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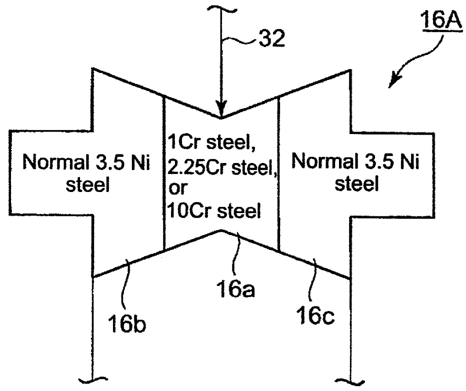
(54) ROTOR FOR LOW-PRESSURE TURBINE

(57) The object of the invention is to provide a low-pressure turbine rotor capable of maintaining mechanical strength characteristics, and without problems in terms of quality without increasing manufacturing costs and manufacturing days, even if high temperature steam is introduced into the low-pressure turbine. A low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine includes a member formed from 1CrMov steel, 2.25CrMoV steel, or 10CrMoV steel arranged on a steam inlet side, and a member formed from 3.5Ni steel arranged on a steam outlet side, which are joined together by welding. Alternatively, the member arranged on the steam inlet side and the member arranged on the steam outlet side, both of which are formed from 3.5Ni steel, are joined together by welding, and the member arranged on the steam inlet side is made of low-impurity 3.5Ni steel containing, by weight %, Si: 0.1% or less, Mn: 0.1% or less, and inevitable impurities containing, by weight %, P: 0.02% or less, S: 0.02% or less, Sn: 0.02% or less, As: 0.02% or less, Sb: 0.02% or less, Al: 0.02% or less, and Cu: 0.1% or less.

FIG. 2



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Description

Technical Field

[0001] The present invention relates to a low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine, and particularly, to a low-pressure turbine rotor suitably used in a steam turbine facility in which the steam inlet temperature attains a high-temperature of 380°C or higher.

Background Art

[0002] Three methods of atomic power, thermal power, and hydraulic power generation, are now used as main power generation methods, and from a viewpoint of resource quantity and energy density, the three power generation methods are also expected to be used as main power generation methods in the future. Especially, since thermal power generation is safe and its utility value is high as a power generation method with a high capacity to respond to load change, it is expected that thermal power generation will also continue to play an important role in the power generation field in the future.

[0003] A steam turbine facility used for coal-fired thermal power generation including a steam turbine, generally has a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine, and steam in the range of 600°C is used for the steam turbine facility. In such a steam turbine facility, steam in the 600°C range supplied from a boiler is introduced into the high-pressure turbine in a high-pressure blade stage composed of blades and a vanes to rotate the high-pressure turbine to perform expansion work. Thereafter, the steam is exhausted from the high-pressure turbine and is introduced into the intermediate-pressure turbine to rotate the intermediate-pressure turbine to perform expansion work, similarly to the high-pressure turbine. Further, the steam is introduced into the low-pressure turbine to perform expansion work and is exhausted and condensed to a condenser.

[0004] Generally the low-pressure turbine rotor in such a steam turbine facility is formed from 3.5Ni steel (for example, 3.5NiCrMoV steel, etc.), and the inlet steam temperature of the low-pressure turbine was set to 380°C or lower that is a temperature such that 3.5Ni steel is able to maintain mechanical strength characteristics and toughness.

[0005] In the above steam turbine facility, a technique adopting a steam condition of 630°C or higher is recently required in order to reduce emissions of CO_2 and further improve thermal efficiency.

[0006] If steam of 630°C or higher is introduced into the high-pressure turbine, and the same high-pressure turbine and intermediate-pressure turbine as a conventional case using steam in the 600°C range are used, there is a possibility that the inlet steam temperature of the low-pressure turbine may rise as high as about 400 to 430°C, greater than conventional, and the rotor of the low-pressure turbine is not able to maintain its mechanical strength characteristics and toughness due to the rise in temperature.

[0007] Especially, in the case of double-stage reheating, second-stage reheating pressure becomes low. Thus, the inlet steam temperature of the low pressure turbine of the double-stage reheating rises higher than single-stage reheating, and design conditions become strict.

[0008] In order to maintain the mechanical strength characteristics and toughness of the low-pressure turbine rotor using steam of 630°C or higher and formed from 3.5Ni steel, it is considered that the expansion work amounts in the high-pressure turbine and the intermediate-pressure turbine are increased higher than ever before to reduce the steam temperature at the inlet of the low-pressure turbine to 380°C or lower. However, for that purpose it is necessary to increase the number of blade stages of the high-pressure turbine and the intermediate-pressure turbine, and there is a problem that the whole turbine becomes enlarged.

[0009] Thus, Patent Document 1 disclosed a low-pressure turbine rotor capable of reducing the content of impurities contained in 3.5Ni steel which constitutes the low-pressure turbine rotor, and limiting the content to a minute amount, thereby suppressing changes in the structure of the metal which induces embrittlement over time, such as grain boundary segregation of impurity elements caused by heating, and stably performing operations even if steam of 380°C or higher is introduced.

[0010] Stricter impurity management than ever before is required in the technique disclosed in Patent Document 1. However, especially, the low-pressure turbine rotor is large-sized. Therefore, when an integral low-pressure turbine rotor is used in the technique disclosed in Patent Document 1, a problem occurs in that reliability in terms of quality of a turbine rotor to be manufactured remains unstable such that cost increases, manufacturing days increase and delivery dates become delayed, and the content of impurities exceeds a criteria, for example, due to dispersion.

Prior Art Document

Patent Document

[0011] [Patent Document 1] Japanese Patent Application Laid-Open No. 2006-170006

Summary of the Invention

[0012] Accordingly, the invention was made in view of the problems of the conventional technique, and the object thereof is to provide a low-pressure turbine rotor capable of maintaining mechanical strength characteristics, and without problems in terms of quality without increasing manufacturing costs and manufacturing days, even if high temperature steam is introduced into the low-pressure turbine.

[0013] In order to solve the above problem, the present invention provides a low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine. The turbine rotor includes a member formed from 1CrMoV steel (hereinafter referred to as 1Cr steel), 2.25CrMoV steel (hereinafter referred to as 2.25Cr steel), or 10CrMoV steel (hereinafter referred to as 10Cr steel) arranged on a steam inlet side, and a member formed from 3.5Ni steel arranged on a steam outlet side, which are joined together by welding.

[0014] Since 1Cr steel, 2.25Cr steel, and 10Cr steel are materials which have conventionally been used for high-pressure turbine rotors or intermediate-pressure turbine rotors, the material management methods are established, and also easily available. Moreover, the above materials have a more excellent high-temperature resistance than 3.5Ni steel.

[0015] Additionally, 3.5Ni steel has stress corrosion cracking (SCC) susceptibility lower than 1Cr steel and 2.25Cr steel. Additionally, 10Cr steel is more expensive than 3.5Ni steel.

[0016] Thus, steam inlet side into which high-temperature steam is introduced includes a member formed from 1Cr steel, 2.25Cr steel, or 10Cr steel, and steam outlet side in which a flow passage (blade length) increases and higher strength is required includes a member formed from 3.5Ni steel, whereby it is possible to form a low-pressure turbine rotor which is excellent against high-temperature and stress corrosion cracking, and even if high-temperature steam is introduced, it is possible to maintain its mechanical strength characteristics and toughness.

[0017] Moreover, although 3.5Ni steel and 1Cr steel are almost the same from the viewpoint of embrittlement, 2.25Cr steel and 10Cr steel are superior to 3.5Ni steel. Accordingly, if a member made of 1Cr steel is used for the steam inlet side, the embrittlement susceptibility of the whole low-pressure turbine rotor is almost the same as the conventional low-pressure turbine rotor the entirety of which is made of 3.5Ni steel. However, if a member made of 2.25Cr steel or 10Cr steel is used for the steam inlet side, the embrittlement susceptibility of the whole low-pressure turbine rotor is superior to the conventional low-pressure turbine rotor the entirety of which is made of 3.5Ni steel. Therefore, the member on the steel inlet side is more preferably formed from 2.25Cr steel or 10Cr steel.

[0018] Additionally, there is provided a low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine. The turbine rotor includes a member arranged on a steam inlet side and a member arranged on a steam outlet side, which are joined together by welding, both the members are formed from 3.5Ni steel, and the member arranged on the steam inlet side is formed from low-impurity 3.5Ni steel.

[0019] Additionally, the low-impurity 3.5Ni steel arranged on the steam inlet side contains, by weight %, Si: 0.1% or less, Mn: 0.1% or less, and inevitable impurities, by weight %, containing P: 0.02% or less, S: 0.02% or less, Sn: 0.02% or less, As: 0.02% or less, Sb: 0.02% or less, Al: 0.02% or less, and Cu: 0.1% or less.

[0020] By using the member made of 3.5Ni steel the impurity content of which is reduced and limited to a minute amount for the steam inlet side into which high-temperature steam is introduced, it is possible to suppress changes in the metal structure which induce embrittlement over time, such as grain boundary segregation of impurity elements caused by heating, and even if steam of 380°C or higher is introduced, it is possible to stably perform operation.

[0021] Moreover, by using a member made of 3.5Ni steel the impurity content of which is reduced not for the whole rotor but for the steam inlet side into which high-temperature steam is introduced, it is possible to fabricate a low-pressure turbine rotor in which an increase in manufacturing costs and manufacturing days is suppressed, and the uncertainness in reliability in terms of quality is also small.

[0022] Additionally, the low-pressure turbine rotor is used in a steam turbine facility where the inlet steam temperature of the low-pressure turbine is 380°C or higher,
a region where the temperature of the steam passing through the low-pressure turbine becomes 380°C or higher includes the member arranged on the steam inlet side, and a region where the temperature of the steam passing through the low-pressure turbine is less than 380°C includes the member arranged on the steam outlet side.

[0023] The normal 3.5Ni steel has a high possibility of inducing embrittlement over time, such as grain boundary segregation of impurity elements, if steam temperature becomes 380°C or higher. Thus, a region where steam temperature becomes 380°C or higher includes the member arranged on the steam inlet side, and a region where steam temperature is less than 380°C includes the member arranged on the steam outlet side, whereby the normal 3.5Ni steel does not contact steam of 380°C or higher, and it is possible to suppress embrittlement of a member formed from the 3.5Ni steel arranged on the steam outlet side.

[0024] The low-pressure turbine rotor is used in a steam turbine facility where the inlet steam temperature of at least one of the high-pressure turbine and the intermediate-pressure turbine is 630°C or higher.

[0025] Thereby, the high-pressure turbine and the intermediate-pressure turbine are not enlarged, it is possible to reduce emissions of CO_2 from the steam turbine facility, and it is possible to improve the thermal efficiency of the steam turbine facility.

[0026] As described above, according to the invention, it is possible to provide a low-pressure turbine rotor capable of maintaining mechanical strength characteristics, and without problems in terms of quality without increasing manufacturing costs and manufacturing days, even if high temperature steam is introduced into the low-pressure turbine.

Brief Description of the Drawings

[0027]

[FIG. 1] FIG. 1 is a view illustrating the configuration of a steam turbine power generation facility in Embodiment 1.
[FIG. 2] FIG. 2 is a plan view schematically illustrating the configuration of a low-pressure turbine rotor in Embodiment 1.
[FIG. 3] FIG. 3 is a plan view schematically illustrating the configuration of a low-pressure turbine rotor in Embodiment 2.
[FIG. 4] FIG. 4 is a graph illustrating the embrittlement factors of 1Cr steel, 2.25Cr steel, 10Cr steel, and 3.5Ni steel.

Detailed Description of the Preferred Embodiment

[0028] Preferred examples of the invention will be illustratively described below in detail with reference to the drawings. Here, the dimensions, materials, shapes, relative arrangements, etc. of component parts described in this example are not meant to limit the scope of the invention, but are merely simple explanatory examples, as long as there is no specific description of limitations.

[Example 1]

[0029] FIG. 1 is a view illustrating the configuration of a steam turbine power generation facility in Embodiment 1.

[0030] With reference to FIG. 1, a power generation facility composed of a steam turbine facility using a low-pressure turbine rotor of the invention will be described. In addition, FIG. 1 is an example of single-stage reheating, and the invention is also applied to implementation of double-stage reheating and a high temperature rise (630°C or higher) only by reheating, and is not particularly limited.

[0031] The steam turbine power generation facility 10 illustrated in FIG. 1 mainly includes a high-pressure turbine 14, an intermediate-pressure turbine 12, a low-pressure turbine 16, a power generator 18, a condenser 20, and a boiler 24. The steam passes through in order of a boiler 24, a main steam pipe 26, the high-pressure turbine 14, a low-temperature reheat pipe 28, the boiler 24, the high-temperature reheat pipe 30, the intermediate-pressure turbine 12, a crossover pipe 32, the low-pressure turbine 16, the condenser 20, a water feed pump 22, and the boiler 24.

[0032] The steam overheated to 630°C or higher in the boiler 24 is introduced into the high-pressure turbine 14 through the main steam pipe 26. The steam introduced into the high-pressure turbine 14 is exhausted and is returned to the boiler 24 through the low-temperature reheat pipe 28 after having performed expansion work. The steam returned to the boiler 24 is reheated in the boiler 24 and turned into steam of 630°C or higher, and is sent to the intermediate-pressure turbine 12 through the high-temperature reheat pipe 30. The steam introduced into the intermediate-pressure turbine 12 is exhausted, is turned into steam of about 400 to 430°C, and is sent to the low-pressure turbine 16 through the crossover pipe 32 after having performed expansion work. The steam introduced into the low-pressure turbine 16 is exhausted and is sent to the condenser 20 after having performed expansion work. The steam sent to the condenser 20 is condensed in the condenser 20, is increased in pressure in the water feed pump 22, and is returned to the boiler 24. The power generator 18 is rotationally driven by the expansion work of each turbine to generate power.

[0033] FIG. 2 is a plan view schematically illustrating the configuration of the rotor used for the low-pressure turbine 16 in Embodiment 1.

[0034] The low-pressure turbine rotor used for the steam turbine power generation facility as mentioned above will be described with reference to FIG. 2.

(Configuration)

[0035] First, the configuration of the rotor according to this example used for the low-pressure turbine 16 into which steam of about 400 to 430°C is introduced will be described with reference to FIG. 2.

[0036] As illustrated in FIG. 2, the low-pressure turbine rotor 16A includes one member (hereinafter referred to as chrome steel portion) 16a made of 1Cr steel, 2.25Cr steel, or 10Cr steel, and two members (hereinafter referred to as normal 3.5Ni steel portions) 16b and 16c made of 3.5Ni steel.

[0037] The chrome steel portion 16a is joined to the normal 3.5Ni steel portions 16b and 16c, respectively, by welding at both ends thereof, thereby forming the low-pressure turbine rotor 16A integrated in order of the normal 3.5Ni steel portion 16b, the chrome steel portion 16a, and the normal 3.5Ni steel portion 16c from one end.

[0038] Additionally, the chrome steel portion 16a is arranged at a position exposed to steam of 380°C or higher, and the normal 3.5Ni steel portions 16b and 16c are arranged at positions exposed to steam of less than 380°C.

(Materials)

[0039] Next, the materials of the chrome steel portion 16a and the 3.5Ni steel portions 16b and 16c which constitutes the low-pressure turbine rotor 16A, will be described.

(A) Chrome steel portion

[0040] The chrome steel portion is formed from 1Cr steel, 2.25Cr, or 10Cr steel which has excellent in high-temperature resistance, and is easily available.

[0041] The 1Cr steel may include, for example, a material having composition containing, by weight %, C: 0.2 to 0.4%, Si: 0.35% or less, Mn: 1.5% or less, Ni: 2.0% or less, Cr: 0.5 to 1.5%, Mo: 0.5 to 1.5%, V: 0.2 to 0.3%, and the balance: Fe with inevitable impurities.

[0042] The 2.25Cr Steel may include, for example, a material having composition containing, by weight %, C: 0.2 to 0.35%, Si: 0.35% or less, Mn: 1.5% or less, Ni: 0.2 to 2.0%, Cr: 1.5 to 3.0%, Mo: 0.9 to 1.5%, V: 0.2 to 0.3%, and the balance: Fe with inevitable impurities.

[0043] The 10Cr steel may include, for example, a material having composition containing, by weight %, C: 0.05 to 0.4%, Si: 0.35% or less, Mn: 2.0% or less, Ni: 3.0% or less, Cr: 7 to 13%, Mo: 0.1 to 3.0%, V: 0.01 to 0.5%, N: 0.01 to 0.1%, Nb: 0.01 to 0.2%, and the balance: Fe with inevitable impurities.

[0044] The 10Cr steel of another example may include, for example, a material having composition containing, by weight %, C: 0.05 to 0.4%, Si: 0.35% or less, Mn: 2.0% or less, Ni: 7.0% or less, Cr: 8 to 15%, Mo: 0.1 to 3.0%, V: 0.01 to 0.5%, N: 0.01 to 0.1%, Nb: 0.2% or less, and the balance: Fe with inevitable impurities.

[0045] FIG. 4 is a graph illustrating the embrittlement factor of 1Cr steel, 2.25Cr steel, 10Cr steel, and 3.5Ni steel. The ordinate axis represents embrittlement factors (ΔFATT), and values used as the index of the easiness of embrittlement. As the numeric value of this factor is higher, susceptibility to embrittlement is higher and embrittlement is easier. The abscissa axis represents J-Factors and values used as the index of the concentration of impurities. As is clear from FIG. 4, materials easily embrittle as the impurity concentration increases. Moreover, 1Cr steel and 3.5Ni steel have almost the same embrittlement factors, the embrittlement factor of 2.25Cr steel is lower than that, and the embrittlement factor of 10Cr steel is lower still.

[0046] Accordingly, if a member made of 1Cr steel is used for the chrome steel portion 16a, it can be said that the embrittlement susceptibility of the whole low-pressure turbine rotor is almost the same as the conventional low-pressure turbine rotor in which the whole rotor is made of 3.5Ni steel. However, if members made of 2.25Cr steel or 10Cr steel are used for the chrome steel portions 16b and 16c, it can be said that the embrittlement susceptibility of the whole low-pressure turbine rotor is lower than the conventional low-pressure turbine rotor in which the whole rotor is made of 3.5Ni steel, i.e., the turbine rotor hardly embrittles. Therefore, the chrome steel portion 16a is more preferably formed from 2.25Cr steel or 10Cr steel.

(B) Normal 3.5Ni steel portion

[0047] The 3.5Ni steel may include, for example, a material having composition containing, by weight %, C: 0.4% or less, Si: 0.35% or less, Mn: 1.0% or less, Cr: 1.0 to 2.5%, V: 0.01 to 0.3%, Mo: 0.1 to 1.5%, Ni: 3.0 to 4.5%, and the balance: Fe with inevitable impurities.

(Manufacturing method)

[0048] Joining is made by welded portions between the chrome steel portion 16a and the normal 3.5Ni steel portions 16b and 16c by welding.

[0049] Although the method of the welding is not particularly limited if the welded portions are able to withstand the operational conditions of the low-pressure turbine, it is possible to include a general welding method of supplying a weld wire to an arc generated by a welding torch as an example as a filler.

[0050] For example, a narrow groove welding joint, etc. is adopted as the shape of the welded portions. In welding, a filler supplied as a weld wire by melting caused by an arc is laminated for every single pass, and the filler is filled into the narrow groove welding joint, thereby joining together the chrome steel portion 16a and the normal 3.5Ni steel portions 16b and 16c. The 3.5Ni steel that is the same material as the normal 3.5Ni steel portion is used as the filler.

[0051] The following effects are obtained by using the low-pressure turbine rotor described above.

[0052] Since 1Cr steel, 2.25Cr steel, and 10Cr steel are materials which have conventionally been used for high-pressure turbine rotors or intermediate-pressure turbine rotors, the materials management methods are established, and also easily available. Moreover, the above materials have more excellent high-temperature resistance than 3.SNi steel. Additionally, 3.5Ni steel has stress corrosion cracking (SCC) susceptibility lower than 1Cr steel, 2.25Cr steel, and 10Cr steel. Thus, steam inlet side into which high-temperature steam is introduced includes a member formed from 1Cr steel, 2.25Cr steel, or 10Cr steel, and steam outlet side in which a flow passage diameter (blade diameter) increases and higher strength is required includes a member formed from 3.5Ni steel, whereby it is possible to form a low-pressure turbine rotor which is excellent against high-temperature and stress corrosion cracking, and even if high-temperature steam is introduced, it is possible to maintain its mechanical strength characteristics.

[0053] Additionally, the normal 3.5Ni steel has a high possibility of inducing embrittlement over time, such as grain boundary segregation of impurity elements, if the steam temperature becomes 380°C or higher. Thus, a region where the steam temperature becomes 380°C or higher includes a member arranged on the steam inlet side, and a region where steam temperature is less than 380°C includes a member arranged on the steam outlet side, whereby the normal 3.5Ni: steel does not contact the steam of 380°C or higher, and it is possible to suppress embrittlement of a member formed from the 3.5Ni steel arranged on the steam outlet side.

[0054] Moreover, since it is possible to maintain the mechanical strength characteristics of the low-pressure turbine rotor even if the inlet steam temperature of the low-pressure turbine is made higher than ever before, it is possible to use steam of 630°C or higher without enlarging the high-pressure turbine and the intermediate-pressure turbine, it is possible to reduce emissions of CO_2 from the steam turbine facility, and it is possible to improve the thermal efficiency of the steam turbine facility.

[Example 2]

(Configuration)

[0055] In Embodiment 2, a low-pressure turbine rotor 16B of another form will be described.

[0056] In Embodiment 2, as illustrated in FIG. 3, the low-pressure turbine rotor 16B includes one member (referred to as a low-impurity 3.5Ni steel portion) 16d made of low-impurity 3.5Ni steel with little impurity content, and the normal 3.5Ni steel portions 16b and 16c.

[0057] That is, Embodiment 2 is a form in which the low-impurity 3.5Ni steel portion 16d is adopted instead of the chrome steel portion 16a of the low-pressure turbine rotor with the form of Embodiment 1 illustrated in FIG. 2. Hereinafter, since configurations other than the low-impurity 3.5Ni steel portion 16d are the same as those of Embodiment 1, the description thereof is omitted.

[0058] Additionally, the low-impurity 3.5Ni steel portion 16d is arranged at a position exposed to steam of 380°C or higher, and the normal 3.5Ni steel portions 16b and 16c are arranged at positions exposed to steam of less than 380°C.

(Materials)

[0059] The materials of the low-impurity 3.5Ni steel portion 16d will be described.

[0060] The low-impurity 3.5Ni steel portion 16d is formed from a 3.5Ni steel portion with little impurity content. The low-impurity 3.5Ni steel portion 16d may include, for example, a material having composition containing, by weight %, C: 0.4% or less, Si: 0.1% or less, Mn: 0.1% or less, Cr : 1.0 to 2.5%, V: 0.01 to 0.3%, Mo: 0.1 to 1.5%, Ni: 3.0 to 4.5%, and the balance: Fe with inevitable impurities, and the inevitable impurities contain, by weight %, P: 0.02% or less, S: 0.02% or less, Sn: 0.02% or less, As: 0.02% or less, Sb: 0.02% or less, Al: 0.02% or less, and Cu: 0.1% or less.

(Manufacturing method)

[0061] Joining is made by welded portions between the low-impurity 3.5Ni steel portion 16d and the normal 3.5Ni steel portions 16b and 16c by welding.

[0062] As illustrated in FIG. 4, as the 3.5Ni steel has lower impurity concentration, embrittlement susceptibility is lower and embrittlement hardly occurs.

[0063] Accordingly, by using the member 16d made of low-impurity 3.5Ni steel the impurity content of which is reduced and limited to a minute amount for the steam inlet side into which high-temperature steam is introduced, it is possible to suppress changes in metal structure which induces embrittlement over time, such as grain boundary segregation of impurity elements caused by heating, and even if the steam of 380°C or higher is introduced, it is possible to stably perform operation.

[0064] Moreover, by using a member made of 3.5Ni steel the impurity content of which is reduced not for the whole rotor but for the steam inlet side into which high-temperature steam is introduced, it is possible to fabricate a low-pressure turbine rotor in which an increase in manufacturing costs and manufacturing days is suppressed, and the instability of reliability in terms of quality is also small.

[0065] Additionally, the normal 3.5Ni steel has a high possibility of inducing embrittlement over time, such as grain boundary segregation of impurity elements, if steam temperature becomes 380°C or higher. Thus, a region where steam temperature becomes 380°C or higher includes the member arranged on the steam inlet side, and a region where steam temperature is less than 380°C includes the member arranged on the steam outlet side, whereby the normal 3.5Ni steel does not contact the steam of 380°C or higher, and it is possible to suppress embrittlement of a member formed from the 3.5Ni steel arranged on the steam outlet side.

[0066] Moreover, since it is possible to maintain the mechanical strength characteristics of the low-pressure turbine rotor even if the inlet steam temperature of the low-pressure turbine is made higher than ever before, it is possible to use the steam of 630°C or higher without enlarging the high-pressure turbine and the intermediate-pressure turbine, it is possible to reduce emissions of CO_2 from the steam turbine facility, and it is possible to improve the thermal efficiency of the steam turbine facility.

Industrial Applicability

[0067] It is possible to utilize the invention as a low-pressure turbine rotor capable of maintaining its mechanical strength characteristics, and without problems in terms of quality, without increasing manufacturing costs and manufacturing days, even if high temperature steam is introduced into the low-pressure turbine.

Claims

1. A low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine, the turbine rotor comprising a member formed from 1CrMoV steel, 2.25CrMoV steel, or 10CrMoV steel arranged on a steam inlet side, and a member formed from 3.5Ni steel arranged on a steam outlet side, which are joined together by welding.

2. A low-pressure turbine rotor used in a steam turbine facility including a high-pressure turbine, an intermediate-pressure turbine, and a low-pressure turbine, the turbine rotor comprising a member arranged on a steam inlet side and a member arranged on a steam outlet side, which are joined together by welding, both the members being formed from 3.5Ni steel, and the member arranged on the steam inlet side being formed from low-impurity 3.5Ni steel.

3. The low-pressure turbine rotor according to Claim 2, wherein the low-impurity 3.5Ni steel arranged on the steam inlet side contains, by weight %, Si: 0.1% or less, Mn: 0.1% or less, and inevitable impurities, by weight %, containing P: 0.02% or less, S: 0.02% or less, Sn: 0.02% or less, As: 0.02% or less, Sb: 0.02% or less, Al: 0.02% or less, and Cu: 0.1% or less.

4. The low-pressure turbine rotor according to Claim 1 or 2,
wherein the low-pressure turbine rotor is used in a steam turbine facility where the inlet steam temperature of the low-pressure turbine is 380°C or higher, a region where the temperature of the steam passing through the low-pressure turbine attains temperatures of 380°C or higher includes the member arranged on the steam inlet side, and
a region where the temperature of the steam passing through the low-pressure turbine is less than 380°C includes the member arranged on the steam outlet side.

5. The low-pressure turbine rotor according to any one of Claims 1 to 4,
wherein the low-pressure turbine rotor is used in a steam turbine facility where the inlet steam temperature of at least one of the high-pressure turbine and the intermediate-pressure turbine is 630°C or higher.

FIG. 1

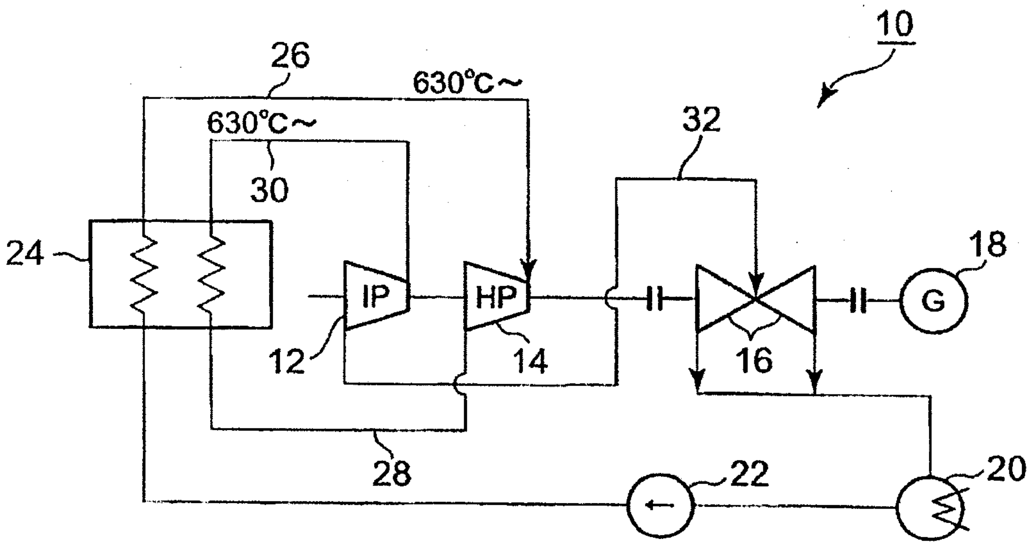

10
26
630°C~
630°C~
30
32
24
IP
HP
18
G
12
14
16
28
22
20

FIG. 2

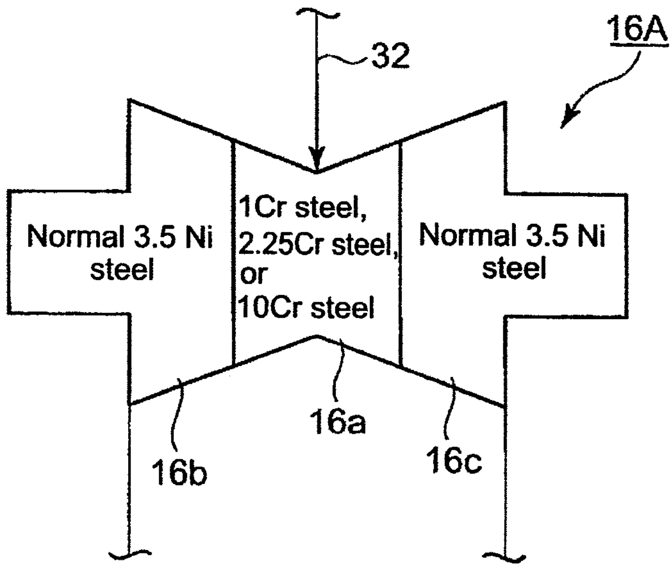

32
16A
Normal 3.5 Ni steel
1Cr steel, 2.25Cr steel, or 10Cr steel
Normal 3.5 Ni steel
16b
16a
16c

FIG. 3

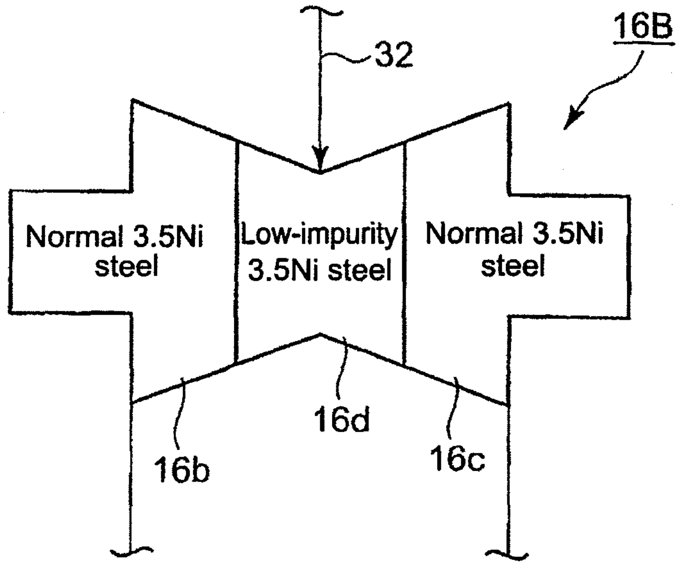
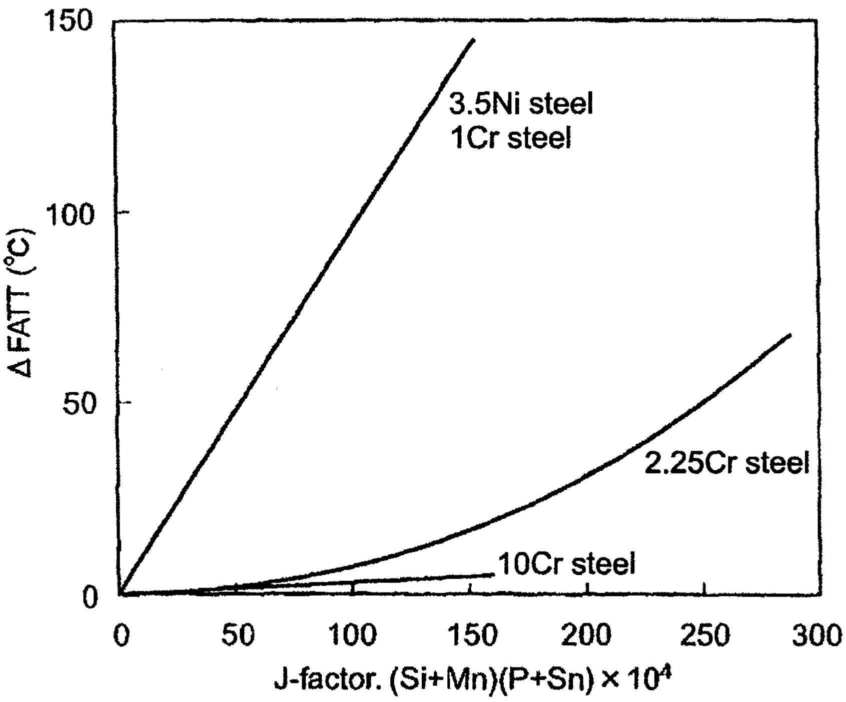

16B
32
Normal 3.5Ni steel
Low-impurity 3.5Ni steel
Normal 3.5Ni steel
16b
16d
16c

FIG. 4


150
100
50
0
Δ FATT (°C)
3.5Ni steel
1Cr steel
2.25Cr steel
10Cr steel
0
50
100
150
200
250
300
J-factor. (Si+Mn)(P+Sn) × 10⁴

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063896

A. CLASSIFICATION OF SUBJECT MATTER
F01D25/00(2006.01)i, F01D1/04(2006.01)i, F01D5/02(2006.01)i, F01D5/06 (2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D25/00, F01D1/04, F01D5/02, F01D5/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-145271 A (Mitsubishi Heavy Industries, Ltd.), 20 May, 2003 (20.05.03), Par. Nos. [0006] to [0007]; Fig. 7 (Family: none)	1-5
Y	JP 2007-278064 A (Hitachi, Ltd.), 25 October, 2007 (25.10.07), Par. Nos. [0049] to [0050]; Fig. 6 (Family: none)	1-5
Y	JP 2006-170006 A (Toshiba Corp.), 29 June, 2006 (29.06.06), Par. Nos. [0016] to [0056]; Figs. 1, 2 & US 2006/0127216 A1 & EP 1672173 A2	2-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"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 when the document is taken alone
"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

Date of the actual completion of the international search	Date of mailing of the international search report
11 September, 2009 (11.09.09)	29 September, 2009 (29.09.09)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063896

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-321630 A (Toshiba Corp.), 13 December, 2007 (13.12.07), Par. Nos. [0051] to [0052]; Fig. 4 (Family: none)	4,5
A	JP 2000-064805 A (Mitsubishi Heavy Industries, Ltd.), 29 February, 2000 (29.02.00), Par. Nos. [0013] to [0014]; Fig. 1 & US 6152697 A & EP 964135 A2 & DE 69924561 T	1-5
A	JP 2008-093668 A (Hitachi, Ltd.), 24 April, 2008 (24.04.08), Par. Nos. [0078] to [0126]; Figs. 1 to 7 (Family: none)	1-5
A	JP 57-176305 A (Hitachi, Ltd.), 29 October, 1982 (29.10.82), Page 1, lower right column, line 14 to page 2, upper right column, line 2; Figs. 1 to 4 (Family: none)	1-5

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Patent documents cited in the description

- JP 2006170006 A **[0011]**