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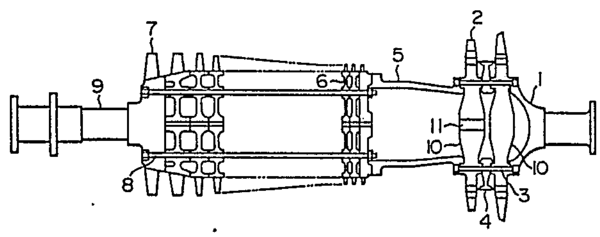
(54) **HEAT-RESISTANT STEEL AND GAS TURBINE MADE OF THE SAME.**

(57) Heat-resistant steel consisting, in weight percent, of 0.05 to 0.2% of C, up to 0.5% of Si, up to 0.6% of Mn, 8 to 13% of Cr, 1.5 to 3% of Mo, 2 to 3% of Ni, 0.05 to 0.3% of V, at least one of Nb and Ta with the sum being from 0.02 to 0.2%, 0.02 to 0.1% of N, with the ratio Mn/Ni being up to 0.11, and the balance consisting substantially of Fe. The heat-resistant steel of the present invention is used at least for a turbine disc of a gas turbine consisting of a turbine shaft, a plurality of turbine discs connected to the shaft with spacers between them by turbine stacking bolts, turbine buckets implanted in the discs, a distant piece connected to the disc by the bolts, a plurality of compressor discs connected to the distant piece by compressor stacking bolts, compressor blades implanted in the compressor discs and a compressor stub shaft shaped integrally with the initial stage of the compressor discs. Furthermore, the heat-resistant steel of the invention can be used for the stacking bolt, the spacer, the distant piece and the compressor blade. The heat-resistant steel of the present invention has the characteristics such as creep rupture strength of at least 50 kg/mm² at 450 °C for 10^5 C hours and a 25° V-notch Charpy impact value of at least 5 kg-m/cm² after heat treatment at 500 °C for 10^3 hours.



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DESCRIPTION

TITLE MODIFIED
see front page

Title of the Invention:

HEAT-RESISTANT STEEL AND GAS TURBINE MADE THEREOF

[Technical Field]

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

[Background Art]

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.

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.

[Disclosure of Invention]

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 characterized in that said heat-resistant steel comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 substantially Fe.

The present invention also relates to a heat-resistant steel characterized by comprising 0.07 to 0.15% by weight of C, 0.01 to 0.1% by weight or less of Si, 0.1 to 0.4% by weight or less 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 substantially Fe and having a wholly tempered martensite structure.

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

In the steel of the present invention, it is necessary 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.

$$\text{Cr equivalent} = -40\text{C} - 2\text{Mn} - 4\text{Ni} - 30\text{N} + 6\text{Si} + \text{Cr} + 4\text{Mo} + 11\text{V} + 5\text{Nb} + 2.5\text{Ta}$$

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 while 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 having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 kg-m/cm^2 at 25°C after heating at 500°C for 10^3 hr, or that said disc comprises a heat-resistant steel having the above-described composition.

A plurality of turbine discs are 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/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 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 10^5-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 0.6% or less. In particular, since Mn is effective as a desulfurizer, the Mn content is preferably 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 0.5% or less. As with Mo, W contributes to an increase in the strength and may be contained in an amount of 1% or less. The high-temperature strength may be improved by addition of 0.01% of B, 0.3% or less of Aℓ, 0.5% or less of Ti, 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, 0.01% or less of rare earth elements, and 0.5% or less of Cu.

In the heat treatment for the material of the present invention, the material is 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 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, 0.5% by weight or less of Si, 1% by weight or less of Mn, 8 to 13% by weight of Cr, 3% by weight or less 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 substantially Fe. 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, 0.5% by weight or less 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 substantially Fe, 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/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ 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/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 20°C after heating at 500°C for 10^3 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 substantially Fe and having a tensile strength of at least 80 kg/mm^2 at room temperature and a V-notch Charpy impact value of at least 20 $kg\text{-}m/cm^2$ 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 substantially Fe and having a tensile strength of at least 80 kg/mm^2 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 substantially Ni, 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 substantially Fe. 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 substantially Fe, 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 substantially Ni 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 substantially Co 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 substantially Ni. 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 suppling 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 10^5 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 comparative 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 10^5 hr (> 50 kg/mm^2) and V-notch Charpy impact value at 25°C after embrittlement treatment [at least 4 kg-m (5 $kg\text{-}m/cm^2$)] 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/mm^2 at 450°C for 10^5 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/cm^2). Further, when the ratio is 0.10 or less, the impact value is as high as 6 kg-m (7.5 kg-m/cm^2). 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/cm^2) or more, and when the Ni content is 2.5% or more, the impact value is 7 kg-m/cm^2 or more.

Fig. 5 is a diagram showing the relationship between the creep rupture strength at 450°C for 10^5 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/mm^2, 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/cm^2) after embrittlement under the same conditions as those described above and a creep rupture strength of 55.2 kg/mm^2 at 450°C for 10^5 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 electroslag 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 10^5 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/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of 7 $kg\text{-}m/cm^2$ 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/mm^2 or more and a V-notch Charpy impact value of 7 $kg\text{-}m/cm^2$ 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 ≧ 81 kg/mm^2; and a V-notch Charpy impact value at 20°C ≧ 5 $kg\text{-}m/cm^2$).

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} ($kg\text{-}m/cm^2$)	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 down-stream 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.

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	-	-
Shroud segment (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 disameter (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.

WHAT IS CLAIMED IS:

1. A heat-resistant steel characterized by comprising 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 substantially Fe.

2. A heat-resistant steel characterized by comprising 0.07 to 0.15% by weight of C, 0.01 to 0.1% by weight of Si, 0.1 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 substantially Fe, and having a wholly tempered martensite structure.

3. A heat-resistant steel characterized by comprising 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 substantially Fe and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 kg-m/cm^2 at 25°C after heating at 500°C for 10^3 hr.

4. A heat-resistant steel characterized by comprising 0.05 to 0.2% by weight of C, 0.5% by weight

or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01% by weight or less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earth elements with the balance being substantially Fe.

5. A gas turbine 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 having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 hr and that a ratio (t/D) of the thickness (t) of the central section of said disc to the outer diameter (D) thereof is 0.15 to 0.30.

6. A gas turbine 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 comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 substantially Fe and has a wholly tempered martensite structure.

7. A gas turbine 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 comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01% by weight or less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earth elements with the balance being substantially Fe and has a wholly tempered martensite structure.

8. A turbine spacer for a gas turbine having an annular shape for connecting a plurality of turbine discs on the outer circumferential side thereof with

bolts therethrough, characterized in that said spacer is made of a martensitic steel having a martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 kg-m/cm^2 at 25°C after heating at 500°C for 10^3 hr.

9. A distance piece for a gas turbine having a cylindrical shape for connecting a turbine disc to a compressor disc therethrough with a bolt, characterized in that said distance piece is made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 kg-m/cm^2 at 25°C after heating at 500°C for 10^3 hr and a ratio (t/D) of the minimum thickness (t) of said cylindrical distance piece to the maximum outer diameter (D) thereof is 0.05 to 0.10.

10. A distance piece for a gas turbine having a cylindrical shape for connecting a turbine disc to a compressor disc therethrough with a bolt, characterized in that said distance piece comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less of Mn, 8 to 13% by weight of Cr, 1.5 to 3.0% 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 with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less and has a wholly tempered martensite structure.

11. A distance piece for a gas turbine having a cylindrical shape for connecting a turbine disc to a compressor disc therethrough with a bolt, characterized in that said distance piece comprises

0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01% by weight or less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earth elements with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less, and has a wholly tempered martensite structure.

12. A compressor disc for a gas turbine having in its outer circumferential section a plurality of grooves into which blades are embedded, having on its outer circumferential side a plurality of through-holes into which bolts are inserted to connect a plurality of said discs and having a maximum thickness in its central section and a section provided with through-holes, characterized in that at least the final stage on the high gas temperature side of said disc is made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 hr and that a ratio (t/D) of the minimum thickness (t) of said disc to the outer diameter (D) thereof is 0.05 to 0.10.

13. A compressor disc for a gas turbine having

in its outer circumferential section a plurality of grooves into which blades are embedded, having on its outer circumferential side a plurality of through-holes into which bolts are inserted to connect a plurality of said discs and having a maximum thickness in its central section and a section provided with through-holes, characterized in that at least the final stage on the high gas temperature side of said disc comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less and has a wholly tempered martensite structure.

14. A compressor disc for a gas turbine having in its outer circumferential section a plurality of grooves into which blades are embedded, having on its outer circumferential side a plurality of through-holes into which bolts are inserted to connect a plurality of said discs and having a maximum thickness in its central section and a section provided with through-holes, characterized in that at least the final stage on the high gas temperature side of said disc comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01% by weight or

less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earth elements with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less, and has a wholly tempered martensite structure.

15. Stacking bolts for a gas turbine respectively for use in connection of a plurality of turbine discs and a plurality of compressor discs, characterized in that at least one of said stacking bolts is made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 hr.

16. 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 the first stage of said compressor disc, 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/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 hr and a ratio (ℓ/D) of the spacing (ℓ) between said

individual gas turbine discs to the diameter (D) thereof is 0.15 to 0.25.

17. A gas turbine according to claim 16, wherein said final stage compressor disc has a rigidity higher than that of the preceding discs.

18. A gas turbine according to claim 16, wherein at least one of said turbine stacking bolt, said distance piece, said turbine spacer, said compressor disc at least from the final stage to the central stage, and said compressor stacking bolt is made of a martensitic steel.

19. A gas turbine according to claim 18, wherein said martensitic steel comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1.5% by weight or less of Mn, 8 to 13% by weight of Cr, 1.5 to 3.5% by weight of Mo, 3% by weight or less 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 with the balance being Fe and unavoidable impurities.

20. A gas turbine according to claim 19, wherein said martensitic steel has a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$.

21. A gas turbine according to any of claims 16 to 20, wherein said turbine stub shaft comprises 0.2 to 0.4% by weight of C, 0.5 to 1.5% by weight of Mn, 0.1 to 0.5% by weight of Si, 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, 0.1 to 0.3% by weight of V with the balance being Fe and unavoidable impurities.

22. A gas turbine according to any of claims 16 to 20, wherein said turbine spacer comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, 8 to 13% by weight

of Cr, 1.5 to 3.5% by weight of Mo, 3% by weight or less of Ni, 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.

23. A gas turbine according to any of claims 16 to 20, wherein said turbine stacking bolt comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, 8 to 13% by weight of Cr, 1.5 to 3% by weight of Mo, 3% by weight or less of Ni, 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.

24. A gas turbine according to any of claims 16 to 20, wherein said turbine distance piece comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, 8 to 13% by weight of Cr, 1.5 to 3% by weight of Mo, 3% by weight or less of Ni, 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.

25. A gas turbine according to any of claims 16 to 20, wherein said compressor stacking bolt comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, 8 to 13% by weight of Cr, 1.5 to 3% by weight of Mo, 3% by weight or less of Ni, 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.

26. A gas turbine according to any of claims 16 to 20, wherein said compressor blade is made of a martensitic steel comprising 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, and 10 to 13% by weight of Cr with the balance being Fe and unavoidable impurities.

27. A gas turbine according to any of claims 16 to 20, wherein said compressor disc disposed from the first to central stages on the upstream side thereof comprises 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 substantially Fe and said compressor disc disposed from said central stage towards the downstream side thereof comprises 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 substantially Fe.

28. A gas turbine according to any of claims 16 to 20, wherein said compressor stub shaft comprises 0.15 to 0.3% by weight of C, 0.6% by weight or less of Mn, 0.5% by weight or less of Si, 2.0 to 4.0% by weight of Ni, 1 to 2% by weight of Cr, 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.

29. A gas turbine comprising a turbine stub shaft, a plurality of turbine discs connected to said shaft with turbine stacking bolts 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 the first stage of said compressor disc, characterized in that at least said turbine disc comprises 0.05 to 0.2% by weight of C, 0.5% by weight

or less of Si, 0.6% by weight or less 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 with the balance being substantially Fe, the Mn to Ni ratio being 0.01 or less, and has a wholly tempered martensite structure.

30. A gas turbine comprising a turbine stub shaft, a plurality of turbine discs connected to said shaft with turbine stacking bolts 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 compressor stacking bolts, a compressor blade embedded into said compressor disc and a compressor stub shaft formed integrally with the first stage of said compressor disc, characterized in that at least said turbine disc comprises 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01% by weight or less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earch elements with the balance being substantially Fe, the Mn to Ni ratio being 0.11

or less, and has a wholly tempered martensite structure.

31. A gas turbine according to any of claims 16 to 20, wherein said turbine disc, said distance piece, and at least the final stage on the high temperature side of said compressor disc are each made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 $kg\text{-}m/cm^2$ at 25°C after heating at 500°C for 10^3 hr.

32. A gas turbine according to any of claim 31, wherein said turbine disc, said distance piece, and at least the final stage on the high temperature side of said compressor disc each comprise 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less, and has a wholly tempered martensite structure.

33. A gas turbine according to any of claim 31, wherein said turbine disc, said distance piece, and at least the final stage on the high temperature side of said compressor disc each comprise 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 0.6% by weight or less 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 and at least one member selected from among 1% by weight or less of W, 0.5% by weight or less of Co, 0.5% by weight or less of Cu, 0.01%

by weight or less of B, 0.5% by weight or less of Ti, 0.3% by weight or less of Aℓ, 0.1% by weight or less of Zr, 0.1% by weight or less of Hf, 0.01% by weight or less of Ca, 0.01% by weight or less of Mg, 0.01% by weight or less of Y, and 0.01% by weight or less of rare earth elements with the balance being substantially Fe, the Mn to Ni ratio being 0.11 or less, and has a wholly tempered martensite structure.

34. A gas turbine according to any of claims 16 to 20, wherein said turbine stacking bolt, said spacer, said turbine disc, said distance piece, said compressor stacking bolt, and the final stage on the high temperature side of said compressor disc are each made of a martensitic steel having a wholly tempered martensite structure and having a creep rupture strength of at least 50 kg/mm^2 at 450°C for 10^5 hr and a V-notch Charpy impact value of at least 5 kg-m/cm^2 at 25°C after heating at 500°C for 10^3 hr.

35. A gas turbine according to any of claims 16 to 34 which comprises a turbine stub shaft; a plurality of turbine discs connected to said shaft with turbine stacking bolts through a spacer interposed between said turbine discs; a turbine blade embedded into said turbine disc; a shroud formed in an annular shape and being in sliding contact with the leading end of said turbine blade; a plurality of combustors each comprising a turbine nozzle for leading a high-temperature gas flow to said blade for rotating said blade and a cylindrical material for producing said high-temperature gas; a distance piece connected to said turbine disc with said turbine stacking bolt; a plurality of compressor discs connected to said distance piece with compressor stacking bolts; a compressor blade embedded into said compressor disc; and a compressor stub shaft formed integrally with

the first stage of said compressor disc, characterized in that said shroud at a section corresponding to the first stage of said turbine blade is made of a Ni-base cast alloy having a wholly austenitic structure 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 substantially Ni and said shroud at sections corresponding to the remaining stages of said turbine blade is made of an Fe-base 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 substantially Fe.

36. A gas turbine according to any of claims 16 to 36 which comprises a turbine stub shaft; a plurality of turbine discs connected to said shaft with turbine stacking bolts through a spacer interposed between said turbine discs; a turbine blade embedded into said turbine disc; a plurality of combustors each comprising a turbine nozzle for leading a high-temperature gas flow to said blade for rotating said blade, a diaphragm for fixing said turbine nozzle and a cylindrical material for producing said high-temperature gas; a distance piece connected to said turbine disc with said turbine stacking bolt; a plurality of compressor discs connected to said distance piece with compressor stacking bolts; a compressor blade embedded into said compressor disc; and a compressor stub shaft formed integrally with the first stage of said compressor disc, characterized in that said diaphragm at its first-stage turbine

nozzle section for leading a high-temperature gas flow to said first-stage turbine bucket comprises 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 9 to 15% by weight of Ni with the balance being substantially Fe.

37. A gas turbine according to any of claims 16 to 36 which comprises a turbine stub shaft; a plurality of turbine discs connected to said shaft with turbine stacking bolts through a spacer interposed between said turbine discs; a turbine blade embedded into said turbine disc; a plurality of combustors each comprising a turbine nozzle for leading a high-temperature gas flow to said blade for rotating said blade and a cylindrical material for producing said high-temperature gas; a distance piece connected to said turbine disc with said turbine stacking bolt; a plurality of compressor discs connected to said distance piece with compressor stacking bolts; a compressor blade embedded into said compressor disc; a compressor nozzle for leading air to said compressor blade; and a compressor stub shaft formed integrally with the first stage of said compressor disc, characterized in that said compressor nozzle is made of a martensitic steel comprising 0.05 to 0.2% by weight of C, 0.5% by weight or less of Si, 1% by weight or less of Mn, and 10 to 13% by weight or less of Cr and optionally 0.5% or less of Ni and 0.5% or less of Mo with the balance being substantially Fe, said compressor disc disposed on the low-temperature side including said first stage comprises 0.15 to 0.3% 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 to 4% 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 substantially Fe and said compressor disc disposed at the remaining stages on the high temperature side thereof comprises 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 to 2% by weight of Mo, and 0.1 to 0.3% by weight of V with the balance being substantially Fe.

38. A gas turbine according to any of claims 16 to 37 which comprises a turbine stub shaft; a plurality of turbine discs connected to said shaft with turbine stacking bolts through a spacer interposed between said turbine discs; a turbine blade embedded into said turbine disc; a plurality of combustors each comprising a turbine nozzle for leading a high-temperature gas flow to said blade for rotating said blade and a cylindrical material for producing said high-temperature gas; a distance piece connected to said trubine disc with said turbine stacking botl; a plurality of compressor discs connected to said distance piece with compressor stacking bolts; a compressor blade embedded into said compressor disc; and a compressor stub shaft formed integrally with the first stage of said compressor disc, characterized in that said turbine blade is made of a Ni-base cast alloy comprising 0.07 to 0.25% by weight of C, 1% by weight or less of Si, 1% by weight of less of Mn, 12 to 20% by weight of Cr, 5 to 15% by weight of Co, 1 to 5% by weight of Mo, 1 to 5% by weight of W, 0.005 to 0.03% by weight of B, 2 to 7% by weight of Ti, and 3 to 7% 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 substantially Ni and has γ'

and γ" phases, that said turbine nozzle is made of a Co-base cast alloy comprising 0.20 to 0.6% 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 substantially Co and 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 contains eutectic carbide and secondary carbide in an austenite phase matrix and that said combustor is made of a Ni-base alloy having a wholly austenitic structure and comprising 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 substantially Ni.

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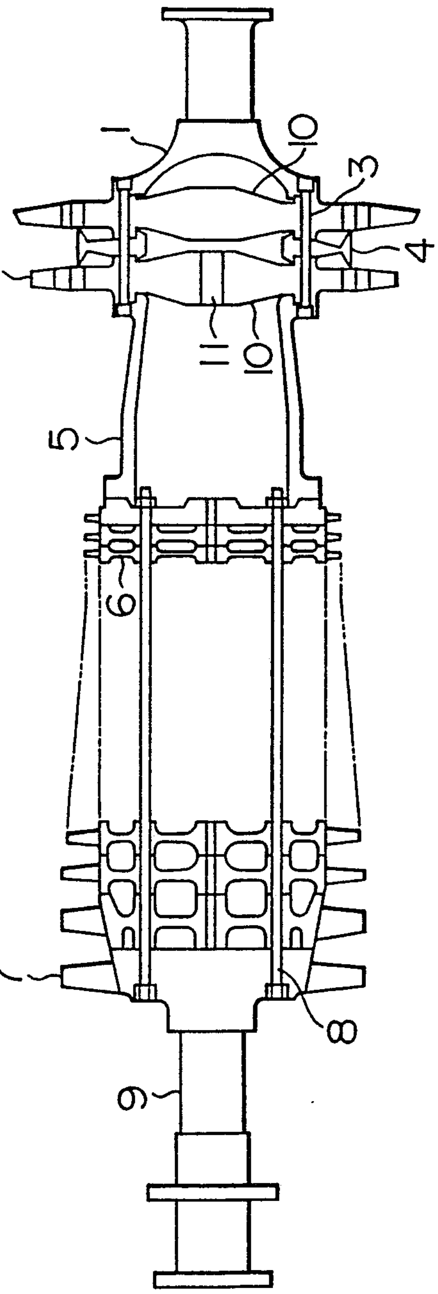


FIG. 1

FIG. 2

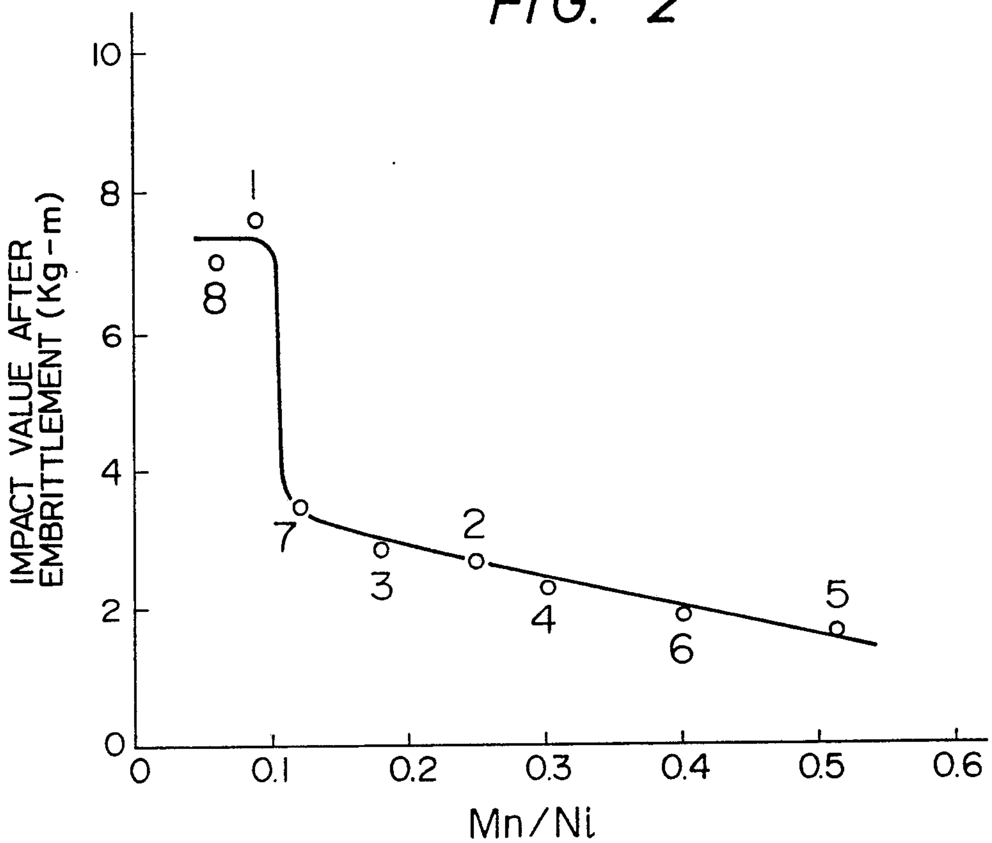

IMPACT VALUE AFTER EMBRITTLEMENT (Kg-m)
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Mn/Ni
1
8
7
2
3
4
6
5

FIG. 3

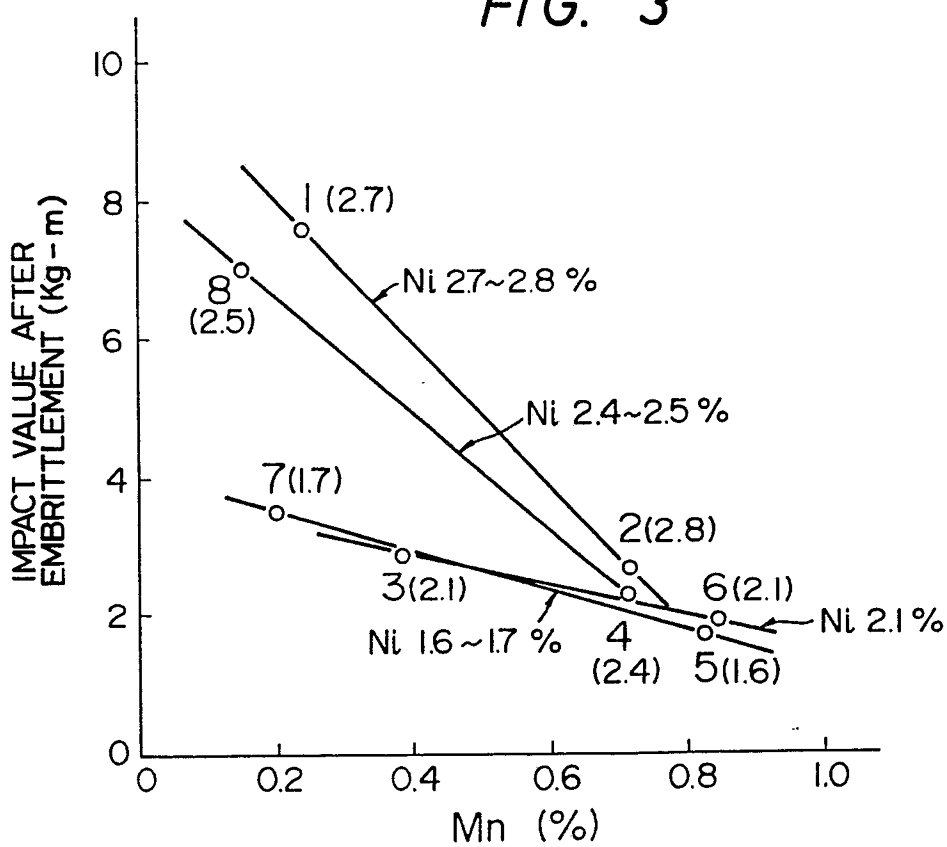
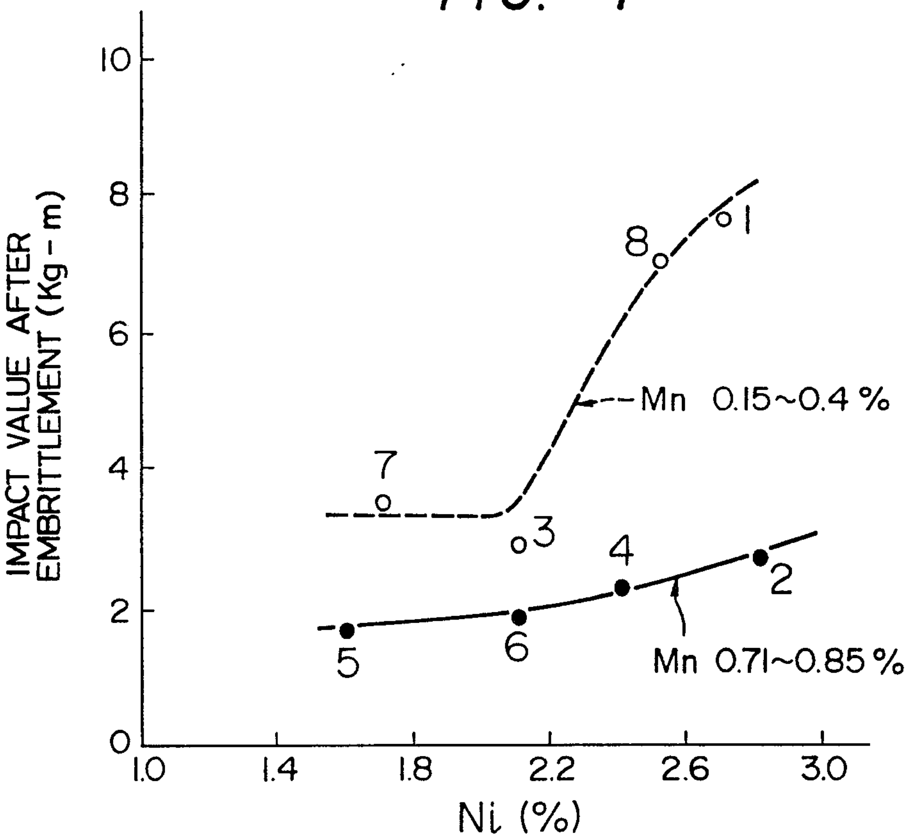
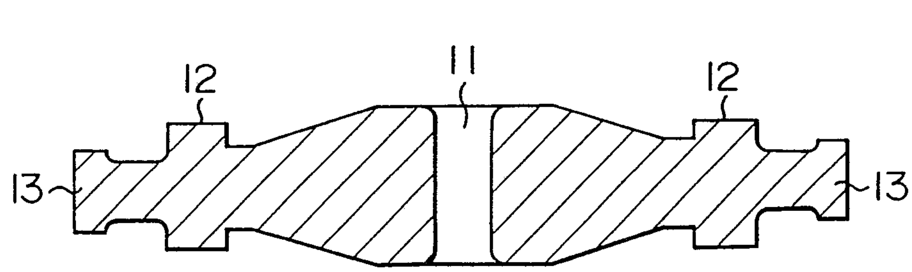

IMPACT VALUE AFTER EMBRITTLEMENT (Kg-m)
10
8
6
4
2
0
0
0.2
0.4
0.6
0.8
1.0
Mn (%)
1 (2.7)
8 (2.5)
Ni 2.7~2.8 %
Ni 2.4~2.5 %
7(1.7)
3(2.1)
2(2.8)
6(2.1)
Ni 2.1 %
Ni 1.6 ~ 1.7 %
4 (2.4)
5(1.6)

FIG. 4



IMPACT VALUE AFTER EMBRITTLEMENT (Kg-m)
10
8
6
4
2
0
1.0
1.4
1.8
2.2
2.6
3.0
Ni (%)
7
3
8
1
4
2
5
6
Mn 0.15~0.4 %
Mn 0.71~0.85 %

FIG. 6



11
12
12
13
13

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FIG. 5

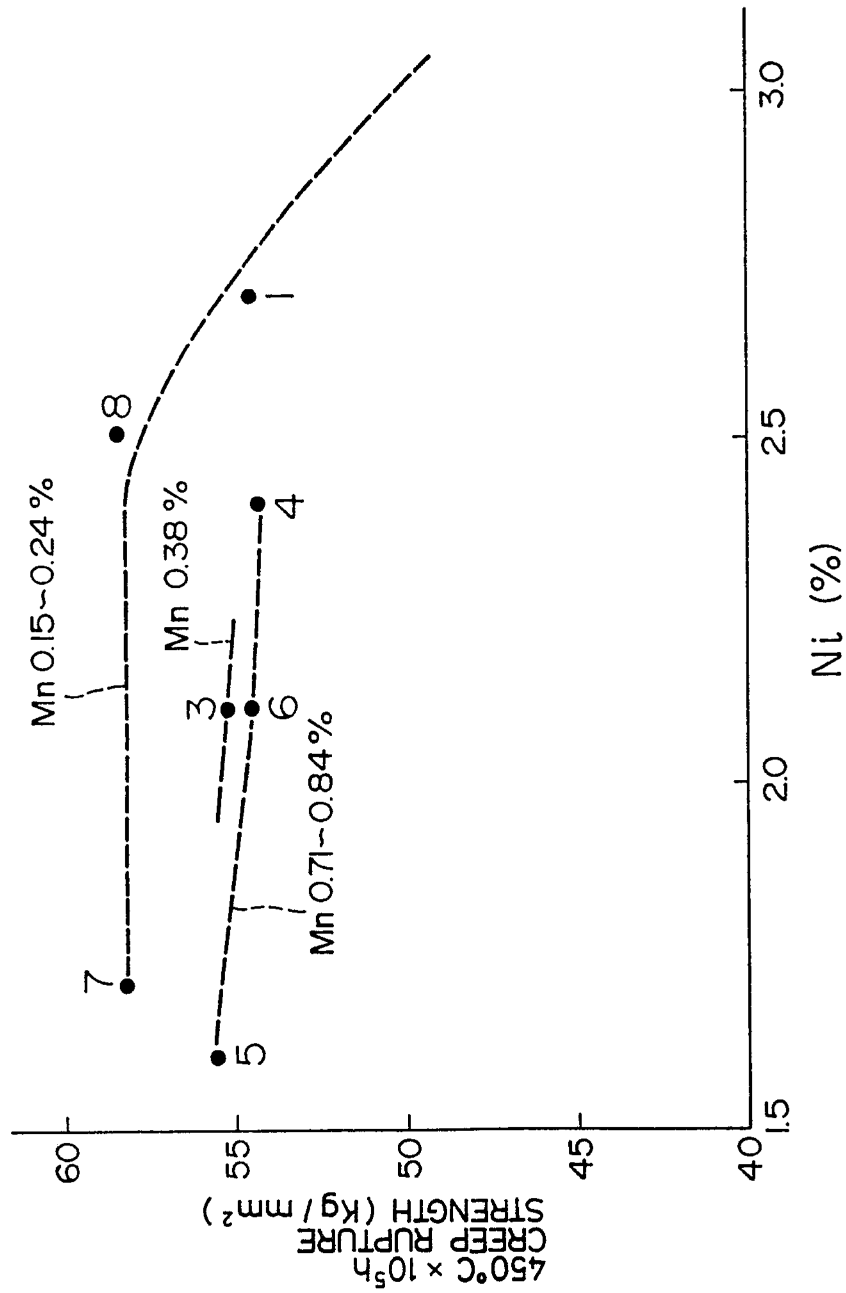

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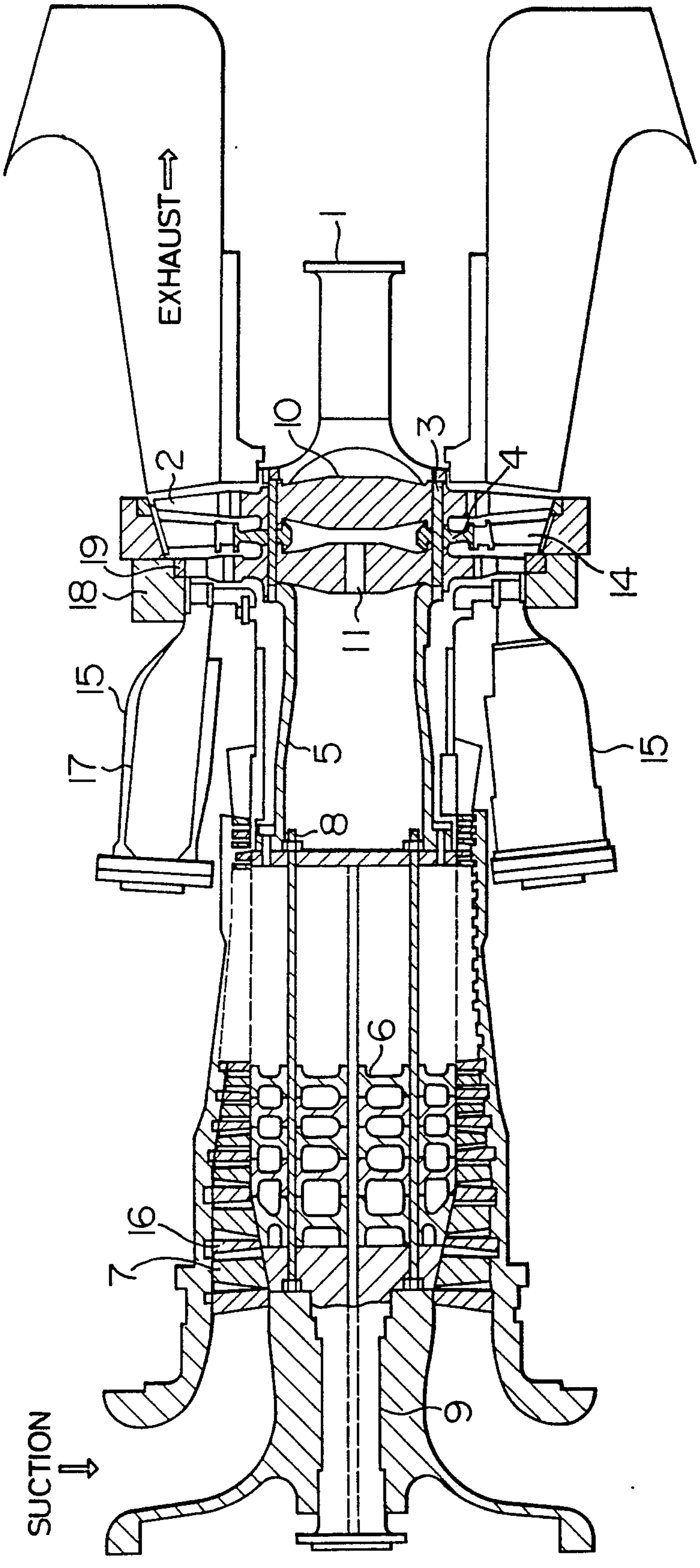
FIG. 7



INTERNATIONAL SEARCH REPORT 0298127

International Application No PCT/JP88/00007

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl[4] C22C19/05, 19/07, 38/46, 38/48, 38/50, 38/54, F01D5/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	C22C19/03-19/07, 38/40-38/58

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	JP, B2, 61-51025 (Toshiba Corp.) 7 November 1986 (07. 11. 86) Column 1, lines 2 to 10 (Family: none)	1-3,5,6, 8-10,12,13, 15-26,29, 31,32,34
X	JP, A, 54-146211 (Toshiba Corp.) 15 November 1979 (15. 11. 79) P.1, left column, lines 5 to 12 (Family: none)	1-3,5,6, 8-10,12,13, 15-26,29,31, 32,34
X	JP, A, 56-35754 (Daido Steel Co., Ltd.) 8 April 1981 (08. 04. 81) P.1, left column, line 14 to right column, line 5 (Family: none)	4,5,7-9,11, 12,14-18, 30,31,33,34
X	JP, A, 59-118858 (Toshiba Corp.) 9 July 1984 (09. 07. 84) P.1, left column, lines 6 to 11 (Family: none)	27, 28, 37
Y	JP, A, 58-45360 (Toshiba Corp.) 16 March 1983 (16. 03. 83) P.1, left column, line 6 to right column, line 8 (Family: none)	27, 28, 37

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
March 16, 1988 (16. 03. 88)	March 22, 1988 (22. 03. 88)
International Searching Authority [1]	**Signature of Authorized Officer** [20]
Japanese Patent Office	

International Application No. PCT/JP88/00007

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Y	JP, A, 58-34164 (Toshiba Corp.) 28 February 1983 (28. 02. 83) P.1, left column, lines 5 to 13 (Family: none)	27, 28, 37
Y	JP, A, 57-207159 (Toshiba Corp.) 18 December 1982 (18. 12. 82) P.1, left column, lines 5 to 13 (Family: none)	27, 28, 37
Y	JP, A, 57-126958 (Toshiba Corp.) 6 August 1982 (06. 08. 82) P.1, left column, lines 4 to 12 (Family: none)	27, 28, 37

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers............, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers............, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/JP88/00007

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	JP, A, 56-112443 (Nippon Chutanko Kabushiki Kaisha) 4 September 1981 (04. 09. 81) P.1, left column, lines 5 to 15 & FR, A, 2475577 & DE, A, 3104583	21, 27, 37
X	JP, B2, 58-13608 (Toshiba Corp.) 15 March 1983 (15. 03. 83) Column 1, line 22 to column 2, line 9 (Family: none)	21, 27, 37
Y	JP, B2, 61-32384 (Hitachi, Ltd.) 26 July 1986 (26. 07. 86) Column 1, line 1 to column 2, line 6	21, 27, 37

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE[10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers............, because they relate to subject matter[12] not required to be searched by this Authority, namely:

2.☐ Claim numbers............, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out[13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING[11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/JP88/00007

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	(Family: none)	
Y	JP, B2, 57-15654 (Mitsubishi Metal Corporation) 31 March 1982 (31. 03. 82) Column 2, lines 6 to 30 (Family: none)	35, 38
Y	JP, A, 51-62126 (Mitsubishi Metal Corporation) 29 May 1976 (29. 05. 76) P.1, right column, line 15 to p.2, right column, line 5 (Family: none)	35, 38
Y	JP, A, 50-35023 (Mitsubishi Metal	35, 38

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE[10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers............, because they relate to subject matter[12] not required to be searched by this Authority, namely:

2.☐ Claim numbers............, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out[13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING[11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/JP88/00007

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	Corporation) 3 April 1975 (03. 04. 75) P.1, right column, line 13 to p.2, right column, line 2 (Family: none)	
Y	JP, A, 57-200544 (Toshiba Corp.) 8 December 1982 (08. 12. 82) P.1 - p.2, left column, line 7 (Family: none)	36
X	JP, B2, 58-37382 (Mitsubishi Heavy Industries, Ltd.) 16 August 1983 (16. 08. 83) Column 1, line 17 to column 2, line 16	38

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers..........., because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers..........., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/JP88/00007

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	(Family: none)	
X	JP, A, 55-82745 (Hitachi, Ltd.) 21 June 1980 (21. 06. 80) P.1, left column, line 4 to right column, line 1, P.5 (Family: none)	38
X	JP, B2, 57-54535 (Hitachi, Ltd.) 18 November 1982 (18. 11. 82) Column 1, line 27 to column 2, line 1 (Family: none)	38

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers............, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers............, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

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