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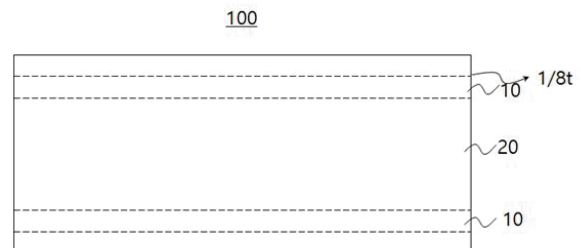
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(54) **NON-ORIENTED ELECTRICAL STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) A non-oriented electrical steel sheet according to an embodiment of the present invention contains, in wt%, 1.5 to 5.0 % of Si :=, 0.1 to 2.0 % of Al, 0.1 to 2.0 % of Mn, with the remainder comprising Fe and inevitable impurities, wherein the ratio ($G_{s_{out}}/G_{s_{in}}$) of the average grain size ($G_{s_{out}}$) on the surface of the steel sheet or in a surface layer, which is a region extending at least 1/8 and less than 1/4 of the total thickness of the steel sheet from the surface of the steel sheet, to the average grain size ($G_{s_{in}}$) in an inner layer, which is a region extending 1/4 -3/4 of the total thickness of the steel sheet from the surface of the steel sheet, is 0.60 to 0.95, and the ratio ($Hv_{1/8}/(Hv_{1/2})$) of the hardness ($Hv_{1/8}$) at the 1/8 point (1/8t) of the total thickness of the steel sheet from the surface of the steel sheet to the hardness ($Hv_{1/2}$) at the 1/2 point (1/2t) of the total thickness of the steel sheet from the surface of the steel sheet is at least 1.05 or more.

[Figure 1]



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Description**[Technical Field]**

[0001] An embodiment of the present invention relates to a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, an embodiment of the present invention relates to a non-oriented electrical steel sheet with simultaneously improved punchability and magnetic properties, and a method for manufacturing the same, by simultaneously controlling the hardness and crystal grain size of a surface layer and an inner layer by adjusting a heating rate and a dew point during a heating process in annealing a cold-rolled sheet.

[Background Art]

[0002] A non-oriented electrical steel sheet is mainly used in a motor that converts electrical energy into mechanical energy, and excellent magnetic properties of the non-oriented electrical steel sheet are required to exhibit high efficiency in the process. Particularly in recent years, as an eco-friendly automobile driven by a motor instead of an internal combustion engine has been drawing attention, the demand for a non-oriented electrical steel sheet used as a material for a drive motor core has been increasing, and for this purpose, a non-oriented electrical steel sheet excellent in both magnetic properties and strength is required.

[0003] The magnetic properties of a non-oriented electrical steel sheet are mainly evaluated by core loss and magnetic flux density. The core loss means an energy loss that occurs at a specific magnetic flux density and frequency, and the magnetic flux density means a degree of magnetization obtained under a specific magnetic field. The lower the core loss, the more a motor with high energy efficiency can be manufactured under the same conditions, and the higher the magnetic flux density, the more a motor can be miniaturized or copper loss can be reduced. Therefore, by using a non-oriented electrical steel sheet having a low core loss and a high magnetic flux density, a drive motor with excellent efficiency and torque can be made, and through this, a driving range and output of an eco-friendly automobile can be improved.

[0004] The characteristics of the non-oriented electrical steel sheet that need to be considered also change depending on the operating conditions of the motor. As a general standard for evaluating the properties of a non-oriented electrical steel sheet used in a motor, W15/50, which is the core loss when a 1.5T magnetic field is applied at a commercial frequency of 50 Hz, is widely used. However, in a non-oriented electrical steel sheet with a thickness of 0.35 mm or less used in an eco-friendly automobile drive motor, the magnetic properties at a low magnetic field of 1.0T or less and a high frequency of 400 Hz or more are often important, and thus the properties of the non-oriented electrical steel sheet are often evaluated by the $W_{10/400}$ core loss.

[0005] Meanwhile, in order to manufacture a motor from a non-oriented electrical steel sheet, it goes through a process of punching the non-oriented electrical steel sheet into a motor shape and stacking it. In this case, when the punchability is poor and a cut surface of the sheet is not smooth, or when the occurrence of burrs is severe, it can adversely affect the performance of the finally manufactured motor.

[Disclosure]**[Technical Problem]**

[0006] An embodiment of the present invention provides a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, an embodiment of the present invention provides a non-oriented electrical steel sheet with simultaneously improved punchability and magnetic properties, and a method for manufacturing the same, by simultaneously controlling the hardness and crystal grain size of a surface layer and an inner layer by adjusting a heating rate and a dew point during a heating process in annealing a cold-rolled sheet.

[Technical Solution]

[0007] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, by wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with the balance being Fe and unavoidable impurities, wherein a ratio ($G_{\text{sout}}/G_{\text{sin}}$) of an average grain size (G_{sout}) in a surface layer, which is a region from 1/8 or more to less than 1/4 of a total thickness of the steel sheet from a surface of the steel sheet, to an average grain size (G_{sin}) in an inner layer, which is a region from 1/4 to 3/4 of the total thickness of the steel sheet from the surface of the steel sheet, is 0.60 to 0.95, and a ratio ($Hv_{1/8}/Hv_{1/2}$) of a hardness ($Hv_{1/8}$) at a point at 1/8 of the total thickness of the steel sheet (1/8t) from the surface of the steel sheet to a hardness ($Hv_{1/2}$) at a point at 1/2 of the total thickness of the steel sheet (1/2t) is 1.05 or more.

[0008] The non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy the following Equation 1:

[Equation 1]

$$[\text{Si}] \times [\text{Mn}] / (4 \times [\text{Al}]) \leq 1.0$$

(In Equation 1, [Si], [Mn], and [Al] represent the contents (wt%) of Si, Mn, and Al, respectively.)

[0009] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0010] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Sn, Sb, Bi, Pb, Ge, and As at 0.005 to 0.200 wt%, respectively or in total.

[0011] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

[0012] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[0013] The average grain size (G_{sin}) in the inner layer may be 70 to 90 μm .

[0014] The average grain size (G_{sout}) in the surface layer may be 55 to 75 μm .

[0015] The hardness ($Hv_{1/2}$) at a point at 1/2 of the total thickness of the steel sheet (1/2t) from the surface of the steel sheet may be 220 to 235 Hv.

[0016] The hardness ($Hv_{1/8}$) at a point at 1/8 of the total thickness of the steel sheet (1/8t) from the surface of the steel sheet may be 240 to 270 Hv.

[0017] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention includes manufacturing a hot-rolled steel sheet by hot rolling a slab including, by wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with the remainder Fe and inevitable impurities; manufacturing a cold-rolled sheet by cold rolling the hot-rolled steel sheet; and cold-rolled sheet annealing the cold-rolled sheet.

[0018] The manufacturing the cold-rolled sheet includes first heating of heating the cold-rolled sheet in a temperature range of 300 °C or more and less than 500 °C; second heating of heating the cold-rolled sheet in a temperature range of 500 to 700 °C; and soaking, and satisfies the following Equation 2 and Equation 3.

[Equation 2]

$$\text{HR1}/\text{DP1} \leq 1.5$$

[Equation 3]

$$\text{HR2}/\text{DP2} \geq 6$$

(In Equation 2 and Equation 3, HR1 and HR2 are heating rates (°C/sec) in the first heating and the second heating, respectively, and DP1 and DP2 are dew point temperatures (°C) in the first heating and the second heating, respectively.)

[0019] The slab may satisfy the following Equation 1:

[Equation 1]

$$[\text{Si}] \times [\text{Mn}] / (4 \times [\text{Al}]) \leq 1.0$$

(In Equation 1, [Si], [Mn], and [Al] represent the contents (wt%) of Si, Mn, and Al in the slab, respectively.)

[0020] The slab may further comprise one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0021] The slab may further include one or more of Sn, Sb, Bi, Pb, Ge, and As at 0.005 to 0.200 wt%, respectively or in total.

[0022] The slab may further include one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), and Zn: 0.01 wt% or less (excluding 0%).

[0023] The slab may further include one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), Co: 0.05 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[0024] In the first heating, a heating rate may be 50°C/sec or less.

[0025] In the first heating, the dew point temperature may be 30°C or more.

[0026] In the second heating, the heating rate may be 50°C/sec or more.

[0027] In the second heating, the dew point temperature may be more than 0°C to 10°C or less.

[Advantageous Effects]

[0028] The non-oriented electrical steel sheet according to an embodiment of the present invention can control the burr height to be low during punching and also has excellent high-frequency core loss.

[0029] Ultimately, the non-oriented electrical steel sheet according to an embodiment of the present invention contributes to enabling manufacturing of a motor for an eco-friendly automobile, a motor for a high-efficiency home appliance, and a super-premium class electric motor.

[Description of the Drawings]

[0030] FIG. 1 is a schematic diagram that schematically shows a cross-section of a non-oriented electrical steel sheet according to an embodiment of the present invention.

[Mode for Invention]

[0031] Terms such as first, second, and third are used to describe various parts, components, regions, layers, and/or sections, but are not limited thereto. These terms are only used to distinguish one part, component, region, layer, or section from another part, component, region, layer, or section. Thus, a first part, component, region, layer, or section described below could be termed a second part, component, region, layer, or section without departing from the scope of the present invention.

[0032] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. The meaning of "comprising" as used in the specification specifies the presence of stated features, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, and/or components.

[0033] When a part is referred to as being "on" or "above" another part, it can be directly on or above the other part, or intervening parts may be present. In contrast, when a part is referred to as being "directly on" another part, there are no intervening parts present.

[0034] In addition, unless otherwise specified, % means wt%, and 1ppm is 0.0001 wt%.

[0035] In an embodiment of the present invention, the meaning of further including an additional element means including it by replacing the balance of iron (Fe) by the amount of the additional element.

[0036] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0037] Hereinafter, embodiments of the present invention will be described in detail so that those of ordinary skill in the art can easily carry them out. However, the present invention may be embodied in many different forms and is not limited to the embodiments described herein.

[0038] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, by wt%, Si : 1.5 to 5.0%, Al : 0.1 to 2.0%, Mn : 0.1 to 2.0% with the remainder including Fe and inevitable impurities.

[0039] Hereinafter, the reasons for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.5 to 5.0 wt%

[0040] Silicon (Si) serves to increase the electrical resistivity of the material to lower core loss and increase strength through solid solution strengthening. When Si is added in too small an amount, the effect of improving core loss and strength may be insufficient. If Si is added in too large an amount, the hardness of the material may increase, leading to poor productivity and punchability. Therefore, Si may be included at 1.5 to 5.0 wt%. More specifically, Si may be included at 2.0 to 4.5 wt%. More specifically, Si may be included at 3.2 to 3.75 wt%.

Al: 0.1 to 2.0 wt%

[0041] Aluminum (Al) serves to increase the electrical resistivity of the material to lower core loss, improve rollability, and enhance workability during cold rolling. When Al is added in too small an amount, it may be difficult to obtain a high-frequency core loss reduction effect, and a precipitation temperature of AlN may be lowered, causing a nitride to form finely and deteriorating magnetic properties. When Al is added in too large an amount, a nitride is excessively formed, deteriorating magnetic properties, and causing a problem in all processes such as steelmaking and continuous casting, which can greatly reduce productivity. Therefore, Al may be included at 0.1 to 2.0 wt%. More specifically, it may be included at 0.5 to 1.8 wt%. More specifically, it may be included at 0.7 to 1.5 wt%.

Mn: 0.1 to 2.0 wt%

[0042] Manganese (Mn) serves to increase the electrical resistivity of the material to improve core loss and to form a sulfide. When Mn is added in too small an amount, the sulfide is finely formed, causing deterioration of magnetic properties, and when Mn is added in too large an amount, fine MnS may precipitate excessively and a magnetic domain structure may change, adversely affecting core loss. Therefore, Mn may be included at 0.1 to 2.0 wt%. More specifically, it may be included at 0.2 to 1.8 wt%. More specifically, it may be included at 0.4 to 1.5 wt%.

[0043] In an embodiment of the present invention, the electrical resistivity of the non-oriented electrical steel sheet may be $55 \mu\Omega\cdot\text{cm}$ or more. For reducing eddy current loss in a high-frequency rotating machine, the higher the electrical resistivity, the better, but if it is too high, the magnetic flux density may be poor. In an embodiment of the present invention, the electrical resistivity may be estimated from the equation: $13.25 + 11.3 \times ([\text{Si}] + [\text{Al}] + [\text{Mn}]/2 + [\text{Cu}]/2 + [\text{Cr}]/2)$. In this case, when it does not contain Cu and Cr, it may be calculated as 0. More specifically, the electrical resistivity may be 58 to $80 \mu\Omega\cdot\text{cm}$.

[0044] The non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy the following Equation 1.

[Equation 1]

$$[\text{Si}] \times [\text{Mn}] / (4 \times [\text{Al}]) \leq 1.00$$

(in Equation 1, [Si], [Mn], and [Al] represent the contents (wt%) of Si, Mn, and Al)

[0045] Si and Mn cause surface oxidation during high-temperature annealing. When the contents of Si and Mn are too large compared to the Al content and the value of Equation 1 exceeds an upper limit, internal oxidation may occur rapidly at a dew point of 0°C or higher, and the core loss may be rapidly deteriorated. More specifically, the value of Equation 1 may be 0.40 to 0.90.

[0046] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P: 0.1 wt% or less (excluding 0 %), C: 0.005 wt% or less (excluding 0 %), S: 0.005 wt% or less (excluding 0 %), Ti: 0.005 wt% or less (excluding 0 %), and N: 0.005 wt% or less (excluding 0 %).

P: 0.1 wt% or less

[0047] Phosphorus (P) not only serves to increase the electrical resistivity of the material, but may also improve the magnetic flux density as a grain boundary segregation element. However, when too much P is added, it increases the brittleness of the steel sheet, resulting in poor weldability. More specifically, P may be included at 0.0001 to 0.0500 wt%. More specifically, P may be included at 0.0010 to 0.0200 wt%.

C: 0.005 wt% or less

[0048] Carbon (C) may cause magnetic aging and combine with other impurity elements to form a carbide, which

may interfere with grain boundary or magnetic domain wall movement and deteriorate magnetic properties. More specifically, C may be included at 0.0001 to 0.003 wt%.

S: 0.005 wt% or less

[0049] Sulfur (S) may form fine precipitates such as MnS and CuS, which may worsen magnetic properties and heating processability. More specifically, S may be included at 0.0001 to 0.0030 wt%.

Ti: 0.005 wt% or less

[0050] Titanium (Ti) has a very strong tendency to form precipitates in steel, and may form a fine carbide, nitride, or sulfide inside a base material, thereby suppressing crystal grain growth and magnetic domain wall movement, which may deteriorate core loss. More specifically, Ti may be included at 0.0001 to 0.0030 wt%.

N: 0.005 wt% or less

[0051] Nitrogen (N) not only forms a fine AlN precipitate inside the base material, but may also combine with other impurities to form a fine precipitate, which may suppress crystal grain growth and magnetic domain wall movement, thereby worsening core loss. More specifically, N may be included at 0.0001 to 0.0030 wt%.

[0052] The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise one or more of Sn, Sb, Bi, Pb, Ge, and As at 0.005 to 0.200 wt%, respectively or in total.

Sn

[0053] Tin (Sn) segregates at a grain boundary and surface, serving to improve the texture of the material and suppress surface oxidation, and thus it may be added to improve magnetic properties. When too much Sn is added, grain boundary segregation becomes severe, deteriorating surface quality, and increasing hardness, which may cause fracture of the cold-rolled sheet and decrease rollability. Specifically, Sn may be further included at 0.005 to 0.200 wt%. More specifically, it may be further included at 0.010 to 0.080 wt%.

Sb

[0054] Antimony (Sb) segregates at a grain boundary and surface, serving to improve the texture of the material and suppress surface oxidation, and thus it may be additionally added to improve magnetic properties. When too much Sb is added, grain boundary segregation becomes severe, deteriorating surface quality, and increasing hardness, which may cause fracture of the cold-rolled sheet and decrease rollability. Specifically, Sb may be further included at 0.005 to 0.200 wt%. More specifically, it may be further included at 0.010 to 0.080 wt%.

Bi, Pb, Ge, and As

[0055] When bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are additionally added, they segregate at a grain boundary, alleviating stress concentration at the grain boundary during cold rolling, thereby suppressing the recrystallization of <111>//ND oriented crystal grains in the subsequent recrystallization annealing process, thus improving the magnetic flux density. When these are added appropriately, the aforementioned effects may be additionally obtained, but when too much is included, a large amount of segregation occurs, which suppresses crystal grain growth, and the magnetic flux density and core loss may rather be poor.

[0056] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

Cu: 0.005 to 0.200 wt%

[0057] Copper (Cu), along with Mn, plays a role in forming a sulfide. When Cu is further added, when it is added in too small an amount, (Cu-Mn)S may precipitate finely and deteriorate magnetic properties. When too much Cu is added, hot brittleness may occur, which may form cracks during continuous casting or hot rolling. More specifically, Cu may be included at 0.01 to 0.10 wt%.

Cr: 0.01 to 0.50 wt%

[0058] Chromium (Cr) serves to increase electrical resistivity and improve core loss. When too little Cr is added, the effect of increasing electrical resistivity may not be sufficient. When too much Cr is included, the magnetic flux density may decrease. More specifically, Cr may be included at 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0059] Nickel (Ni) may react with an impurity element to form a fine sulfide, a carbide, and a nitride, which may have a detrimental effect on magnetic properties. More specifically, Ni may be included at 0.001 to 0.03 wt%.

Zn: 0.01 wt% or less

[0060] When the content of zinc (Zn) is excessive, it may act as an impurity and cause poor magnetic properties. Therefore, Zn may be further added in the aforementioned range. More specifically, Zn may be included at 0.001 to 0.005 wt%.

Co: 0.05 wt% or less

[0061] Cobalt (Co) does not form a precipitate of a fine size that lowers the magnetic properties of the steel sheet, but it may increase high-temperature strength, which can make the shape of the coil poor after hot rolling.

[0062] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 wt% or less (excluding 0 %), B: 0.0050 wt% or less (excluding 0 %), V: 0.0050 wt% or less (excluding 0 %), Ca: 0.0050 wt% or less (excluding 0 %), Nb: 0.0050 wt% or less (excluding 0 %), Zr : 0.0050 wt% or less (excluding 0 %), Te: 0.0100 wt% or less (excluding 0 %), and Mg: 0.0050 wt% or less (excluding 0 %).

Mo: 0.030 wt% or less

[0063] When molybdenum (Mo) is added in excess, it may suppress the segregation of a segregation element, which may reduce the effect of texture improvement. Therefore, Mo may be included at 0.03 wt% or less. The lower limit is not particularly limited, but it may be included at 0.001 wt% or more as it serves to improve texture by segregating at the surface and grain boundary. More particularly, Mo may be included at 0.001 to 0.010 wt%. More particularly, Mo may be included at 0.005 to 0.010 wt%.

B: 0.0050 wt% or less

[0064] When boron (B) is added in excess, it may cause deterioration of magnetic properties through the formation of inclusions in the steel. Therefore, B may be included at 0.005 wt%. The lower limit is not particularly limited, but due to steelmaking costs, it may be 0.0001 wt%. More specifically, B may be included at 0.0001 to 0.0030 wt%.

V: 0.0050 wt% or less

[0065] Vanadium (V) has a very strong tendency to form a precipitate in steel, and it forms fine carbides or nitrides inside the base material, which suppresses crystal grain growth and magnetic domain wall movement, thereby deteriorating core loss. Therefore, the V content may be 0.0050 wt% or less. The lower limit is not particularly limited, but due to steelmaking costs, it may be 0.0003 wt%. That is, V may be included at 0.0003 to 0.0050 wt%. More specifically, V may be included at 0.0003 to 0.0030 wt%.

Ca: 0.0050 wt% or less

[0066] Calcium (Ca) has a very strong tendency to form a precipitate in steel, and it forms a fine sulfide inside the base material, which suppresses crystal grain growth and magnetic domain wall movement, thereby deteriorating core loss.

Nb: 0.0050 wt% or less

[0067] Niobium (Nb) has a very strong tendency to form a precipitate in steel, and it forms a fine carbide or nitride inside the base material, which suppresses crystal grain growth and magnetic domain wall movement, thereby deter-

riorating core loss. Therefore, the Nb content may be 0.0050 wt% or less. The lower limit is not particularly limited, but due to steelmaking costs, it may be 0.0003 wt%. That is, Nb may be included at 0.0003 to 0.0050 wt%. More specifically, Nb may be included at 0.0003 to 0.0030 wt%.

5 Zr: 0.0050 wt% or less

[0068] When zirconium (Zr) is added in excess, it may cause deterioration of magnetic properties through the formation of inclusions in the steel. Therefore, Zr may be included at 0.005 wt% or less. The lower limit is not particularly limited, but due to steelmaking costs, it may be 0.0001 wt%. That is, Zr may be included at 0.0001 to 10 0.0050 wt%. More specifically, Zr may be included at 0.0005 to 0.0030 wt%.

Te: 0.0100 wt% or less

[0069] Tellurium (Te) diffuses into an oxide layer on a surface of the hot-rolled coil, increasing the friction coefficient 15 between the oxide layer and the rolling work roll, and concentrates under the oxide layer to improve hardness, and thus it may be added to cause the fractured oxide layer to fall off without being pressed into the base material during rolling. When the amount of Te added is too small, its effect may be insignificant. If too much Te is added, the oxide layer easily falls off, causing the base material to come into direct contact with the work roll, which reduces the above effect, and excessive deformation bands may be generated in the steel sheet during cold rolling, which can develop a 20 {111}ND texture that is unfavorable to magnetic properties. More specifically, tellurium may be included at 0.0001 to 0.007 wt%.

Mg: 0.0050 wt% or less

25 **[0070]** Magnesium (Mg) is an element that mainly combines with S to form sulfides, and may affect a surface oxide layer of the base iron. Therefore, Mg may be included at 0.0050 wt% or less. The lower limit is not particularly limited, but due to steelmaking costs, it may be 0.0001 wt%. That is, Mg may be included at 0.0001 to 0.0050 wt%. More specifically, it may be included at 0.0005 to 0.0030 wt%.

30 **[0071]** The remainder includes Fe and inevitable impurities. The inevitable impurities are impurities mixed in during the steelmaking and the manufacturing process of the non-oriented electrical steel sheet, and since this is widely known in the field, a detailed description thereof will be omitted. In an embodiment of the present invention, the addition of elements other than the aforementioned alloy components is not excluded, and they may be included in various ways within a range that does not harm the technical spirit of the present invention. When an additional element is further included, it is included by replacing the remainder of Fe.

35 **[0072]** As described above, in an embodiment of the present invention, by appropriately adjusting the alloy component of the steel sheet and adjusting the heating rate and dew point during the heating process in annealing the cold-rolled sheet, the hardness and crystal grain size of the surface layer and the inner layer may be simultaneously controlled.

40 **[0073]** FIG. 1 is a schematic diagram that schematically shows a cross-section of a non-oriented electrical steel sheet according to an embodiment of the present invention.

[0074] As shown in FIG. 1, a non-oriented electrical steel sheet 100 according to an embodiment of the present invention includes a surface layer 10, which is a region from 1/8 or more to less than 1/4 of the total thickness of the steel sheet from a surface of the steel sheet, and an inner layer 20, which is a region from 1/4 to 3/4 of the total thickness of the steel sheet from the surface of the steel sheet. As shown in FIG. 1, the surface layer 10 exists not only 45 on one surface but on both surfaces. In this case, the lower surface layer may exist in a region of more than 3/4 and 7/8 or less of the total thickness of the steel sheet from the surface of the steel sheet. The inner layer 20 exists between the surface layers 10.

[0075] A ratio ($G_{s_{out}}/G_{s_{in}}$) of an average grain size $G_{s_{out}}$ in the surface layer 10 to an average grain size $G_{s_{in}}$ in the inner layer 20 is 0.60 to 0.95. As the frequency increases, more eddy current flows on the surface due to the skin effect, and thus it is advantageous to control the grain size of the surface layer 10 to be fine. On the other hand, when the grain size of the surface layer 10 is too small, the magnetic properties at the commercial frequency 50 Hz may be deteriorated. More specifically, the ratio ($G_{s_{out}}/G_{s_{in}}$) of the average grain size $G_{s_{out}}$ in the surface layer 10 to the average grain size $G_{s_{in}}$ in the inner layer 20 may be 0.65 to 0.9. 50

[0076] In an embodiment of the present invention, the crystal grain size may be measured based on a cross-section including the thickness of the steel sheet, more specifically, the TD plane. The number of crystal grains in each region is measured with an optical microscope, the area per crystal grain is measured, and through this, the crystal grain size can be obtained. The crystal grain size can be obtained by assuming a virtual circle with the same area and using a diameter of that circle. 55

[0077] The average grain size $G_{s_{in}}$ in the inner layer 20 may be 70 to 90 μm . When the grain size of the inner layer 20 is too small, the core loss at 50 to 400 Hz may be poor. When the grain size of the inner layer 20 is too large, the magnetic properties at frequencies exceeding 400 Hz may be poor. More specifically, the grain size of the inner layer 20 may be 72 to 88 μm .

[0078] The average grain size $G_{s_{out}}$ in the surface layer 10 may be 55 to 75 μm . When the grain size of the surface layer 10 is too small, the magnetic properties at the commercial frequency 50 Hz may be deteriorated. When the grain size of the surface layer 10 is too large, the surface processability may be deteriorated. More specifically, the grain size of the surface layer 10 may be 56 to 72 μm .

[0079] In an embodiment of the present invention, a ratio ($Hv_{1/8}/Hv_{1/2}$) of a hardness $Hv_{1/8}$ at a point at 1/8 (1/8t) of the total thickness of the steel sheet from the surface of the steel sheet to a hardness $Hv_{1/2}$ at a point at 1/2 (1/2t) of the total thickness of the steel sheet is 1.05 or more. When the hardness of the surface layer 10 is greater than that of the inner layer 20, it is helpful in reducing the burr height after punching. More specifically, the ratio ($Hv_{1/8}/Hv_{1/2}$) of the hardness $Hv_{1/8}$ at a point at 1/8 (1/8t) of the total thickness of the steel sheet from the surface of the steel sheet to the hardness $Hv_{1/2}$ at a point at 1/2 (1/2t) of the total thickness of the steel sheet may be 1.08 to 1.20.

[0080] In an embodiment of the present invention, the hardness value means Vickers hardness, and an average value was used after measuring 5 points at 1 mm intervals in the TD direction.

[0081] The hardness $Hv_{1/2}$ at a point at 1/2 (1/2t) of the total thickness of the steel sheet from the surface of the steel sheet may be 220 to 235 Hv. When the hardness $Hv_{1/2}$ is too low, the strength is low and fracture may occur during high-speed rotation. When the hardness $Hv_{1/2}$ is too high, the material is too hard and fracture may occur during processing. More specifically, the hardness $Hv_{1/2}$ may be 225 to 233 Hv.

[0082] The hardness $Hv_{1/8}$ at a point at 1/8 (1/8t) of the total thickness of the steel sheet from the surface of the steel sheet may be 240 to 270 Hv. When the hardness $Hv_{1/8}$ is too low, the surface is softer than the inside, and thus it is not effective in reducing burrs. When the hardness $Hv_{1/8}$ is too high, surface fracture may occur too excessively. More specifically, the hardness $Hv_{1/8}$ may be 245 to 265 Hv.

[0083] As described above, in an embodiment of the present invention, by controlling the grain size and hardness for each thickness, punchability and magnetic properties can be simultaneously improved.

[0084] Specifically, in an embodiment of the present invention, when punching is performed with a tolerance of 8 % and a punching speed of 300 spm (strokes per minute), the height of the burr may be 0.020 μm or less. More specifically, the burr height may be 0.005 to 0.015 μm .

[0085] As described above, in an embodiment of the present invention, the core loss $W_{10/800}$ of the non-oriented electrical steel sheet based on a thickness of 0.25 mm may be 35.0 W/Kg or less. The core loss $W_{10/800}$ is the core loss when a magnetic flux density of 1.0T is induced at a frequency of 800 HZ. More specifically, the core loss $W_{10/400}$ of the non-oriented electrical steel sheet may be 30.0 to 35.0 W/kg.

[0086] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention includes manufacturing a hot-rolled steel sheet by hot rolling a slab, manufacturing a cold-rolled sheet by cold rolling the hot-rolled steel sheet, and annealing the cold-rolled sheet.

[0087] Hereinafter, each step will be described in detail.

[0088] First, a slab is hot rolled.

[0089] Since the alloy components of the slab have been described in the alloy components of the aforementioned non-oriented electrical steel sheet, a duplicate description will be omitted. The alloy components do not substantially change during the manufacturing process of the non-oriented electrical steel sheet, and therefore the alloy components of the non-oriented electrical steel sheet and the slab are substantially the same.

[0090] Specifically, the slab includes, by wt%, Si: 1.5 to 5.0 %, Al: 0.1 to 2.0 %, Mn: 0.1 to 2.0 %, the reminder Fe, and inevitable impurities.

[0091] As for other additional elements, they have been described in the description of the alloy components of the non-oriented electrical steel sheet, and therefore a duplicate description will be omitted.

[0092] The slab may be heated before hot rolling. A heating temperature of the slab is not limited, but the slab may be heated to 1200 °C or less. When the slab heating temperature is too high, a precipitate such as AlN, MnS, and the like existing in the slab are re-dissolved and then finely precipitate during hot rolling and annealing, which can suppress crystal grain growth and deteriorate magnetic properties.

[0093] Next, the slab is hot rolled to manufacture a hot-rolled sheet. A hot rolled plate thickness may be 1.0 to 4.5 mm. The finishing rolling temperature in the manufacturing the hot-rolled sheet may be 800 °C or more. Specifically, it may be 800 to 1000 °C. The hot-rolled sheet may be coiled at a temperature of 600°C or more. More specifically, the thickness of the hot-rolled sheet may be 1.5 to 4.3 mm.

[0094] After manufacturing the hot-rolled steel sheet, annealing the hot-rolled sheet may be further included. In this case, the soaking temperature may be 800 to 1100 °C. When the annealing temperature is too low, a recrystallized structure is not formed or grows finely, and thus the effect of increasing magnetic flux density is small, and when the annealing temperature is too high, the magnetic properties are rather deteriorated, and the workability of rolling may

be poor due to deformation of the sheet shape. More specifically, the temperature range may be 830 to 1080°C. The soaking time may be 30 to 300 seconds. The hot-rolled sheet annealing may also be omitted.

[0095] Next, the hot-rolled steel sheet is cold rolled to manufacture a cold-rolled sheet. In this case, cold rolling may be performed with a reduction ratio of 40 to 85 %. When the reduction ratio is too low, the strain energy accumulated in the rolled steel sheet is small, making it difficult to recrystallize in the subsequent annealing process, so the rolled structure remains, which can cause problems in improving magnetic flux density and core loss. Conversely, when the reduction ratio is too high, the recrystallization of <111>//ND oriented crystal grains is promoted in the subsequent annealing process and the crystal grains also become fine, which can cause a problem of poor magnetic flux density and increased core loss. More specifically, the reduction ratio may be 60 to 75 %. The cold rolling may use a Tandem cold rolling mill that continuously cold rolls a steel sheet using multiple rolling stands or a Reverse rolling mill that discontinuously cold rolls using 12 or more rolling rolls. The final rolling thickness may be 0.1 mm to 0.35 mm.

[0096] The manufacturing the cold-rolled sheet may be performed once or two or more times with an intermediate annealing in between.

[0097] Next, the cold-rolled sheet is annealed in the cold-rolled sheet annealing. In an embodiment of the present invention, by controlling the heating rate and dew point in a specific temperature range during heating in the annealing of the cold-rolled sheet, punchability and magnetic properties can be simultaneously improved.

[0098] Specifically, the manufacturing the cold-rolled sheet includes first heating of heating the cold-rolled sheet in a temperature range of 300 °C or more and less than 500 °C; second heating of heating the cold-rolled sheet in a temperature range of 500 to 700 °C; and soaking, and satisfies the following Equation 2 and Equation 3.

[Equation 2]

$$HR1/DP1 \leq 1.5$$

[Equation 3]

$$HR2/DP2 \geq 6.0$$

(In Equation 2 and Equation 3, HR1 and HR2 are heating rates (°C/sec) in the first heating and the second heating, respectively, and DP1 and DP2 are dew point temperatures (°C) in the first heating and the second heating, respectively.)

[0099] In the temperature range of 300 °C or more and less than 500 °C, which corresponds to the initial stage of annealing, by slowing down the heating rate and keeping the dew point high, Si, Al, and Mn existing inside the material diffuse and concentrate on the surface. In addition, internal oxidation of the material may be suppressed by controlling the heating rate and dew point as in Equation 2. When the value of Equation 2 is too large, it is difficult to achieve the aforementioned purpose. More specifically, the value of Equation 2 may be 0.1 to 1.3. In an embodiment of the present invention, the heating rate and dew point may vary in the corresponding temperature range, and in this case, it may be the average heating rate and dew point in the corresponding temperature range. The average may be an average over time.

[0100] In the first heating, the heating rate HR1 may be 50 °C/sec or less. When the heating rate HR1 is too high, it may be difficult to control the optimal crystal grain size. More specifically, the heating rate HR1 may be 10 to 48 °C/sec.

[0101] In the first heating, the dew point temperature may be 30 °C or more. When the dew point temperature DP1 is too low, it may be difficult to finely control the surface crystal grains. More specifically, the dew point temperature DP1 may be 35 to 65 °C.

[0102] In the temperature range of 500 to 700 °C, the heating rate is increased and the dew point is managed to be low to promote the formation of a texture favorable to magnetic properties. When the value of Equation 3 is too small, a thick internal oxide layer is formed, which may adversely affect the magnetic properties. More specifically, the value of Equation 3 may be 8.0 to 35.0.

[0103] In the second heating, the heating rate may be 50 °C/sec or more. When the heating rate HR2 is too low, a problem of decreasing magnetic flux density may occur. More specifically, the heating rate HR2 may be 55 to 90 °C/sec.

[0104] In the second heating, the dew point temperature may be more than 0 °C to 10 °C or less. When the dew point temperature DP2 is too low, an external oxide layer may develop. When the dew point temperature DP2 is too high, an internal oxide layer may develop. More specifically, the dew point temperature DP2 may be 2 to 8°C.

[0105] In the soaking, the soaking temperature may be 850 to 1100 °C. When the soaking temperature is too low, a problem may occur in that the crystal grains do not grow sufficiently, increasing hysteresis loss and deteriorating core

loss. When the soaking temperature is too high, a problem may occur in that the crystal grains grow excessively, increasing eddy current loss. More specifically, the soaking temperature may be 900 to 1050°C. The soaking time may be 30 to 120 seconds.

[0106] During the cold-rolled sheet annealing process, a processed structure formed in the cold rolling may be all (i.e., 99 % or more) recrystallized.

[0107] After annealing the cold-rolled sheet, an insulating film may be formed. The insulating film may be treated with an organic, inorganic, or organic-inorganic composite film, and it is also possible to treat it with other insulating film-forming agents.

[0108] Hereinafter, the present invention will be described in more detail through embodiments. However, these embodiments are only for illustrating the present invention, and the present invention is not limited thereto.

Example 1

[0109] Slabs were manufactured with the components including components in Table 1 and the remainder Fe and inevitable impurities. The C, S, N, and Ti of the slabs were all controlled to 0.0025 wt%. These were heated to 1150 °C and hot rolled at a finishing temperature of 850 °C to manufacture a hot-rolled sheet with a plate thickness of 2.0 mm.

[0110] Thereafter, the hot-rolled sheet was annealed at 1,100 °C for 4 minutes and then pickled. It was then cold rolled to a thickness of 0.25 mm. The conditions for annealing the cold-rolled sheet are shown in Table 2, and a soaking zone temperature was 1000 °C and a soaking time was 60 seconds. For hardness, Vickers hardness was measured with a load of 100g, and the average value was obtained by measuring 5 points at 1 mm intervals. Punching was performed using a small simple die in a laboratory, and the tolerance was 8 % and the speed was 300 spm. The burr height was measured using a micrometer. The grain size was determined by averaging the number of crystal grains per corresponding area on the TD plane, and the high-frequency core loss was measured using a single sheet tester.

(Table 1)

Division	Si	Al	Mn	Resistivity ($\mu\Omega\cdot\text{cm}$)	Value of Equation 1
1	3.4	0.8	0.8	65	0.85
2	3.2	1.1	0.7	66	0.51
3	3.5	1.2	0.8	71	0.58
4	3.5	1.5	0.4	72	0.23
5	3.5	1.2	1.2	73	0.88
6	3.5	1.1	0.8	70	0.64
7	3.2	0.9	1.3	67	1.16
8	3.4	1.0	1.0	69	0.85
9	3.6	1.5	0.9	76	0.54
10	3.5	1.5	1.2	77	0.70
11	3.2	1.2	1.1	69	0.73
12	3.3	1.4	1.0	72	0.59
13	3.3	1.4	0.8	71	0.47
14	3.5	1.2	1.1	73	0.80
15	3.6	0.9	0.5	67	0.50

(Table 2)

Division	First heating Heating speed(° C/sec)	First heating Dew point(°C)	HR1/DP1	Second heating Heating speed(° C/sec)	Second heating Dew point(°C)	HR2/DP2
1	45	35	1.3	75	6	12.5
2	49	31	1.6	52	5	10.4

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(continued)

Division	First heating Heating speed(° C/sec)	First heating Dew point(°C)	HR1/DP1	Second heating Heating speed(° C/sec)	Second heating Dew point(°C)	HR2/DP2
3	36	66	0.5	88	4	22.0
4	41	57	0.7	65	5	13.0
5	55	32	1.7	67	5	13.4
6	35	35	1.0	52	9	5.8
7	40	32	1.3	62	6	10.3
8	25	25	1.0	52	5	10.4
9	35	40	0.9	75	5	15.0
10	38	45	0.8	45	4	11.3
11	48	55	0.9	55	6	9.2
12	20	38	0.5	75	12	6.3
13	18	61	0.3	69	8	8.6
14	15	51	0.3	58	4	14.5
15	16	47	0.3	62	2	31.0

(Table 3)

Division	Hv1/8 (Hv)	Hv1/2 (Hv)	Hv1/8 /Hv1/ 2	G _{sout} (μm)	G _{sin} (μm)	G _{sout} / G _{sin}	Burr height (μm)	W10/ 800(W/kg)	Remarks
1	254	225	1.13	58	75	0.77	0.015	33.8	Inventive Ex- ample
2	235	225	1.04	67	62	1.08	0.021	35.7	Comparative Exam ple
3	254	225	1.13	62	78	0.79	0.009	33.1	Invent ive Exam ple
4	250	227	1.10	71	87	0.82	0.014	34.1	Invent ive Exam ple
5	239	230	1.04	73	75	0.97	0.034	35.7	Comp arativ e Exam ple
6	234	227	1.03	81	78	1.04	0.025	36.7	Comp arativ e Exam ple
7	245	235	1.04	84	87	0.97	0.027	35.2	Comp arative Exam ple
8	241	234	1.03	88	86	1.02	0.037	36.1	Comp arativ e Exam ple
9	261	228	1.14	68	84	0.81	0.013	33.7	Invent ive Exam ple
10	241	235	1.03	78	81	0.96	0.028	35.4	Comp arativ e Exam ple
11	245	231	1.06	70	85	0.82	0.011	32.1	Invent ive Exam ple
12	238	228	1.04	67	62	1.08	0.024	35.2	Comp arative Exam ple

(continued)

Division	Hv _{1/8} (Hv)	Hv _{1/2} (Hv)	Hv _{1/8} /Hv _{1/2}	G _{sout} (μm)	G _{sin} (μm)	G _{sout} / G _{sin}	Burr height (μm)	W10/ 800(W/kg)	Remarks
13	257	227	1.13	64	81	0.79	0.007	34.1	Invent ive Exam ple
14	249	225	1.11	57	72	0.79	0.009	33.2	Invent ive Exam ple
15	264	227	1.16	56	84	0.67	0.012	34.8	Invent ive Exam ple

[0111] As shown in Tables 1 to 3, it can be confirmed that in the inventive examples where the steel components were appropriately controlled and the process conditions were appropriately controlled such that the grain size and hardness by thickness were appropriately controlled, the burr height was small, and at the same time, the core loss was excellent.

[0112] On the other hand, it can be confirmed that when the process conditions were not properly controlled such that the grain size and hardness by thickness were not properly formed, the burr height was high, or the core loss was poor.

[0113] The present invention is not limited to the embodiments, but can be manufactured in various different forms, and it will be understood by those of ordinary skill in the art to which the present invention belongs that other specific forms can be implemented without changing the technical spirit or essential features of the present invention. Therefore, it should be understood that the embodiments described above are illustrative in all respects and not restrictive.

[Description of symbols]

[0114]

100: non-oriented electrical steel sheet, 10: surface layer,
20: inner layer

Claims

1. A non-oriented electrical steel sheet, comprising, by wt%: Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with the remainder Fe and inevitable impurities,

wherein a ratio (G_{sout}/G_{sin}) of an average grain size (G_{sout}) in a surface layer, which is a region from 1/8 or more to less than 1/4 of a total thickness of the steel sheet from a surface of the steel sheet, to an average grain size (G_{sin}) in an inner layer, which is a region from 1/4 to 3/4 of the total thickness of the steel sheet from the surface of the steel sheet, is 0.60 to 0.95, and,

a ratio ($Hv_{1/8}/Hv_{1/2}$) of a hardness ($Hv_{1/8}$) at a point at 1/8 of the total thickness of the steel sheet (1/8t) from the surface of the steel sheet to a hardness ($Hv_{1/2}$) at a point at 1/2 of the total thickness of the steel sheet (1/2t) is 1.05 or more.

2. The non-oriented electrical steel sheet of claim 1,

satisfying the following Equation 1:

[Equation 1]

$$[Si] \times [Mn]/(4 \times [Al]) \leq 1.0$$

(in Equation 1, [Si], [Mn], and [Al] represent the contents (wt%) of Si, Mn, and Al, respectively.

3. The non-oriented electrical steel sheet of claim 1, further comprising one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%), S: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

4. The non-oriented electrical steel sheet of claim 1, further comprising one or more of Sn, Sb, Bi, Pb, Ge, and As at 0.005 to 0.200 wt%, respectively or in total.

5. The non-oriented electrical steel sheet of claim 1, further comprising one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

6. The non-oriented electrical steel sheet of claim 1, further comprising one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

7. The non-oriented electrical steel sheet of claim 1, wherein:
the average grain size ($G_{s_{in}}$) in the inner layer is 70 to 90 μm .

8. The non-oriented electrical steel sheet of claim 1, wherein:
the average grain size ($G_{s_{out}}$) in the surface layer is 55 to 75 μm .

9. The non-oriented electrical steel sheet of claim 1, wherein:
the hardness ($Hv_{1/2}$) at a point at 1/2 of the total thickness of the steel sheet (1/2t) from the surface of the steel sheet is 220 to 235 H.

10. The non-oriented electrical steel sheet of claim 1, wherein:
the hardness ($Hv_{1/8}$) at a point at 1/8 of the total thickness of the steel sheet (1/8t) from the surface of the steel sheet is 240 to 270 Hv.

11. A method for manufacturing a non-oriented electrical steel sheet, comprising:

manufacturing a hot-rolled steel sheet by hot rolling a slab including by wt%: Si: 1.5 to 5.0%, Al: 0.1 to 2.0%, and Mn: 0.1 to 2.0%, with the remainder Fe and inevitable impurities;
manufacturing a cold-rolled sheet by cold rolling the hot-rolled steel sheet; and
cold-rolled sheet annealing the cold-rolled sheet,
wherein the manufacturing the cold-rolled sheet includes first heating of heating the cold-rolled sheet in a temperature range of 300 °C or more and less than 500 °C,
second heating of heating the cold-rolled sheet in a temperature range of 500 to 700 °C, and
soaking, and
satisfies the following Equation 2 and Equation 3:

[Equation 2]

$$HR1/DP1 \leq 1.5$$

[Equation 3]

$$HR2/DP2 \geq 6$$

(in Equation 2 and Equation 3, HR1 and HR2 are heating rates (°C/sec) in the first heating and the second heating, respectively, and DP1 and DP2 are dew point temperatures (°C) in the first heating and the second heating, respectively.)

12. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the slab satisfies the following Equation 1:

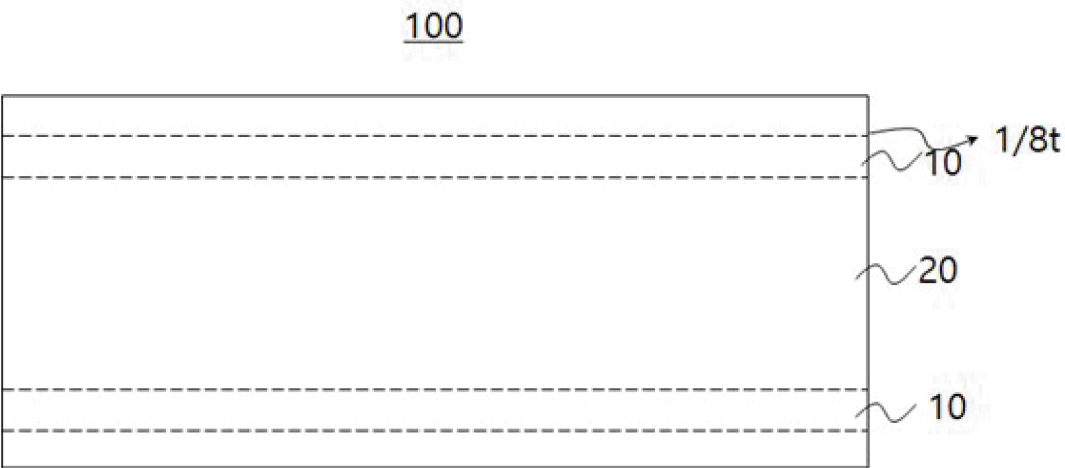
[Equation 1]

$$[\text{Si}] \times [\text{Mn}] / (4 \times [\text{Al}]) \leq 1.0$$

(in Equation 1, [Si], [Mn], and [Al] represent the contents (wt%) of Si, Mn, and Al in the slab, respectively.)

13. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the slab further comprises one or more of P: 0.1 wt% or less (excluding 0%), C: 0.005 wt% or less (excluding 0%),
S: 0.005 wt% or less (excluding 0%), Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).
14. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the slab further includes one or more of Sn, Sb, Bi, Pb, Ge, and As at 0.005 to 0.200 wt%, respectively or in total.
15. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the slab further includes one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).
16. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the slab further comprises one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).
17. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
wherein the heating rate in the first heating is 50°C/sec or less.
18. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the dew point temperature in the first heating is 30°C or more.
19. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the heating rate in the second heating is 50°C/sec or more.
20. The method for manufacturing a non-oriented electrical steel sheet of claim 11, wherein:
the dew point temperature in the second heating is more than 0°C to 10°C or less.

【Figure 1】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/097018

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/06(2006.01)i; C22C 38/04(2006.01)i; C22C 38/14(2006.01)i; C22C 38/00(2006.01)i;
C22C 38/42(2006.01)i; C22C 38/58(2006.01)i; C22C 38/52(2006.01)i; C22C 38/12(2006.01)i; C21D 8/12(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)

C22C 38/02(2006.01); C21D 8/12(2006.01); C22C 38/00(2006.01); C22C 38/34(2006.01); C22C 38/60(2006.01)

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

Korean utility models and applications for utility models: IPC as above

Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 무방향(non-oriented), 전기강판(electrical steel sheet), 결정립 입경(grain size), 경도(hardness), 이슬점(dew point), 가열속도(heating velocity)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2023-0095257 A (POSCO) 29 June 2023 (2023-06-29) See claims 1, 7 and 9-10.	1-20
A	JP 7173286 B2 (NIPPON STEEL CORP.) 16 November 2022 (2022-11-16) See claim 1.	1-20
A	JP 2008-031490 A (JFE STEEL K.K.) 14 February 2008 (2008-02-14) See claim 1.	1-20
A	KR 10-2021-0125073 A (NIPPON STEEL CORPORATION) 15 October 2021 (2021-10-15) See claims 1 and 4.	1-20
A	KR 10-2020-0009321 A (POSCO) 30 January 2020 (2020-01-30) See paragraphs [0022]-[0028] and claim 12.	1-20

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

* Special categories of cited documents:

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

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Date of the actual completion of the international search 18 March 2025	Date of mailing of the international search report 19 March 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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