(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 950 969 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
09.02.2022 Bulletin 2022/06

(21) Application number: **20778917.3**

(22) Date of filing: **12.03.2020**

(51) International Patent Classification (IPC):
C21D 8/02 *(2006.01)* ***C21D 9/00*** *(2006.01)*
C22C 38/00 *(2006.01)* ***C22C 38/38*** *(2006.01)*
C22C 38/60 *(2006.01)* ***C21D 1/18*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C21D 1/18; C21D 8/02; C21D 9/00; C22C 38/00; C22C 38/38; C22C 38/60

(86) International application number:
PCT/JP2020/010947

(87) International publication number:
WO 2020/195915 (01.10.2020 Gazette 2020/40)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **28.03.2019 JP 2019063177**

(71) Applicant: **NIPPON STEEL Stainless Steel Corporation**
Tokyo 100-0005 (JP)

(72) Inventors:
- **YOSHIZAWA Toshiki**
  Tokyo 100-0005 (JP)
- **MATSUHASHI Tooru**
  Tokyo 100-0005 (JP)

(74) Representative: **Vossius & Partner**
Patentanwälte Rechtsanwälte mbB
Siebertstraße 3
81675 München (DE)

(54) FERRITIC STAINLESS STEEL SHEET FOR AUTOMOBILE BRAKE DISK ROTORS, AUTOMOBILE BRAKE DISK ROTOR, AND HOT-STAMPED ARTICLE FOR AUTOMOBILE BRAKE DISK ROTORS

(57) A ferritic stainless steel sheet for an automobile brake disc rotor includes: 0.001 to 0.05 mass% of C; 0.001 to 0.05 mass% of N; 0.3 to 4.0 mass% of Si; 0.01 to 2.0 mass% of Mn; 0.01 to 0.05 mass% of P; 0.0001 to 0.02 mass% of S; 10 to 20 mass% of Cr; one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and a balance consisting of Fe and impurities. After a hot stamping treatment, a crystal grain size is in a range from 100 to 200 μm, and precipitates each having a grain size of 500 nm or less are present at a density of 0.01 to 20 pieces per square micrometer.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a ferritic stainless steel sheet for an automobile brake disc rotor, an automobile brake disc rotor and a hot-stamped product for an automobile brake disc rotor, which have excellent heat resistance and formability, and specifically to a ferritic stainless steel sheet suitably used for an automobile brake disc rotor and the like that are required to have high-temperature strength.

BACKGROUND ART

[0002] A disc brake is widely used as one of automobile brake systems. This disc brake reduces a speed of an automobile by pressing a disc-like structure connected to a tire, called a disc rotor, between brake pads to cause friction, thereby converting kinetic energy to thermal energy. As a material for this disc rotor, flake graphite cast iron (hereinafter referred to as cast iron) is used in light of thermal conductivity, a cost and the like.

[0003] Cast iron, to which an element improving corrosion resistance is not added, is inferior in corrosion resistance and thus gathers red rust upon being left. This red rust conventionally is not so noticeable due to a position of the disc that is lower than a line of sight and a shape of a wheel. However, since aluminum is used for a material for the wheel and a spoke is made thinner in order to respond to a request for improvement in fuel efficiency, the rust of the disc cannot be left ignored, thereby generating a need for improving corrosion resistance.

[0004] A material having excellent corrosion resistance is exemplified by stainless steel. Specifically, a martensitic material, i.e., SUS410, is widely used for a two-wheeled vehicle such as a motorcycle. This is because the disc rotor for the two-wheeled vehicle is exposed to be easily noticeable and thus corrosion resistance is considered as important. However, stainless steel is inferior in thermal conductivity to cast iron. In the two-wheeled vehicle, a brake system being exposed to have excellent cooling performance allows use of even stainless steel with no problem. In a case of an automobile, since a brake system including a tire is housed in a wheelhouse, the disc rotor is less likely to be cooled and has low thermal conductivity, whereby stainless steel has not been applied thereto.

[0005] However, for recent EV, FCV, HV and the like, a "regenerative brake" that converts kinetic energy to electrical energy during running to recover the electrical energy has been increasingly adopted. This application reduces frictional heat generated by friction between the disc rotor and the pads, allowing a growing possibility for application thereof also to stainless steel that is inferior in thermal conductivity to cast iron.

[0006] Another problem that prevents application of stainless steel to the disc brake of the automobile is formability. The disc rotor for the two-wheeled vehicle is in a form of a ring-shaped disc, and is produced, without requiring large machining, by punching plate-shaped stainless steel. On the other hand, the current disc rotor for the automobile is in a form of a disc whose center is squeezed, called a hat shape, and is produced by casting. Machining stainless steel to be formed into this shape requires deep drawing. However, stainless steel used for the two-wheeled vehicle is martensitic stainless steel, which has extremely high hardness and entails machining difficulty. As one method of solution thereto, hot stamping involving pressing at a high temperature recently has been increasingly used. The hot stamping also allows forming stainless steel into a hat shape with a high precision.

[0007] Against this background, in order to meet the request for improvement in fuel efficiency, the disc rotor needs to be made thinner and lighter. However, since cast iron is low in strength and the disc rotor is typically produced by casting, there is a limit to thinning thereof. In addition, since a temperature to be reached at braking of the automobile is said to be near 700 degrees C at a maximum, it may be difficult to apply martensitic stainless steel having a heat resistance temperature of near 500 degrees C. Moreover, a temperature to be reached under driving conditions of frequent braking on a mountain road or the like may be 300 degrees C.

[0008] Patent Literature 1 relates to a stainless steel disc rotor for the automobile but mainly focuses on formability not on high-temperature strength. Furthermore, Patent Literature 2 improves strength by martensitic phases including highly saturated solid solution C and N but does not describe strength near 700 degrees C. Both Patent Literatures 1 and 2 adopt a martensitic structure but are not found to reliably provide heat resistance near 700 degrees C.

CITATION LIST

PATENT LITERATURE(S)

[0009]

Patent Literature 1: JP 5700172 B
Patent Literature 2: JP 2016-117925 A

SUMMARY OF THE INVENTION

PROBLEM(S) TO BE SOLVED BY THE INVENTION

[0010] The invention relates to a ferritic stainless steel sheet for an automobile brake disc rotor having excellent heat resistance and formability. A target component, which is an intended use of the invention whose problem is to be solved, is a braking system component for an automobile, particularly a disc rotor.

[0011] The disc rotor for the automobile having a hat shape requires formability. In addition, since a temperature to be reached is usually about 100 degrees C in driving on a city road and about 300 degrees C in driving on a mountain road while being near 700 degrees C at a maximum, thinning thereof requires strength in an intermediate to high temperature range. Since cast iron is molded by casting, thinning of the disc rotor deteriorates metal flow, which may result in a failure of molding. Moreover, since cast iron is low in strength, the thinning of the disc rotor cannot reliably secure sufficient strength as a disc rotor. Ferritic stainless steel can be formed into a hat shape through hot stamping with a high precision. However, stainless steel having low strength cannot be thinned. Meanwhile, stainless steel having high strength, due to requiring an excessive load in hot stamping, cannot be formed into a hat shape with a high precision or is likely to cause cracking. Martensitic stainless steel is excellent in formability in hot stamping but has a heat resistance temperature of about 500 degrees C, thus failing to achieve both formability and heat resistance.

[0012] The invention provides a ferritic stainless steel sheet for an automobile brake disc rotor, an automobile brake disc rotor and a hot-stamped product for an automobile brake disc rotor, which have excellent heat resistance and formability.

MEANS FOR SOLVING THE PROBLEM(S)

[0013] In order to solve the above problems, the inventors have focused on and studied in detail precipitates of a ferritic stainless steel sheet. The precipitates may be formed in the steel in a temperature range in which the component according to the invention is formed through hot stamping. The finely dispersed precipitates can improve strength of a material. However, presence of the precipitates before the forming results in excessively high strength to reduce elongation of the steel, making it likely for cracking to occur during the forming. Accordingly, it has been believed that finely forming the precipitates during the hot stamping can reliably secure formability and strength after the hot stamping. After intense studies to achieve the above objects, the inventors have obtained the following findings.

[0014] By appropriately controlling an added amount of Si, setting a finishing temperature after hot rolling in a range from 900 to 1100 degrees C and setting a winding temperature at 650 degrees C or less, a crystal grain size is increased during heating in the hot stamping to form the precipitates during the hot stamping. Setting the finishing temperature at more than 950 degrees C effectively increases the crystal grain size to improve strength also in an intermediate temperature range. Since the precipitates are finely formed in crystal grains of the steel, excellent high-temperature strength during use as a disc rotor can be attained. The precipitates formed at grain boundaries are likely to grow and coarsen. In this regard, it has been found that the precipitates are formed mainly in the crystal grains by appropriately controlling the crystal grain size during heating in the hot stamping. The precipitates in the crystal grains are less likely to grow than the precipitates at the grain boundaries and thus are less likely to coarsen during use. The precipitates are finely formed in the grains during the hot stamping, thereby effectively exhibiting precipitation strengthening. Accordingly, a heat-resistant ferritic stainless steel sheet applicable to a disc rotor has been successfully provided.

[0015] A summary of the invention for solving the above problems is as follows.

[1] A ferritic stainless steel sheet for an automobile brake disc rotor includes: 0.001 to 0.05 mass% of C; 0.001 to 0.05 mass% of N; 0.3 to 4.0 mass% of Si; 0.01 to 2.0 mass% of Mn; 0.01 to 0.05 mass% of P; 0.0001 to 0.02 mass% of S; 10 to 20 mass% of Cr; one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and a balance consisting of Fe and impurities,
through a heat treatment (hereinafter referred to as a "hot stamping pseudo heat treatment") in which the steel sheet is heated to 1000 degrees C and subsequently cooled by being retained in a range from 890 to 700 degrees C for one to ten minutes, a crystal grain size is in a range from 100 to 200 μm, and precipitates each having a grain size of 500 nm or less are at a density of 0.01 to 20 pieces per square micrometer, and the ferritic stainless steel sheet is a ferritic stainless steel for hot stamping.

[2] A ferritic stainless steel sheet for an automobile brake disc rotor includes: 0.001 to 0.05 mass% of C; 0.001 to 0.05 mass% of N; 0.3 to 4.0 mass% of Si; 0.01 to 2.0 mass% of Mn; 0.01 to 0.05 mass% of P; 0.0001 to 0.02 mass% of S; 10 to 20 mass% of Cr; one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and a balance consisting of Fe and impurities,
the ferritic stainless steel sheet in which a crystal grain size is in a range from 100 to 200 μm and precipitates each having a grain size of 500 nm or less are present at a density of 0.01 to 20 pieces per square micrometer is in a

form of a hot-stamped product.

[3] A ferritic stainless steel sheet for an automobile brake disc rotor includes: 0.001 to 0.05 mass% of C; 0.001 to 0.05 mass% of N; 0.3 to 4.0 mass% of Si; 0.01 to 2.0 mass% of Mn; 0.01 to 0.05 mass% of P; 0.0001 to 0.02 mass% of S; 10 to 20 mass% of Cr; one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and a balance consisting of Fe and impurities.

[4] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangement, the ferritic stainless steel sheet is a ferritic stainless steel sheet for hot stamping.

[5] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangement, fracture elongation at 1000 degrees C is 50% or more, and 0.2% proof strength at 700 degrees C after the hot stamping pseudo heat treatment is 80 MPa or more.

[6] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangement, 0.2% proof strength at 700 degrees C is 80 MPa or more.

[7] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangements, the crystal grain size is in a range from 130 to 200 μm.

[8] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangement, fracture elongation at 1000 degrees C is 50% or more.

[9] In the ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangement, 0.2% proof strength at 300 degrees C is 170 MPa or more.

[10] The ferritic stainless steel sheet for an automobile brake disc rotor with the above arrangements further includes, in place of a part of Fe, at least one of 0.0001 to 0.0030 mass% of B, 0.001 to 4.0 mass% of Al, 0.01 to 3.0 mass% of Cu, 0.01 to 3.0 mass% of Mo, 0.001 to 2.0 mass% of W, 0.001 to 1.0 mass% of V, 0.01 to 0.5 mass% of Sn, 0.01 to 1.0 mass% of Ni, 0.0001 to 0.01 mass% of Mg, 0.005 to 0.5 mass% of Sb, 0.001 to 0.3 mass% of Zr, 0.001 to 0.3 mass% of Ta, 0.001 to 0.3 mass% of Hf, 0.001 to 0.3 mass% of Co, 0.0001 to 0.01 mass% of Ca, 0.001 to 0.2 mass% of REM, and 0.0002 to 0.3 mass% of Ga.

[11] An automobile brake disc rotor is made of the stainless steel sheet with the above arrangements.

[12] A hot-stamped product for an automobile brake disc rotor is made of the stainless steel sheet with the above arrangements.

[0016] According to the above aspects of the invention, a ferritic stainless steel sheet improves in heat resistance and formability to provide a material suitable for an automobile brake disc rotor, thereby attaining significant effects such as reducing a weight and improving an appearance thereof.

DESCRIPTION OF EMBODIMENT(S)

[0017] In producing an automobile brake disc rotor using a ferritic stainless steel sheet through hot stamping, the steel sheet is heated to about 1000 degrees C for the hot stamping. The steel sheet before the hot stamping is required to have sufficient ductility for the hot stamping, which is performed at about 1000 degrees C. Meanwhile, an automobile brake disc rotor after the hot stamping is required to achieve sufficient high-temperature strength.

[0018] As described above, a temperature range for forming through the hot stamping may allow formation of precipitates. The precipitates being finely dispersed in the steel can improve strength of a material. However, presence of the precipitates before the forming results in excessively high strength to reduce elongation, making it likely for cracking to occur during the forming through the hot stamping. Accordingly, the invention secures hot stamping formability and strength after the hot stamping by finely forming the precipitates during the hot stamping.

[0019] A crystal grain size of the steel during the hot stamping is given an attention. In a case where the crystal grain size is small, a ratio of grain boundaries in the steel is high, thus resulting in formation of more precipitates at the grain boundaries during the hot stamping. The precipitates formed at the grain boundaries are likely to grow and coarsen, and thus fine precipitates are not likely to be obtained. According to the invention, it has been found that the precipitates are formed mainly in the grains by growing and appropriately controlling the crystal grain size during heating in the hot stamping. The precipitates in the grains are less likely to grow than the precipitates at the grain boundaries and thus are less likely to coarsen during use. The precipitates are finely formed in the grains during the hot stamping to effectively exhibit precipitation strengthening after the hot stamping, thereby securing strength after the forming.

[0020] As described above, according to the invention, it has been found that: finely forming the precipitates in the grains is crucial in terms of high-temperature strength after the hot stamping; and for this purpose, growing the crystal grain size during the heating in the hot stamping to a certain extent is required. Specifically, it has been found that refinement of the precipitates can be achieved by having the crystal grain size after the hot stamping in a range from 100 to 200 μm. In addition, it also has been found that the crystal grain size during the hot stamping is the same as the crystal grain size after the hot stamping. With a crystal grain size in the above range, the precipitates are finely formed in the grains and are not likely to grow, from which it is presumed that there is a corresponding relationship therebetween.

[0021] Accordingly, a metal structure in the invention has been defined by the crystal grain size after the hot stamping. By controlling the crystal grain size after the hot stamping in a range from 100 to 200 μm, the precipitates are finely formed during the hot stamping and are not likely to grow, thereby effectively exhibiting precipitation strengthening. With a crystal grain size after the hot stamping being 100 μm or more, the precipitates are finely formed and thus sufficient proof strength up to near 700 degrees C has been obtained. Moreover, with a crystal grain size after the hot stamping being 130 μm or more, sufficient proof strength has been obtained also in an intermediate temperature range (i.e., near 300 degrees C).

[0022] The crystal grains in the steel grow by the heating in the hot stamping to increase the crystal grain size. There is a tendency that the larger the crystal grain size before the hot stamping is, the larger the crystal grain size during and after the hot stamping also is. The crystal grain size after the hot stamping exceeding 200 μm means that the crystal grain size of the steel sheet before the hot stamping is also large, and consequently, toughness of the steel sheet significantly reduces. Accordingly, an upper limit of the crystal grain size after the hot stamping has been set at 200 μm.

[0023] In order to effectively exhibit precipitation strengthening after the hot stamping, the precipitates each having a grain size of 500 nm or less are defined to be present at a density of 0.01 to 20 pieces per square micrometer in the steel after the hot stamping. With the precipitates each having a grain size of 500 nm or less being present at a density of 0.01 to 20 pieces per square micrometer, sufficient proof strength up to near 700 degrees C is obtained. With a grain size exceeding 500 nm, precipitation strengthening is not likely to function. With a density of the precipitates being less than 0.01 pieces per square micrometer, precipitation strengthening is also not likely to function due to a small precipitation amount. A density exceeding 20 pieces per square micrometer excessively increases strength, making it likely for cracking to occur. In view of the above, it is preferable that the precipitates being in the grains and each having a grain size of 500 nm or less are present at a density of 0.01 to 20 pieces per square micrometer.

[0024] In a case where a product to be evaluated is a hot-stamped product, or a final product in a form of an automobile brake disc rotor, the crystal grain size and the density of the precipitates in the steel can be evaluated. Meanwhile, in a case where the product to be evaluated is a steel sheet before the hot stamping, the crystal grain size and the density of the precipitates in the steel may be evaluated after subjecting the steel sheet to a hot stamping pseudo heat treatment. The hot stamping pseudo heat treatment may be a heat treatment including: heating the steel sheet to 1000 degrees C; and subsequently cooling by retaining the steel sheet in a range from 890 to 700 degrees C for one to ten minutes (e.g., two minutes).

[0025] A basis for defining contents of respective components in the steel will be described below.

[0026] C deteriorates formability and corrosion resistance to reduce high-temperature elongation and high-temperature strength of a steel sheet, and precipitates Cr carbonitrides and Nb carbonitrides to make a density of the obtained precipitates excessive after hot stamping. Accordingly, the C content is preferably as small as possible and thus is set at 0.05% or less. The C content is preferably 0.020% or less, more preferably 0.0015% or less. However, since an excessive reduction in the C content increases a refining cost, the C content is preferably 0.001% or more.

[0027] Similarly to C, N deteriorates formability and corrosion resistance to reduce high-temperature elongation and high-temperature strength of a steel sheet, and precipitates Cr carbonitrides and Nb carbonitrides to make a density of the obtained precipitates excessive after hot stamping. Accordingly, the N content is preferably as small as possible and thus is set at 0.05% or less. The N content is preferably 0.020% or less, more preferably 0.015% or less. However, since an excessive reduction in the N content increases a refining cost, the N content is preferably 0.001% or more.

[0028] Si is an element useful as a deoxidizer and is also an element improving high-temperature strength, oxidation resistance and high-temperature salt-damage resistance. The high-temperature strength, oxidation resistance and high-temperature salt-damage resistance improve in line with an increase in the Si content. In order to improve the high-temperature strength, controlling of precipitation is crucial, and thus this effect is attained by finely forming precipitates in a large amount. Si has an effect of finely forming aging precipitates and the effect is stably exhibited at 0.3% or more of Si. However, excessive addition of Si: reduces ductility of a steel sheet at a normal temperature and a high temperature to harden a hot-rolled steel sheet, thereby reducing toughness; and causes refinement of a crystal grain size and formation of excessive precipitates during hot stamping. Accordingly, an upper limit of the Si content is set at 4.0%.In terms of picklability and toughness, the Si content is preferably in a range from 0.3% to 3.5%.In terms of productivity, the Si content is preferably 3.0% or less.

[0029] Mn is an element added as a deoxidizer and contributes to increasing high-temperature strength in an intermediate temperature range. However, addition of Mn at more than 2.0%: causes MnS (which does not contribute to strengthening) to precipitate in a large amount to reduce the high-temperature strength after a pseudo heat treatment; and precipitates Mn oxides on a surface layer at a high temperature to make it likely to cause unfavorable adhesion of scales and abnormal oxidation. In particular, there is a tendency that combined addition of Mn with Mo and W causes abnormal oxidation with respect to the Mn amount. Accordingly, an upper limit of the Mn content is set at 2.0%.In terms of picklability and normal-temperature ductility in producing a steel sheet, the Mn content is preferably in a range from 0.01% to 1.5%, more preferably 1.0% or less.

[0030] P is an impurity mixed mainly from a material in steelmaking refining. As the P content increases, toughness

and weldability of a steel sheet reduce. Thus, the P content is preferably reduced as low as possible, but the P content of less than 0.01% increases a production cost due to use of a low-P material. Accordingly, the P content in the invention is set at 0.01% or more. The P content is more preferably 0.02% or more. Meanwhile, the P content of more than 0.05% not only causes more significant hardening but also deteriorates corrosion resistance, toughness and picklability. Accordingly, an upper limit of the P content is set at 0.05%.The P content is more preferably 0.04% or less.

[0031] S is an element deteriorating corrosion resistance and oxidation resistance. However, since an effect of improving workability through bonding of S to Ti and C is exhibited at 0.0001% or more of S, a lower limit of the S content is set at 0.0001%.In terms of a refining cost, the S content is preferably 0.0010% or more. Meanwhile, excessive addition of S allows S to be bonded to Ti and C to reduce an amount of solid solution Ti and coarsen precipitates, thereby reducing toughness and high-temperature strength of a steel sheet. Accordingly, an upper limit of the S content is set at 0.02%.In terms of high-temperature oxidation properties, the S content is preferably 0.0090% or less.

[0032] Cr is an essential element for ensuring oxidation resistance and corrosion resistance in the invention. Less than 10% of Cr cannot secure, particularly, oxidation resistance, to further reduce proof strength at 700 degrees C after hot stamping and coarsen a crystal grain size. Meanwhile, since more than 20% of Cr causes a reduction in workability and deterioration of toughness and makes the number of precipitates after hot stamping excessively large, the Cr content is set in a range from 10 to 20%.In terms of productivity and scale peelability, the Cr content is preferably in a range from 12% to 18%, more preferably 15% or less.

[0033] One or both of 0.001 to 0.5% of Ti and 0.01 to 0.8% of Nb are contained.

[0034] Ti is an element bonded to C, N and S to improve corrosion resistance, intergranular corrosion resistance, normal-temperature ductility and deep drawability. Accordingly, Ti is added as required. Combined addition where Ti is added in an appropriate amount with Nb and Mo increases an amount of solid solution of Nb and Mo and improves high-temperature strength in hot rolling and annealing, thereby improving thermal fatigue properties. This effect is exhibited at 0.001% or more of Ti and thus a lower limit of the Ti content is set at 0.001%.Meanwhile, addition of more than 0.5% of Ti not only increases an amount of solid solution Ti to reduce ductility of a steel sheet at a normal temperature and a high temperature but also makes the number of precipitates after hot stamping excessive and further forms coarse Ti precipitates to be an initiation point of cracking in hole expansion, thereby deteriorating press workability. Since oxidation resistance also deteriorates, an added amount of Ti is set at 0.5% or less. In terms of occurrence of surface flaws and toughness, the Ti content is preferably in a range from 0.05% to 0.2%.

[0035] Nb is an element effective in improving high-temperature strength through solid solution strengthening and precipitation strengthening by fine precipitates. Nb also has a function of fixing C and N as carbonitrides to contribute to growth of recrystallization texture affecting corrosion resistance and an r value of a product sheet. These effects are exhibited at 0.01% or more of Nb and thus a lower limit of the Nb content is set at 0.01%.Meanwhile, since addition of more than 0.8% of Nb reduces high-temperature ductility of the steel sheet and makes the number of precipitates after hot stamping excessive to further significantly harden the steel sheet and deteriorate productivity, an upper limit of the Nb content is set at 0.8%.In terms of a material cost and toughness, the Nb content is preferably in a range from 0.3% to 0.6%.

[0036] In addition to the above components, a balance consists of Fe and impurities as components in the steel. The invention may further contain the following components in place of a part of Fe as required.

[0037] B is an element improving secondary workability, high-temperature strength and thermal fatigue properties of a product in pressing. B causes fine precipitation of Laves phases and the like and exhibits long-term stability of this precipitation strengthening, thereby contributing to inhibiting a reduction in strength and improving a thermal fatigue life. This effect is exhibited at 0.0001% or more of B. Meanwhile, since excessive addition of B not only causes hardening and deteriorates susceptibility to intergranular corrosion and oxidation resistance but also causes weld cracking, the B content is set at 0.0030% or less. In terms of corrosion resistance and a production cost, the B content is preferably 0.0010% or less, more preferably 0.0005% or less.

[0038] Al is an element to be added as a deoxidizing element and improve oxidation resistance. Al is also useful for improving high-temperature strength as a solid solution strengthening element. This effect is stably exhibited at 0.001% or more of Al. Meanwhile, since excessive addition of Al hardens steel to significantly reduce uniform elongation and toughness, an upper limit of the Al content is set at 4.0%.In terms of occurrence of surface flaws, weldability and productivity, the Al content is preferably in a range from 0.01% to 2.2%.

[0039] Cu is an element effective in improving corrosion resistance. This effect is stably exhibited at 0.01% or more of Cu. Although Cu also improves high-temperature strength through precipitation strengthening by precipitation of ε-Cu, excessive addition of Cu reduces hot workability. Accordingly, an upper limit of the Cu content is set at 3.0%.In terms of thermal fatigue properties, productivity and weldability, the Cu content is preferably 1.6% or less.

[0040] Mo is an element effective in solid solution strengthening at a high temperature and improves corrosion resistance and high-temperature salt-damage resistance. Accordingly, Mo is added at 0.01% or more as required. Since addition of 3.0% or more of Mo significantly deteriorates normal-temperature ductility and oxidation resistance, the Mo content is set at 3.0% or less. In terms of thermal fatigue properties and productivity, the Mo content is preferably in a

range from 0.3% to 0.9%.

[0041] Similarly to Mo, W is an element effective in solid solution strengthening at a high temperature and forms Laves phases (Fe_2W) to exhibit an effect of precipitation strengthening. In particular, combined addition of W with Nb and Mo forms Laves phases of Fe_2(Nb, Mo, W), however, addition of W inhibits coarsening of the Laves phases to improve precipitation strengthening capability. This effect is exhibited by addition of 0.001% or more of W. Meanwhile, since addition of more than 2.0% of W increases a cost and reduces normal-temperature ductility, an upper limit of the W content is set at 2.0%.In terms of productivity, low-temperature toughness and oxidation resistance, an added amount of W is preferably 1.5% or less.

[0042] V is an element improving corrosion resistance and thus is added as required. This effect is stably exhibited by addition of 0.001% or more of V. Meanwhile, since addition of more than 1% of V coarsens precipitates to reduce high-temperature strength and deteriorate oxidation resistance, an upper limit of the V content is set at 1%.In terms of a production cost and productivity, the V content is preferably in a range from 0.08% to 0.5%.

[0043] Sn is an element improving corrosion resistance, improves high-temperature strength in an intermediate temperature range, and thus is added as required. These effects are exhibited at 0.01% or more of Sn. Meanwhile, since addition of more than 0.5% of Sn significantly reduces productivity and toughness, the Sn content is set at 0.5% or less. In terms of oxidation resistance and a production cost, the Sn content is preferably 0.1% or more.

[0044] Ni is an element improving acid resistance, toughness and high-temperature strength and thus is added as required. These effects are exhibited at 0.01% or more of Ni. Meanwhile, since addition of more than 1.0% of Ni increases a cost, the Ni content is set at 1.0% or less. In terms of productivity, the Ni content is preferably in a range from 0.08% to 0.5%.

[0045] Mg may be added as a deoxidizing element and is an element refining a slab structure to contribute to improving formability. In addition, Mg oxides become precipitation sites of carbonitrides such as Ti(C, N) and Nb(C, N) and have an effect of allowing finely dispersed precipitation thereof. This effect is exhibited at 0.0001% or more of Mg, thereby contributing to improving toughness. However, since excessive addition of Mg deteriorates weldability, corrosion resistance and surface quality, an upper limit of the Mg content is set at 0.01%.In terms of a refining cost, the Mg content is preferably in a range from 0.0003% to 0.0010%.

[0046] Sb contributes to improving corrosion resistance and high-temperature strength, and is added at 0.005% or more as required. Since addition of more than 0.5% of Sb may excessively cause slab cracking and a reduction in ductility in producing a steel sheet, an upper limit of the Sb content is set at 0.5%.In terms of a refining cost and productivity, the Sb content is preferably in a range from 0.01% to 0.3%.

[0047] Similarly to Ti and Nb, Zr is a carbonitride forming element and an element improving corrosion resistance and deep drawability, and thus is added as required. These effects are exhibited at 0.001% or more of Zr. Meanwhile, since addition of more than 0.3% of Zr significantly deteriorates productivity, the Zr content is set at 0.3% or less. In terms of a cost and surface grade, the Zr content is preferably in a range from 0.1% to 0.2%.

[0048] Zr, Ta and Hf are bonded to C and N to contribute to improving toughness and thus are added at 0.001 % or more as required. However, since addition of more than 0.3% of Zr, Ta and Hf increases a cost and significantly deteriorates productivity, an upper limit of each of the Zr, Ta and Hf contents is set at 0.3%.In terms of a refining cost and productivity, the Zr, Ta and Hf contents are each preferably in a range from 0.01% to 0.08%.

[0049] Co contributes to improving high-temperature strength and thus is added at 0.001% or more as required. Since addition of more than 0.3% of Co deteriorates toughness, an upper limit of the Co content is set at 0.3%.In terms of a refining cost and productivity, the Co content is preferably in a range from 0.01% to 0.1%.

[0050] Ca may be added for desulfurization, of which effect is exhibited at 0.0001 % or more of Ca. However, since addition of more than 0.01% of Ca forms coarse CaS to deteriorate toughness and corrosion resistance, an upper limit of the Ca content is set at 0.01%.In terms of a refining cost and productivity, the Ca content is preferably in a range from 0.0003% to 0.0020%.

[0051] REM may be added as required in order to improve toughness and oxidation resistance through refinement of various precipitates, of which effect is exhibited at 0.001% or more of REM. However, since addition of more than 0.2% of REM significantly deteriorates castability and reduces ductility, an upper limit of the REM content is set at 0.2%.In terms of a refining cost and productivity, the REM content is preferably 0.05% or less. Specifically, REM (rare-earth elements) collectively refers to two elements of scandium (Sc) and yttrium (Y) and fifteen elements (lanthanoid) from lanthanum (La) to lutetium (Lu) according to general definition. These elements may be added alone or may be added in a form of a mixture.

[0052] Ga may be added at 0.3% or less in order to improve corrosion resistance and inhibit hydrogen embrittlement. In order to form sulfides and hydrides, a lower limit of the Ga content is preferably 0.0002%.In terms of productivity, a cost, ductility and toughness, the Ga content is preferably 0.0020% or less.

[0053] Although other components are not specifically defined in the invention, 0.001 to 0.1% of Bi or the like may be added as required in the invention. It should be noted that the contents of common harmful elements such as As and Pb and impurity elements are preferably reduced as much as possible.

[0054] Next, a production method will be described.

[0055] The production method of a steel sheet according to the invention includes processes of steelmaking, hot rolling, annealing and pickling. In the steelmaking, steel containing the above essential components and components added as required is suitably melted in a converter furnace and subsequently subjected to secondary refining. The molten steel is formed into a slab according to a known casting process (continuous casting). The slab is heated to a predetermined temperature and hot-rolled to have a predetermined thickness through continuous rolling. The hot rolling is performed by rolling the slab using a hot rolling mill including a plurality of stands, which is followed by winding.

[0056] The annealing process after the hot rolling may be omitted.

[0057] In order for a crystal grain size during hot stamping to fall in a range from 100 to 200 μm, a finishing temperature after the hot rolling is preferably in a range from 900 to 1100 degrees C. Afinishing temperature of less than 900 degrees C does not sufficiently grow the crystal grain size of the steel sheet, consequently failing to grow the crystal grain size after the hot stamping to 100 μm or more. Meanwhile, a finishing temperature of more than 1100 degrees C excessively grows the crystal grain size of the steel sheet to make the crystal grain size after the hot stamping more than 200 μm. The finishing temperature after the hot rolling is more preferably more than 950 degrees C. Setting the finishing temperature at more than 950 degrees C allows the crystal grain size to grow to be 130 μm or more, thereby exhibiting an effect of improving strength in an intermediate temperature range.

[0058] Moreover, since a winding temperature of more than 650 degrees C reduces toughness of the hot-rolled steel sheet, the winding temperature is preferably 650 degrees C or less.

[0059] Next, a forming method will be described. In forming of the steel sheet according to the invention, the hot stamping in which the steel sheet is heated to a predetermined temperature, formed into a hat shape at a high temperature and subsequently cooled is used. A heating temperature is set in a range from 900 to 1000 degrees C, and the cooling is performed subsequent to the forming. In order to finely form precipitates in a large amount, the cooling is performed by retaining the steel sheet in a range from 890 to 700 degrees C for one to ten minutes. Since a retention time of less than one minute does not cause sufficient precipitation to make an amount of precipitation strengthening small, a lower limit of the retention time is set at one minute. The excessively long retention time grows and coarsens finely formed precipitates to reduce the amount of precipitation strengthening. Since the excessively long retention time also significantly reduces productivity, an upper limit of the retention time is set at ten minutes. In terms of stability of the precipitates, the retention time is preferably in a range from 1.5 minutes to five minutes.

[0060] A "ferritic stainless steel sheet for an automobile brake disc rotor in a form of a hot-stamped product" in the invention refers to a steel sheet obtained after hot stamping. In other words, the ferritic stainless steel sheet refers to a hot-stamped product for an automobile brake disc rotor for which a stainless steel sheet is used.

[0061] In addition, the hot-stamped product for an automobile brake disc rotor made of a stainless steel sheet refers to a hot-stamped product for an automobile brake disc rotor obtained by subjecting a steel sheet to hot stamping.

[0062] Moreover, the automobile brake disc rotor made of a stainless steel sheet refers to an automobile brake disc rotor obtained by subjecting a stainless steel sheet to hot stamping and further machining.

Example(s)

[0063] Steel having chemical composition shown in Tables 1 and 2 was melted and cast into a slab. The slab was hot-rolled under hot rolling conditions shown in Tables 3 and 4 to prepare a 6-mm-thick hot-rolled coil. The coil was pickled. In Table 1, Nos. A1 to A34 are steel according to the invention. In Table 2, Nos. B1 to B14 are comparative steel and No. B15 is steel without being subjected to a heat treatment. Numerical values outside respective ranges of the invention are underlined.

[0064] The thus obtained hot-rolled steel sheet (other than B15) was subjected to a hot stamping pseudo heat treatment (hereinafter simply referred to as a "pseudo heat treatment") by: heating the steel sheet to 1000 degrees C; then retaining the steel sheet in a range from 890 to 700 degrees C for two minutes; and subsequently water-cooling the steel sheet. In a case where the steel sheet after the pseudo heat treatment had cracking, "cracking" was indicated in a column of "Quality after Pseudo Heat Treatment/Notes" in Table 4.

[0065] The material that was subjected to the hot stamping pseudo heat treatment was measured for a crystal grain size at a t/4 portion (according to JIS G 0551, and numerical values were rounded off to the closest whole number). By setting an image magnification at 50 times and the number of imaging fields at five, an average crystal grain size of the five imaging fields was calculated. Furthermore, five fields of the same material that was subjected to the pseudo heat treatment were observed under bright field microscopy at the image magnification of 12500 times using a 200 kV field emission transmission electron microscope (EM-2100F) produced by JEOL Ltd., thereby evaluating precipitates. An equivalent circle diameter of the precipitates observed in the bright field microscope image was measured to obtain the grain size of the precipitates. The precipitates each having a grain size of 500 nm or less were used to calculate an average density of the precipitates at the five fields.

[0066] A high-temperature tensile test piece was taken from the material that was subjected to the pseudo heat

treatment such that a rolling direction thereof was a tensile direction. The test piece was subjected to a tensile test at 300 degrees C and 700 degrees C to measure 0.2% proof strength (according to JIS G 0567, and numerical values were rounded off to the closest whole number). Here, at 0.2% proof strength at 300 degrees C of 150 MPa or more and 0.2% proof strength at 700 degrees C of 80 MPa or more, the material is applicable to a general disc rotor and thinning thereof is achievable. Accordingly, steel having 0.2% proof strength at 300 degrees C of 150 MPa or more and 0.2% proof strength at 700 degrees C of 80 MPa or more was evaluated to pass and was indicated by a mark "A" in Tables 3 and 4. In addition, steel having 0.2% proof strength at 300 degrees C of 170 MPa or more and 0.2% proof strength at 700 degrees C of 100 MPa or more was evaluated to be particularly superior and was indicated by a mark "S". Steel other than the above was evaluated to fail and was indicated by a mark "X".

[0067] In order to evaluate press formability of the hot-rolled steel sheet before the hot stamping at a high temperature, a high-temperature tensile test piece was taken from the hot-rolled steel sheet such that a rolling direction thereof was a tensile direction. The test piece was subjected to a tensile test at 1000 degrees C to measure fracture elongation (according to JIS G 0567, and numerical values were rounded off to the closest whole number). Here, at fracture elongation at 1000 degrees C of 50% or more, the steel sheet can be machined into a hat shape. Accordingly, steel having fracture elongation at 1000 degrees C of 50% or more was evaluated to pass and was indicated by a mark "A" in Tables 3 and 4. Moreover, steel having fracture elongation at 1000 degrees C of 65% or more was evaluated to be particularly superior and was indicated by a mark "S". Steel other than the above was evaluated to fail and was indicated by a mark "X".

[0068] In order to evaluate toughness of the hot-rolled steel sheet, a Charpy test piece (C direction notch) was prepared from the hot-rolled steel sheet and subjected to a Charpy impact test at a normal temperature. In a case where an average impact value of three tests was 10 J/cm^2 or less, "unfavorable toughness" was indicated in a column of "Notes" for steel sheet quality.

Table 1

	No.	Components Contained (mass%)										
		C	N	Si	Mn	P	S	Cr	Ti	Nb	Others	
Examples	A1	0.048	0.005	1.24	0.36	0.026	0.0008	13.6	0.009	0.41	-	
	A2	0.003	0.047	0.88	0.37	0.032	0.0008	14	0.009	0.42	-	
	A3	0.004	0.004	0.33	0.38	0.031	0.0008	13.1	0.007	0.40	-	
	A4	0.005	0.011	3.92	0.35	0.023	0.0006	13.5	0.009	0.44	-	
	A5	0.012	0.014	1.07	0.03	0.026	0.0006	13.1	0.009	0.40	-	
	A6	0.013	0.011	0.92	1.98	0.032	0.0007	13.2	0.009	0.41	-	
	A7	0.011	0.013	1.20	0.39	0.013	0.0008	13.9	0.008	0.44	-	
	A8	0.007	0.010	0.97	0.39	0.048	0.0007	13.4	0.009	0.47	-	
	A9	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	-	
	A10	0.013	0.007	0.82	0.30	0.031	0.0183	13.8	0.007	0.44	-	
	A11	0.012	0.004	1.22	0.36	0.031	0.0005	10.1	0.009	0.40	-	
	A12	0.008	0.006	1.26	0.34	0.029	0.0008	19.9	0.009	0.45	-	
	A13	0.009	0.012	1.12	0.40	0.024	0.0008	13.6	0.002	0.47	-	
	A14	0.014	0.010	0.81	0.36	0.027	0.0008	13.4	0.492	0.42	-	
	A15	0.008	0.005	0.87	0.38	0.034	0.0009	13.9	0.009	0.02	-	
	A16	0.012	0.008	1.10	0.37	0.029	0.0008	13.9	0.007	0.79	-	
	A17	0.004	0.006	1.09	0.37	0.032	0.0008	13.5	0.001	-	-	
	A18	0.006	0.006	1.02	0.37	0.033	0.0009	13.3	0.488	-	-	
	A19	0.008	0.006	1.22	0.31	0.034	0.0008	13.6	-	0.03	-	
	A20	0.007	0.004	0.82	0.38	0.022	0.0005	13.9	-	0.78	-	
	A21	0.011	0.007	0.84	0.37	0.029	0.0006	13.4	0.007	0.41	-	
	A22	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	B	0.0003
	A23	0.012	0.010	1.02	0.38	0.033	0.0002	13.8	0.009	0.41	Al	0.02
	A24	0.012	0.010	0.98	0.38	0.033	0.0002	13.8	0.009	0.41	Cu	0.04
	A25	0.012	0.010	1.01	0.38	0.033	0.0002	13.8	0.009	0.41	Mo	0.20
	A26	0.012	0.010	0.98	0.38	0.033	0.0002	13.8	0.009	0.41	W	0.100
	A27	0.012	0.010	1.04	0.38	0.033	0.0002	13.8	0.009	0.41	V	0.122
	A28	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	Sn, Sb	0.05, 0.02
	A29	0.012	0.010	0.98	0.38	0.033	0.0002	13.8	0.009	0.41	Ni	0.32
	A30	0.012	0.010	1.02	0.38	0.033	0.0002	13.8	0.009	0.41	Mg, Ca	0.0003, 0.0005
	A31	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	Co	0.101
	A28	0.012	0.010	0.97	0.38	0.033	0.0002	13.8	0.009	0.41	Ta, Hf	0.101, 0.01
	A29	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	Zr	0.012
	A30	0.012	0.010	1.01	0.38	0.033	0.0002	13.8	0.009	0.41	REM	0.01
	A31	0.012	0.010	0.99	0.38	0.033	0.0002	13.8	0.009	0.41	Ga	0.0051
	A32	0.012	0.006	1.04	0.33	0.031	0.0003	13.5	0.009	0.41	-	
	A33	0.010	0.007	0.91	0.31	0.031	0.0003	13.5	0.009	0.42	-	
	A34	0.009	0.009	0.91	0.31	0.031	0.0003	13.1	0.009	0.44	-	

Table 2

	No.	Components Contained (mass%)									
		C	N	Si	Mn	P	S	Cr	Ti	Nb	Others
Comparatives	B1	0.055	0.014	0.89	0.40	0.034	0.0008	13.6	0.008	0.41	-
	B2	0.008	0.062	1.28	0.33	0.029	0.0006	13.2	0.010	0.44	-
	B3	0.008	0.005	0.21	0.39	0.023	0.0006	13.2	0.010	0.45	-
	B4	0.003	0.004	4.23	0.30	0.023	0.0009	13.5	0.008	0.45	-
	B5	0.003	0.010	1.15	2.13	0.033	0.0008	13.7	0.010	0.43	-
	B6	0.008	0.004	0.88	0.32	0.058	0.0005	13.7	0.009	0.42	-
	B7	0.008	0.013	1.14	0.38	0.031	0.0387	13.1	0.008	0.41	-
	B8	0.010	0.003	1.25	0.35	0.028	0.0007	9.3	0.008	0.47	-
	B9	0.011	0.013	1.28	0.33	0.024	0.0005	20.9	0.010	0.47	-
	B10	0.003	0.010	1.22	0.40	0.025	0.0007	13.3	0.580	0.43	-
	B11	0.005	0.009	0.97	0.30	0.033	0.0006	13.9	0.010	0.87	-
	B12	0.007	0.005	0.87	0.35	0.032	0.0007	13.8	0.009	0.02	-
	B13	0.009	0.005	0.88	0.38	0.034	0.0009	13.9	0.010	0.41	-
	B14	0.009	0.005	0.82	0.33	0.022	0.0006	13.3	0.010	0.40	-
Untreated	B15	0.014	0.010	1.02	0.33	0.032	0.0006	13.3	0.009	0.42	-

Table 3

	No.	Hot Rolling Conditions		Steel Sheet Quality		Quality after Pseudo Heat Treatment				
		Finishing Temperature (°C)	Winding Temperature (°C)	Fracture Elongation at 1000 °C (%)	Notes	Crystal Grain Size (μm)	Number of Precipitates (pieces/ μm^2)	Proof Strength at 700 °C (MPa)	Proof Strength at 300 °C (MPa)	Notes
Examples	A1	1100	400	S		199	6.7	A	S	
	A2	900	630	A		103	5.7	A	A	
	A3	900	630	A		117	19.8	S	A	
	A4	1000	500	A		164	18	A	S	
	A5	1100	400	A		186	12.8	A	S	
	A6	1000	630	A		133	17	A	S	
	A7	1000	630	A		137	9	A	S	
	A8	1000	630	A		132	10.6	A	S	
	A9	1000	500	A		154	14.2	A	S	
	A10	1000	500	A		165	15.9	A	S	
	A11	1000	500	A		164	17.2	A	S	
	A12	1100	400	S		197	2.6	A	S	
	A13	1000	400	A		163	18.2	A	S	
	A14	1100	400	A		179	6.8	A	S	
	A15	1100	400	S		190	18.6	A	S	
	A16	900	630	A		112	13.8	A	A	
	A17	900	630	A		102	19.1	S	A	
	A18	1000	500	A		156	14.3	A	S	
	A19	900	630	A		112	13.7	A	A	
	A20	1000	500	A		166	7.5	A	S	
	A21	900	630	A		107	3.1	A	A	
	A22	1000	500	A		150	16.1	A	S	
	A23	1000	500	A		154	16.2	A	S	
	A24	1000	500	A		155	14.1	A	S	
	A25	1000	500	A		140	14.0	A	S	
	A26	1000	500	A		153	14.2	A	S	
	A27	1000	500	A		149	16.3	A	S	
	A28	1000	500	A		153	13.9	A	S	
	A29	1000	500	A		154	13.2	A	S	
	A30	1000	500	A		151	17.1	A	S	
	A31	1000	500	A		157	14.1	A	S	
	A28	1000	500	A		153	14.2	A	S	
	A29	1000	500	A		155	17.1	A	S	
	A30	1000	500	A		154	16.9	A	S	
	A31	1000	500	A		160	13.4	A	S	
	A32	955	550	A		131	10.2	A	S	
	A33	955	550	A		136	13.3	A	S	
	A34	955	600	A		148	16.6	A	S	

Table 4

	No.	Hot Rolling Conditions		Steel Sheet Quality		Quality after Pseudo Heat Treatment				
		Finishing Temperature (°C)	Winding Temperature (°C)	Fracture Elongation at 1000 °C (%)	Notes	Crystal Grain Size (μm)	Number of Precipitates (pieces/ μm^2)	Proof Strength at 700 °C (MPa)	Proof Strength at 300 °C (MPa)	Notes
Comparatives	B1	1100	400	X		181	25.2	A	A	
	B2	1100	500	X		172	24.8	A	A	
	B3	900	630	A		115	0.003	X	X	
	B4	1100	400	X	unfavorable toughness	81	28.2	S	A	cracking
	B5	1100	400	A		155	15.4	X	X	
	B6	1100	400	A	unfavorable toughness	181	9.3	A	A	
	B7	1100	400	A	unfavorable toughness	177	8.8	A	A	
	B8	1100	400	S	unfavorable toughness	231	14.3	X	X	
	B9	1000	500	X	unfavorable toughness	148	21.3	S	A	cracking
	B10	1100	500	X		173	22.1	S	A	cracking
	B11	1100	500	X		187	23.4	S	A	cracking
	B12	1150	400	A	unfavorable toughness	253	19.1	A	A	
	B13	850	400	X		88	0.002	X	X	
	B14	1000	700	A	unfavorable toughness	170	10.5	A	A	
Untreated	B15	1000	500	S		153	0.003	X	X	

[0069] As is evident from Tables 1 to 4, Examples have superior 0.2% proof strength at 700 degrees C after the hot stamping pseudo heat treatment to that of Comparatives. It has been found that the Examples, of which finishing temperature of the hot-rolled steel sheet is more than 950 degrees C, have a crystal grain size of 130 μm or more and all have particularly superior proof strength at 300 degrees C that is evaluated to be "S". In a case where even one of 0.2% proof strength at 300 degrees C and 700 degrees C after the pseudo heat treatment and fracture elongation of the hot-rolled steel sheet at 1000 degrees C was evaluated to fail and in a case where toughness of the hot-rolled steel sheet was unfavorable, application thereof to a disc rotor was determined as unsuitable. Accordingly, it has been found that the steel defined in the invention is excellent in heat resistance and formability.

[0070] Comparatives B1 and B2, which respectively had C and N concentrations exceeding the upper limit thereof, had unfavorable fracture elongation at 1000 degrees C of the steel sheets.

[0071] Comparative B3, whose Si concentration was below the lower limit thereof, had an insufficient number of precipitates after the pseudo heat treatment, thereby being low in proof strength at 300 degrees C and 700 degrees C. Comparative B4, whose Si concentration exceeded the upper limit thereof, had unfavorable elongation at 1000 degrees C of the steel sheet, an excessively small crystal grain size and an excessive number of precipitates after the pseudo heat treatment, thereby causing cracking.

[0072] Comparative B5, whose Mn concentration exceeded the upper limit thereof, had insufficient proof strength at 300 degrees C and 700 degrees C.

[0073] Comparatives B6 and B7, which respectively had P and S concentrations exceeding the upper limit thereof, had unfavorable toughness of the steel sheets.

[0074] Comparative B8, whose Cr concentration was below the lower limit thereof, had reduced high-temperature strength, resulting in unfavorable proof strength at 300 degrees C and 700 degrees C after the pseudo heat treatment. As is evident from an excessively large crystal grain size after the pseudo heat treatment, Comparative B8 also had an excessively large crystal grain size of the steel sheet, thereby causing unfavorable toughness of the steel sheet.

[0075] Comparatives B9, B10 and B11, which respectively had Cr, Ti and Nb concentrations exceeding the upper limit thereof, had unfavorable fracture elongation at 1000 degrees C of the steel sheets and an excessive number of precipitates during the pseudo heat treatment, thereby causing cracking.

[0076] As is evident from the finishing temperature of the hot rolling exceeding the upper limit thereof and an excessively

large crystal grain size after the pseudo heat treatment, Comparative B12 had an excessively large crystal grain size of the steel sheet, thereby causing unfavorable toughness of the steel sheet.

[0077] Comparative B13, whose finishing temperature of hot rolling was below the lower limit thereof, had an excessively small crystal grain size after the pseudo heat treatment and an excessively small number of precipitates, consequently obtaining unfavorable proof strength at 300 degrees C and 700 degrees C.

[0078] Comparative B14, whose winding temperature of the hot rolling exceeded the upper limit thereof, had unfavorable toughness of the steel sheet.

[0079] B15, which was indicated by "Untreated" in the left column in Table 2, was not subjected to the hot stamping pseudo heat treatment but evaluated for a crystal grain size, the number of precipitates and proof strength at 300 degrees C and 700 degrees C. As a result of failing to progress precipitation and obtaining an excessively small number of precipitates, B15 had unfavorable proof strength at 300 degrees C and 700 degrees C.

Claims

1. A ferritic stainless steel sheet for an automobile brake disc rotor, comprising:

0.001 to 0.05 mass% of C;
0.001 to 0.05 mass% of N;
0.3 to 4.0 mass% of Si;
0.01 to 2.0 mass% of Mn;
0.01 to 0.05 mass% of P;
0.0001 to 0.02 mass% of S;
10 to 20 mass% of Cr;
one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and
a balance consisting of Fe and impurities, wherein
through a heat treatment (hereinafter referred to as a "hot stamping pseudo heat treatment") in which the steel sheet is heated to 1000 degrees C and subsequently cooled by being retained in a range from 890 to 700 degrees C for one to ten minutes, a crystal grain size is in a range from 100 to 200 μm, and precipitates each having a grain size of 500 nm or less are at a density of 0.01 to 20 pieces per square micrometer, and
the ferritic stainless steel sheet is a ferritic stainless steel for hot stamping.

2. A ferritic stainless steel sheet for an automobile brake disc rotor, comprising:

0.001 to 0.05 mass% of C;
0.001 to 0.05 mass% of N;
0.3 to 4.0 mass% of Si;
0.01 to 2.0 mass% of Mn;
0.01 to 0.05 mass% of P;
0.0001 to 0.02 mass% of S;
10 to 20 mass% of Cr;
one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and
a balance consisting of Fe and impurities, wherein
the ferritic stainless steel sheet in which a crystal grain size is in a range from 100 to 200 μm and precipitates each having a grain size of 500 nm or less are present at a density of 0.01 to 20 pieces per square micrometer is in a form of a hot-stamped product.

3. A ferritic stainless steel sheet for an automobile brake disc rotor, comprising:

0.001 to 0.05 mass% of C;
0.001 to 0.05 mass% of N;
0.3 to 4.0 mass% of Si;
0.01 to 2.0 mass% of Mn;
0.01 to 0.05 mass% of P;
0.0001 to 0.02 mass% of S;
10 to 20 mass% of Cr;
one or both of 0.001 to 0.5 mass% of Ti and 0.01 to 0.8 mass% of Nb; and
a balance consisting of Fe and impurities.

4. The ferritic stainless steel sheet for an automobile brake disc rotor according to claim 3, wherein the ferritic stainless steel sheet is a ferritic stainless steel sheet for hot stamping.

5. The ferritic stainless steel sheet for an automobile brake disc rotor according to claim 1, wherein fracture elongation at 1000 degrees C is 50% or more, and 0.2% proof strength at 700 degrees C after the hot stamping pseudo heat treatment is 80 MPa or more.

6. The ferritic stainless steel sheet for an automobile brake disc rotor according to claim 2, wherein 0.2% proof strength at 700 degrees C is 80 MPa or more.

7. The ferritic stainless steel sheet for an automobile brake disc rotor according to any one of claims 1, 2, 5 and 6, wherein the crystal grain size is in a range from 130 to 200 μm.

8. The ferritic stainless steel sheet for an automobile brake disc rotor according to claim 3 or 4, wherein fracture elongation at 1000 degrees C is 50% or more.

9. The ferritic stainless steel sheet for an automobile brake disc rotor according to claim 7, wherein 0.2% proof strength at 300 degrees C is 170 MPa or more.

10. The ferritic stainless steel sheet for an automobile brake disc rotor according to any one of claims 1 to 9, further comprising, in place of a part of Fe, at least one of 0.0001 to 0.0030 mass% of B, 0.001 to 4.0 mass% of Al, 0.01 to 3.0 mass% of Cu, 0.01 to 3.0 mass% of Mo, 0.001 to 2.0 mass% of W, 0.001 to 1.0 mass% of V, 0.01 to 0.5 mass% of Sn, 0.01 to 1.0 mass% of Ni, 0.0001 to 0.01 mass% of Mg, 0.005 to 0.5 mass% of Sb, 0.001 to 0.3 mass% of Zr, 0.001 to 0.3 mass% of Ta, 0.001 to 0.3 mass% of Hf, 0.001 to 0.3 mass% of Co, 0.0001 to 0.01 mass% of Ca, 0.001 to 0.2 mass% of REM, and 0.0002 to 0.3 mass% of Ga.

11. An automobile brake disc rotor being made of the stainless steel sheet according to any one of claims 1 to 10.

12. A hot-stamped product for an automobile brake disc rotor, the hot-stamped product being made of the stainless steel sheet according to any one of claims 1 to 10.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/010947

A. CLASSIFICATION OF SUBJECT MATTER
C21D 8/02(2006.01)i; C21D 9/00(2006.01)i; C22C 38/00(2006.01)i; C22C 38/38(2006.01)i; C22C 38/60(2006.01)i; C21D 1/18(2006.01)i
FI: C22C38/00 302Z; C22C38/38; C22C38/60; C21D1/18 C; C21D9/00 A; C21D8/02 D
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)
C21D8/02; C21D9/00; C22C38/00-38/60; C21D1/18; F16D65/12

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X A	JP 9-268350 A (KAWASAKI STEEL CORP.) 14.10.1997 (1997-10-14) claims, paragraphs [0001], [0050]-[0054]	3, 10-11 1-2, 4-9, 12
X Y A	JP 2006-291240 A (JFE STEEL CORPORATION) 26.10.2006 (2006-10-26) claims, paragraphs [0001], [0014]-[0051]	3, 10-11 4, 12 1-2, 5-9

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 May 2020 (28.05.2020)	16 June 2020 (16.06.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/010947

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X Y A	JP 2005-307346 A (JFE STEEL CORPORATION) 04.11.2005 (2005-11-04) claims, paragraphs [0001], [0026]-[0039]	10-11 12 1-9
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No.
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REFERENCES CITED IN THE DESCRIPTION

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