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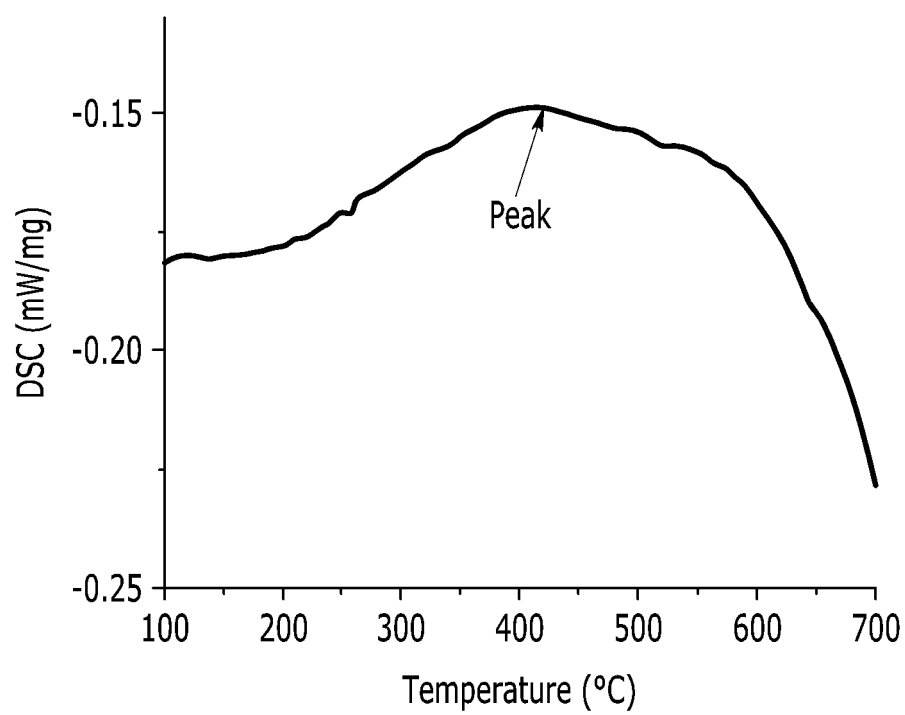
(54) **HOT-ROLLED STEEL SHEET FOR NON-ORIENTED ELECTRICAL STEEL SHEET, METHOD FOR MANUFACTURING SAME, AND METHOD FOR MANUFACTURING NON-ORIENTED ELECTRICAL STEEL SHEET**

(57) A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, and balance including Fe

and other unavoidable impurities, where a peak of a heat flow curved line measured during a heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C.

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FIG. 1



Description**[Technical Field]**

5 **[0001]** An embodiment of the present invention relates to a hot-rolled steel sheet for a non-oriented electrical steel sheet, a manufacturing method thereof, and a manufacturing method of a non-oriented electrical steel sheet. Specifically, an embodiment of the present invention relates to a hot-rolled steel sheet for a non-oriented electrical steel sheet, in which the fraction of ordered phase within hot-rolled steel sheet is suppressed by appropriately adjusting the speed after hot rolling, a manufacturing method thereof, and a manufacturing method of a non-oriented electrical steel sheet.

[Background Art]

15 **[0002]** A non-oriented electrical steel sheet is mainly used in a motor that converts electrical energy to mechanical energy, and an excellent magnetic property 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.

20 **[0003]** 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.

25 **[0004]** 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.

30 **[0005]** Among the important 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 added amount of Si, Al, and Mn increases the resistivity of steel, thereby decreasing the eddy current loss among the iron loss of non-oriented electrical steel sheets, which has the effect of reducing iron loss, and since the ratio of the eddy current loss among the iron loss is greater in the case of the high-frequency iron loss, this 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.

35 **[0006]** Meanwhile, as the content of Si, Al, and Mn increases, problems with the magnetic flux density of the material may also occur due to formation of ordered phases of B2 and DO3 in regions where the above elements are locally enriched. Although the exact principle has not yet been revealed, it is known that if ordered phases exist in the hot-rolled steel sheets, which serve as the raw material for electrical steel sheet, it is difficult to secure magnetic flux density in the final non-oriented electrical steel sheets.

40 **[0007]** Ultimately, when manufacturing electrical steel sheets with increased Si, Al, and Mn content to reduce iron loss, it is necessary to secure hot-rolled steel sheets in which the formation of ordered phases of B2 and DO3 in localized areas is controlled.

[Disclosure]**[Technical Problem]**

55 **[0008]** An embodiment of the present invention provides a hot-rolled steel sheet for a non-oriented electrical steel sheet, a manufacturing method thereof, and a manufacturing method of a non-oriented electrical steel sheet. Specifically, an embodiment of the present invention provides a hot-rolled steel sheet for a non-oriented electrical steel sheet,

in which the fraction of ordered phase within hot-rolled steel sheet is suppressed by appropriately adjusting the speed after hot rolling, a manufacturing method thereof, and a manufacturing method of a non-oriented electrical steel sheet.

[Technical Solution]

[0009] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention includes, in wt%, Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, and balance including Fe and other unavoidable impurities, where a peak of a heat flow curved line measured during a heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C.

[0010] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy Formula 1 below,

[Formula 1]

$$0.6 \leq ([Al] + [Mn]) / [Si] \leq 1,$$

[0011] Where, in Formula 1, [Al], [Mn] and [Si] represents the content (wt%) of Al, Mn, and Si, respectively.

[0012] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% or less (excluding 0%), S: 0.0005 to 0.005 wt%, Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0013] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include 0.005 to 0.200 wt% of one or more of Sn, Sb, Bi, Pb, Ge, and As, either individually or in their combined total.

[0014] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05% or less (excluding 0%).

[0015] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[0016] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may have resistivity (ρ) of 63 $\mu\Omega\text{cm}$ or higher at 25 °C.

[0017] A manufacturing method of a hot-rolled steel sheet for a non-oriented electrical steel sheet, may include manufacturing a hot-rolled steel sheet by hot-rolling a slab including, in wt%, Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, and balance including Fe and other unavoidable impurities, and cooling the hot-rolled steel sheet,

[0018] The cooling may cool a temperature range of 400 to 100 °C at 30 °C/second or more.

[0019] Winding the hot-rolled steel sheet may be included after the cooling of the hot-rolled steel sheet, and the winding of the hot-rolled steel sheet may be performed at a temperature of 100 °C or lower.

[0020] The cooling may be performed in the temperature range of 400 to 100 °C at 30 °C/second to 100 °C/second.

[0021] The slab may further include one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% or less (excluding 0%), S: 0.0005 to 0.005 wt%, Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).

[0022] The slab may further include 0.005 to 0.200 wt% of one or more of Sn, Sb, Bi, Pb, Ge, and As, either individually or in their combined total.

[0023] 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%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05% or less (excluding 0%).

[0024] 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%).

[0025] A manufacturing method of a non-oriented electrical steel sheet, may include preparing a hot-rolled steel sheet including Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, in wt%, and balance including Fe and other unavoidable impurities, and in which a peak of a heat flow curved line measured during a heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C, manufacturing a cold-rolled steel sheet by cold rolling the hot-rolled steel sheet, and annealing the cold-rolled steel sheet.

[0026] The manufactured non-oriented electrical steel sheet may have an iron loss ($W_{10/400}$) of 12.0 W/Kg or less, and a magnetic flux density (B_{50}) of 1.60T or more.

[Advantageous Effects]

[0027] According to a hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention, formation of ordered phases is inhibited, and the non-oriented electrical steel sheet manufactured by using this shows excellent magnetic flux density and high-frequency iron loss at the same time.

[0028] 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 motor cores.

[Description of the Drawings]

[0029]

FIG. 1 is differential scanning calorimetry (DSC) analysis graph of a steel sheet manufactured in Inventive Example 1.

FIG. 2 is differential scanning calorimetry (DSC) analysis graph of a steel sheet manufactured in Inventive Example 15.

FIG. 3 is differential scanning calorimetry (DSC) analysis graph of a steel sheet manufactured in Comparative Example 3.

[Mode for Invention]

[0030] 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.

[0031] 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.

[0032] 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.

[0033] Unless otherwise stated, % means wt%, and 1 ppm is 0.0001 wt%.

[0034] In embodiments of the present invention, inclusion of an additional element means replacing the remaining iron (Fe) by an additional amount of the additional elements.

[0035] 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.

[0036] The present invention will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the invention are shown. 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 invention.

[0037] A non-oriented electrical steel sheet according to an embodiment of the present invention may include Si: 1.5 to 4.5%, Al: 0.5 to 2.5%, and Mn: 0.1 to 2.5%, in wt%, with the balance of Fe and unavoidable impurities.

[0038] Hereinafter, the reason for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 2.50 to 4.50 wt%

[0039] Silicon (Si) is a major element added in order to increase the resistivity of steel and thereby to lower eddy current loss among the iron loss, and is added in order to secure low iron loss, particularly the property of low iron loss characteristic in a high-frequency region. If too little Si is added, the effect of improving iron may not be sufficient. If too much Si is added, magnetic flux density may decrease significantly, and the possibility of formation of ordered phases

of B2 and DO3 in local regions may increase. More specifically, it may contain 2.70 to 4.30 wt%. More specifically, it may contain 3.00 to 4.00 wt%.

Mn: 0.10 to 2.50 wt%

[0040] Manganese (Mn), along with Si, Al, or the like, is an element that increases resistivity and lowers iron loss. However, if the added amount is excessively small, it may form fine sulfides, which may be disadvantageous for texture control during subsequent annealing heat treatment after hot rolling. If the added amount is excessively large, magnetic flux density may decrease significantly, and the risk of formation of ordered phases of B2 and DO3 in local regions of the hot-rolled steel sheet may increase. More specifically, it may contain 0.30 to 2.30 wt%. More specifically, it may contain 0.50 to 2.10 wt%.

Al: 1.00 to 2.50 wt%

[0041] Aluminum (Al), along with Si, is an added element that plays an important role in reducing iron loss by increasing resistivity, and also reduces magnetic anisotropy, thereby decreasing magnetic deviation in a rolling direction and a direction perpendicular to rolling. However, if the added amount is small,

[0042] The effect of reducing iron loss is not significant, and if the added amount is excessively large, the magnetic flux density is significantly deteriorated, and the risk of formation of ordered phases of B2 and DO3 in local regions of the hot-rolled steel sheet may increase. More specifically, it may contain 1.05 to 2.30 wt%. More specifically, it may contain 1.10 to 2.25 wt%.

[0043] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy Formula 1 below.

[Formula 1]

$$0.6 \leq ([Al] + [Mn]) / [Si] \leq 1$$

(in Formula 1, [Al], [Mn] and [Si] represents the content (wt%) of Al, Mn, and Si, respectively.)

[0044] The iron loss of the non-oriented electrical steel sheet is divided into a hysteresis loss and an 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 eddy current loss in the total iron loss increases, so it is necessary to control the resistivity of the steel above a certain level for excellent high-frequency iron loss, and it was confirmed that the higher the resistivity, the better the characteristics can be secured. Among Si, Al, and Mn, Si is the element that most significantly increases the resistivity of steel, but increasing the added amount of Si increases the brittleness of the steel, leading to inferior productivity. Accordingly, in order to raise the resistivity of steel and also to secure the, appropriate amounts of Al and Mn in addition to Si need to be added, and when they are controlled to Formula 1 as a result of reviewing an appropriate addition ratio, an excellent magnetism may be obtained while securing the producibility. More specifically, the value of Formula 1 may be 0.63 to 0.99.

[0045] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of P:0.002 to 0.02 wt%, C:0.005 wt% or less (excluding 0%), S:0.0005 to 0.005 wt%, Ti:0.005 wt% or less (excluding 0%), and N:0.005 wt% or less (excluding 0%).

P:0.002 to 0.02 wt%

[0046] Phosphorus (P) has the effect of improving the texture of steel as a grain boundary and surface segregation element. However, if the amount added is insufficient, the effect may be minimal. If too much phosphorus is added, grain growth can be inhibited, thereby reducing iron loss and reducing rolling performance due to grain boundary segregation, which can also lower productivity. More specifically, P may be further included in an amount of 0.003 to 0.015 wt%.

C: 0.005 wt% or less

[0047] Carbon (C) may be limited to 0.005 wt% or less, since it combines with Ti, Nb, or the like to form carbides, which deteriorates magnetism, and when the final product is processed into an electrical product and used, the iron loss increases due to magnetic aging, which reduces the efficiency of the electrical device. More specifically, C may be included in an amount of 0.0001 to 0.003 wt%.

S: 0.0005 to 0.005 wt%

[0048] Since sulfur (S) is an element that forms sulfides such as MnS, CuS and (Cu,Mn)S, which are detrimental to magnetic properties, it is desirable to add it in the lowest possible amount. However, if it is added in an amount of less than 0.0005 wt%, it is actually disadvantageous for the formation of texture and promotes the formation of fine sulfides, which may reduce magnetism. If too much sulfur is added, magnetism may deteriorate due to an increase in sulfides. More specifically, S may be included in an amount of 0.0010 to 0.0045 wt%.

Ti: 0.005 wt% or less

[0049] Titanium (Ti) forms fine carbides and nitrides by bonding with C and N, which inhibits grain growth and lowers magnetic flux density, and as more is added, the texture also deteriorates due to the increased carbides and nitrides, which can lead to poor magnetism. More specifically, Ti may be included in an amount of 0.0001 to 0.005 wt%. More specifically, Ti may be included in an amount of 0.0001 to 0.003 wt%.

N: 0.005 wt% or less

[0050] Nitrogen (N) is an element harmful to magnetism, as it forms nitrides by strongly bonding with Al, Ti, Nb, or the like, thereby inhibiting grain growth, so it can be included in small amounts. More specifically, N may be included in an amount of 0.0001 to 0.0030 wt%.

[0051] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include 0.005 to 0.200 wt% of one or more of Sn, Sb, Bi, Pb, Ge, and As, either individually or in their combined total.

Sn and Sb

[0052] Tin (Sn) and antimony (Sb) are elements for improving the texture, and may be added for additional improvement of magnetism. More specifically, Sn may be included in an amount of 0.005 to 0.200 wt% or Sb may be included in an amount of 0.005 to 0.200 wt%.

Bi, Pb, Ge, and As

[0053] If bismuth (Bi), lead (Pb), germanium (Ge), and arsenic (As) are additionally added, the magnetic flux density can be additionally improved. 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. More specifically, one or more of Bi, Pb, Ge, and As may be included in an amount of 0.200 wt% or less, either individually or in their combined total. More specifically, one or more of Bi, Pb, Ge, and As may be included in an amount of 0.0001 to 0.200 wt%, individually or in their combined total. More specifically, one or more of Bi, Pb, Ge, and As may be included in an amount of 0.001 to 0.100 wt%, individually or in their combined total.

[0054] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Cu: 0.005 to 0.2 wt%, Cr: 0.01 to 0.5 wt%, Ni: 0.05 wt% or less (excluding 0%), Zn: 0.01 wt% or less (excluding 0%), and Co: 0.05 wt% or less (excluding 0%).

Cu: 0.005 to 0.200 wt%

[0055] Copper (Cu) may be added for reasons such as improving magnetism, but it may react with impurity elements to form fine sulfides, carbides, and nitrides, which have a detrimental effect on magnetism. More specifically, Cu may be included in an amount of 0.01 to 0.10 wt%.

Cr: 0.01 to 0.50 wt%

[0056] Chromium (Cr) plays a role in improving 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 contained, magnetic flux density may be deteriorated. More specifically, Cr may be included in an amount of 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0057] Nickel (Ni) may be added for reasons such as improving magnetism, but it may react with impurity elements to form fine sulfides, carbides, and nitrides, which 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

[0058] When zinc (Zn) is excessively contained, it may deteriorate magnetism by acting as an impurity. Accordingly, Zn may be further added within the above-described range. More specifically, Zn may be included in an amount of 0.001 to 0.005 wt%.

Co: 0.05 wt% or less

[0059] Cobalt (Co) does not form fine precipitates that degrade the magnetism of the steel sheet, but it may increase high-temperature strength, leading to poor coil shape after hot rolling. More specifically, Co may be included in an amount of 0.001 to 0.02 wt%.

[0060] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

Mo: 0.030 wt% or less

[0061] If molybdenum (Mo) is excessively added, 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. Its lower limit 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

[0062] When boron (B) is excessively added, deterioration of magnetism may be caused through formation of inclusions in the steel, or the like. Therefore, B may be included in an amount of 0.005 wt% or less. Its lower limit is not particularly limited, but may be set to 0.0001 wt% due to steel-making costs. More specifically, B may be included in an amount of 0.0001 to 0.0030 wt%.

V: 0.0050 wt% or less

[0063] Vanadium (V) has a strong tendency to form precipitates inside the steel, and forms fine carbides or nitrides within the base material, which inhibits grain growth and domain wall movement, thereby deteriorating iron loss. Accordingly, the content of V may be respectively 0.0050 wt% or less. Its lower limit is not particularly limited, but it may be set to 0.0003 wt% due to steel-making 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

[0064] Calcium (Ca) has a strong tendency to form precipitates inside the steel, and forms fine sulfides within the base material, which inhibits grain growth and domain wall movement, thereby deteriorating iron loss.

Nb: 0.0050 wt% or less

[0065] Niobium (Nb) has a strong tendency to form precipitates inside the steel, and forms fine carbides or nitrides within the base material, which inhibits grain growth and domain wall movement, thereby deteriorating iron loss. Therefore, the content of Nb may be 0.0050 wt% or less. Its lower limit is not particularly limited, but it may be set to 0.0003 wt% due to steel-making 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

[0066] When zirconium (Zr) is excessively added, deterioration of magnetism may be caused through formation of inclusions in the steel, or the like. Therefore, Zr may be included in an amount of 0.005 wt% or less. Its lower limit is not particularly limited, but may be set to 0.0001 wt% due to steel-making costs. That is, Zr may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may contain 0.0005 to 0.0030 wt%.

Te: 0.0100 wt% or less

[0067] 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 being enriched 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 added amount of Te is excessively 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 of 0.0001 to 0.007 wt% may be included.

Mg: 0.0050 wt% or less

[0068] Magnesium (Mg) is an element that mainly combines with sulfur to form sulfides, and may affect the surface oxide layer on iron. Therefore, Mg may be or less included in an amount of 0.0050 wt%. Its lower limit is not particularly limited, but may be set to 0.0001 wt% due to steel-making costs. That is, Mg may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, it may contain 0.0005 to 0.0030 wt%.

[0069] The balance includes Fe and unavoidable impurities. The unavoidable 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 compositions 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.

[0070] In a hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention, a peak of a heat flow curved line measured during the heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C.

[0071] In steel grades with high Si, Al, and Mn content, ordered phases of B2 and DO3 are highly likely to be formed in regions where these elements are locally enriched in hot-rolled steel sheets. In an embodiment of the present invention, it was discovered that when manufacturing a non-oriented electrical steel sheet by using a hot-rolled steel sheet with a high fraction of ordered phase, it is disadvantageous to secure magnetic flux density. When an ordered phase exists, the formation of a texture unfavorable to securing magnetic flux density may be promoted at the interface between the ordered and non-ordered phases during subsequent deformation and annealing processes. On the other hand, the fraction of ordered phase at a room temperature may measure by differential scanning calorimetry (DSC). When observing the heat flow curved line depending on the temperature while heating the steel sheet at a constant rate, the presence of the ordered phase and the difference in relative fraction of the material before heating can be determined by observing the peak of the exothermic reaction in which the non-ordered phase transitions to the ordered phase. In other words, the lower fraction of ordered phase at room temperature, the lower temperature at which the peak of the corresponding curve is located. This can be attributed to the phenomenon where, even in hot-rolled steel sheets where the fraction of ordered phase is controlled to be low through an appropriate cooling method, the ordered phase may be formed when heated, and the lower fraction of ordered phase at room temperature, the more ordered phase is formed at a relatively low temperature. In an embodiment of the present invention, as a result of analyzing the magnetic flux density of the final electrical steel sheet and the DSC peak, it was confirmed that when the peak is 475 °C or lower, the magnetic flux density (B_{50}) is 1.60T or higher. The lower limit of the peak is better as it is lower, but in order to satisfy the iron loss proposed in the present invention, a certain level of Si, Mn, and Al content must be added, so it needs to be 325 °C or higher. Accordingly, in the present invention, a peak of a heat flow curved line measured during the heating process of the hot-rolled steel sheet by using differential scanning calorimetry (DSC) may be 325 to 475 °C. More specifically, it may be 330 to 465 °C. More specifically, it may be 340 to 460 °C. The method of analyzing DSC involves removing the scale present on the surface layer of the hot-rolled steel sheet, then measuring the heat flow during the heating process at a heating rate of 10°C/min up to 600 to 700 °C using DSC, and measuring the temperature at which a peak is generated during that process. At this time, the peak is determined based on the shape of the heat flow curve, that is, the location where the graph changes from an increasing trend to a

decreasing trend.

[0072] A hot-rolled steel sheet for a non-oriented electrical steel sheet according to an embodiment of the present invention may have resistivity (ρ) of 63 $\mu\Omega\text{cm}$ or higher at 25 °C. The higher the resistivity, the better the high-frequency iron loss can be improved. More specifically, the resistivity (ρ) at 25 °C may be 65 to 85 $\mu\Omega\text{cm}$.

[0073] A manufacturing method of a non-oriented electrical steel sheet according to an embodiment of the present invention includes a step of manufacturing a hot-rolled steel sheet by hot-rolling a slab and a step of cooling the hot-rolled steel sheet.

[0074] Hereinafter, each step will be described in detail.

[0075] First, the slab is hot-rolled.

[0076] The alloy composition of the slab has been described in the alloy composition of the hot-rolled steel sheet for a non-oriented electrical steel sheet described above, so redundant descriptions will be omitted. Since the alloy composition does not substantially change during the manufacturing process of hot-rolled steel sheets, the alloy composition of hot-rolled steel sheets and slabs is substantially the same. Furthermore, since the alloy composition does not substantially change during the manufacturing process of non-oriented electrical steel sheets after the production of hot-rolled steel sheets, the alloy composition of the hot-rolled steel sheets and the finally manufactured non-oriented electrical steel sheets is substantially identical.

[0077] Specifically, the slab includes Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, in wt%, and balance including Fe and other unavoidable impurities.

[0078] Other additional elements have been described in the alloy composition of the hot-rolled steel sheet for a non-oriented electrical steel sheet, so redundant descriptions will be omitted.

[0079] The slab may be heated before hot-rolling. The heating temperature of the slab is not limited, but the slab may be heated to 1,200 °C or less. When the slab heating temperature is excessively 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 deteriorating magnetism.

[0080] Subsequently, a hot-rolled sheet is manufactured by hot-rolling the slab. A hot-rolled sheet thickness may be 1.0 to 4.5 mm. In the embodiment of the present invention, a step of preliminary cold rolling before cold rolling may be additionally included, so that even if the hot-rolled sheet thickness is relatively thick, a non-oriented electrical steel sheet of an appropriate thickness may be manufactured. More specifically, the hot-rolled sheet thickness may be 1.5 to 3.5 mm.

[0081] The step of manufacturing the hot-rolled sheet may include a step of finish-rolling at a temperature of 850°C or higher.

[0082] If the hot-rolling finish rolling temperature is excessively low, the rolling load increases and the hot rolling workability deteriorates. In addition, a lot of deformation structures remain in the hot-rolled steel sheet, which may cause an increase in the rolling load during the subsequent preliminary cold rolling process. In addition, during intermediate annealing, recrystallization of <111>ND orientation grains from the deformation structure is promoted, resulting in a lower magnetic flux density. Therefore, the higher the hot-rolling finish rolling temperature, the better, and more specifically, it is preferable to perform finish-rolling at a temperature of 860 to 1,000°C.

[0083] After finishing rolling, the hot-rolled steel sheet may be cooled before coiling. In one embodiment of the present invention, by controlling the cooling rate and coiling temperature after hot rolling, the fraction of ordered phase can be reduced.

[0084] The cooling step may be performed in a temperature range of 400 to 100 °C at rate of 30 °C/second or more. It is known that in steel having high contents of Si, Al, and Mn, the ordered phases is generated in the range of 400 to 100 °C when being cooled after hot rolling, and when that range is cooled at a rate of 30 °C/s or higher, the effect of suppressing the fraction of ordered phase in the hot-rolled steel sheet can be obtained. If the cooling rate is excessively high, shape defects caused by variations in cooling rates across different parts of the hot-rolled steel sheet may occur. More specifically, it may be cooled at 30 °C/second to 100 °C/second. More specifically, it may be cooled at 31 to 90 °C/second. The cooling rate may be an average cooling rate in the temperature range of 400 to 100 °C.

[0085] The step of coiling the hot-rolled steel sheet may be performed at a temperature of 100 °C or lower. When rapid cooling is performed after coiling, material deviation issues may occur due to the difference in cooling rate between the inner and outer sections of the coil. In an embodiment of the present invention, this problem can be resolved by coiling the hot-rolled steel sheet may be coiled at a temperature of 100 °C or lower. Methods such as air-cooled and water-cooled methods may be used to cool the hot-rolled steel sheet. More specifically, the coiling step may be performed at 70°C to 90°C. When the coiling temperature is low, although a problem of excessive cooling deviation in the width direction may occur during the process of cooling the hot-rolled steel sheet to the coiling temperature, where the cooling of the edge portion of the hot-rolled steel sheet is excessively fast, this can be resolved by controlling the amount of air blowing and water flow at the edge portion to suppress excessive cooling.

[0086] Alternatively, cooling may be performed after coiling the hot-rolled steel sheet. Even at this time, cooling may be performed at the cooling rate described above. To ensure a cooling rate, the wound coil can be immersed in a water

bath for cooling.

[0087] A manufacturing method of a non-oriented electrical steel sheet according to an embodiment of the present invention includes preparing a hot-rolled steel sheet containing Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, in wt%, and balance including Fe and other unavoidable impurities, and in which a peak of a heat flow curved line measured during the heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C; manufacturing a cold-rolled steel sheet by cold rolling hot-rolled steel sheet; and annealing the cold-rolled steel sheet.

[0088] A hot-rolled steel sheet and a manufacturing method thereof has been described above, so redundant descriptions will be omitted.

[0089] After manufacturing the hot-rolled steel sheet, annealing of the hot-rolled steel sheet may be performed before cold rolling. When annealing the hot-rolled sheet, the soaking temperature may be 850 to 1,100 °C. If the annealing temperature is excessively 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 excessively 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 1,170 °C. The soaking time may be 15 to 180 seconds. The hot-rolled sheet annealing may be omitted as needed.

[0090] Returning to the description of a manufacturing method of a non-oriented electrical steel sheet, a cold-rolled sheet is manufactured by cold rolling a hot-rolled steel sheet. In this case, cold rolling may be performed at a reduction ratio of 30 to 80%. If the reduction ratio is excessively low, the strain energy accumulated in the rolled steel sheet is small, making it difficult to recrystallize in the subsequent annealing process, so the rolled structure remains, which may cause problems in improving the magnetic flux density and iron loss. To the contrary, 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 40 to 70%. The thickness may be 0.1 mm to 0.3 mm. More specifically, it may be 0.15 to 0.25 mm. The cold rolling may use a tandem cold roller that continuously cold-rolls the steel sheet by utilizing a plurality of rolling stands, or a reverse roller that non-continuously cold-rolls by using rolling rolls of 12 or more stages.

[0091] Cold rolling can be performed as a single cold rolling step if necessary, or as two cold rolling steps with intermediate annealing in between. In any case, the final reduction ratio needs to be in a range of 30 to 80%, to secure excellent magnetism, through an appropriate texture control.

[0092] Subsequently, the cold-rolled steel sheet is annealed. 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 the hysteresis loss and the 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 the annealing temperature that may secure an optimal grain size, and the annealing temperature may be 850 to 1,100 °C. When the annealing temperature is excessively low, the hysteresis loss increases because the grains are excessively fine, and when the annealing temperature is excessively high, the grains are excessively coarse and thus the eddy current loss increases, so that the iron loss may be deteriorated. More specifically, the annealing may be performed in a range of 900 to 1,050 °C.

[0093] After the cold rolled sheet annealing step, a step of forming an insulating film may be further included to secure insulation and corrosion resistance to the steel sheet. Since the insulating film is widely known, a detailed description thereof will be omitted.

[0094] The non-oriented electrical steel sheet manufactured in an embodiment of the present invention has excellent magnetic flux density and, at the same time, excellent high-frequency iron loss. Specifically, the non-oriented electrical steel sheet according to the embodiment of the present invention may have an iron loss ($W_{10/400}$) of 12.0 W/kg or less and a magnetic flux density (B_{50}) of 1.60 T or more.

[0095] B_{50} refers to the magnetic flux density induced in a magnetic field of 5,000 A/m.

[0096] $W_{10/400}$ is the iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz.

[0097] In the embodiment of the present invention, B_{50} and $W_{10/400}$ are represented by averaging the measured values in the rolling direction (RD direction) and the rolling vertical direction (TD direction). More specifically, in the embodiment of the present invention, the non-oriented electrical steel sheet may have an iron loss ($W_{10/400}$) of 8.0 to 10.5 W/Kg and a magnetic flux density (B_{50}) of 1.61 T to 1.65 T.

[0098] A non-oriented electrical steel sheet according to an embodiment of the present invention may have resistivity (ρ) of 63 $\mu\Omega\text{cm}$ or higher at 25 °C. More specifically, it may be 65 to 90.

[0099] Hereinafter, the present invention will be described in further detail through Examples. However, Examples are merely for providing examples of the present invention, and the present invention is not limited thereto.

Example 1

[0100] A slab was manufactured with the composition shown in Table 1 below. The balance is Fe. The slab was heated to 1,180 °C, hot-rolled to a thickness of 2.1 mm, and then cooled in a temperature range of 400 to 100 °C at a cooling rate specified in Table 2 below. Thereafter, it was wound at the coiling temperature summarized in Table 2 below. When the coiling temperature is greater than 400 °C, the temperature range of 400 to 100 °C was cooled at the cooling rate summarized in Table 2 below by coiling before cooling and immersing in a water bath.

[0101] The heat flow of the hot-rolled steel sheet that was cooled after hot rolling was measured by differential scanning calorimetry (DSC) during the heating process at a heating rate of 10°C/s with the surface scale removed, and the temperature at which the peak was generated was measured and summarized in Table 2.

[0102] The manufactured hot-rolled steel sheet was annealed at 1,000 °C. In addition, the annealed hot-rolled sheet was pickled and cold-rolled to a thickness of 0.2 mm, and then finally annealing was performed at 1,000 °C.

[0103] After processing the magnetic measurement specimens from the final material of the annealed cold-rolled sheet, the resistivity, the iron loss $W_{10/400}$, and the magnetic flux density B_{50} at room temperature were measured, and the results are also shown in Table 2 below. Meanwhile, in the present experiment, the iron loss $W_{10/400}$ represents an average loss (W/Kg) in the rolling direction and the direction perpendicular to rolling when a magnetic flux density of 1.0 Tesla is induced at a frequency of 400 Hz, and the magnetic flux density B_{50} represents a magnitude of magnetic flux density (Tesla) induced when a magnetic field of 5,000A/m is applied.

[Table 1]

(wt%)	C	Si	Mn	P	S	Al	Ti
Inventive Example 1	0.0013	4.20	1.82	0.013	0.0034	1.53	0.0022
Inventive Example 2	0.0016	2.96	0.74	0.003	0.0031	1.33	0.0007
Inventive Example 3	0.0037	3.65	2.09	0.005	0.0008	1.23	0.0042
Inventive Example 4	0.0012	3.09	0.70	0.005	0.0014	2.19	0.0026
Inventive Example 5	0.0021	2.89	1.71	0.015	0.0037	1.16	0.0031
Inventive Example 6	0.0036	4.22	1.57	0.005	0.0024	1.32	0.0035
Inventive Example 7	0.0037	3.66	1.75	0.004	0.0036	1.77	0.0017
Inventive Example 8	0.0020	4.02	1.03	0.011	0.0008	1.89	0.0038
Inventive Example 9	0.0029	3.32	0.51	0.009	0.0039	2.04	0.0023
Inventive Example 10	0.0038	3.16	1.00	0.005	0.0040	1.05	0.0007
Inventive Example 11	0.0018	3.60	0.73	0.005	0.0029	2.22	0.0034
Inventive Example 12	0.0025	3.70	0.60	0.009	0.0024	2.38	0.0034
Inventive Example 13	0.0014	3.33	2.08	0.012	0.0032	1.13	0.0034
Inventive Example 14	0.0012	3.06	1.31	0.015	0.0037	1.60	0.0024
Inventive Example 15	0.0025	3.40	0.77	0.011	0.0042	1.97	0.0007
Comparative Example 1	0.0016	1.96	0.74	0.003	0.0031	1.33	0.0007
Comparative Example 2	0.0021	1.89	1.71	0.015	0.0037	1.16	0.0031
Comparative Example 3	0.0013	4.52	1.82	0.013	0.0034	1.53	0.0022
Comparative Example 4	0.0036	4.51	1.57	0.005	0.0024	1.32	0.0035
Comparative Example 5	0.0029	3.32	0.08	0.009	0.0039	2.04	0.0023
Comparative Example 6	0.0025	3.70	0.07	0.009	0.0024	2.38	0.0034
Comparative Example 7	0.0014	3.33	2.52	0.012	0.0032	1.13	0.0034
Comparative Example 8	0.0012	3.25	2.53	0.008	0.0027	0.75	0.0028
Comparative Example 9	0.0038	3.16	1.00	0.005	0.0040	0.98	0.0007
Comparative Example 10	0.0021	2.89	1.71	0.015	0.0037	0.97	0.0031
Comparative Example 11	0.0025	3.70	0.60	0.009	0.0024	2.52	0.0034

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(continued)

(wt%)	C	Si	Mn	P	S	Al	Ti
Comparative Example 12	0.0018	3.60	0.73	0.005	0.0029	2.51	0.0034
Comparative Example 13	0.0013	4.20	1.82	0.013	0.0034	1.53	0.0022
Comparative Example 14	0.0016	2.96	0.74	0.003	0.0031	1.33	0.0007
Comparative Example 15	0.0037	3.65	2.09	0.005	0.0008	1.23	0.0042
Comparative Example 16	0.0012	3.09	0.70	0.005	0.0014	2.19	0.0026
Comparative Example 17	0.0021	2.89	1.71	0.015	0.0037	1.16	0.0031
Comparative Example 18	0.0036	4.22	1.57	0.005	0.0024	1.32	0.0035
Comparative Example 19	0.0037	3.66	1.75	0.004	0.0036	1.77	0.0017
Comparative Example 20	0.0020	4.02	1.03	0.011	0.0008	1.89	0.0038
Comparative Example 21	0.0029	3.32	0.51	0.009	0.0039	2.04	0.0023
Comparative Example 22	0.0038	3.16	1.00	0.005	0.0040	1.05	0.0007

[Table 2]

	Hot-rolled steel sheet 400-100 °C cooling rate (°C/second)	Coiling temperature (°C)	Water bath cooling	DSC Peak location (°C)
Inventive Example 1	40	620	○	421
Inventive Example 2	51	675	○	452
Inventive Example 3	49	699	○	471
Inventive Example 4	59	673	○	405
Inventive Example 5	72	666	○	342
Inventive Example 6	78	572	○	400
Inventive Example 7	52	575	○	428
Inventive Example 8	62	92	X	341
Inventive Example 9	31	74	X	345
Inventive Example 10	34	91	X	406
Inventive Example 11	43	76	X	363
Inventive Example 12	41	81	X	446
Inventive Example 13	54	72	X	459
Inventive Example 14	79	77	X	375
Inventive Example 15	78	84	X	386
Comparative Example 1	70	650	○	460
Comparative Example 2	52	97	X	332
Comparative Example 3	72	656	○	492
Comparative Example 4	66	82	X	485
Comparative Example 5	51	656	○	351
Comparative Example 6	43	98	X	334
Comparative Example 7	45	604	○	478
Comparative Example 8	45	84	X	482
Comparative Example 9	79	691	○	400

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(continued)

	Hot-rolled steel sheet 400-100 °C cooling rate (°C/second)	Coiling temperature (°C)	Water bath cooling	DSC Peak location (°C)
Comparative Example 10	73	97	X	450
Comparative Example 11	78	585	○	480
Comparative Example 12	74	82	X	483
Comparative Example 13	22	610	X	486
Comparative Example 14	19	553	X	486
Comparative Example 15	21	557	X	486
Comparative Example 16	29	658	X	480
Comparative Example 17	19	575	X	486
Comparative Example 18	20	145	X	487
Comparative Example 19	23	145	X	481
Comparative Example 20	19	144	X	481
Comparative Example 21	27	141	X	480
Comparative Example 22	28	149	X	487

[Table 3]

	Resistivity ($\mu \Omega \text{ cm}$)	$W_{10/400}(\text{W/Kg})$	$B_{50} \text{ (T)}$
Inventive Example 1	87.9	8.3	1.61
Inventive Example 2	65.5	10.1	1.63
Inventive Example 3	79.8	9.1	1.62
Inventive Example 4	76.5	9.8	1.62
Inventive Example 5	68.3	9.7	1.61
Inventive Example 6	84.3	9.3	1.62
Inventive Example 7	84.1	8.8	1.61
Inventive Example 8	85.4	9.0	1.62
Inventive Example 9	76.3	9.4	1.63
Inventive Example 10	66.2	10.3	1.63
Inventive Example 11	82.7	8.4	1.61
Inventive Example 12	84.9	8.0	1.61
Inventive Example 13	75.0	9.8	1.62
Inventive Example 14	72.9	10.1	1.63
Inventive Example 15	77.9	9.1	1.62
Comparative Example 1	62.5	12.1	1.63
Comparative Example 2	62.7	12.3	1.62
Comparative Example 3	88.9	8.2	1.56
Comparative Example 4	85.1	9.1	1.55
Comparative Example 5	62.5	12.3	1.65
Comparative Example 6	61.2	12.5	1.64
Comparative Example 7	74.8	9.9	1.59

(continued)

	Resistivity ($\mu \Omega \text{ cm}$)	$W_{10/400}$ (W/Kg)	B_{50} (T)
Comparative Example 8	72.6	10.0	1.58
Comparative Example 9	62.8	12.1	1.64
Comparative Example 10	62.5	12.3	1.63
Comparative Example 11	86.1	8.2	1.58
Comparative Example 12	84.3	8.3	1.57
Comparative Example 13	87.7	8.1	1.57
Comparative Example 14	64.3	9.7	1.55
Comparative Example 15	78.5	9.3	1.56
Comparative Example 16	75.8	9.6	1.55
Comparative Example 17	69.3	10.1	1.56
Comparative Example 18	85.2	9.6	1.52
Comparative Example 19	84.3	8.9	1.52
Comparative Example 20	84.8	9.2	1.55
Comparative Example 21	75.3	9.3	1.52
Comparative Example 22	73.5	10.5	1.56

[0104] As appears in Table 1 to Table 3, in the case of the Inventive Example in which the steel composition is appropriately adjusted and the cooling rate and coiling temperature after hot rolling are appropriately adjusted, it can be confirmed that the fraction of ordered phase is small, the DSC peak temperature is within an appropriate range, and the non-oriented electrical steel sheet produced through this has excellent magnetism.

[0105] In Comparative Examples 1 to 4, it can be confirmed that the Si content is not appropriately contained, and magnetism is deteriorated. It can be confirmed that in Comparative Examples 1 and 2, an excessively small amount of Si is contained so that the resistivity and iron loss deteriorates, and in Comparative Examples 3 and 4, an excessively large amount of Si is contained so that a large amount of ordered phases are generated and a DSC peak is formed at a high temperature. This confirms that the magnetic flux density is inferior.

[0106] It can be confirmed that Comparative Examples 5 to 8, the Mn content is not appropriately included thereby deteriorating magnetism. It can be confirmed that in Comparative Examples 5 and 6, Mn is excessively small, thereby deteriorating the resistivity and iron loss, and in Comparative Examples 7 and 8, Mn is excessively included, a large amount of ordered phases is generated, and the DSC peak is formed at a high temperature. This confirms that the magnetic flux density is inferior.

[0107] In Comparative Example 9 to 12, the Al content is not appropriately included, thereby deteriorating magnetism. It can be confirmed that in Comparative Examples 9 and 10, Al is excessively small, thereby deteriorating the resistivity and iron loss, and in Comparative Examples 11 and 12, Al is excessively included, a large amount of ordered phases is generated, and the DSC peak is formed at a high temperature. This confirms that the magnetic flux density is inferior.

[0108] It can be confirmed that in Comparative Examples 13 to 22, the cooling rate is not appropriately secured, so that a large amount of ordered phases is generated, and the DSC peak is formed at a high temperature. This confirms that the magnetic flux density is inferior.

[0109] The present invention is not limited to the embodiments and can be manufactured in various different forms, and a person skilled in the art to which the present invention belongs will understand that it can be implemented in other specific forms without changing the technical concept or essential features of the present invention. Therefore, the embodiments described above should be understood as exemplary in all respects and not limiting.

Claims

1. A hot-rolled steel sheet for a non-oriented electrical steel sheet, the hot-rolled steel sheet comprising, in wt%, Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, and balance comprising Fe and other unavoidable impurities, wherein a peak of a heat flow curved line measured during a heating process by using differential scanning

calorimetry (DSC) exists at 325 to 475 °C.

2. The hot-rolled steel sheet of claim 1, wherein Formula 1 below is satisfied:

[Formula 1]

$$0.6 \leq ([Al] + [Mn]) / [Si] \leq 1;$$

wherein, in Formula 1, [Al], [Mn] and [Si] represents the content (wt%) of Al, Mn, and Si, respectively.

3. The hot-rolled steel sheet of claim 1, further comprising one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% or less (excluding 0%), S: 0.0005 to 0.005 wt%, Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).
4. The hot-rolled steel sheet of claim 1, further comprising 0.005 to 0.200 wt% of one or more of Sn, Sb, Bi, Pb, Ge, and As, either individually or in their combined total.
5. The hot-rolled 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% or less (excluding 0%).
6. The hot-rolled steel sheet of claim 1, further comprising one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), V: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Nb: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).
7. The hot-rolled steel sheet of claim 1, having resistivity (ρ) of 63 $\mu\Omega\text{cm}$ or higher at 25 °C.
8. A manufacturing method of a hot-rolled steel sheet for a non-oriented electrical steel sheet, comprising:
 manufacturing a hot-rolled steel sheet by hot-rolling a slab comprising, in wt%, Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, and balance comprising Fe and other unavoidable impurities; and
 cooling the hot-rolled steel sheet,
 wherein the cooling cools a temperature range of 400 to 100 °C at 30 °C/second or more.
9. The manufacturing method of a hot-rolled steel sheet of claim 8, further comprising:
 winding the hot-rolled steel sheet, after the cooling of the hot-rolled steel sheet,
 wherein the winding of the hot-rolled steel sheet is performed at a temperature of 100 °C or lower.
10. The manufacturing method of a hot-rolled steel sheet of claim 8, wherein the cooling is performed in the temperature range of 400 to 100 °C at 30 °C/second to 100 °C/second.
11. The manufacturing method of a hot-rolled steel sheet of claim 8, wherein the slab further comprises one or more of P: 0.002 to 0.02 wt%, C: 0.005 wt% or less (excluding 0%), S: 0.0005 to 0.005% wt%, Ti: 0.005 wt% or less (excluding 0%), and N: 0.005 wt% or less (excluding 0%).
12. The manufacturing method of a hot-rolled steel sheet of claim 8, wherein the slab further comprises 0.005 to 0.200 wt% of one or more of Sn, Sb, Bi, Pb, Ge, and As, either individually or in their combined total.
13. The manufacturing method of a hot-rolled steel sheet of claim 8, wherein the slab further comprises 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% or less (excluding 0%).
14. The manufacturing method of a hot-rolled steel sheet of claim 8, wherein the slab further comprises one or more

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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%).

5 **15.** A manufacturing method of a non-oriented electrical steel sheet, comprising:

10 preparing a hot-rolled steel sheet comprising Si: 2.5 to 4.5%, Mn: 0.1 to 2.5%, Al: 1.0 to 2.5%, in wt%, and balance comprising Fe and other unavoidable impurities, and in which a peak of a heat flow curved line measured during a heating process by using differential scanning calorimetry (DSC) exists at 325 to 475 °C;
 manufacturing a cold-rolled steel sheet by cold rolling the hot-rolled steel sheet; and
 annealing the cold-rolled steel sheet.

15 **16.** The non-oriented electrical steel sheet of claim 15, wherein the manufactured non-oriented electrical steel sheet has an iron loss ($W_{10/400}$) of 12.0 W/Kg or less, and a magnetic flux density (B_{50}) of 1.60T or more.

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FIG. 1

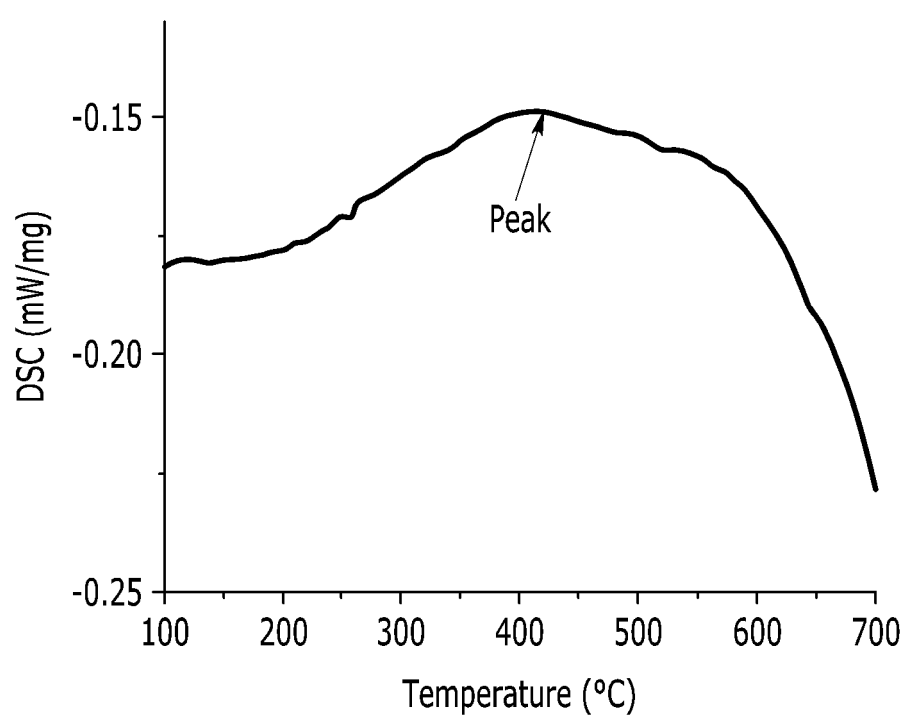


FIG. 2

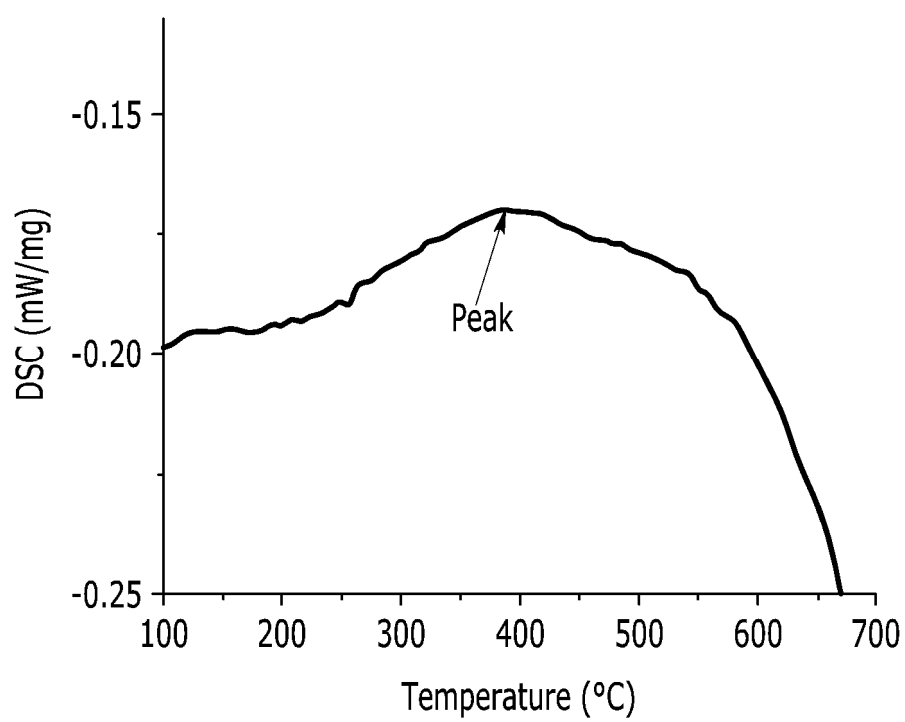
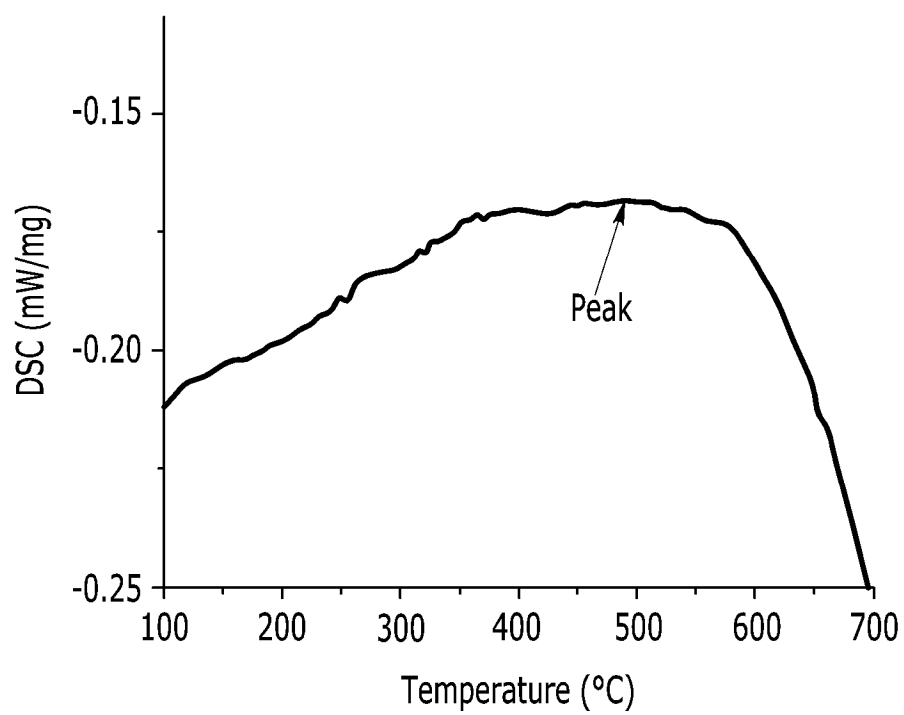


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063292

A. CLASSIFICATION OF SUBJECT MATTER

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

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 시차주사열량계(differential scanning calorimetry), 무방향성(non-oriented), 열연강판(hot-rolled steel sheet), 비저항(electrical resistivity), 냉각속도(cooling rate)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2020-0143916 A (POSCO) 28 December 2020 (2020-12-28) See paragraphs [0020] and [0141], claims 1-3, 8 and 12 and table 3.	1-16
Y	KR 10-2015-0007609 A (POSCO) 21 January 2015 (2015-01-21) See paragraphs [0094] and [0096] and claim 5.	1-16
A	KR 10-2000-0035297 A (JFE STEEL CORPORATION) 26 June 2000 (2000-06-26) See claim 7.	1-16
A	KR 10-1246466 B1 (HYUNDAI STEEL COMPANY) 21 March 2013 (2013-03-21) See paragraphs [0097]-[0108] and claims 1 and 4.	1-16
A	JP 2019-035116 A (NIPPON STEEL & SUMITOMO METAL) 07 March 2019 (2019-03-07) See claim 4.	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

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“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

15 April 2025

Date of mailing of the international search report

15 April 2025

Name and mailing address of the ISA/KR

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Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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