D) et l'épaisseur (t) dudit disque de compresseur au diamètre (D) de celui-ci est dans l'intervalle de 0,05 à 0,10.
11. Boulons d'empilement pour turbine à gaz qui sont respectivement utilisés pour connecter une pluralité de disques de turbine et de disques de compresseur, fait d'un acier martensitique selon l'une quelconque des revendications 1 à 3.
12. Turbine à gaz comprenant :
 - un faux arbre de turbine ;
 - une pluralité de disques de turbine connectés auxdits faux arbres de turbine par des boulons d'empilement de turbine avec un espaceur de turbine ou des espaceurs de turbine interposé(s) entre eux ;
 - des lames de turbine noyées dans chacun desdits disques de turbine ;
 - une pièce de distance connectée auxdits disques de turbine par lesdits boulons d'empilement de turbine ;
 - une pluralité de disques de compresseur connectés à ladite pièce de distance par des boulons d'empilement de compresseur ;
 - des lames de compresseur noyées dans chacun des disques de compresseur ; et
 - un faux arbre de compresseur intégral avec le premier disque d'étage desdits disques de compresseur ;
 - où au moins lesdits disques de turbine sont faits d'un acier martensitique selon l'une quelconque des revendications 1 à 3.
13. Turbine à gaz selon la revendication 12, où le rapport (1/D) du vide (1) entre lesdits disques de turbine au diamètre (D) externe de ceux-ci est de 0,15 à 0,25.
14. Turbine à gaz selon la revendication 12 ou la revendication 13, où ledit disque d'étage final desdits disques de compresseur est plus rigide que le disque de l'étage précédent.
15. Turbine à gaz selon l'une quelconque des revendications 12 à 14 où au moins un desdits boulons d'empilement

de turbine, de ladite pièce de distance, dudit espaceur de turbine, desdites lames de compresseur, d'au moins lesdits disques de compresseur à partir des étages central à final et desdits boulons d'empilement de compresseur est ou sont fait(s) d'un acier martensitique selon l'une quelconque des revendications 1 à 3.

5 **16.** Turbine à gaz selon l'une quelconque des revendications 12 à 14 où au moins un desdits boulons d'empilement de turbine, ladite pièce de distance, ledit espaceur de turbine, au moins lesdits disques de compresseur à partir des étages final à central et lesdits boulons d'empilement de compresseur est ou sont fait(s) d'un acier martensitique, lequel acier est un acier selon l'une quelconque des revendications 1 à 3.

10 **17.** Turbine à gaz selon l'une quelconque des revendications 12 à 16 où ledit faux arbre de turbine est fait d'un acier Cr-Mo-V consistant de

0,2 à 0,4 % en poids de C,
0,5 à 1,5 % en poids de Mn,
15 0,1 à 0,5 % en poids de Si,
0,5 à 1,5 % en poids de Cr,
moins de 0,5 % en poids de Ni,
1,0 à 2,0 % en poids de Mo,
0,1 à 0,3 % en poids de V et
20 le reste étant du fer et les impuretés inévitables.

18. Turbine à gaz selon la revendication 15 où ledit espaceur de turbine est fait d'un acier résistant à la chaleur et consistant de

25 0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
moins de 1 % en poids de Mn,
8 à 13 % en poids de Cr,
1,5 à 3,0 % en poids de Mo,
30 moins de 3 % en poids de Ni,
0,05 à 0,3 % en poids de V,
0,02 à 0,2 % en poids de Nb,
0,02 à 0,1 % en poids de N et
35 le reste étant du fer et les impuretés inévitables.

19. Turbine à gaz selon la revendication 15 où lesdits boulons d'empilement de turbine sont respectivement faits d'un acier résistant à la chaleur consistant de

40 0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
moins de 1 % en poids de Mn,
8 à 13 % en poids de Cr,
1,5 à 3,0 % en poids de Mo,
45 moins de 3 % en poids de Ni,
0,05 à 0,3 % en poids de V,
0,02 à 0,2 % en poids de Nb,
0,02 à 0,1 % en poids de N et
le reste étant du fer et les impuretés inévitables.

50 **20.** Turbine à gaz selon la revendication 15 où ladite pièce de distance de turbine est faite d'un acier résistant à la chaleur consistant de

0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
55 moins de 1 % en poids de Mn,
8 à 13 % en poids de Cr,
1,5 à 3,0 % en poids de Mo,
moins de 3 % en poids de Ni,

0,05 à 0,3 % en poids de V,
0,02 à 0,2 % en poids de Nb,
0,02 à 0,1 % en poids de N et
le reste étant du fer et les impuretés inévitables.

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- 21.** Turbine à gaz selon la revendication 15 où lesdits boulons d'empilement de compresseur sont respectivement faits d'un acier résistant à la chaleur consistant de

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0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
moins de 1 % en poids de Mn,
8 à 13 % en poids de Cr,
1,5 à 3,0 % en poids de Mo,
moins de 3 % en poids de Ni,
0,05 à 0,3 % en poids de V,
0,02 à 0,2 % en poids de Nb,
0,02 à 0,1 % en poids de N et
le reste étant du fer et les impuretés inévitables.

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- 22.** Turbine à gaz selon la revendication 15 où lesdites lames de compresseur sont faites respectivement d'un acier martensitique consistant de

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0,05 à 0,2 % en poids de C,
moins de 0,5 % en poids de Si,
moins de 1 % en poids de Mn,
10 à 13 % en poids de Cr, et
le reste étant du fer et les impuretés inévitables.

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- 23.** Turbine à gaz selon l'une quelconque des revendications 12 à 22, où lesdits disques de compresseur disposés à partir du premier étage à l'étage central sur le côté en amont d'un écoulement de gaz sont respectivement faits d'un acier Ni-Cr-Mo-V consistant de

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0,15 à 0,30 % en poids de C,
moins de 0,5 % en poids de Si,
moins de 0,6 % en poids de Mn,
1 à 2 % en poids de Cr,
2,0 à 4,0 % en poids de Ni,
0,5 à 1,0 % en poids de Mo,
0,05 à 0,2 % en poids de V, et

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le reste étant du fer et les impuretés inévitables
et où lesdits disques de compresseur disposés à partir dudit étage central vers le côté en aval sauf pour au moins l'étage final sont respectivement faits d'un acier Cr-Mo-V consistant de

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0,2 à 0,4 % en poids de C,
0,1 à 0,5 % en poids de Si,
0,5 à 1,5 % en poids de Mn,
0,5 à 1,5 % en poids de Cr,
moins de 0,5 % en poids de Ni,
1,2 à 2,0 % en poids de Mo,
0,1 à 0,3 % en poids de V et

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le reste étant du fer et les impuretés inévitables.

- 24.** Turbine à gaz selon l'une quelconque des revendications 12 à 23, où ledit faux arbre de compresseur est fait d'un acier Cr-Mo-V consistant de

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0,15 à 0,3 % en poids de C,
moins de 0,6 % en poids de Mn,
moins de 0,5 % en poids de Si,
2,0 à 4,0 % en poids de Ni,

1 à 2 % en poids de Cr,
0,5 à 1 % en poids de Mo,
0,05 à 0,2 % en poids de V et
le reste étant du fer et les impuretés inévitables.

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25. Turbine à gaz selon la revendication 12 ou la revendication 13 où ledit acier desdits disques de turbine a une structure complètement martensitique trempée.

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26. Turbine à gaz selon l'une quelconque des revendications 12 à 15, où au moins un dit disque de compresseur utilisé en tant que disque d'étage final sur un côté à température élevée est fait d'un acier martensitique selon l'une quelconque des revendications 1 à 3.

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27. Turbine à gaz selon l'une quelconque des revendications 18 à 21, où lesdits boulons d'empilement de turbine, ledit espaceur, lesdits disques de turbine, ladite pièce de distance, lesdits boulons d'empilement de compresseur et ledit disque de compresseur utilisés en tant qu disque d'étage final sur un côté à température élevée sont respectivement faits d'un acier martensitique ayant une résistance à la rupture au fluage de 10^5 -h, à 450°C supérieure à 50 kg/mm² et une valeur d'impact Charpy à encoche en V à 25°C supérieure à 5 kg - m/cm² après avoir été chauffé à 500°C pendant 10³ heures, et ayant une structure complètement martensitique trempée.

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28. Turbine à gaz selon l'une quelconque des revendications 12 à 27, comprenant :

un dit faux arbre de turbine ;
une dite pluralité des disques de turbine connectés audit faux arbre de turbine par des boulons d'empilement de turbine avec ledit espaceur desdits espaceurs interposé entre eux ;
lesdites lames de turbine noyées dans chacun desdits disques de turbine ;
une enveloppe de protection formée en une forme annulaire pour produire un contact en glissement avec les extrémités circonférentielles externes desdites lames de turbine ;
une pluralité de brûleurs à deux étages de gazéification ayant chacun une buse de turbine pour diriger l'écoulement du gaz à haute température vers lesdites lames de turbine pour provoquer leur rotation et un corps cylindrique pour générer ledit gaz à haute température ;
ladite pièce de distance connectée auxdits disques de turbine par lesdits boulons d'empilement de turbine ;
ladite pluralité des disques de compresseur connectée à ladite pièce de distance par lesdits boulons d'empilement de compresseur ;
lesdites lames de compresseur noyées dans chacun desdits disques de compresseur ; et
ledit faux arbre de compresseur intégral avec le disque du premier étage desdits disques de compresseur ;
où ladite enveloppe de protection est sur sa portion correspondant à ladite lame de turbine du premier étage, faite d'un alliage à base de Ni consistant de

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0,05 à 0,2 % en poids de C,
moins de 2 % en poids de Si,
moins de 2 % en poids de Mn,
17 à 27 % en poids de Cr,
moins de 5 % en poids de Co,

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5 à 15 % en poids de Mo,
10 à 30 % en poids de Fe,
moins de 5 % en poids de W,
moins de 0,02 % en poids de B et

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le reste étant du Ni et les impuretés inévitables et ayant une structure complètement austénitique, et, sur ses portions correspondant auxdites lames de turbine disposées sur les étages restants, faite d'un alliage coulé à base de Fe consistant de

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0,03 à 0,6 % en poids de C,
moins de 2 % en poids de Si,
moins de 2 % en poids de Mn,
20 à 27 % en poids de Cr,
20 à 30 % en poids de Ni,
0,1 à 0,5 % en poids de Nb,
0,1 à 0,5 % en poids de Ti, et
le reste étant du fer et les impuretés inévitables.

29. Turbine à gaz selon l'une quelconque des revendications 12 à 28, comprenant :

ledit faux arbre de turbine ;
 ladite pluralité de disques de turbine connectée auxdits faux arbres de turbine par lesdits boulons d'empilement
 de turbine avec ledit espaceur ou lesdits espaceurs interposé(s) entre eux ;
 lesdites lames de turbine noyées dans chacun desdits disques de turbine ;
 ladite pluralité de brûleurs à deux étages de gazéification ayant chacun ladite buse de turbine pour diriger
 l'écoulement du gaz à haute température vers lesdites lames de turbine pour provoquer leur rotation, ayant
 un diaphragme pour fixer ladite buse de turbine et ayant ledit corps cylindrique pour générer ledit gaz à haute
 température ;
 ladite pièce de distance connectée auxdits disques de turbine par lesdits boulons d'empilement de turbine ;
 ladite pluralité de disques de compresseur connectée à ladite pièce de distance par des boulons d'empilement
 de compresseur ;
 lesdites lames de compresseur noyées dans chacun desdits disques de compresseur ; et
 ledit faux arbre de compresseur intégral avec le disque du premier étage desdits disques de compresseur ;
 où ledit diaphragme est, sur sa portion de lame de turbine du premier étage pour diriger l'écoulement du gaz
 à haute température vers lesdites lames de turbine de premier étage, fait d'un acier Cr-Ni consistant de

moins de 0,05 % en poids de C,
 moins de 1 % en poids de Si,
 moins de 2 % en poids de Mn
 16 à 22 % en poids de Cr,
 8 à 15 % en poids de Ni et
 le restant étant du fer et les impuretés inévitables.

30. Turbine à gaz selon l'une quelconque des revendications 12 à 29 comprenant :

ledit faux arbre de turbine ;
 ladite pluralité de disques de turbine connectée auxdits faux arbres de turbine par lesdits boulons d'empilement
 de turbine avec ledit ou lesdits espaceurs interposé(s) entre eux ;
 lesdites lames de turbine noyées dans chacun desdits disques de turbine ;
 ladite pluralité de brûleurs à deux étages de gazéification ayant chacun une dite buse de turbine pour diriger
 l'écoulement du gaz à haute température vers lesdites lames de turbine pour provoquer leur rotation et ledit
 corps cylindrique pour générer ledit gaz à haute température ;
 ladite pièce de distance connectée auxdits disques de turbine par lesdits boulons d'empilement de turbine ;
 ladite pluralité de disques de compresseur connectée à ladite pièce de distance par lesdits boulons d'empilement
 de compresseur ;
 lesdites lames de compresseur noyées dans chacun desdits disques de compresseur ;
 une buse de compresseur pour diriger l'air vers lesdites lames de compresseur ; et
 ledit faux arbre de compresseur intégral avec le disque du premier étage desdits disques de compresseur ;
 où ladite buse de compresseur est faite d'un acier martensitique consistant de

0,05 à 0,2 % en poids de C,
 moins de 0,5 % en poids de Si,
 moins de 1 % en poids de Mn,
 10 à 30 % en poids de Cr,
 moins de 0,5 % en poids de Ni et
 moins de 0,5 % en poids de Mo, et
 le reste étant du fer et les impuretés inévitables ;

lesdits disques de compresseur qui sont disposés dans un intervalle de basse température incluant ledit premier étage sont respectivement faits d'un alliage Ni-Cr-Mo-V consistant de

0,05 à 0,3 % en poids de C,
 moins de 0,5 % en poids de Si,
 moins de 0,6 % en poids de Mn,
 1 à 2 % en poids de Cr,
 2 à 4 % en poids de Ni,

0,5 à 1 % en poids de Mo,
0,5 à 0,2 % en poids de V et
le reste étant du fer et les impuretés inévitables ; et

5 lesdits disques de compresseur qui sont disposés sur les étages restants du côté haute température sont respectivement faits d'un acier Cr-Mo-V consistant de

0,2 à 0,4 % en poids de C,
0,1 à 0,5 % en poids de Si,
10 0,5 à 1,5 % en poids de Mn,
0,5 à 1,5 % en poids de Cr,
moins de 0,5 % en poids de Ni,
1 à 2 % en poids de Mo,
0,1 à 0,3 % en poids de V et
15 le reste étant du Fer et les impuretés inévitables.

31. Turbine à gaz selon l'une quelconque des revendications 12 à 30, comprenant :

ledit faux arbre de turbine ;
20 ladite pluralité de disques de turbine connectée auxdits faux de turbine par lesdits boulons d'empilement de turbine avec ledit ou lesdits espaceurs interposés entre eux ;
lesdites lames de turbine noyées dans chacun desdits disques de turbine ;
ladite pluralité de brûleurs à deux étages de gazéification ayant chacun ladite buse de turbine pour diriger
l'écoulement du gaz à haute température vers lesdites lames de turbine pour provoquer leur rotation et ledit
25 corps cylindrique pour générer ledit gaz à haute température ;
ladite pièce de distance connectée auxdits disques de turbine par lesdits boulons d'empilement de turbine ;
ladite pluralité de disques de compresseur connectée à ladite pièce de distance par lesdits boulons d'empilement de compresseur ;
lesdites lames de compresseur noyées dans chacun desdits disques de compresseur ; et
30 ledit faux arbre de compresseur intégral avec le disque du premier étage des disques de compresseur ;
où lesdites lames de turbine sont respectivement faites d'un alliage coulé à base de Ni consistant de

0,07 à 0,25 % en poids de C,
moins de 1 % en poids de Si,
35 moins de 1 % en poids de Mn,
12 à 20 % en poids de Cr,
5 à 15 % en poids de Co,
1 à 5 % en poids de Mo,
1 à 5 % en poids de W,
40 0,005 à 0,03 % en poids de B,
2 à 7 % en poids de Ti,
3 à 7 % en poids de Al,
au moins un élément choisi parmi

45 moins de 1,5 % en poids de Nb,
0,01 à 0,5 % en poids de Zr,
0,01 à 0,5 % en poids de Hf et
0,01 à 0,5 % en poids de V, et
le reste étant du nickel et les impuretés inévitables,
50 et ayant des phases γ' et γ'' ;

ladite buse de turbine est faite de soit un alliage coulé à base de Co consistant de

0,20 à 0,6 % en poids de C,
55 moins de 2 % en poids de Si,
moins de 2 % en poids de Mn,
25 à 35 % en poids de Cr,
5 à 15 % en poids de Ni,

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3 à 10 % en poids de W,
0,003 à 0,03 % en poids de B et
le reste étant du Co et les impuretés inévitables et

5 ayant une matrice austénitique contenant à l'intérieur un carbure eutectique et un carbure secondaire,
soit dudit alliage coulé à base de Co contenant de plus, en addition à la composition, ci-dessus au moins un
élément choisi parmi

10 0,1 à 0,3 % en poids de Ti,
0,1 à 0,5 % en poids de Nb et
0,1 à 0,3 % en poids de Zr, et
ayant une matrice austénitique contenant à l'intérieur un carbure eutectique et un carbure secondaire ; et

15 lesdits brûleurs à deux étages de gazéification sont respectivement faits d'un alliage à base de Ni consistant de

0,05 à 0,2 % en poids de C,
moins de 2 % en poids de Si,
moins de 2 % en poids de Mn,
20 à 25 % en poids de Cr,
20 0,5 à 5 % en poids de Co,
5 à 15 % en poids de Mo,
10 à 30 % en poids de Fe,
moins de 5 % en poids de W,
moins de 0,02 % en poids de B et
25 le reste étant du Ni et les impuretés inévitables, et

ayant une structure complètement austénitique.

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FIG. 1

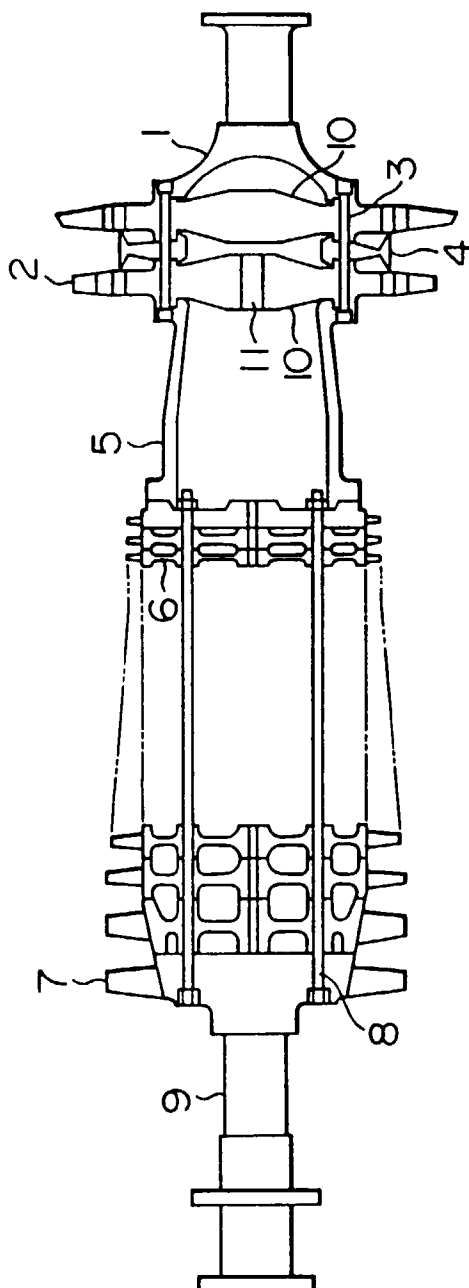


FIG. 2

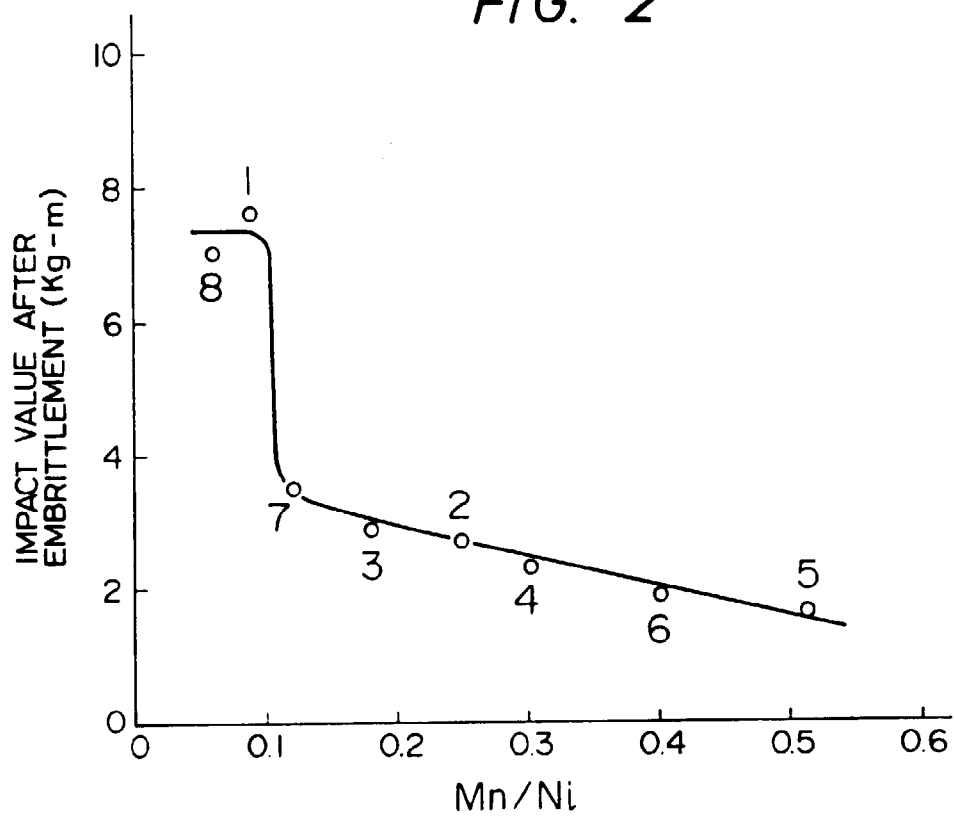


FIG. 3

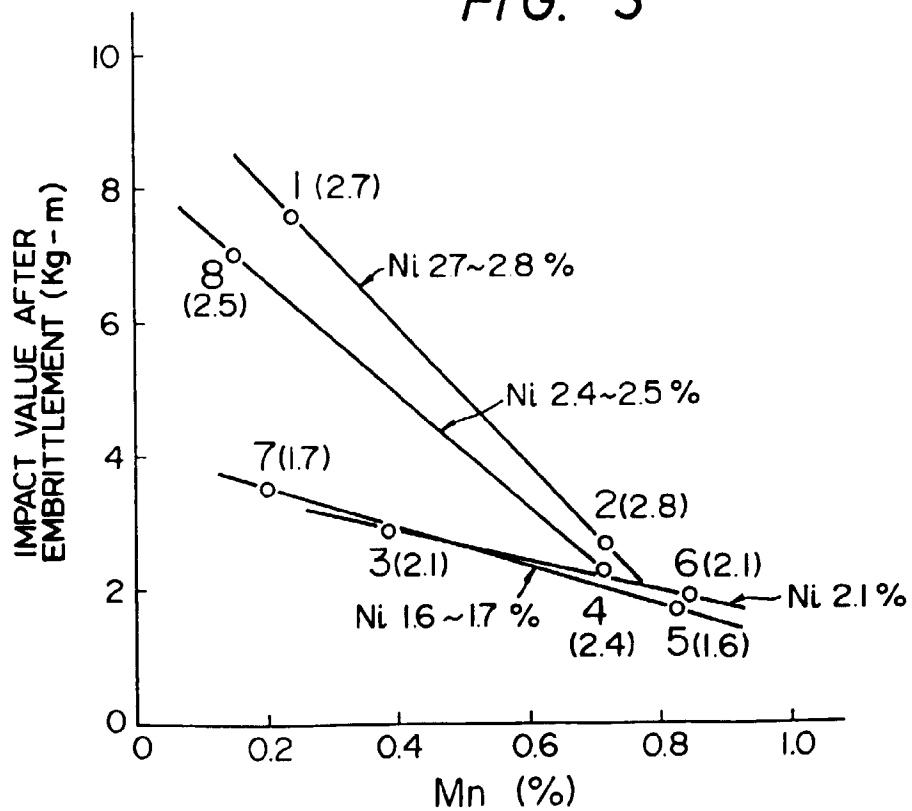


FIG. 4

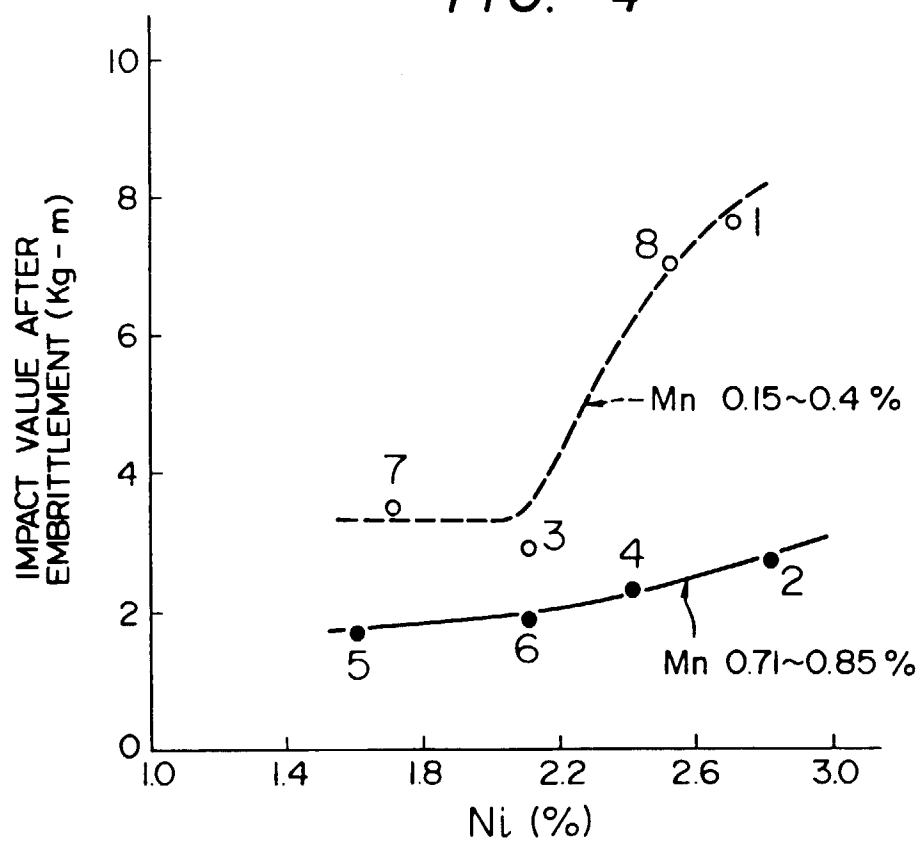


FIG. 6

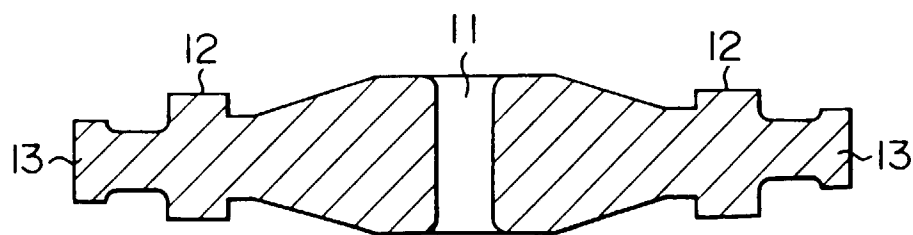


FIG. 5

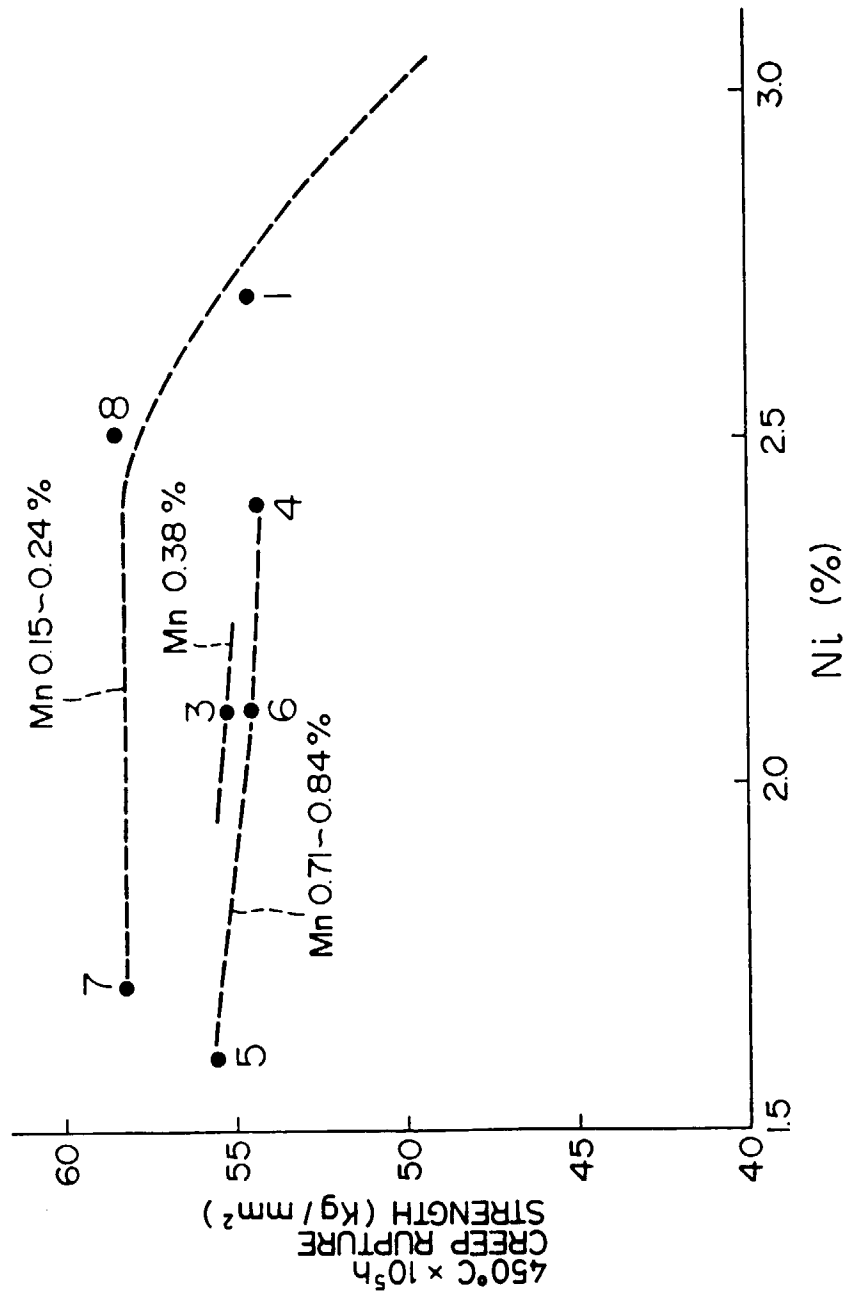


FIG. 7

