



(11)

EP 4 826 038 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: **24904465.2**

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

(51) International Patent Classification (IPC):
C22C 38/02 ^(2006.01) **C22C 38/04** ^(2006.01)
C22C 38/06 ^(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/KR2024/097011

(87) International publication number:
WO 2025/127902 (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 20230183898**

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

(57) An embodiment of the present invention provides a non-oriented electrical steel sheet including: in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5%, with a balance being Fe and inevitable impurities, wherein an area ratio of grains that are 30 μm smaller than an average grain size to grains that are 30 μm larger than the average grain size is 12% or more, an area ratio of grains having a grain size of 20 μm or less is 0.8% or less, and the non-oriented electrical steel sheet satisfies the following Formula 1.

[Formula 1]

$$GS_{STD}/GS_{AVE} \leq 0.7$$

(In Formula 1, GS_{STD} means the standard deviation of the grains, and GS_{AVE} means the average grain size.)

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Description**[Technical Field]**

5 **[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 and a method for manufacturing the same, in which strength and magnetism are simultaneously improved by appropriately forming grain sizes by controlling the reduction ratio and temperature of each pass in finish rolling during a hot-rolled sheet manufacturing process.

[Background Art]

10 **[0002]** A non-oriented electrical steel sheet is mainly used in a motor that converts electrical energy to mechanical energy, and an excellent magnetic characteristic of the non-oriented electrical steel sheet is required to achieve high efficiency while the motor converts the electrical energy to the mechanical energy. In particular, recently, as environmentally-friendly vehicles driven by motors instead of internal combustion engines have been gaining attention, the demand for non-oriented electrical steel sheets used as driving motor core materials is increasing, and for this purpose, non-oriented electrical steel sheets with excellent magnetic properties and strength are required. The magnetic properties of non-oriented electrical steel sheets are mainly evaluated by iron loss and magnetic flux density. The iron loss means energy loss occurring at a specific magnetic flux density and frequency, and the magnetic flux density means a degree of magnetization obtained in a specific magnetic field. Lower iron loss allows for more energy-efficient motors to be manufactured under the same conditions, and higher magnetic flux density allows for smaller motors or reduced copper loss. Therefore, by using non-oriented electrical steel sheets with low iron loss and high magnetic flux density, a driving motor with excellent efficiency and torque may be manufactured, thereby improving the driving range and output of environmentally-friendly vehicles. Depending on operational conditions of the motor, the characteristics of the non-oriented electrical steel sheet that should be considered is also varied. The general standard for evaluating the characteristics of non-oriented electrical steel sheets used in motors is widely used as W15/50, which is the iron loss when a 1.5T magnetic field is applied at a commercial frequency of 50Hz. However, in the case of non-oriented electrical steel sheets with a thickness of 0.35 mm or less used in environmentally-friendly vehicle driving motors, magnetic properties are often important at low magnetic fields of 1.0 T or less and high frequencies of 400 Hz or higher, so the properties of non-oriented electrical steel sheets are often evaluated using the $W_{10/400}$ iron loss. In addition, due to the increase in rotation speed, strength characteristics that were not previously considered important are now being evaluated as important characteristics. Therefore, reflecting the recent energy efficiency enhancement policies and the utilization trends of non-oriented electrical steel sheets, the development technology of non-oriented electrical steel sheets with low high-frequency core loss, high magnetic flux density, and excellent strength may be considered essential. Among the important magnetic characteristics of the non-oriented electrical steel sheet, a most basic and efficient method for lowering iron loss is to increase the amount of Si, Al, and Mn, which are elements with high resistivity, or to reduce a thickness of the steel sheet. Increasing the amount of Si, Al, and Mn added increases the resistivity of the steel, which reduces the eddy current loss among the iron losses of non-oriented electrical steel sheets, thereby reducing the iron loss, and in the case of high-frequency iron loss, the ratio of eddy current loss among the iron losses is greater, so it may be a very effective method for reducing high-frequency iron loss. However, the effect varies depending on the additive ratio, and since the magnetic flux density deteriorates as the amount of alloying elements added increases, the appropriate additive ratio and the additive ratio between the Si, Al, and Mn additions must be appropriately controlled to secure excellent iron loss and magnetic flux density. The method of making the thickness thin is also a method that greatly reduces eddy current loss, and is very effective in reducing iron loss, but thin steel sheets have the disadvantage of poor productivity and workability. As a method to improve the magnetic flux density while lowering the iron loss of the non-oriented electrical steel sheet, technologies for improving magnetic properties by improving texture by using special additive elements such as REM or for introducing additional manufacturing processes such as warm rolling, rolling twice, and annealing twice have been reported. However, all of these technologies cause an increase in manufacturing cost or have difficulties in mass production, so it is necessary to develop a technology that produces excellent magnetic properties and is easy to produce commercially. In addition, technologies for suppressing and controlling formation of inclusions by significantly suppressing an amount of impurities added and adding an element such as Ca are being developed, but these technologies also cause an increase in manufacturing cost, and it is difficult to clearly secure effects thereof. The strength of the steel sheet tends to increase as the alloy content increases. However, since Si, Al, and the like are brittle elements and have different effects on strength, the content and ratio of the components must be optimized in order to secure high strength characteristics. On the other hand, the finer the grain size, the better the strength, but there is an optimal grain size that minimizes iron loss, so in order to secure both low iron loss and high strength characteristics, a technology to

appropriately control the grain size is also necessary.

[Disclosure]

[Technical Problem]

[0003] 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 and a method for manufacturing the same, in which strength and magnetism are simultaneously improved by appropriately forming grain sizes by controlling the reduction ratio and temperature of each pass in finish rolling during a hot-rolled sheet manufacturing process.

[Technical Solution]

[0004] An embodiment of the present invention provides a non-oriented electrical steel sheet including: in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5%, with a balance being Fe and inevitable impurities, wherein an area ratio of grains that are 30 μm smaller than an average grain size to grains that are 30 μm larger than the average grain size is 12% or more, an area ratio of grains having a grain size of 20 μm or less is 0.8% or less, and the non-oriented electrical steel sheet satisfies the following Formula 1.

[Formula 1]

$$GS_{STD}/GS_{AVE} \leq 0.7$$

(In Formula 1, GS_{STD} means the standard deviation of the grains, and GS_{AVE} means the average grain size.)

[0005] The GS_{STD} may be 30 to 100 μm .

[0006] The GS_{AVE} may be 50 to 160 μm .

[0007] The non-oriented electrical steel sheet according to the 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%).

[0008] The non-oriented electrical steel sheet according to the embodiment of the present invention may further include 0.005 to 0.200 wt% of each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

[0009] The non-oriented electrical steel sheet according to the 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%).

[0010] The non-oriented electrical steel sheet according to the embodiment of the present invention 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%).

[0011] In the non-oriented electrical steel sheet according to the embodiment of the present invention, a resistivity (ρ) at 25°C may be 63 $\mu\Omega\cdot\text{cm}$ or more.

[0012] In the non-oriented electrical steel sheet according to the embodiment of the present invention, a core loss (W10/400) may be 12.0 W/Kg or less, and a magnetic flux density (B50) may be 1.60 T or more.

[0013] Another embodiment of the present invention provides a method for manufacturing a non-oriented electrical steel sheet, including: a step of 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%, with a balance being Fe and inevitable impurities, to manufacture a hot-rolled sheet; cold rolling the hot-rolled steel sheet to manufacture a cold-rolled sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0014] The step of manufacturing the hot-rolled steel sheet may include a rough rolling step and a finish rolling step, the finish rolling step may be performed through n passes, where n is 3 or more, and for a reduction ratio (R_f) of an intermediate pass, not a first or last pass, a largest absolute value of a difference between an average reduction ratio (R_{AVE}) of all passes of the finish rolling and the reduction ratio of the intermediate pass may be 40% or less.

[0015] The finish rolling step may have a difference (FET-FDT) between a finish rolling entry temperature (FET) and a finish rolling exit temperature (FDT) of 150°C or less.

[0016] The slab 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%).

[0017] The slab may further include 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

[0018] 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%).

[0019] 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%), and Mg: 0.0050 wt% or less (excluding 0%).

[Advantageous Effects]

[0020] The non-oriented electrical steel sheet according to the embodiment of the present invention has excellent magnetic flux density, iron loss, and yield strength simultaneously because the grain size is appropriately formed.

[0021] Ultimately, the non-oriented electrical steel sheet according to the embodiment of the present invention contributes to the manufacture of environmentally-friendly automobile motors, high-efficiency home appliance motors, and super premium-grade electric motors.

[Mode for Invention]

[0022] It will be understood that, although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers, and/or sections, they are not limited thereto. These terms are only used to distinguish one element, component, region, layer, or section from another element, component, region, layer, or section. Therefore, a first part, component, area, layer, or section to be described below may be referred to as second part, component, area, layer, or section within the range of the present invention.

[0023] The technical terms used herein are to simply mention a particular embodiment and are not meant to limit the present invention. An expression used in the singular encompasses an expression of the plural, unless it has a clearly different meaning in the context. In the specification, it is to be understood that the terms such as "including", "having", etc., are intended to indicate the existence of specific features, regions, numbers, stages, operations, elements, components, and/or combinations thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other features, regions, numbers, stages, operations, elements, components, and/or combinations thereof may exist or may be added.

[0024] When referring to a part as being "on" or "above" another part, it may be positioned directly on or above the other part, or another part may be interposed therebetween. In contrast, when referring to a part being "directly above" another part, no other part is interposed therebetween.

[0025] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0026] In embodiments of the present invention, inclusion of an additional element means replacing the balance of iron (Fe) by an additional amount of the additional elements.

[0027] Unless otherwise defined, all terms used herein, including technical or scientific terms, have the same meanings as those generally understood by those with ordinary knowledge in the field of art to which the present invention belongs. Terms defined in commonly used dictionaries are further interpreted as having meanings consistent with the relevant technical literature and the present disclosure, and are not to be construed as having idealized or very formal meanings unless defined otherwise.

[0028] Hereinafter, embodiments of the present invention will be described in detail so that those skilled in the art to which the present invention pertains may easily carry out the invention. As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present disclosure.

[0029] A non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, and Mn: 0.1 to 2.5%, with the balance being Fe and inevitable impurities.

[0030] Hereinafter, the reason for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.50 to 5.00 wt%

[0031] Silicon (Si) increases the resistivity of the material, lowers iron loss, and increases strength through solid solution strengthening. If too little Si is added, an effect of improving the iron loss and strength may be insufficient. If too much Si is added, the magnetic flux density may decrease significantly and the rollability may become poor due to increased brittleness. Accordingly, Si may be included in an amount of 1.5 to 5.0 wt%. More specifically, it may be included in an amount of 2.50 wt% to 4.50 wt%. More specifically, it may be included in an amount of 2.70 to 3.85 wt%.

Al: 0.10 to 2.50 wt%

[0032] Aluminum (Al) increases the resistivity of the material, lowers iron loss, improves rollability, and reduces magnetic anisotropy, thereby reducing magnetic deviation in the rolling direction and the direction perpendicular to the rolling direction. If too little Al is added, it may be difficult to obtain the effect of reducing high-frequency iron loss. If too much Al is added, nitride may be formed excessively, which may deteriorate magnetism. Accordingly, Al may be included in an amount of 0.10 to 2.50 wt%. More specifically, it may be included in an amount of 0.50 wt% to 2.50 wt%. More specifically, it may be included in an amount of 0.60 to 2.30 wt%.

Mn: 0.10 to 2.50 wt%

[0033] Manganese (Mn) improves the iron loss by increasing the resistivity of the material and serves to improve the texture. If too little Mn is added, fine sulfides are formed, causing magnetic deterioration, and if too much Mn is added, it may have a negative effect on the magnetic flux density. Accordingly, Mn may be included in an amount of 0.10 to 2.50 wt%. More specifically, it may be included in an amount of 0.15 wt% to 1.80 wt%.

[0034] In the embodiment of the present invention, the resistivity of the non-oriented electrical steel sheet at 25°C may be 63.0 $\mu\Omega\cdot\text{cm}$ or more. The iron loss of the non-oriented electrical steel sheet is divided into hysteresis loss and eddy current loss, and if the resistivity of the steel increases by adding elements such as Si, Al, and Mn, the eddy current loss may be significantly reduced. In particular, as the frequency increases, the proportion of the total iron loss occupied by the eddy current loss increases, so in order to obtain excellent high-frequency iron loss, it is necessary to control the resistivity of the steel to a certain level or higher, and through the present invention, when the resistivity (ρ) of the steel is 63 $\mu\Omega\cdot\text{cm}$ or higher, excellent characteristics may be secured. More specifically, the resistivity (ρ) may be 64.0 to 90.0 $\mu\Omega\cdot\text{cm}$.

[0035] In the embodiment of the present invention, resistivity may be measured using a 4-point method and the like.

[0036] The non-oriented electrical steel sheet according to the 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 at 0.100 wt% or less

[0037] Phosphorus (P) is a grain boundary and surface segregation element, and has an effect of improving texture of steel. However, if too much P is added, it may lower the iron loss by inhibiting grain growth and lower the rollability due to grain boundary segregation, which may also lower the productivity. More specifically, P may be included in an amount of 0.0001 to 0.0500 wt%. More specifically, P may be included in an amount of 0.0010 to 0.0200 wt%.

C: 0.0050 wt% or less

[0038] Carbon (C) may cause magnetic aging and combine with other impurity elements to form carbides, which may impede grain boundary or domain wall movement and deteriorate magnetic properties. More specifically, C may be included in an amount of 0.0005 to 0.0045 wt%.

S: 0.0050 wt% or less

[0039] Sulfur (S) may form fine precipitates, MnS and CuS, which may worsen magnetic properties and hot workability. More specifically, S may be included in an amount of 0.0005 to 0.0045 wt%.

Ti: 0.0050 wt% or less

[0040] Titanium (Ti) has a strong tendency to form precipitates inside the steel, and may deteriorate the iron loss by forming fine carbides, nitrides, or sulfides inside the base material, thereby suppressing grain growth and domain wall movement. More specifically, Ti may be included in an amount of 0.0005 to 0.0035 wt%.

N: 0.0050 wt% or less

[0041] Nitrogen (N) not only forms fine AlN precipitates inside the base material, but also combines with other impurities to form fine precipitates, which may suppress grain growth and domain wall movement, thereby worsening iron loss. Specifically, N may be included in an amount of 0.0005 to 0.0045 wt%.

[0042] The non-oriented electrical steel sheet according to the embodiment of the present invention may further

include 0.005 to 0.200 wt% of each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

Sn

[0043] Tin (Sn) may be segregated at grain boundaries and surfaces to improve the texture of the material and suppress surface oxidation, and thus may be added to improve magnetic properties. When too much Sn is added, grain boundary segregation is severe, the surface quality is deteriorated, hardness is increased, and the cold-rolled sheet is broken, thereby reducing rollability. Specifically, Sn may be further included in an amount of 0.005 to 0.200 wt%. More specifically, it may further include 0.010 to 0.080 wt%.

Sb

[0044] Antimony (Sb) may be segregated at grain boundaries and surfaces to improve the texture of the material and suppress surface oxidation, and thus may be additionally added to improve magnetic properties. When too much Sb is added, grain boundary segregation is severe, the surface quality is deteriorated, hardness is increased, and the cold-rolled sheet is broken, thereby reducing rollability. Specifically, Sb may be further included in an amount of 0.005 to 0.200 wt%. More specifically, it may further include 0.010 to 0.080 wt%.

Bi, Pb, Ge, and As

[0045] When additionally added, bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) segregate at grain boundaries, thereby alleviating stress concentration at grain boundaries during cold rolling, thereby suppressing recrystallization of <111>ND orientation grains in the subsequent recrystallization annealing process, thereby improving magnetic flux density. If these are added appropriately, the aforementioned effects may be additionally obtained, but if they are included in too much, a large amount of segregation may occur, inhibiting grain growth and resulting in lower magnetic flux density and iron loss.

[0046] The non-oriented electrical steel sheet according to the 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%

[0047] Copper (Cu) serves to form sulfides together with Mn. When Cu is further added, if too little Cu is added, (Cu·Mn)S may be finely precipitated and magnetism may be degraded. If too much Cu is added, high temperature brittleness occurs, which may form cracks during casting or hot rolling. More specifically, Cu may be included in an amount of 0.01 to 0.10 wt%.

Cr: 0.01 to 0.50 wt%

[0048] Chromium (Cr) serves to improve iron loss by increasing resistivity. If too little Cr is added, the effect of increasing resistivity may not be sufficient. If too much Cr is included, the magnetic flux density may deteriorate. Specifically, Cr may be contained in an amount of 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0049] Nickel (Ni) may react with impurity elements to form fine sulfides, carbides, and nitrides, which may have a detrimental effect on magnetism. More specifically, Ni may be included in an amount of 0.001 to 0.03 wt%.

Zn: 0.01 wt% or less

[0050] If the content of zinc (Zn) is excessive, it may act as an impurity and deteriorate magnetism. Therefore, Zn may be further added within the above-mentioned range. More specifically, Zn may be included in an amount of 0.001 to 0.005 wt%.

Co: 0.05 wt% or less

[0051] Cobalt (Co), while not forming fine precipitates that degrade the magnetism of the steel sheet, may increase high-temperature strength, leading to poor coil shape after hot rolling.

[0052] The non-oriented electrical steel sheet according to the embodiment of the present invention 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

[0053] If molybdenum (Mo) is added in excessive amounts, the effect of improving the texture may be reduced by suppressing the segregation of segregation elements. Therefore, Mo may be included in an amount of 0.03 wt% or less. The lower limit thereof is not particularly limited, but it may be included in an amount of 0.001 wt% or more because it serves to improve the texture by segregating on the surface and grain boundaries. More specifically, Mo may be included in an amount of 0.001 to 0.010 wt%. More specifically, Mo may be included in an amount of 0.005 to 0.010 wt%.

B: 0.0050 wt% or less

[0054] If boron (B) is added in excessive amounts, it may cause deterioration of magnetism through the formation of inclusions in the steel. Therefore, B may be included in an amount of 0.005 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. More specifically, B may be included in an amount of 0.0001 to 0.0030 wt%.

V: 0.0050 wt% or less

[0055] Vanadium (V) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine carbides or nitrides inside the base material, thereby suppressing grain growth and domain wall movement. Therefore, the content of V may each be 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0003 wt% due to steelmaking costs. That is, V may be included in an amount of 0.0003 to 0.0050 wt%. More specifically, V may be included in an amount of 0.0003 to 0.0030 wt%.

Ca: 0.0050 wt% or less

[0056] Calcium (Ca) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine sulfides inside the base material, thereby suppressing grain growth and domain wall movement.

Nb: 0.0050 wt% or less

[0057] Niobium (Nb) has a strong tendency to form precipitates inside the steel, and they deteriorate the iron loss by forming fine carbides or nitrides inside the base material, thereby suppressing grain growth and domain wall movement. Therefore, the Nb content may be 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0003 wt% due to steelmaking costs. That is, Nb may be included in an amount of 0.0003 to 0.0050 wt%. More specifically, Nb may be included in an amount of 0.0003 to 0.0030 wt%.

Zr: 0.0050 wt% or less

[0058] If zirconium (Zr) is added in excessive amounts, it may cause deterioration of magnetism through the formation of inclusions in the steel. Therefore, Zr may be included in an amount of 0.005 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. That is, Zr may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may be included in an amount of 0.0005 wt% to 0.0030 wt%.

Te: 0.0100 wt% or less

[0059] Tellurium (Te) diffuses into the oxide layer on the surface of a hot-rolled coil, increases the coefficient of friction between the oxide layer and the rolling work roll, and improves hardness by concentrating under the oxide layer, so that it may be added to prevent the oxide layer that is broken during rolling from being pressed into the base metal and to be removed. If the amount of Te added is too small, the effect may be insignificant. If too much Te is added, the oxide layer is easily removed, causing the base material to come into direct contact with the work roll, thereby reducing the above effect, and excessive deformation bands may be generated within the steel sheet during cold rolling, which may lead to the development of {111}ND texture, which is unfavorable for magnetism

More specifically, tellurium may be included in an amount of 0.0001 to 0.007 wt%.

Mg: 0.0050 wt% or less

[0060] Magnesium (Mg) is an element that mainly combines with sulfur to form sulfides, and may affect the surface oxide layer of iron. Therefore, Mg may be included in an amount of 0.0050 wt% or less. The lower limit thereof is not particularly limited, but it may be set at 0.0001 wt% due to steelmaking costs. That is, Mg may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may be included in an amount of 0.0005 wt% to 0.0030 wt%.

[0061] The balance includes Fe and inevitable impurities. The inevitable impurities are impurities mixed in the steel-making and the manufacturing process of the non-oriented electrical steel sheet, which are widely known in the field, and thus a detailed description thereof will be omitted. In the embodiment of the present invention, the addition of elements other than the above-described alloy components is not excluded, and various elements may be included within a range that does not hinder the technical concept of the present invention. When the additional elements are further included, they replace the balance of Fe.

[0062] As described above, in the embodiment of the present invention, by appropriately forming the grain size of grains, strength and magnetism may be improved simultaneously.

[0063] The non-oriented electrical steel sheet according to the embodiment of the present invention has an area ratio of grains having a grain size 30 μm smaller than the average grain size to grains having a grain size 30 μm larger than the average grain size of 12.0% or more. That is, in the embodiment of the present invention, by forming grains having a difference of $\pm 30 \mu\text{m}$ or less from the average grain in a large area, the iron loss may be reduced. The more fine grains there are, the greater the hysteresis loss, which results in poor iron loss, and if there are too many coarse grains, the eddy current loss increases, which results in poor iron loss. More specifically, the area ratio of grains that are 30 μm smaller than the average grain size to grains that are 30 μm larger than the average grain size may be 12.5 to 20.0%.

[0064] In the embodiment of the present invention, the grain may be measured based on a cross-section including the thickness direction of the steel sheet, more specifically, the TD plane. The grain size may be obtained by observing the grain with an optical microscope, assuming a circle having the same area as the grains, and calculating the diameter of the circle. The specimen may be measured as a specimen including at least the entire thickness and having an area of 10 mm in the longitudinal direction, and may be measured at least three times or more.

[0065] The area ratio of grains having a grain size of 20 μm or less may be 0.80% or less. Fine grains having a grain size of 20 μm or less may be minimized by controlling the process from the hot rolling step, and since the iron loss deteriorates as fine grains are formed, their occupied area may be minimized. More specifically, the area ratio of grains having a grain size of 20 μm or less may be 0.20 to 0.75%.

[0066] The non-oriented electrical steel sheet according to the embodiment of the present invention satisfies the following Formula 1.

[Formula 1]

$$GS_{STD}/GS_{AVE} \leq 0.70$$

(In Formula 1, GS_{STD} means the standard deviation of the grains, and GS_{AVE} means the average grain size.)

[0067] The standard deviation of the grains may be specifically the parent standard deviation. More specifically, it may be calculated by the following formula for n grains.

$$\sqrt{\frac{\sum_{i=1}^n (GS_i - GS_{AVE})^2}{n}}$$

[0068] GS_i represents the grain size of the i-th grain, and GS_{AVE} represents the average grain size.

[0069] Formula 1 implies that the fine and coarse grains should be reduced so that the grain size becomes uniform. More specifically, the value of Formula 1 may be 0.30 to 0.67.

[0070] GS_{STD} may be 30 to 100 μm . More specifically, GS_{STD} may be 33 to 95 μm .

[0071] GS_{AVE} may be 50 to 160 μm . More specifically, GS_{AVE} may be 60 to 155 μm .

[0072] As described above, in the embodiment of the present invention, by appropriately forming the grain size,

strength and magnetism may be improved simultaneously. Specifically, the non-oriented electrical steel sheet according to the embodiment of the present invention may have a core loss (W10/400) of 12.0 W/kg or less and a magnetic flux density (B50) of 1.60 T or more. The thickness standard may be 0.20 mm. More specifically, the core loss (W10/400) 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 (W10/400) is iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz. The magnetic flux density (B50) refers to the magnetic flux density induced in a magnetic field of 5000 A/m. The iron loss (10/400) and the magnetic flux density (B50) may be measured with a single sheet tester for the rolling direction and the rolling vertical direction, and measured as the average value.

[0073] In addition, the embodiment of the present invention also has excellent mechanical strength. The yield strength may be 480 MPa or more. More specifically, the yield strength may be 480 MPa or more and 650 MPa or less. The yield strength may be measured by a 0.2% off-set method during a tensile test.

[0074] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention includes 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 sheet; and a cold-rolled sheet annealing step of annealing the cold-rolled sheet.

[0075] Hereinafter, respective steps will be specifically described.

[0076] First, the slab is hot-rolled.

[0077] The alloy composition of the slab has been described in the alloy composition of the non-oriented electrical steel sheet described above, so duplicate descriptions will be omitted. Since the alloy composition does not substantially change during the manufacturing process of the non-oriented electrical steel sheet, the alloy composition of the non-oriented electrical steel sheet and the slab are substantially the same.

[0078] Specifically, the slab includes, in wt%, Si: 1.5 to 5.0%, Al: 0.1 to 2.5%, Mn: 0.1 to 2.5%, with the balance being Fe and inevitable impurities.

[0079] Other additional elements have been described in the alloy composition of the non-oriented electrical steel sheet, so duplicate descriptions will be omitted.

[0080] The slab may be heated before hot-rolling. The heating temperature of the slab is not limited, but the slab may be heated at 1,200 °C or less. When the slab heating temperature is too high, precipitates such as AlN and MnS present in the slab are re-dissolved and then finely precipitated during hot-rolling and annealing, thereby inhibiting grain growth and reducing magnetism.

[0081] Next, the slab is hot-rolled to manufacture the hot-rolled sheet.

[0082] In the embodiment of the present invention, it has been found that in order to improve the texture, it is necessary to precisely control the conditions from the hot rolling step. Specifically, it was found that it was necessary to control the reduction ratio and temperature of each pass in finish rolling.

[0083] In the embodiment of the present invention, the step of manufacturing the hot-rolled steel sheet includes a rough rolling step and a finish rolling step. The rough rolling step is the process of first rolling the slab moved from the casting machine into bar shape, and consists of 3 to 4 rolling mills. The finish rolling step is a process of rolling the rough-rolled steel sheet to the final hot-rolled target thickness to make a hot-rolled coil, and consists of a continuous multi-stage rolling mill.

[0084] The finish rolling step is performed through n passes, where n is 3 or more.

[0085] With respect to the reduction ratio (R_j) of an intermediate pass that is not the first or last pass, the largest absolute value of the difference between the average reduction ratio (R_{AVE}) of all passes of the finish rolling and the reduction ratio of the intermediate pass is 40% or less.

[0086] The average (R_{AVE}) of the reduction ratios of all passes of the finish rolling may be expressed by the following formula.

$$\frac{\sum_{i=1}^n R_i}{n}$$

[0087] Wherein, R_i represents the reduction ratio of the i-th pass.

[0088] That is, the average (R_{AVE}) of the reduction ratios of all passes of the finish rolling may be expressed as $(R_1+R_2+\dots+R_n)/n$.

[0089] Meanwhile, R_j means the reduction ratio (R_j) of the intermediate pass, not the first pass (R_1) or the last pass (R_n). The absolute value of the difference between the average (R_{AVE}) of the reduction ratios of all passes of the finish rolling and the reduction ratio of the intermediate pass may be expressed as $|(R_{AVE}-R_j)|$, and the largest value of these may be 40% or less. That is, it may be expressed as $\text{Max}[(R_{AVE}-R_j)] \leq 40.0\%$.

[0090] This means that the deviation between the pass reduction ratios in the finish rolling is not large. If the above value is too large, a large number of coarse or fine grains are generated, ultimately resulting in poor magnetism and yield strength. More specifically, the largest absolute value of the difference between the average (R_{AVE}) of the reduction ratios of all passes of the finish rolling and the reduction ratio of the intermediate pass may be 20.0 to 39.5%.

[0091] In addition, the finish rolling step may have a difference (FET-FDT) between the finish rolling entry temperature (FET) and the rolling exit temperature (FDT) of 150°C or less. If this temperature difference is excessively large, non-uniformity may increase in the microstructure itself after rolling, which may result in uneven microstructure in the final product. More specifically, the difference (FET-FDT) between the finish rolling entry temperature (FET) and the finish rolling exit temperature (FDT) may be 50 to 148°C. The finish rolling entry temperature may be based on the steel sheet temperature immediately before entering the finish rolling mill, and the finish rolling exit temperature may be based on the steel sheet temperature immediately after exiting the finish rolling mill.

[0092] In the embodiment of the present invention, the finish rolling may be 3 to 7 passes (that is, n is 3 to 7). If the number of passes is too small, the rolling load may be too large, making the work difficult. If the number of passes is too large, productivity may be reduced.

[0093] A thickness of the hot-rolled sheet may be 1.0 to 4.5 mm. In the manufacturing of the hot-rolled sheet, a finish rolling temperature may be 800 °C or higher. Specifically, it may be 800 to 1,000 °C. The hot-rolled sheet may be wound at temperatures of 700 °C or less. 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, a step of annealing the hot-rolled sheet may be further included. In this case, the soaking temperature may be 850 to 1100°C. If the annealing temperature is too low, the recrystallized structure is not formed or grows finely, so the effect of increasing the magnetic flux density is small, while if the annealing temperature is too high, the magnetic properties may deteriorate, and the rolling workability may deteriorate due to deformation of the sheet shape. More specifically, the temperature range may be 830 to 1080°C. The soaking time may be 10 to 300 seconds. The hot-rolled sheet annealing step 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 at a reduction ratio of 40 to 95%. If 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 the rolled structure remains, which may cause problems in improving the magnetic flux density and iron loss. Conversely, if the reduction ratio is too high, the recrystallization of <111>/ND orientation grains may be promoted during the subsequent annealing process, and the grains may become finer, resulting in a lower magnetic flux density and an increase in iron loss. More specifically, the reduction ratio may be 60 to 85%. The cold rolling step may be performed using 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. The final rolled thickness may be from 0.1 mm to 0.35 mm.

[0096] The step of manufacturing the cold-rolled sheet may be performed once or twice or more with intermediate annealing therebetween.

[0097] Next, the cold-rolled sheet is annealed in the cold-rolled sheet annealing step. In the process of annealing the cold-rolled sheet, the annealing temperature is not largely limited as long as it is a temperature that is generally applied to the non-oriented electrical steel sheet. The iron loss of the non-oriented electrical steel sheet is closely related to the grain size. The iron loss of the non-oriented electrical steel sheet may be divided into hysteresis loss and eddy current loss, and in this case, the hysteresis loss decreases as the grain size increases, while the eddy current loss increases as the grain size increases, and accordingly, there is an appropriate grain size that minimizes a sum of the hysteresis loss and the eddy current loss. Accordingly, it is important to derive and apply an annealing temperature that may secure an optimal grain size, and the annealing temperature is suitable when it is 850 to 1100 °C. When the annealing temperature is too low, the hysteresis loss increases because the grains are too fine, and when the annealing temperature is too high, the grains are too coarse and thus the eddy current loss increases, so that the iron loss is deteriorated. In addition, the annealing time is 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 the formation of an oxide layer.

[0098] In the cold-rolled sheet annealing process, the processed texture formed in the cold-rolling step may be entirely (that is, 99 % or more) recrystallized.

[0099] After the cold-rolled sheet annealing, an insulating film may be formed. The insulating film may be formed as an organic, inorganic, and organic/inorganic composite film, and it may be formed with other insulating coating materials.

[0100] Hereinafter, the present invention will be described in more detail through examples. However, the examples are only for illustrating the present invention, and the present invention is not limited thereto.

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Example 1

[0101] A slab was manufactured with components containing the following Table 1 and the balance Fe and other inevitable impurities. This was heated to 1180°C and hot-rolled under the conditions listed in Table 2 below, hot-rolled to a thickness of 2.1 mm, and then coiled at 700°C. The hot-rolled steel sheet was annealed at 1000°C for 60 seconds. After hot-rolled sheet annealing, the pickled specimens were cold-rolled to a thickness of 0.2 mm, and finally cold-rolled sheet annealing was performed. In this case, the cold-rolled sheet annealing was performed at 1000°C for 50 seconds.

[0102] The grain size was analyzed using an optical microscope and an image analyzer after cutting the steel sheet along the TD plane to obtain a specimen.

[0103] The resistivity at 25°C was measured using the 4-point method.

[0104] The yield strength was measured using the 0.2% off-set method during a tensile test.

[0105] Iron loss (W10/400) and magnetic flux density (B50) were measured using a single sheet tester.

(Table 1)

Steel Type	Si	Mn	Al	P	C	S	Ti	N	Resistivity ($\mu\Omega\text{cm}$)
1	2.95	0.16	1.80	0.014	0.0014	0.0015	0.0005	0.0027	67.8
2	3.08	1.80	2.18	0.008	0.0021	0.0026	0.0015	0.0027	82.9
3	3.78	1.41	0.85	0.009	0.0011	0.0042	0.0020	0.0018	73.5
4	4.00	0.38	1.87	0.011	0.0042	0.0045	0.0008	0.0020	81.7
5	3.35	0.56	1.54	0.007	0.0040	0.0017	0.0006	0.0013	71.7
6	3.60	0.21	0.99	0.003	0.0023	0.0017	0.0035	0.0022	66.3
7	3.67	1.73	0.82	0.006	0.0029	0.0023	0.0013	0.0006	73.8
8	3.37	0.46	0.92	0.004	0.0024	0.0014	0.0033	0.0035	64.3
9	2.98	1.62	1.19	0.009	0.0026	0.0029	0.0020	0.0043	69.5
10	3.66	1.59	0.77	0.004	0.0014	0.0020	0.0026	0.0012	72.3
11	2.98	0.70	1.34	0.005	0.0026	0.0024	0.0029	0.0016	66.0
12	4.00	1.57	1.39	0.011	0.0017	0.0029	0.0033	0.0021	83.0
13	3.65	1.12	1.34	0.008	0.0017	0.0030	0.0008	0.0013	76.0
14	4.14	1.12	0.75	0.006	0.0034	0.0045	0.0016	0.0035	74.8
15	3.81	0.50	1.78	0.004	0.0016	0.0021	0.0035	0.0020	79.2
16	2.48	0.26	1.14	0.009	0.0026	0.0028	0.0008	0.0011	55.6
17	3.99	1.68	0.48	0.005	0.0016	0.0010	0.0020	0.0018	73.3
18	2.42	1.34	0.46	0.004	0.0018	0.0034	0.0022	0.0012	53.4
19	3.05	0.56	0.82	0.008	0.0007	0.0009	0.0037	0.0036	60.1
20	3.75	0.19	1.85	0.004	0.0037	0.0041	0.0037	0.0018	77.6
21	3.45	1.37	1.13	0.003	0.0028	0.0022	0.0036	0.0042	72.7
22	3.09	1.68	0.95	0.004	0.0038	0.0033	0.0022	0.0027	68.4
23	2.92	0.70	2.08	0.014	0.0033	0.0005	0.0008	0.0042	73.7
24	3.12	1.53	1.22	0.015	0.0026	0.0008	0.0034	0.0014	70.9
25	3.27	0.53	1.59	0.011	0.0032	0.0017	0.0029	0.0036	71.2
26	2.93	1.24	1.27	0.005	0.0009	0.0026	0.0013	0.0016	67.7
27	2.92	1.14	1.33	0.009	0.0013	0.0014	0.0027	0.0024	67.7
28	3.05	1.63	0.51	0.013	0.0031	0.0009	0.0022	0.0015	62.7
29	3.48	0.34	1.03	0.004	0.0033	0.0044	0.0006	0.0016	66.1

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(continued)

Steel Type	Si	Mn	Al	P	C	S	Ti	N	Resistivity ($\mu\Omega\text{cm}$)
30	2.88	1.43	0.76	0.014	0.0044	0.0024	0.0014	0.0045	62.5

(Table 2)

Steel Type	FET-FDT(°C)	Max (R _{AVE} -R _j) (%)	GS _{AVE} (μm)	GS _{STD} (μm)	GS _{STD} /GS _{AVE}	GS _{AVE} ±30 μm or less grain fraction (area%)	20 μm or less grain fraction (area%)
1	83	29.9	108	67	0.62	19.5	0.55
2	88	35.6	107	38	0.36	18.9	0.31
3	117	31.8	145	46	0.32	12.2	0.44
4	131	29.0	142	60	0.42	13.1	0.41
5	127	37.6	150	62	0.41	16.5	0.52
6	98	24.0	110	54	0.49	14.3	0.21
7	59	26.0	149	91	0.61	19.3	0.67
8	147	37.8	87	37	0.43	12.4	0.56
9	112	21.6	133	52	0.39	13.4	0.23
10	101	24.6	102	33	0.32	12.9	0.28
11	142	32.6	99	45	0.45	15.8	0.45
12	92	39.5	92	56	0.61	12.6	0.40
13	134	29.6	64	42	0.66	15.1	0.60
14	56	24.2	133	48	0.36	13.2	0.71
15	147	22.2	138	58	0.42	14.0	0.56
16	128	22.1	137	87	0.64	14.9	0.42
17	170	25.7	64	50	0.78	11.0	0.79
18	130	24.3	99	66	0.67	13.9	0.34
19	84	36.2	104	53	0.51	15.5	0.53
20	165	37.8	118	85	0.72	11.5	0.75
21	156	22.7	76	46	0.61	11.4	0.94
22	59	43.2	68	48	0.71	12.6	0.83
23	108	44.7	110	83	0.75	11.9	0.44
24	58	48.8	130	93	0.72	11.1	0.85
25	175	46.5	100	76	0.76	11.0	1.01
26	151	36.9	58	42	0.72	12.5	0.89
27	161	43.3	52	38	0.73	11.9	0.67
28	167	35.1	73	54	0.74	10.1	0.90
29	98	41.4	134	57	0.43	9.5	0.94
30	172	48.8	144	107	0.74	9.9	1.07

(Table 3)

Steel Type	Yield strength (MPa)	W10/400(W/Kg)	B50(T)	Classification
1	511	9.96	1.63	Inventive example
2	531	8.96	1.62	Inventive example
3	535	8.92	1.62	Inventive example
4	605	9.19	1.64	Inventive example
5	519	9.84	1.64	Inventive example
6	509	9.63	1.63	Inventive example
7	522	9.43	1.64	Inventive example
8	507	9.18	1.63	Inventive example
9	487	10.05	1.64	Inventive example
10	516	9.68	1.63	Inventive example
11	488	9.91	1.64	Inventive example
12	563	8.84	1.62	Inventive example
13	580	8.91	1.62	Inventive example
14	552	9.16	1.62	Inventive example
15	555	9.04	1.62	Inventive example
16	405	12.32	1.59	Comparative example
17	529	12.69	1.59	Comparative example
18	360	12.05	1.59	Comparative example
19	468	13.19	1.58	Comparative example
20	549	12.63	1.57	Comparative example
21	541	12.02	1.57	Comparative example
22	485	12.15	1.59	Comparative example
23	522	12.58	1.58	Comparative example
24	506	12.18	1.59	Comparative example
25	523	12.39	1.57	Comparative example
26	482	12.38	1.58	Comparative example
27	484	12.03	1.58	Comparative example
28	449	13.01	1.58	Comparative example
29	467	12.86	1.59	Comparative example
30	442	12.76	1.59	Comparative example

[0106] As shown in Tables 1 to 3, No. 1 to 15, in which the steel composition and finish rolling conditions were properly controlled and the grain size was properly formed, can be confirmed to have excellent iron loss, magnetic flux density, and yield strength at the same time.

[0107] On the other hand, No. 16 to 30, in which the steel composition or the finish rolling conditions were not properly controlled and many fine or coarse grains were formed, can be confirmed to have poor iron loss, magnetic flux density, or yield strength.

[0108] The present invention may be embodied in many different forms, and should not be construed as being limited to the disclosed embodiments. In addition, it will be understood by those skilled in the art that various changes in form and details may be made thereto without departing from the technical spirit and essential features of the present invention. Therefore, it is to be understood that the above-described embodiments are for illustrative purposes only, and the scope of the present invention is not limited thereto.

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%, with a balance being Fe and inevitable impurities,
wherein an area ratio of grains that are 30 μm smaller than an average grain size to grains that are 30 μm larger than the average grain size is 12% or more,
an area ratio of grains having a grain size of 20 μm or less is 0.8% or less, and
the non-oriented electrical steel sheet satisfies the following Formula 1:

[Formula 1]

$$\text{GS}_{\text{STD}}/\text{GS}_{\text{AVE}} \leq 0.7$$

(In Formula 1, GS_{STD} means the standard deviation of the grains, and GS_{AVE} means the average grain size).

2. The non-oriented electrical steel sheet of claim 1, wherein the GS_{STD} is 30 to 100 μm .
3. The non-oriented electrical steel sheet of claim 1, wherein the GS_{AVE} is 50 to 160 μm .
4. 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%).
5. The non-oriented electrical steel sheet of claim 1, further comprising 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.
6. 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%).
7. 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%).
8. The non-oriented electrical steel sheet of claim 1, wherein a resistivity (ρ) at 25°C is 63 $\mu\Omega\cdot\text{cm}$ or more.
9. The non-oriented electrical steel sheet of claim 1, wherein a core loss ($W_{10/400}$) is 12.0 W/Kg or less, and a magnetic flux density (B_{50}) is 1.60 T or more.
10. A method for manufacturing a non-oriented electrical steel sheet, comprising:

a step of 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%, with a balance being Fe and inevitable impurities, to manufacture a hot-rolled sheet;
cold rolling the hot-rolled steel sheet to manufacture a cold-rolled sheet; and
a cold-rolled sheet annealing step of annealing the cold-rolled sheet,
wherein the step of manufacturing the hot-rolled steel sheet includes a rough rolling step and a finish rolling step,
the finish rolling step is performed through n passes, where n is 3 or more, and
for a reduction ratio (R_j) of an intermediate pass, not a first or last pass,
a largest absolute value of a difference between an average reduction ratio (R_{AVE}) of all passes of the finish rolling and the reduction ratio of the intermediate pass is 40% or less.

11. The method for manufacturing the non-oriented electrical steel sheet of claim 10, wherein the finish rolling step has a difference (FET-FDT) between a finish rolling entry temperature (FET) and a finish rolling exit temperature (FDT) of 150°C or less.

12. The method for manufacturing the non-oriented electrical steel sheet of claim 10, wherein the slab further includes 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%).

13. The method for manufacturing the non-oriented electrical steel sheet of claim 10, wherein the slab further includes 0.005 to 0.200 wt% in each or a combined amount of one or two or more of Sn, Sb, Bi, Pb, Ge, and As.

14. The method for manufacturing the non-oriented electrical steel sheet of claim 10, 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%).

15. The method for manufacturing the non-oriented electrical steel sheet of claim 10, wherein the slab further includes 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%).

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/097011

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/04(2006.01)i; C22C 38/06(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), 조압연(rough rolling), 마무리압연(finish rolling), 편차(deviation)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 7231133 B1 (JFE STEEL CORP.) 01 March 2023 (2023-03-01) See paragraphs [0060] and [0062] and claims 1-3.	1-9
X	KR 10-2023-0095280 A (POSCO) 29 June 2023 (2023-06-29) See claims 3-5, 7, 9, 11 and 16 and table 2.	10-15
X	KR 10-0702242 B1 (EBG GESELLSCHAFT FÜR ELEKTROMAGNETISCHE WERKSTOFFE MBH) 03 April 2007 (2007-04-03) See claims 1, 6-7 and 11.	10-15
A	KR 10-2019-0078345 A (POSCO) 04 July 2019 (2019-07-04) See claims 1-2 and 5-6.	1-15
A	JP 7235188 B1 (JFE STEEL CORP.) 08 March 2023 (2023-03-08) See claims 1-3.	1-15

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

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Date of the actual completion of the international search 07 March 2025	Date of mailing of the international search report 07 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.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
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International application No.

PCT/KR2024/097011

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