



(11) **EP 4 826 040 A1**

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

(43) Date of publication:
21.10.2026 Bulletin 2026/43

(21) Application number: **24904467.8**

(22) Date of filing: **16.12.2024**

(51) International Patent Classification (IPC):
C22C 38/02 ^(2006.01) **C22C 38/06** ^(2006.01)
C22C 38/04 ^(2006.01) **C22C 38/00** ^(2006.01)
C22C 38/14 ^(2006.01) **C22C 38/42** ^(2006.01)
C22C 38/58 ^(2006.01) **C22C 38/52** ^(2006.01)
C22C 38/12 ^(2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/12; C22C 38/00; C22C 38/02; C22C 38/04;
C22C 38/06; C22C 38/12; C22C 38/14;
C22C 38/42; C22C 38/52; C22C 38/58; H01F 1/147

(86) International application number:
PCT/KR2024/097019

(87) International publication number:
WO 2025/127904 (19.06.2025 Gazette 2025/25)

(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 ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **15.12.2023 KR 20230183897**

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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 disclosure includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5% and includes the balance of Fe and an inevitable impurity. The non-oriented electrical steel sheet satisfies Equation 1 below.

[Equation 1]

$$0.45 \leq (VA+VB+VC)/(VD+VE+VF) \leq 1.45.$$

In Equation 1, each of VA, VB, VC, VD, VE, and VF represents an area fraction (%) of a texture having an orientation within 15° from each of (001)[0-10], (001)[-1-10], (100)[025], (223)[1-10], (111)[3-41], and (112)[1-10].

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Description**[Technical Field]**

[0001] An embodiment of the present disclosure relates to a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, the embodiment of the present disclosure relates to the non-oriented electrical steel sheet that develops a specific texture by adjusting a reduction ratio of each pass in finishing rolling during a hot-rolled sheet manufacturing process to simultaneously improve a strength and a magnetic characteristic, and the method for manufacturing the same.

[Background Art]

[0002] A non-oriented electrical steel sheet is mainly used in a motor that converts an electrical energy into a mechanical energy, and in order to achieve a high efficiency in the process, an excellent magnetic characteristic of the non-oriented electrical steel sheet is required. In particular, as an eco-friendly vehicle driven by the motor instead of an internal combustion engine has recently been gaining attention, demand for the non-oriented electrical steel sheet used as a core material of a driving motor is increasing, and for this purpose, the non-oriented electrical steel sheet with the excellent magnetic characteristic and an excellent strength is required. A magnetic characteristic of the non-oriented electrical steel sheet is mainly evaluated by an iron loss and a magnetic flux density. The iron loss may refer to an energy loss that occurs at a specific magnetic flux density and a specific frequency, and the magnetic flux density may refer to a degree of magnetization obtained under a specific magnetic field. When the iron loss is low, the motor with a high energy efficiency may be manufactured under the same condition, and when the magnetic flux density is high, the motor may be miniaturized or a copper loss may be reduced. Therefore, the driving motor with an excellent efficiency and an excellent torque may be produced by using the non-oriented electrical steel sheet with the low iron loss and the high magnetic flux density, so that driving distance and output of the eco-friendly vehicle are improved. A characteristic of the non-oriented electrical steel sheet that should be considered is changed depending on an operating condition of the motor. $W_{15/50}$ that is an iron loss when a 1.5T magnetic field is applied at a commercial frequency of 50 Hz is widely used as a general criterion for evaluating the characteristic of the non-oriented electrical steel sheet used in the motor. However, because a magnetic characteristic is often important at a low magnetic field of 1.0 T or less and a high frequency of 400 Hz or higher in the non-oriented electrical steel sheet with a thickness of 0.35 mm or less used in a driving motor of the eco-friendly vehicle, a characteristic of the non-oriented electrical steel sheet is often evaluated using a $W_{10/400}$ iron loss. Additionally, a strength characteristic that was not very important due to increase in a rotational speed thereof is also evaluated as an important characteristic. Therefore, if recent energy efficiency improvement policy and direction of utilization of the non-oriented electrical steel sheet are reflected, it may be said that a technology of developing the non-oriented electrical steel sheet with a low high-frequency iron loss, a high magnetic flux density, and an excellent strength is essential. The most basic and effective method for reducing the iron loss among important magnetic characteristics of the non-oriented electrical steel sheet is a method for increasing an addition amount of Si, Al, or Mn that is an element with high resistivity or thinning a thickness of the steel sheet. Increasing the addition amount of Si, Al, or Mn may increase resistivity of a steel to reduce an eddy current loss among the iron loss of the non-oriented electrical steel sheet so that it has an effect of reducing the iron loss, and a high-frequency iron loss may have a larger proportion of the eddy current loss among the iron loss so that the increasing the addition amount of Si, Al, or Mn is a very effective method for reducing the high-frequency iron loss. However, the effect varies depending on an addition ratio, and as an addition amount of an alloying elements increases, the magnetic flux density is deteriorated. Therefore, in order to secure an excellent iron loss and an excellent magnetic flux density, the addition ratio between an appropriate addition amount of Si, Al, or Mn and the addition amount of Si, Al, or Mn should be appropriately controlled. The method for thinning the thickness of the steel sheet is also a method for greatly reducing the eddy current loss and is very effective in reducing the iron loss, but a thin steel sheet has a disadvantage of low productivity and processability. Various technologies such as improving a texture by using a special additional element such as REM to improve a magnetic property and introducing an additional manufacturing process such as warm rolling, double rolling, or double annealing have been reported to improve the magnetic flux density while reducing the iron loss of the non-oriented electrical steel sheet. However, because all of the technologies cause increase in a manufacturing cost or difficulty in mass production, it may be said that there is a need to develop a technology that is superior in the magnetic characteristic and easy to commercially produce. In addition, technologies are being developed to suppress and control formation of an inclusion by maximally suppressing an addition amount of an impurity and adding an element such as Ca, but this also causes the increase in the manufacturing cost and it is not easy to clearly secure the effect. A strength of the steel sheet tends to increase as an amount of alloy increases. However, because Si, Al, and the like are highly brittle elements and have different effects on the strength, contents and a ratio of components should be optimized to secure a high strength character-

istic. As a size of a grain is fine, the strength is improved, but there is an optimal size of the grain so that a technology appropriately controlling the size of the grain is also necessary to secure both the low iron loss and the high strength characteristic.

5 [Disclosure]

[Technical Problem]

10 **[0003]** An embodiment of the present disclosure provides a non-oriented electrical steel sheet and a method for manufacturing the same. Specifically, the embodiment of the present disclosure provides the non-oriented electrical steel sheet that develops a specific texture by adjusting a reduction ratio of each pass in finishing rolling during a hot-rolled sheet manufacturing process to simultaneously improve a strength and a magnetic characteristic, and the method for manufacturing the same.

15 [Technical Solution]

[0004] A non-oriented electrical steel sheet according to an embodiment of the present disclosure includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5% and includes the balance of Fe and an inevitable impurity. The non-oriented electrical steel sheet satisfies Equation 1 below.

[Equation 1]

$$0.45 \leq (VA+VB+VC)/(VD+VE+VF) \leq 1.45.$$

25 **[0005]** In Equation 1, each of VA, VB, VC, VD, VE, and VF represents an area fraction (%) of a texture having an orientation within 15° from each of (001)[0-10], (001)[-1-10], (100)[025], (223)[1-10], (111)[3-41], and (112)[1-10].

[0006] The non-oriented electrical steel sheet may satisfy Equation 2 below.

30 [Equation 2]

$$0.35 \leq VC/VE \leq 1.35$$

35 **[0007]** In Equation 2, each of VC and VE may represent the area fraction (%) of the texture having the orientation within 15° from each of (100)[025] and (111)[3-41].

[0008] The non-oriented electrical steel sheet may further include at least one 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%).

40 **[0009]** The non-oriented electrical steel sheet may further include 0.005 to 0.200 wt% of each or a combined amount of one or more of Sn, Sb, Bi, Pb, Ge, and As.

[0010] The non-oriented electrical steel sheet may further include at least one 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%).

45 **[0011]** The non-oriented electrical steel sheet may further include at least one 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%).

[0012] Resistivity at 25°C may be 63 μΩ·cm or more.

50 **[0013]** An iron loss ($W_{10/400}$) may be 2.0 W/Kg or less, and a magnetic flux density (B50) may be 1.60 T or more.

[0014] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present disclosure includes: manufacturing a hot-rolled steel sheet by hot-rolling a slab including, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5% and including the balance of Fe and an inevitable impurity; manufacturing a cold-rolled sheet by cold-rolling the hot-rolled steel sheet; and annealing the cold-rolled sheet. The manufacturing of the hot-rolled steel sheet includes rough rolling and finish rolling, the finishing rolling is performed through n passes where n is 2 or more, and satisfies Equation 3 below.

[Equation 3]

$$R1 / (R1 + R2 + \dots + Rn) \geq 0.2.$$

[0015] In Equation 3, R1 to Rn represent reduction ratios (%) of first to nth passes, respectively.

[0016] The finish rolling may satisfy Equation 4 below.

[Equation 4]

$$R1/Rn \leq 8$$

[0017] In Equation 4, R1 and Rn may represent the reduction ratios (%) of the first and nth passes, respectively.

[0018] The reduction ratio (R1) of the first pass in the finishing rolling may be 35 to 80%.

[0019] The reduction ratio (Rn) of the last pass in the finishing rolling may be 7 to 35%.

[0020] The slab may further include at least one 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 0.005 to 0.200 wt% of each or a combined amount of one or more of Sn, Sb, Bi, Pb, Ge, and As.

[0022] The slab may further include at least one 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 at least one 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%).

[Advantageous Effects]

[0024] A non-oriented electrical steel sheet according to an embodiment of the present disclosure may have an improved texture to have an excellent magnetic flux density, an excellent iron loss, and an excellent yield strength at the same time.

[0025] Ultimately, the non-oriented electrical steel sheet according to an embodiment of the present disclosure may contribute to manufacturing a motor for an eco-friendly vehicle, a motor for high-efficiency home appliance, and a super premium class electric motor.

[Mode for Invention]

[0026] Terms such as "first", "second", and "third" are used herein to describe various portions, components, regions, layers, and/or sections, but are not limited thereto. The terms are used only to distinguish one portion, component, region, layer, or section from another portion, component, region, layer, or section. Accordingly, a first portion, component, region, layer, or section described below may be referred to as a second portion, component, region, layer, or section within a scope that does not depart from a scope of the present disclosure.

[0027] A technical term used herein is intended only to refer to a specific embodiment, and is not intended to limit the present disclosure. Singular forms used herein also include plural forms unless phrases clearly indicate an opposite meaning. A term "include" used in the specification specifies a specific characteristic, region, integer, step, operation, element, and/or component, and does not exclude presence or addition of another characteristic, region, integer, step, operation, element, and/or component.

[0028] When it is said that a portion is "on" or "above" another portion, the portion may be disposed directly on or above the other portion, or another portion may be interposed therebetween. In contrast, when a portion is said to be "directly above" another portion, no other portion is interposed therebetween.

[0029] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0030] In an embodiment of the present disclosure, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional element.

[0031] Although not otherwise defined, all terms used herein, including a technical term and a scientific term, have the same meanings as those generally understood by a person of ordinary skill in the art to which the present disclosure belongs. Terms defined in a dictionary commonly used are additionally interpreted to have a meaning consistent with the relevant technical literature and the presently disclosed contents, and are not interpreted in an

ideal or very formal sense unless otherwise defined.

[0032] Hereinafter, an embodiment of the present disclosure will be described in detail so that a person of ordinary skill in the art to which the present disclosure belongs may easily implement the present disclosure. The present disclosure may be modified in various ways, all without departing from the spirit or scope of the present disclosure.

[0033] A non-oriented electrical steel sheet according to an embodiment of the present disclosure may include, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5%, and may include the balance of Fe and an inevitable impurity.

[0034] Hereinafter, a reason for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.50 to 5.00 wt%

[0035] Silicon (Si) may play a role in lowering an iron loss by increasing resistivity of a material and increasing a strength through solid solution strengthening. If too little Si is added, an effect of improving the iron loss and the strength may be insufficient. If too much Si is added, a magnetic flux density may be greatly reduced, and rollability may be deteriorated due to increase in brittleness. Thus, the non-oriented electrical steel sheet may include 1.5 to 5.0 wt% of Si. For example, the non-oriented electrical steel sheet may include 2.50 to 4.50 wt% of Si. For example, the non-oriented electrical steel sheet may include 2.70 to 3.85 wt% of Si.

Al: 0.10 to 2.50 wt%

[0036] Aluminum (Al) may play a role in increasing resistivity of a material to lower an iron loss and improve rollability, and may play a role in reducing magnetic anisotropy to reduce a magnetic deviation in a rolling direction and a direction perpendicular to the rolling. If too little Al is added, it may be difficult to obtain an effect of reducing a high-frequency iron loss. If too much Al is added, nitride may be excessively formed to degrade a magnetic characteristic. Thus, the non-oriented electrical steel sheet may include 0.10 to 2.50 wt% of Al. For example, the non-oriented electrical steel sheet may include 0.50 to 2.50 wt% of Al. For example, the non-oriented electrical steel sheet may include 0.60 to 2.30 wt% of Al.

Mn: 0.10 to 2.50 wt%

[0037] Manganese (Mn) may play a role in improving an iron loss and improving a texture by increasing resistivity of a material. If too little Mn is added, sulfide may be finely formed to degrade a magnetic characteristic, and if too much Mn is added, a magnetic flux density may be adversely affected. Thus, the non-oriented electrical steel sheet may include 0.10 to 2.50 wt% of Mn. For example, the non-oriented electrical steel sheet may include 0.2 to 1.8 wt% of Mn. For example, the non-oriented electrical steel sheet may include 0.50 to 2.50 wt% of Mn.

[0038] In an embodiment of the present disclosure, the non-oriented electrical steel sheet may have resistivity of $63.0 \mu\Omega\cdot\text{cm}$ or more at 25°C . The iron loss of the non-oriented electrical steel sheet may be divided into a hysteresis loss and an eddy current loss. If resistivity of a steel is increased by adding an element such as Si, Al, or Mn, the eddy current loss may be greatly reduced. For example, as a frequency increases, a proportion of the eddy current loss among the total iron loss may increase. Thus, in order to obtain an excellent high-frequency iron loss, it is necessary to control the resistivity of the steel to a certain level or higher, and if resistivity (ρ) of the steel is $63 \mu\Omega\cdot\text{cm}$ or more, an excellent characteristic may be secured through the present disclosure. In some embodiments, the resistivity (ρ) may be 64.0 to $90.0 \mu\Omega\cdot\text{cm}$.

[0039] In an embodiment of the present disclosure, the resistivity may be measured using a 4-point method or the like.

[0040] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one 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

[0041] Phosphorus (P) may be a grain boundary and surface segregation element, and may have an effect of improving a texture of a steel. However, if too much P is added, an iron loss may be degraded by suppressing growth of a grain and rollability may be deteriorated due to segregation of a grain boundary so that productivity is decreased. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0500 wt% of P. For example, the non-oriented electrical steel sheet may include 0.0020 to 0.0200 wt% of P.

C: 0.0050 wt% or less

[0042] Carbon (C) may cause magnetic aging and may be combined with another impurity element to form carbide so that it impedes a grain boundary or a movement of a magnetic wall to deteriorate a magnetic characteristic. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0035 wt% of C.

S: 0.0050 wt% or less

[0043] Sulfur (S) may form MnS and CuS that are fine precipitates to deteriorate a magnetic characteristic and hot workability. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0040 wt% of S.

Ti: 0.0050 wt% or less

[0044] Titanium (Ti) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide, fine nitride, or fine sulfide within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0035 wt% of Ti.

N: 0.0050 wt% or less

[0045] Nitrogen (N) not only may form a fine AlN precipitate inside a base material but also may be combined with another impurity to form a fine precipitate so that it inhibits growth of a grain and a movement of a magnetic wall to worsen an iron loss. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0040 wt% of N.

[0046] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include 0.005 to 0.200 wt% of each or a combined amount of one or more of Sn, Sb, Bi, Pb, Ge, and As.

Sn

[0047] Tin (Sn) may be segregated on a grain boundary and a surface to play a role in improving a texture of a material and inhibiting surface oxidation so that it is added to improve a magnetic characteristic. If too much Sn is added, segregation of a grain boundary may become severe so that a surface quality is degraded, and hardness may be increased to cause breakage of a cold-rolled sheet so that rollability is reduced. For example, the non-oriented electrical steel sheet may include 0.005 to 0.200 wt% of Sn. For example, the non-oriented electrical steel sheet may include 0.010 to 0.080 wt% of Sn.

Sb

[0048] Antimony (Sb) may be segregated on a grain boundary and a surface to play a role in improving a texture of a material and inhibiting surface oxidation so that it is further added to improve a magnetic characteristic. If too much Sb is added, segregation of a grain boundary may become severe so that a surface quality is degraded, and hardness may be increased to cause breakage of a cold-rolled sheet so that rollability is reduced. For example, the non-oriented electrical steel sheet may include 0.005 to 0.200 wt% of Sb. For example, the non-oriented electrical steel sheet may include 0.010 to 0.080 wt% of Sb.

Bi, Pb, Ge, and As

[0049] When bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are additionally added, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) may be segregated at a grain boundary to relieve stress concentration at the grain boundary during cold rolling. Thus, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) may improve a magnetic flux density by suppressing a recrystallization of <111>/ND orientation grain in annealing of the recrystallization that is a post-process. If bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are properly added, the above-described effect may be additionally obtained, but if too much of them is included, a large amount of segregation may be generated so that the magnetic flux density and an iron loss may be rather degraded by suppressing growth of the grain.

[0050] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one 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%

[0051] Copper (Cu) may play a role in forming sulfide together with Mn. If too little Cu is added, (Cu-Mn)S may be finely precipitated so that a magnetic characteristic is deteriorated. If too much Cu is added, high-temperature brittleness may occur so that a crack is formed during continuous casting or hot rolling. For example, the non-oriented electrical steel sheet may include 0.01 to 0.10 wt% of Cu.

Cr: 0.01 to 0.50 wt%

[0052] Chromium (Cr) may play a role in improving an iron loss by increasing resistivity. If too little Cr is added, a resistivity-increasing effect may not be sufficient. If too much Cr is included, a magnetic flux density may be decreased. For example, the non-oriented electrical steel sheet may include 0.050 to 0.20 wt% of Cr.

Ni: 0.05 wt% or less

[0053] Nickel (Ni) may react with impurity elements to form fine sulfide, fine carbide, and fine nitride so that it has a harmful influence on a magnetic characteristic. For example, the non-oriented electrical steel sheet may include 0.001 to 0.03 wt% of Ni.

Zn: 0.01 wt% or less

[0054] If a content of zinc (Zn) is excessive, zinc (Zn) may act as an impurity to deteriorate a magnetic characteristic. Thus, Zn may be added within the above-described range

[0055] For example, the non-oriented electrical steel sheet may include 0.001 to 0.005 wt% of Zn.

Co: 0.05 wt% or less

[0056] Cobalt (Co) may not form a fine-sized precipitate that degrades a magnetic characteristic of the steel sheet, but may increase a high-temperature strength to cause a defect in a shape of a coil after hot rolling.

[0057] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may further include at least one 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

[0058] If an excessive amount of molybdenum (Mo) is added, segregation of a segregation element may be suppressed so that an effect of improving a texture is reduced. Thus, the non-oriented electrical steel sheet may include 0.03 wt% or less of Mo. A lower limit thereof is not particularly limited, but Mo may play a role in improving the texture by being segregated on a surface and a grain boundary so that the non-oriented electrical steel sheet includes 0.001 wt% or more of Mo. For example, the non-oriented electrical steel sheet may include 0.001 to 0.010 wt% of Mo. For example, the non-oriented electrical steel sheet may include 0.005 to 0.010 wt% of Mo.

B: 0.0050 wt% or less

[0059] If an excessive amount of boron (B) is added, deterioration of a magnetic characteristic may be caused due to formation of an inclusion within a steel or the like. Thus, the non-oriented electrical steel sheet may include 0.005 wt% or less of B. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0001 wt% of B due to a steelmaking cost. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.0030 wt% of B.

V: 0.0050 wt% or less

[0060] Vanadium (V) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide or fine nitride within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of V. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0003 wt% of V due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0003 to 0.0050 wt% of V. For example,

the non-oriented electrical steel sheet may include 0.0003 to 0.0030 wt% of V.

Ca: 0.0050 wt% or less

- 5 **[0061]** Calcium (Ca) may have a strong tendency in which a precipitate is formed within a steel, and may form fine sulfide within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss.

Nb: 0.0050 wt% or less

- 10 **[0062]** Niobium (Nb) may have a strong tendency in which a precipitate is formed within a steel, and may form fine carbide or fine nitride within a base material to suppress growth of a grain and a movement of a magnetic wall so that it deteriorates an iron loss. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of Nb. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0003 wt% of Nb due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0003 to 0.0050 wt% of Nb. For example, the non-oriented electrical steel sheet may include 0.0003 to 0.0030 wt% of Nb.

Zr: 0.0050 wt% or less

- 20 **[0063]** If an excessive amount of zirconium (Zr) is added, deterioration of a magnetic characteristic may be caused due to formation of an inclusion within a steel or the like. Thus, the non-oriented electrical steel sheet may include 0.005 wt% or less of Zr. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0001 wt% of Zr due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0001 to 0.0050 wt% of Zr. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0030 wt% of Zr.

Te: 0.0100 wt% or less

- 30 **[0064]** Because tellurium (Te) is diffused into an oxide layer on a surface of a hot-rolled coil to increase a coefficient of friction between the oxide layer and a rolling work roll and be concentrated at a lower portion of the oxide layer so it improves hardness, tellurium (Te) may be added to prevent the oxide layer crushed during rolling from being pressed into a base material and remove the oxide layer crushed during the rolling. If an amount of Te added is too small, an effect thereof may be minimal. If too much Te is added, the oxide layer may be easily removed so that the base material is in direct contact with the work roll and the effect is reduced, and a deformation band may be excessively generated within the steel sheet during cold rolling so that {111}//ND texture unfavorable to a magnetic characteristic is developed. For example, the non-oriented electrical steel sheet may include 0.0001 to 0.007 wt% of tellurium.

Mg: 0.0050 wt% or less

- 40 **[0065]** Magnesium (Mg) may be an element that is mainly combined with S to form sulfide, and may affect a surface oxide layer of a base iron. Thus, the non-oriented electrical steel sheet may include 0.0050 wt% or less of Mg. A lower limit thereof is not particularly limited, but the non-oriented electrical steel sheet may include 0.0001 wt% of Mg due to a steelmaking cost. That is, the non-oriented electrical steel sheet may include 0.0001 to 0.0050 wt% of Mg. For example, the non-oriented electrical steel sheet may include 0.0005 to 0.0030 wt% of Mg.

- 45 **[0066]** The balance (or the remainder) may include Fe and an inevitable impurity. The inevitable impurity may be an impurity mixed in a steelmaking step and a manufacturing process of the non-directional electrical steel sheet, and because this is widely known in the field, a detailed description thereof will be omitted. An embodiment of the present disclosure does not exclude addition of an element in addition to the above-described alloy component, and may be variously included within a range that does not impair the technical idea of the present disclosure. If the additional element is included, the additional element may replace the balance of iron (Fe).

- 50 **[0067]** As described above, the embodiment of the present disclosure may develop a specific texture to simultaneously improve a strength and a magnetic characteristic.

[0068] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may satisfy Equation 1 below.

55 [Equation 1]

$$0.45 \leq (V_A + V_B + V_C) / (V_D + V_E + V_F) \leq 1.45$$

[0069] In Equation 1, each of VA, VB, VC, VD, VE, and VF may represent an area fraction (%) of a texture having an orientation within 15° from each of (001)[0-10], (001)[-1-10], (100)[025], (223)[1-10], (111)[3-41], and (112)[1-10].

[0070] In an embodiment of the present disclosure, the fraction of each of a (001) plane and a (111) plane parallel to a rolling plane that was previously considered as the texture that greatly affects the magnetic characteristic is also important, but a (223) plane and a (112) plane that are similar textures are also important. In an embodiment of the present disclosure, the fraction and degree of integration of each of (001)[0-10], (001)[-1-10], and (100)[025] textures that are advantageous for magnetization are strengthened, and the fraction and degree of integration of each of (223)[1-10], (111)[3-41], and (112)[1-10] textures that are disadvantageous for magnetization are reduced so that the magnetic characteristic is improved. If a value of Equation 1 is too small, the magnetization may be inferior so that an iron loss is increased. Even if the value of Equation 1 is larger, additional magnetic enhancement may not occur, and a process for achieving this may be complicated. For example, the value of Equation 1 may be 0.50 to 1.40. An orientation of the texture represented by (hkl)[uvw] in Equation 1 may mean orientation representation of the texture in Miller index representation. The Miller index may be a notation used in crystallography to indicate a direction and a plane of a crystal lattice, and (hkl) may be a plane parallel to the rolling plane of the steel sheet in a measured texture. The vector [uvw] may mean a direction parallel to the rolling direction in the measured texture.

[0071] In an embodiment of the present disclosure, the value of Equation 1 may be calculated by observing and analyzing the fraction of the texture through measurement of electron backscatter diffraction (EBSD). In order to secure reliability of data, it may be measured so that at least 5000 grains are included. A tolerance angle may be set to 15° or less.

[0072] The non-oriented electrical steel sheet according to an embodiment of the present disclosure may satisfy Equation 2 below.

[Equation 2]

$$0.35 \leq VC/VE \leq 1.35$$

$$0.35 \leq VC/VE \leq 1.35$$

[0073] In Equation 2, each of VC and VE may represent an area fraction (%) of the texture having an orientation within 15° from each of (100)[025] and (111)[3-41].

[0074] Equation 2 is an equation in which (100)[025] among the texture has a more favorable influence on the magnetic characteristic and (111)[3-41] among the texture has a more bad influence on the magnetic characteristic. If a value of Equation 2 is too small, magnetization may not occur well during magnetization so that an iron loss is greatly inferior. Even if the value of Equation 2 is larger, additional magnetic enhancement may not occur, and a process for achieving this may be complicated. For example, Equation 2 may be 0.35 to 1.30.

[0075] As described above, the embodiment of the present disclosure may develop a specific texture to simultaneously improve a strength and the magnetic characteristic. For example, the non-oriented electrical steel sheet according to an embodiment of the present disclosure may have an iron loss ($W_{10/400}$) of 12.0 W/Kg or less and a magnetic flux density (B50) of 1.60 T or more. A thickness standard thereof may be 0.20 mm. For example, the iron loss ($W_{10/400}$) may be 9.0 to 11.0 W/kg. The magnetic flux density (B50) may be 1.61 to 1.70 T. The iron loss ($W_{10/400}$) may be an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz. The magnetic flux density (B50) may refer to a magnetic flux density induced in a magnetic field of 5000 A/m. The iron loss ($W_{10/400}$) and the magnetic flux density (B50) may be measured with a single sheet tester in the rolling direction and the direction perpendicular to the rolling, and an average value thereof may be measured.

[0076] An embodiment of the present disclosure may have an excellent mechanical strength. For example, a yield strength may be greater than or equal to 480 MPa and less than or equal to 570 MPa. The yield strength may be measured using the 0.2% offset method during a tensile test.

[0077] A method for manufacturing the non-oriented electrical steel sheet according to an embodiment of the present disclosure may include a step of hot-rolling a slab to manufacture a hot-rolled steel sheet; a step of cold-rolling the hot-rolled steel sheet to manufacture a cold-rolled steel sheet; and a cold-rolled steel sheet annealing step of annealing the cold-rolled steel sheet.

[0078] Hereinafter, each step will be described in detail.

[0079] First, the slab may be hot rolled.

[0080] Because an alloy component of the slab is described in the alloy component of the above-described non-oriented electrical steel sheet, a redundant description thereof will be omitted. Because the alloy component is not substantially changed during a manufacturing process of the non-oriented electrical steel sheet, the alloy component of the non-oriented electrical steel sheet and the alloy component of the slab may be substantially the same.

[0081] For example, the slab may include, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5%, and may include the balance of Fe and an inevitable impurity.

[0082] Because another additional element is described in the alloy component of the non-oriented electrical steel sheet, a redundant description thereof will be omitted.

[0083] The slab may be heated before the hot rolling. A heating temperature of the slab is not limited, but the slab may be heated to 1200°C or less. If the heating temperature of the slab is too high, a precipitate such as AlN or MnS present within the slab may be re-dissolved and then may be finely precipitated during the hot rolling and the annealing to inhibit growth of a grain and reduce a magnetic characteristic.

[0084] Next, the slab may be hot rolled to manufacture the hot-rolled sheet.

[0085] In an embodiment of the present disclosure, it has been found that it is necessary to precisely control a condition from the hot rolling step in order to improve the texture. For example, it has been found that it is necessary to control a reduction ratio of each pass in finishing rolling.

[0086] In an embodiment of the present disclosure, the step of manufacturing the hot-rolled steel sheet may include a rough rolling step and a finish rolling step. The rough rolling step may be a process of manufacturing a bar by performing first rolling on the slab moved from a casting machine into a form of the steel sheet, and may include 3 to 4 rolling mills. The finishing rolling step may be a process of manufacturing a hot-rolled coil by rolling the rough-rolled steel sheet (i.e., the bar) to a final hot-rolled target thickness, and may include a continuous multi-stage rolling mill.

[0087] The finishing rolling step is performed through n passes where n is 2 or more, and satisfies Equation 3.

[Equation 3]

$$R1 / (R1 + R2 + \dots + Rn) \geq 0.20$$

[0088] In Equation 3, R1 to Rn may represent reduction ratios (%) of first to nth passes, respectively.

[0089] In an embodiment of the present disclosure, the reduction ratio for each step of the finishing rolling and the first reduction ratio may have a significant influence on formation of the texture. If the reduction ratio of each pass is appropriately adjusted as Equation 3, an α -fiber texture and a γ -fiber texture may be weakened so that the magnetic characteristic is improved. R1 may mean the first pass, and the number of passes may be based on passing through the work roll. The nth pass may be the last pass, and R1+R2+.....+Rn may refer to a sum of reduction ratios of all passes in the finishing rolling step. The reduction ratio may be obtained as (a thickness of the steel sheet before the pass - a thickness of the steel sheet after the pass) / (the thickness of the steel sheet before the pass) $\times$ 100 (%).

[0090] In an embodiment of the present disclosure, the finishing rolling may be 3 to 7 passes (i.e., n may be 3 to 7). If the number of passes is too small, a load of the rolling may be too great so that work becomes difficult. If the number of passes is too large, productivity may be decreased.

[0091] If the reduction ratio (R1) of the first pass of the finishing rolling is too large to satisfy Equation 3, the γ -fiber may be greatly strengthened so that the magnetic characteristic is deteriorated. For example, a value of Equation 3 may be 0.21 to 0.45.

[0092] The finishing rolling step may satisfy Equation 4 below.

[Equation 4]

$$R1 / Rn \leq 8.0$$

[0093] In Equation 4, R1 and Rn may represent reduction ratios (%) of the first and nth passes, respectively.

[0094] If the reduction ratio (Rn) of the last pass of the finishing rolling is too small to satisfy Equation 4, an effect of improving the texture with each of (001)[0-10], (001)[-1-10], and (100)[025] that is a magnetization easy direction may not be sufficient. For example, a value of Equation 4 may be 1.5 to 7.5.

[0095] The reduction ratio (R1) of the first pass in the finishing rolling step may be 35 to 80%. For example, the reduction ratio (R1) of the first pass in the finishing rolling step may be 38 to 80%.

[0096] The reduction ratio (Rn) of the last pass in the finishing rolling step may be 7 to 35%. For example, the reduction ratio (Rn) of the last pass in the finishing rolling step may be 10 to 30%.

[0097] A thickness of the hot-rolled sheet may be 1.0 to 4.5 mm. In a step of manufacturing the hot-rolled sheet, a finishing rolling temperature may be 800°C or higher. For example, the finishing rolling temperature may be 800 to 1000°C. The hot-rolled sheet may be wound at a temperature of 700°C or less. For example, the thickness of the hot-rolled sheet may be 1.5 to 4.3 mm.

[0098] After the hot-rolled steel sheet is manufactured, a step of annealing the hot-rolled steel sheet may be further included. In this case, a soaking temperature may be 800 to 1100°C. If a temperature of the annealing is too low, a

recrystallized structure may not be formed or may grow finely so that an effect of increasing a magnetic flux density is small. If the temperature of the annealing is too high, the magnetic characteristic may actually be deteriorated, and rolling workability may be deteriorated due to deformation of a sheet shape. For example, a range of the temperature may be 830 to 1080°C. A soaking time may be 10 to 300 seconds. The step of annealing the hot-rolled sheet may also be omitted.

[0099] Next, the hot-rolled steel sheet may be cold rolled to manufacture the cold-rolled sheet. In this case, the cold rolling may be performed at a reduction ratio of 40 to 85%. If the reduction ratio is too low, deformation energy accumulated in the rolled steel sheet may be small so that recrystallization becomes difficult in a subsequent annealing process. Thus, a rolling structure may remain so that a problem occurs in improving a magnetic flux density and an iron loss. Conversely, if the reduction ratio is too high, a recrystallization of <111>//ND orientation grain may be promoted in a subsequent annealing process and a grain may be fine so that a problem in which the magnetic flux density is inferior and the iron loss is increased occurs. For example, the reduction ratio may be 60 to 75%. In the cold rolling step, a tandem cold rolling mill that continuously cold-rolls the steel sheet using a plurality of rolling stands or a reverse rolling mill that discontinuously cold-rolls the steel sheet using 12 or more rolling rolls may be used. A final thickness of the rolling may be 0.1 to 0.35 mm.

[0100] In the step of manufacturing the cold-rolled sheet, one cold rolling or two or more cold rollings with intermediate annealing interposed therebetween may be performed.

[0101] Next, the cold-rolled sheet may be annealed in the cold-rolled steel sheet annealing step. In a process of annealing the cold-rolled sheet, an annealing temperature is not particularly limited as long as it is a temperature normally applied to non-oriented electrical steel sheet. The iron loss of the non-oriented electrical steel may be closely related to a size of the grain. The iron loss of the non-oriented electrical steel sheet may be divided into a hysteresis loss and the eddy current loss. The hysteresis loss may be decreased as the size of the grain is increased, and conversely, the eddy current loss may be increased as the size of the grain is increased. Therefore, there may exist an appropriate grain size in which a sum of the hysteresis loss and the eddy current loss is minimized. Therefore, it may be important to derive and apply an annealing temperature that may secure an optimal grain size, and the annealing temperature of 850 to 1100°C may be appropriate. If the annealing temperature is too low, the grain may become too fine so that the hysteresis loss is increased. If the annealing temperature is too high, the grain may become too coarse so that the eddy current loss is increased. Thus, the iron loss may become inferior. An annealing time may be also appropriate if it is 10 to 300 seconds, and the annealing may be performed in a mixed atmosphere of hydrogen or argon and nitrogen to prevent magnetic deterioration due to formation of an oxide layer.

[0102] During a cold-rolled sheet annealing process, all (i.e., 99% or more) of a processed structure formed during the cold rolling step may be recrystallized.

[0103] After the annealing of the cold-rolled sheet, an insulating film may be formed. The insulating film may be treated with an organic film, an inorganic film, or an organic-inorganic composite film, and may also be treated with another insulating film agent.

[0104] Hereinafter, the present disclosure will be described in more detail through an embodiment. However, the embodiment is only intended to illustrate the present disclosure, and the present disclosure is not limited thereto.

Embodiment 1

[0105] A slab is manufactured with components including Table 1 and the balance of Fe and an inevitable impurity. The slab is heated to 1170°C, is hot rolled to a thickness of 2.2 mm, and then is wound at 680°C. In this case, 7 passes are performed in the finishing rolling, and the reduction ratio of each pass is performed as shown in Table 2 below. The hot-rolled sheet is annealed at 1000°C for 50 seconds. After the hot-rolled sheet is annealed, a pickled specimen is cold rolled to a thickness of 0.2 mm, and annealing of the cold-rolled sheet is finally performed. In this case, the annealing of the cold-rolled sheet is performed at 1000°C for 50 seconds.

[0106] The texture is analyzed by cutting the steel sheet in the rolling direction to obtain a specimen and then using the EBSD. In this case, a tolerance angle is set to 15°.

[0107] The yield strength is measured using the 0.2% offset method during the tensile test.

[0108] The iron loss ($W_{10/400}$) and the magnetic flux density (B50) are measured using the single sheet tester.

(Table 1)

Steel grade	Si	Mn	Al	C	P	S	Ti	N	Resistivity ($\mu\Omega \cdot \text{cm}$)
1	3.28	1.45	2.08	0.001 5	0.004	0.004 0	0.000 7	0.002 7	82.0
2	3.64	2.29	1.47	0.002 0	0.009	0.000 9	0.001 8	0.002 3	83.9
3	3.28	1.53	0.63	0.001 3	0.008	0.003 8	0.003 2	0.003 7	66.1

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(continued)

	Steel grade	Si	Mn	Al	C	P	S	Ti	N	Resist ivity ($\mu\Omega\cdot\text{c m}$)
5	4	3.11	0.75	1.07	0.001 1	0.013	0.001 4	0.002 9	0.001 8	64.7
	5	3.28	1.81	2.24	0.002 2	0.010	0.001 1	0.001 3	0.001 6	85.9
	6	3.48	2.07	0.63	0.001 4	0.009	0.001 4	0.001 5	0.001 5	71.4
	7	2.95	0.82	1.48	0.001 0	0.010	0.002 3	0.001 4	0.002 8	67.9
10	8	3.81	0.67	2.05	0.002 9	0.013	0.001 9	0.002 0	0.001 4	83.3
	9	3.34	0.56	0.96	0.001 4	0.010	0.000 9	0.002 7	0.002 8	65.0
	10	3.44	1.29	1.34	0.002 9	0.007	0.003 3	0.003 6	0.001 5	74.6
	11	2.86	1.50	1.56	0.002 4	0.007	0.003 6	0.002 4	0.002 2	71.7
15	12	3.26	1.10	0.99	0.001 1	0.009	0.002 7	0.001 8	0.003 7	67.5
	13	3.01	0.54	1.64	0.002 6	0.012	0.001 3	0.001 3	0.002 8	68.8
	14	2.74	2.50	2.12	0.003 2	0.012	0.001 6	0.000 9	0.002 7	82.3
20	15	3.55	1.34	1.51	0.001 3	0.006	0.002 6	0.002 8	0.002 7	78.0
	16	2.41	0.98	1.30	0.000 7	0.007	0.000 8	0.002 7	0.001 2	60.7
	17	2.99	0.85	0.45	0.003 7	0.003	0.001 9	0.001 5	0.003 4	56.9
	18	3.06	1.11	0.70	0.000 8	0.007	0.002 7	0.002 1	0.002 1	62.0
25	19	3.15	0.62	1.32	0.003 6	0.004	0.003 0	0.002 9	0.002 3	67.3
	20	3.72	0.38	1.54	0.001 2	0.005	0.003 7	0.002 6	0.001 4	74.8
	21	3.83	0.67	1.64	0.001 8	0.007	0.003 8	0.002 5	0.004 0	78.8
30	22	3.06	1.99	1.61	0.000 9	0.006	0.001 5	0.001 7	0.001 2	77.3
	23	2.62	0.75	2.03	0.001 2	0.010	0.001 0	0.003 2	0.002 6	70.0
	24	3.90	1.79	1.60	0.002 1	0.011	0.002 1	0.003 0	0.003 1	85.5
	25	3.30	1.61	0.54	0.003 2	0.010	0.003 7	0.002 3	0.001 5	65.7
35	26	3.71	1.44	0.89	0.003 5	0.003	0.002 7	0.003 4	0.001 6	73.4
	27	2.89	0.67	1.48	0.002 4	0.013	0.002 8	0.001 8	0.001 0	66.4
	28	3.51	2.05	0.50	0.001 9	0.008	0.001 2	0.002 2	0.003 8	70.1
40	29	2.98	1.03	0.83	0.003 9	0.013	0.001 5	0.003 6	0.003 4	62.1
	30	3.20	0.50	0.57	0.002 0	0.008	0.002 8	0.001 2	0.002 9	58.7

(Table 2)

	Steel grade	R1 (%)	R1+R2+...+Rn (%)	Rn (%)	Equation 3	Equation 4
45	1	73	286	13	0.26	5.6
	2	53	235	29	0.23	1.8
	3	44	209	22	0.21	2.0
50	4	36	168	11	0.21	3.3
	5	58	228	25	0.25	2.3
	6	38	100	12	0.38	3.2
55	7	71	180	25	0.39	2.8
	8	52	180	14	0.29	3.7
	9	80	324	13	0.25	6.2

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(continued)

Steel grade	R1 (%)	R1+R2+...+Rn (%)	Rn (%)	Equation 3	Equation 4
10	42	201	23	0.21	1.8
11	55	262	16	0.21	3.4
12	66	221	16	0.30	4.1
13	66	151	17	0.44	3.9
14	71	285	10	0.25	7.1
15	64	286	15	0.22	4.3
16	53	254	13	0.21	4.1
17	38	131	5	0.29	7.6
18	36	132	18	0.27	2.0
19	32	181	24	0.18	1.3
20	71	206	7	0.34	10.1
21	50	288	6	0.17	8.3
22	43	238	18	0.18	2.4
23	28	178	28	0.16	1.0
24	60	186	5	0.32	12.0
25	65	203	6	0.32	10.8
26	80	254	9	0.31	8.9
27	32	350	26	0.09	1.2
28	63	336	7	0.19	9.0
29	38	201	4	0.19	9.5
30	40	221	4	0.18	10.0

(Table 3)

Steel grade	Equation 1	Equation 2	Yield strength (MPa)	W _{10/400} (W/Kg)	B50 (T)	Classification
1	1.09	0.37	530	9.12	1.62	Embodiment
2	1.37	0.92	521	9.20	1.62	Embodiment
3	1.15	0.84	485	9.88	1.63	Embodiment
4	0.55	0.88	487	10.02	1.63	Embodiment
5	1.30	0.70	530	9.35	1.62	Embodiment
6	0.77	0.42	517	9.80	1.63	Embodiment
7	0.50	0.40	481	9.77	1.62	Embodiment
8	0.65	1.28	523	9.19	1.62	Embodiment
9	0.72	0.68	512	9.80	1.63	Embodiment
10	0.67	0.35	544	9.65	1.62	Embodiment
11	1.18	0.82	498	9.82	1.63	Embodiment
12	1.09	1.05	504	10.18	1.64	Embodiment
13	1.02	1.05	511	9.86	1.63	Embodiment
14	0.96	0.92	530	9.50	1.62	Embodiment
15	1.29	0.38	542	10.13	1.64	Embodiment

(continued)

Steel grade	Equation 1	Equation 2	Yield strength (MPa)	$W_{10/400}$ (W/Kg)	B50 (T)	Classification
16	1.20	0.37	414	13.15	1.59	Comparative Example
17	1.06	0.57	429	13.21	1.59	Comparative Example
18	0.89	0.60	458	12.53	1.58	Comparative Example
19	0.85	0.33	508	12.55	1.57	Comparative Example
20	0.38	0.65	490	13.10	1.59	Comparative Example
21	0.20	0.23	506	12.98	1.59	Comparative Example
22	0.43	0.29	520	12.80	1.59	Comparative Example
23	0.38	0.55	490	12.73	1.58	Comparative Example
24	0.56	0.33	587	13.12	1.59	Comparative Example
25	0.35	0.33	483	13.86	1.57	Comparative Example
26	0.36	0.47	539	12.40	1.58	Comparative Example
27	0.48	0.28	486	12.94	1.58	Comparative Example
28	0.41	0.29	502	12.82	1.58	Comparative Example
29	0.37	0.33	467	13.20	1.59	Comparative Example
30	0.40	0.26	461	13.68	1.58	Comparative Example

[0109] As shown in Tables 1 to 3, it may be confirmed that the iron loss, the magnetic flux density, and the yield strength of No. 1 to 15 in which a composition of the steel and a reduction ratio of the finishing rolling are appropriately adjusted so that the specific texture is developed are excellent at the same time.

[0110] It may be confirmed that the iron loss, the magnetic flux density, or the yield strength of No. 16 to 30 in which the composition of the steel and the reduction ratio of the finishing rolling are not appropriately adjusted and the specific texture is not developed is inferior.

[0111] The present disclosure is not limited to the embodiments, may be manufactured in various different forms, and a person of ordinary skill in the art to which the present disclosure belongs will be able to understand that the present disclosure may be implemented in other specific forms without changing the technical idea or essential feature of the present disclosure. Therefore, it should be understood that the embodiments described above are illustrative and not limited in all respects.

Claims

1. A non-oriented electrical steel sheet, comprising, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5% and comprising the balance of Fe and an inevitable impurity,

wherein the non-oriented electrical steel sheet satisfies Equation 1 below:

[Equation 1]

$$0.45 \leq (VA+VB+VC)/(VD+VE+VF) \leq 1.45,$$

wherein in Equation 1, each of VA, VB, VC, VD, VE, and VF represents an area fraction (%) of a texture having an orientation within 15° from each of (001)[0-10], (001)[-1-10], (100)[025], (223)[1-10], (111)[3-41], and (112)[1-10].

2. The non-oriented electrical steel sheet of claim 1, wherein the non-oriented electrical steel sheet satisfies Equation 2 below:

[Equation 2]

$$0.35 \leq VC/VE \leq 1.35,$$

wherein in Equation 2, each of VC and VE represents the area fraction (%) of the texture having the orientation within 15° from each of (100)[025] and (111)[3-41].

3. The non-oriented electrical steel sheet of claim 1, further comprising at least one 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 0.005 to 0.200 wt% of each or a combined amount of one or more of Sn, Sb, Bi, Pb, Ge, and As.

5. The non-oriented electrical steel sheet of claim 1, further comprising at least one 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 at least one 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 resistivity at 25°C is 63 $\mu\Omega \cdot \text{cm}$ or more.

8. The non-oriented electrical steel sheet of claim 1, wherein an iron loss ($W_{10/400}$) is 12.0 W/Kg or less and a magnetic flux density (B50) is 1.60 T or more.

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

manufacturing a hot-rolled steel sheet by hot-rolling a slab including, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5% and including the balance of Fe and an inevitable impurity;
manufacturing a cold-rolled sheet by cold-rolling the hot-rolled steel sheet; and
annealing the cold-rolled sheet,
wherein the manufacturing of the hot-rolled steel sheet includes rough rolling and finish rolling, the finishing rolling is performed through n passes where n is 2 or more, and satisfies Equation 3 below:

[Equation 3]

$$R1 / (R1 + R2 + \dots + Rn) \geq 0.2,$$

wherein in Equation 3, R1 to Rn represent reduction ratios (%) of first to nth passes, respectively.

10. The method of claim 9, wherein the finish rolling satisfies Equation 4 below:

[Equation 4]

$$R1/Rn \leq 8,$$

wherein in Equation 4, R1 and Rn represent the reduction ratios (%) of the first and nth passes, respectively.

11. The method of claim 9, wherein the reduction ratio (R1) of the first pass in the finishing rolling is 35 to 80%.

12. The method of claim 9, wherein the reduction ratio (Rn) of the last pass in the finishing rolling is 7 to 35%.

13. The method of claim 9, wherein the slab further includes at least one 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%).

5 **14.** The method of claim 9, wherein the slab further includes 0.005 to 0.200 wt% of each or a combined amount of one or more of Sn, Sb, Bi, Pb, Ge, and As.

10 **15.** The method of claim 9, wherein the slab further includes at least one 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%).

15 **16.** The method of claim 9, wherein the slab further includes at least one 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%).

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/097019

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/06(2006.01)i; C22C 38/04(2006.01)i; C22C 38/00(2006.01)i; C22C 38/14(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

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 38/06(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), 집합조직(texture, aggregate structure), 방위(crystal orientation), 사상압연(finish rolling), 압하율(reduction rate)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2023-0095280 A (POSCO) 29 June 2023 (2023-06-29) See paragraph [0097], claims 1, 3-5, 7, 9-10 and 16 and table 2.	1-16
A	KR 10-0702242 B1 (EBG GESELLSCHAFT FÜR ELEKTROMAGNETISCHE WERKSTOFFE MBH) 03 April 2007 (2007-04-03) See claims 1, 6-7 and 11.	1-16
A	KR 10-2019-0078345 A (POSCO) 04 July 2019 (2019-07-04) See claim 6.	1-16
A	JP 2020-041169 A (NIPPON STEEL CORP.) 19 March 2020 (2020-03-19) See claim 1.	1-16
A	KR 10-1507942 B1 (POSCO) 18 May 2015 (2015-05-18) See claim 1.	1-16

☐ 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

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

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

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

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

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

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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

“&” document member of the same patent family

Date of the actual completion of the international search

18 March 2025

Date of mailing of the international search report

18 March 2025

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/097019

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KR	10-1507942	B1	18 May 2015	KR	10-2014-0084895	A	07 July 2014		

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