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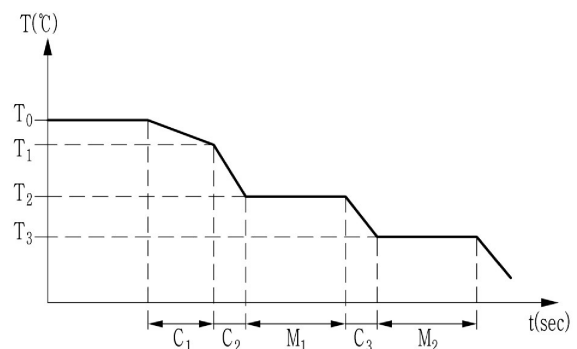
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(54) **NON-ORIENTED ELECTRICAL STEEL SHEET AND MANUFACTURING METHOD THEREFOR**

(57) A non-oriented electrical steel sheet according to an embodiment of the present invention comprises, in weight%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and 0.002 to 0.03% of one or more selected from the group consisting of Mo, V, and Nb, with the balance being Fe and unavoidable impurities, wherein in descending order of grain diameter, a ratio of an average grain diameter of coarse grains in range of 0 to 25% to an average grain diameter of fine grains in range of 75 to 100% is 6.5 or less.

FIG. 1



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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 manufacturing method thereof. Specifically, an embodiment of the present invention relates to a non-oriented electrical steel sheet and a manufacturing method thereof, which improves magnetic properties by appropriately controlling a thermal history during cooling of the steel sheet in an annealing process before cold rolling to appropriately form a grain diameter in the steel sheet.

[Background Art]

10 **[0002]** Recently, with the increase in disasters caused by climate change, countries around the world have been announcing 2050 carbon neutrality roadmaps. In 2020, total carbon emissions reached 39 billion tons, of which emissions from internal combustion engines accounted for 24%, reaching 9.4 billion tons. Therefore, there is a strong demand to achieve carbon neutrality in this field through the electrification of internal combustion engines. To this end, in the mobility sector, electrification is rapidly progressing, led by electric vehicles. In new mobility, the characteristics required for a drive motor are to increase driving range and increase maximum speed. This is directly related to the low core loss characteristics of electrical steel sheets. If the iron loss of the electrical steel sheet is low, the efficiency may be further improved to further increase the driving range. Therefore, high-frequency low core loss characteristics of electrical steel sheets are essential, and for this purpose, electrical steel sheets usually contain a large amount of Si and a large amount of elements such as Al, Mn, and Cr to ensure high-frequency low core loss.

20 **[0003]** However, when a large amount of high-resistivity alloying elements, such as Si, Al, Mn, and Cr, are added, a problem arises in that the magnetic flux density decreases. In particular, for applications where lightweight materials are continuously required, such as drive motors for eco-friendly electric vehicles, the use of a material having high magnetic flux density is essential.

[Disclosure]**[Technical Problem]**

30 **[0004]** An embodiment of the present invention provides a non-oriented electrical steel sheet and a manufacturing method thereof. Specifically, an embodiment of the present invention provides a non-oriented electrical steel sheet and a manufacturing method thereof, which improves magnetic properties by appropriately controlling a thermal history during cooling of the steel sheet in an annealing process before cold rolling to appropriately form a grain diameter in the steel sheet.

[Technical Solution]

40 **[0005]** A non-oriented electrical steel sheet comprising, in weight%:

Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and one or more types of Mo, V, and Nb in an amount of 0.002 to 0.03%, and a balance of Fe and unavoidable impurities, wherein, in descending order of grain diameter, a ratio of the average grain diameter of the coarse grains in range of 0 to 25% to the average grain diameter of the fine grains in range of 75 to 100% is 6.5 or less.

[0006] The density of carbides may be $2.5\text{ea}/\mu\text{m}^2$ or less.

[0007] The average grain diameter in the steel sheet is 40 to 150 μm .

50 **[0008]** The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise one or more of P: 0.1% or less (excluding 0%), C: 0.005% or less (excluding 0%), S: 0.005% or less (excluding 0%), Ti: 0.005% or less (excluding 0%), and N: 0.005% or less (excluding 0%).

[0009] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or two or more types of Sn, Sb, Bi, Pb, Ge, and As in an amount of 0.005 to 0.200 wt% for each or in total content thereof.

55 **[0010]** The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise 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%).

[0011] The non-oriented electrical steel sheet according to an embodiment of the present invention may further

comprise one or more of B: 0.0050 wt% or less (excluding 0%), Ca: 0.0050 wt% or less (excluding 0%), Zr: 0.005 wt% or less (excluding 0%), Te: 0.01 wt% or less (excluding 0%), and Mg: 0.0050 wt% or less (excluding 0%).

[0012] The non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy the following Equation 1.

[Equation 1]

$$(B50_L + B50_C) / 2 \geq 1.60$$

[0013] (Wherein, in Equation 1, $B50_L$ represents a magnetic flux density measured in the rolling direction ($B50$, Tesla), and $B50_C$ represents a magnetic flux density measured in the transverse direction ($B50$, Tesla).)

[0014] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention comprises the steps of: hot rolling a slab comprising, in weight%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and one or more types of Mo, V, and Nb in an amount of 0.002 to 0.03%, and a balance of Fe and unavoidable impurities; annealing before cold rolling for annealing the steel sheet; cold rolling the annealed steel sheet to manufacture a cold-rolled sheet; and cold-rolled sheet annealing.

[0015] The annealing before cold rolling comprises: soaking the steel sheet; a first cooling of cooling the steel sheet to a first cooling temperature at a first cooling rate; a second cooling of cooling the steel sheet to a second cooling temperature at a second cooling rate that is 3 to 17°C/sec higher than the first cooling rate; and a first holding of maintaining the steel sheet for 30 seconds or more within a range of the second cooling temperature $\pm 10^\circ\text{C}$.

[0016] The first cooling temperature may be 580 to 770°C.

[0017] The second cooling temperature may be 280 to 370°C.

[0018] The first cooling rate may be 5 to 20°C/sec, and the second cooling rate may be 10 to 30°C/sec.

[0019] The annealing before cold rolling may further comprise a third cooling of cooling to a third cooling temperature after the first holding.

[0020] The annealing before cold rolling may further comprises a second holding of maintaining for 30 seconds or more within a range of the third cooling temperature $\pm 10^\circ\text{C}$ after the third cooling.

[0021] The third cooling temperature may be 90 to 220°C.

[0022] The third cooling may have an average cooling rate of 30 to 50°C/sec.

[0023] The method may further comprise a preliminary cold rolling of the hot-rolled steel sheet before the annealing before cold rolling.

[Advantageous Effects]

[0024] A non-oriented electrical steel sheet according to an embodiment of the present invention exhibits excellent magnetic flux density and low iron loss in the rolling direction.

[0025] A non-oriented electrical steel sheet according to an embodiment of the present invention has improved cold rollability, thereby improving productivity.

[0026] Ultimately, the non-oriented electrical steel sheet according to an embodiment of the present invention may contribute to the manufacture of a motor for eco-friendly vehicles, a motor for high-efficiency home appliances, or a super-premium grade motor core.

[Brief Description of the Drawings]

[0027] FIG. 1 is a diagram schematically illustrating a cooling pattern in an annealing before cold rolling.

[Mode for Invention]

[0028] Terms such as first, second, and third are used to describe various portions, components, regions, layers, and/or sections, but are not limited thereto. These terms are used only to distinguish one portion, component, region, layer, or section from another portion, component, region, layer, or section. Therefore, a first portion, component, region, layer, or section described below may be referred to as a second portion, component, region, layer, or section without departing from the scope of the present invention.

[0029] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the present invention. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. The term "comprising," when used in this specification, specifies the presence of stated features, regions, integers, steps, operations, elements, and/or components, but does

not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, and/or components.

[0030] When a portion is mentioned as being "above" or "on" another portion, it may be directly above or on the other portion, or another portion may be involved therebetween. In contrast, when a portion is mentioned as being

[0031] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by a person of ordinary skill in the art to which the present invention belongs. Terms defined in commonly used dictionaries shall be interpreted as having a meaning consistent with their meaning in the context of the relevant technical literature and the present disclosure, and shall not be interpreted in an ideal or

[0032] In addition, unless otherwise specified, % means wt%, and 1 ppm is 0.0001 wt%.

[0033] In an embodiment of the present invention, further including an additional element means including the additional element by replacing iron (Fe) as a balance in an amount equal to the amount of the additional element added.

[0034] Hereinafter, embodiments of the present invention will be described in detail so that those skilled in the art may easily practice the present invention. However, the present invention may be implemented in various different forms and is not limited to the embodiments described herein.

[0035] A non-oriented electrical steel sheet according to an embodiment of the present invention comprises, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and one or more types of Mo, V, and Nb in an amount of 0.002 to

[0036] First, reasons for limiting the components of the non-oriented electrical steel sheet will be described.

Si: 1.5 to 4.5 wt%

[0037] Silicon (Si) serves to lower iron loss by increasing the specific resistance of the material, and therefore should be added in a relatively large amount. When Si is added in too small an amount, an effect of improving high-frequency core loss may be insignificant. When Si is added in too large an amount, the hardness of the material increases, so that productivity and punchability become inferior, which is not preferable. More specifically, Si may be included in an amount of 2.0 to 4.0 wt%. More specifically, Si may be included in an amount of 2.5 to 3.5 wt%.

Al: 0.1 to 2.0 wt%

[0038] Aluminum (Al) serves to lower iron loss by increasing the specific resistance of the material, and therefore should be added in a large amount. When Al is added in too small an amount, there is no effect in reducing high-frequency core loss, and nitrides are formed finely, which may deteriorate magnetic properties. When Al is added in too large an amount, it causes a problem of changing the physical properties of mold flux during a continuous casting process, which may significantly reduce productivity. More specifically, Al may be included in an amount of 0.3 to 1.8 wt%, and even more specifically, Al may be included in an amount of 0.5 to 1.7 wt%.

Mn: 0.1 to 2.0 wt%

[0039] Manganese (Mn) serves to improve iron loss by increasing the specific resistance of the material and to form sulfides. When Mn is added in an excessively small amount, MnS may finely precipitate, thereby deteriorating magnetic properties. When Mn is added in an excessively large amount, the formation of <111>ND texture, which is unfavorable for magnetic properties, is promoted, such that the magnetic flux density may be sharply decreased. More specifically, Mn may be included in an amount of 0.3 to 1.8 wt%. More specifically, Mn may be included in an amount of 0.5 to 1.5 wt%.

One or more types of Mo, V, and Nb: 0.0020 to 0.0300 wt%

[0040] Molybdenum (Mo), Vanadium (V), and Niobium (Nb) form carbides and undergo complex precipitation with TiC or the like, which results in the coarsening of precipitates and an improvement in magnetic flux density by reducing the number of fine carbides. When they are appropriately added, the above-described effects may be obtained; however, when they are included in an excessive amount, a large amount of segregation occurs, which suppresses grain growth, such that the magnetic flux density and iron loss may be adversely affected. More specifically, one or more types of Mo, V, and Nb may be included in an amount of 0.0030 to 0.0200 wt%. When only one type among Mo, V, and Nb is included, it is included in an amount of 0.0020 to 0.0300 wt% each. When two or more types among Mo, V, and Nb are included, the sum of the contents of each element may be 0.0020 to 0.0300 wt%.

[0041] The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise one or more of: P: 0.1% or less (excluding 0%), C: 0.003% or less (excluding 0%), S: 0.004% or less (excluding 0%), Ti: 0.003% or less (excluding 0%), and N: 0.003% or less (excluding 0%).

P: 0.1 wt% or less

[0042] Phosphorus (P) is a grain boundary segregation element and may improve magnetic flux density, but when it is added in too large an amount, the brittleness of the steel sheet increases, so that weldability becomes inferior. More specifically, P may be included in an amount of 0.0001 to 0.0500 wt%.

C: 0.0050 wt% or less

[0043] Carbon (C) reacts with N, Ti, Nb, V, and the like to form fine carbides, thereby acting to hinder grain growth and magnetic domain movement, which may deteriorate magnetic properties. In particular, when carbides of less than 0.05 μm exist, the movement of magnetic domains becomes difficult, so that iron loss increases. Therefore, in an embodiment of the present invention, by optimizing the cooling pattern for controlling the size of carbides during the cooling process of the annealing process before cold rolling, even if some carbides exist in the steel sheet, the problem of increased iron loss may be overcome. More specifically, the steel sheet may comprise C in an amount of 0.0001 to 0.0050 wt%. More specifically, the steel sheet may comprise C in an amount of 0.0010 to 0.0035 wt%.

S: 0.0050 wt% or less

[0044] Sulfur (S) is an element that forms sulfides such as MnS, and may deteriorate magnetic properties by suppressing grain growth. More specifically, the composition may comprise S in an amount of 0.0001 to 0.0050 wt%.

More specifically, the composition may comprise S in an amount of 0.0010 to 0.0030 wt%.

Ti: 0.0050 wt% or less

[0045] Titanium (Ti) may be limited because it forms carbonitride and acts to hinder magnetic domain movement. More specifically, Ti may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, Ti may be included in an amount of 0.0010 to 0.0035 wt%.

N: 0.0050 wt% or less

[0046] Nitrogen (N) combines with Ti, Nb, and V to form nitrides, and may reduce grain growth. More specifically, N may be included in an amount of 0.0001 to 0.0050 wt%. More specifically, N may be included in an amount of 0.0010 to 0.0035 wt%.

[0047] The non-oriented electrical steel sheet according to an embodiment of the present invention may further include one or two or more types of Sn, Sb, Bi, Pb, Ge, and As in an amount of 0.005 to 0.200 wt% for each or in total content thereof.

[0048] When the above-mentioned elements are additionally added, they segregate at the grain boundaries to alleviate stress concentration at the grain boundaries during cold rolling, thereby suppressing recrystallization of <111>//ND oriented grains in a subsequent process, i.e., recrystallization annealing, to improve magnetic flux density. When they are appropriately added, the above-described effects may be additionally obtained; however, when they are included in an excessive amount, a large amount of segregation occurs, which suppresses grain growth, such that the magnetic flux density and iron loss may rather be deteriorated. More specifically, the composition may further include one or more elements selected from the group consisting of Sn, Sb, Bi, Pb, Ge, and As in an amount of 0.010 to 0.100 wt% each or in total.

[0049] The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise 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%).

Cu: 0.005 to 0.200 wt%

[0050] Copper (Cu) serves to form sulfides together with Mn. When Cu is further added, if it is added in too small an amount, (Cu·Mn)S may finely precipitate, potentially deteriorating magnetic properties. When Cu is added in an excessive amount, hot shortness occurs, which may lead to the formation of cracks during continuous 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%

[0051] Chromium (Cr) serves to improve iron loss by increasing specific resistance. When Cr is added in too small an amount, the effect of increasing specific resistance may not be sufficient. When Cr is included in too large an amount, magnetic flux density may decrease. More specifically, Cr may be included in an amount of 0.050 to 0.20 wt%.

Ni: 0.05 wt% or less

[0052] Nickel (Ni) reacts with impurity elements to form fine sulfides, carbides, and nitrides, which may have a harmful effect on magnetic properties. More specifically, Ni may be included in an amount of 0.001 to 0.03 wt%.

Zn: 0.01 wt% or less

[0053] When the content of zinc (Zn) is excessive, it acts as an impurity and may deteriorate magnetic properties. Therefore, 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%.

[0054] The non-oriented electrical steel sheet according to an embodiment of the present invention may further comprise one or more of Mo: 0.03 wt% or less (excluding 0%), B: 0.0050 wt% or less (excluding 0%), Ca: 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%).

[0055] These elements react with unavoidably included C, S, and N to form fine carbides, nitrides, or sulfides, which may adversely affect magnetic properties; thus, the upper limit may be restricted as described above.

Other impurities

[0056] In addition to the above-mentioned elements, unavoidable impurities may be included. The unavoidable impurities are impurities introduced during a steelmaking stage and a manufacturing process of a non-oriented electrical steel sheet, and since this is widely known in the field, a specific description thereof is omitted. In an embodiment of the present invention, the addition of elements other than the above-mentioned alloying components is not excluded, and various elements may be included within a range that does not impair the technical spirit of the present invention. When an additional element is further included, the additional element replaces the balance Fe.

[0057] In the non-oriented electrical steel sheet according to an embodiment of the present invention, a ratio of an average grain diameter of coarse grains, which are in the 0 to 25% range of grain diameter in descending order, to an average grain diameter of fine grains, which are in the 75 to 100% range of grain diameter in descending order, is 6.5 or less.

[0058] Fine grains ($GS_{\leq 75\%}$) refer to grains within the lowest 75% based on grain diameter. In other words, based on grain diameter, it refers to the 75% to 100% of grains that have the smallest grain diameters relative to the total 100% of the grains existing within a measurement area. For example, when 100 grains exist in a measurement area, it refers to the 75th to 100th grains when sorted in ascending order of grain diameter. A cross-section for measurement is not particularly limited, but may be a normal plane (TD plane) in the transverse direction (TD direction) of the steel sheet. To reduce measurement deviation, the measurement area may be at least the total thickness $\times$ 3 mm, and the number of measurement specimens may be at least 3 for non-overlapping areas. The grain diameter may be determined as the equivalent circular diameter of a circle having the same area as the corresponding grain.

[0059] Coarse grains ($GS_{\geq 25\%}$) refer to grains in the top 25% by grain diameter. That is, based on grain diameter, it refers to grains within the 0 to 25% range of the largest grain diameters relative to the total number (100%) of grains existing within a measurement area. For example, when 100 grains exist in a measurement area, it refers to the 1st to 25th grains when the grains are arranged in descending order of grain diameter.

[0060] In an embodiment of the present invention, based on the grain diameter, a ratio ($GS_{\geq 25\%}/GS_{\leq 75\%}$) of an average grain diameter of coarse grains in range of 0 to 25% to an average grain diameter of fine grains in range of 75 to 100% is adjusted to 6.5 or less, so that magnetic properties may be further improved by lowering the area fraction of coarse grains disadvantageous for magnetic properties. More specifically, the ratio ($GS_{\geq 25\%}/GS_{\leq 75\%}$) of the average grain diameter of coarse grains in range of 0 to 25% to the average grain diameter of fine grains in range of 75 to 100% may be 2.0 to 6.0.

[0061] More specifically, an average grain diameter of fine grains ($GS_{\leq 75\%}$) of 75 to 100% may be 5 to 25 μm . Also, an average grain diameter of coarse grains ($GS_{\geq 25\%}$) of 0 to 25% may be 80 to 300 μm .

[0062] In an embodiment of the present invention, the density of the carbides may be 2.5 per/ μm^2 or less. The term 'carbides' refers to particles formed by the agglomeration of carbon components within the steel sheet. Specifically, it

refers to a portion containing a higher amount of carbon than the base content of the steel sheet. In an embodiment of the present invention, the carbides are defined as particles containing carbon components and having a carbon agglomeration particle diameter of at least 1 nm when measured by TEM (Transmission Electron Microscopy) and EDS (Energy Dispersive Spectroscopy). A cross-section for the measurement of the carbides is not particularly limited, but may be a normal plane (TD plane) in the transverse direction (TD direction) of the steel sheet. The diameter of the carbides refers to the diameter of an imaginary circle having the same area as the area occupied by the carbides. In an embodiment of the present invention, the carbides may include one or more types selected from the group consisting of Mo, V, and Nb, in addition to C.

[0063] If the density of carbides is high, the absolute number of fine carbides increases, which may adversely affect iron loss. More specifically, the density of carbides may be in a range of 0.1 to 2.3/ μm^2 . More specifically, it may be in a range of 0.5 to 2.3/ μm^2 .

[0064] In an embodiment of the present invention, an average grain diameter in the steel sheet may be 40 to 150 μm . If the average grain diameter is too large or too small, it may adversely affect magnetic properties. More specifically, the average grain diameter in the steel sheet may be 50 to 100 μm .

[0065] In an embodiment of the present invention, the magnetic flux density in the rolling direction and the transverse direction may be excellent.

[0066] Specifically, a non-oriented electrical steel sheet according to an embodiment of the present invention may satisfy the following Equation 1.

[Equation 1]

$$(B50_L + B50_C) / 2 \geq 1.60$$

[0067] (Wherein, in Equation 1, $B50_L$ represents a magnetic flux density measured in the rolling direction ($B50_L$, Tesla), and $B50_C$ represents a magnetic flux density measured in the transverse direction ($B50_C$, Tesla).)

[0068] $B50$ refers to the magnetic flux density induced at a magnetic field of 5000 A/m.

[0069] Equation 1 is essentially a general method for evaluating the magnetic flux density of a non-oriented electrical steel sheet and represents the average value of the magnetic flux density ($B50$) in the rolling direction (L) and the transverse direction (C). More specifically, the value of Equation 1 may be 1.61 to 1.65.

[0070] In addition, the non-oriented electrical steel sheet according to an embodiment of the present invention may have a core loss ($W10/400$) of 13.5 W/kg or less based on 0.25 mm. $W10/400$ is an iron loss when a magnetic flux density of 1.0 T is induced at a frequency of 400 Hz.

[0071] A method for manufacturing a non-oriented electrical steel sheet according to an embodiment of the present invention comprises the steps of: hot rolling a slab to manufacture a hot-rolled steel sheet, the slab comprising, in wt%, Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and 0.002 to 0.03% of one or more selected from the group consisting of Mo, V, and Nb, with the balance being Fe and unavoidable impurities; an annealing before cold rolling for annealing the steel sheet; cold rolling the annealed steel sheet to manufacture a cold-rolled sheet; and cold-rolled sheet annealing for annealing the cold-rolled sheet.

[0072] Hereinafter, each step will be described in detail.

[0073] First, a slab is manufactured. Since the reasons for limiting the addition ratio of each composition in the slab are the same as the reasons for limiting the composition of the non-oriented electrical steel sheet described above, repetitive descriptions will be omitted. Since the composition of the slab is not substantially changed during manufacturing processes such as hot rolling, annealing before cold rolling, cold rolling, and cold-rolled sheet annealing to be described later, the composition of the slab and the composition of the non-oriented electrical steel sheet are substantially the same.

[0074] Before the step of manufacturing a hot-rolled sheet, the slab may be heated to 1000°C or higher. Specifically, the slab is charged into a heating furnace and heated to 1050 to 1250°C. When heated at a temperature exceeding 1250°C, precipitates may be redissolved and may undergo fine precipitation after hot rolling.

[0075] The heated slab is hot-rolled to 3.0 mm or less to produce a hot-rolled steel sheet. In an embodiment of the present invention, a preliminary cold rolling may be additionally included before cold rolling, so that even if the thickness of the hot-rolled sheet is relatively thick, a non-oriented electrical steel sheet having an appropriate thickness may be manufactured. More specifically, the thickness of the hot-rolled sheet may be 1.5 to 3.0 mm.

[0076] The step of manufacturing a hot-rolled sheet may include a finishing rolling at a temperature of 850°C or higher.

[0077] If the finish rolling temperature of hot rolling is too low, the rolling load increases, resulting in decreased hot rolling workability. In addition, a large amount of deformed structure remains in the hot-rolled steel sheet, which may cause the rolling load to increase during a preliminary cold rolling process, which is a subsequent process. Further-

more, during intermediate annealing, recrystallization of <111>/ND oriented grains from the deformed structure is promoted, so that the magnetic flux density becomes inferior. Therefore, the higher the finish rolling temperature of hot rolling, the better; more specifically, it is preferable to perform the finish rolling at a temperature of 860 to 1000°C.

[0078] The step of manufacturing a hot-rolled sheet may include a step of performing water cooling after 0.1 second or more has passed after finishing rolling.

[0079] After finishing rolling, cooling for coiling is performed. In performing water cooling, if water cooling is performed immediately after finishing rolling (i.e., less than 0.1 seconds), the steel sheet is rapidly cooled, resulting in deformation and residual stress, which may make coiling difficult. In addition, in terms of microstructure, the strain stress after finishing rolling remains without being released, which may lead to an increase in rolling load in a subsequent cold rolling and the formation of fine <111>/ND orientation recrystallization grains. Therefore, by maintaining the steel sheet for 0.1 seconds or more so that recovery and recrystallization of the hot-rolled deformed structure may occur immediately after finishing rolling, the rolling load during subsequent preliminary cold rolling is reduced, and the generation of <111>/ND orientation recrystallization grains is suppressed. More specifically, water cooling may be performed after 0.3 to 5.0 seconds, and even more specifically, water cooling may be performed after 0.5 to 3.0 seconds.

[0080] The step of manufacturing a hot-rolled sheet may include a step of coiling at a temperature of 600 to 800°C. A step of rough rolling may also be included before the finishing rolling.

[0081] If the temperature in the coiling is controlled to be too low, recovery and recrystallization of the hot-rolled deformed structure do not occur sufficiently, and the cooling load increases to cool the steel sheet to a low temperature rapidly, which may cause difficulty in coiling the overcooled coil. Conversely, if the temperature is too high, recovery and recrystallization may be promoted, but additional oxidation by oxygen in the atmosphere occurs during coiling, resulting in a thicker scale and a potential problem of intergranular oxidation. The intergranular oxidation of the hot-rolled sheet promotes grain boundary corrosion in a subsequent pickling process, which may lead to a high possibility of surface stripe defects, and rolling rolls may be severely worn. Therefore, the coiling temperature is preferably 600 to 800°C, and more specifically, coiling may be performed at 600 to 750°C.

[0082] In an embodiment of the present invention, after manufacturing a hot-rolled steel sheet, an annealing before cold rolling, which anneals the hot-rolled steel sheet, may be performed immediately. Alternatively, after performing preliminary cold rolling on the hot-rolled steel sheet, an annealing before cold rolling, which anneals the preliminary cold-rolled sheet, may be performed.

[0083] Preliminary cold rolling may be performed in a PCM (Pickling & Cold rolling Mill) comprising a pickling process or a TCM (Tandem Cold rolling Mill) performing only cold rolling to improve rolling productivity, and may be performed at a reduction ratio in the range of 20 to 80% to improve final cold rolling productivity and a fraction of <100>/ND grains in the final product sheet. In addition, when rolling productivity is not considered, it is also possible in the present invention to perform the preliminary cold rolling in a Reverse Mill. The preliminary cold-rolled sheet may have a thickness of 0.5 to 1.8 mm. More specifically, the reduction ratio may be 30 to 70% and the thickness may be 0.8 to 1.5 mm.

[0084] Preliminary cold rolling is distinguished from cold rolling, which will be described later, in that it is a primary rolling in a process of rolling to an intermediate thickness rather than a final product thickness, then performing intermediate annealing, and then cold rolling to the final product thickness.

[0085] The preliminary cold rolling reduction ratio may be calculated as (thickness of the steel sheet before rolling - thickness of the steel sheet after rolling) / thickness of the steel sheet before rolling. If the reduction ratio is too low in the preliminary cold rolling, the rolling load increases during the final cold rolling, resulting in decreased productivity, and the final reduction ratio increases, which may cause a problem of promoting fine <111>/ND orientation recrystallization. Conversely, if the reduction ratio is too high, the cold rolling load increases and the possibility of strip breakage also increases.

[0086] The step of manufacturing a preliminary cold-rolled sheet may be performed at a temperature of 60 to 300°C. This temperature may be increased naturally due to friction between the steel sheet and a rolling roll, or may be increased by applying heat from an external source. If the temperature is too low, the rolling load significantly increases, and the steel sheet may slip between the rolling rolls rather than being rolled, which may cause problems such as twisting. If the temperature is too high, oxidation of Si and Al may occur on the surface of the steel sheet, magnetic properties may deteriorate, and problems such as ignition of rolling oil may occur. More specifically, the step may be performed at a temperature of 70 to 250°C.

[0087] As described above, the preliminary cold rolling may be omitted if necessary.

[0088] Next, in the annealing before cold rolling, the hot-rolled steel sheet or the preliminary cold-rolled sheet is annealed.

[0089] In the annealing before cold rolling, the soaking temperature may be from 800 to 1200°C. If the annealing temperature is too low, a recrystallization structure is not formed or grows finely, such that there is little effect of increasing the magnetic flux density; and if the annealing temperature is too high, the magnetic properties are rather

lowered and rolling workability may deteriorate due to deformation of the sheet shape. More specifically, the temperature range may be from 830 to 1170°C. The soaking time may be from 15 to 180 seconds.

[0090] In an embodiment of the present invention, by controlling the cooling pattern in the annealing before cold rolling, a ratio of the average grain diameter of coarse grains to that of fine grains ($GS_{\geq 25\%}/GS_{\leq 75\%}$) and carbide density may be adjusted.

[0091] In FIG. 1, a cooling pattern in the annealing before cold rolling is schematically illustrated.

[0092] As shown in FIG. 1, the method comprises a soaking for the steel sheet; a first cooling stage (C_1) for cooling the steel sheet to a first cooling temperature (T_1) at a first cooling rate; a second cooling stage (C_2) for cooling the steel sheet to a second cooling temperature (T_2) at a second cooling rate that is 3 to 17°C/sec higher than the first cooling rate; and a first holding stage (M_1) for maintaining the steel sheet within a range of the second cooling temperature (T_2) $\pm$ 10°C for 30 seconds or more.

[0093] The first cooling stage (C_1) cools the steel sheet from a soaking temperature (T_0) to a first cooling temperature (T_1) at a first cooling rate. In an embodiment of the present invention, a cooling temperature in a cooling refers to an average cooling temperature over the entire duration of the cooling. Although FIG. 1 illustrates the cooling performed at a uniform cooling rate, the cooling rate may vary over time.

[0094] The first cooling temperature (T_1) may be 580 to 770°C. If the first cooling temperature (T_1) is too low, it means that cooling was performed at a first cooling rate for a long time, which may cause problems in terms of deformation of the material due to thermal shock and consequent deterioration of magnetic flux density and iron loss due to residual stress. If the first cooling temperature (T_1) is too high, the first cooling stage (C_1) ends early, forming fine carbides, which may cause problems in terms of magnetic flux density and iron loss. In an embodiment of the present invention, the cooling temperature is based on the sheet surface temperature. More specifically, the first cooling temperature (T_1) may be 600 to 750°C.

[0095] The first cooling rate may be 5 to 20°C/sec. If the first cooling rate is too slow, this may cause problems in terms of carbides coarsening and promotion of growth of coarse grains. If the first cooling rate is too fast, a problem may occur in terms of not securing the time necessary for fine grain growth. More specifically, the first cooling rate may be 10 to 15°C/sec.

[0096] Next, in the second cooling stage (C_2), cooling is performed from the first cooling temperature (T_1) to a second cooling temperature (T_2) at a second cooling rate. In this case, the second cooling rate is 3 to 17°C/sec higher than the first cooling rate. When the difference between the second cooling rate and the first cooling rate is small, the total annealing time increases, and problems may occur in that carbide growth is promoted. When the difference between the second cooling rate and the first cooling rate is too large, deterioration of magnetic properties may occur due to residual stress formed by rapid cooling. More specifically, the second cooling rate may be 5 to 15°C/sec higher than the first cooling rate.

[0097] The second cooling temperature (T_2) may be 280 to 370°C. If the second cooling temperature (T_2) is too low, it means that cooling was performed at a second cooling rate for a long time, which may cause problems in terms of an increase in carbides precipitation. If the second cooling temperature (T_2) is too high, the second cooling stage (C_2) ends early, which may cause a problem in that time necessary for fine grain growth is insufficient. More specifically, the second cooling temperature (T_2) may be 300 to 350°C.

[0098] The second cooling rate may be 10 to 30°C/sec. If the second cooling rate is too slow, carbides precipitation may increase. If the second cooling rate is too fast, problems may occur in terms of increasing residual stress due to rapid cooling. More specifically, the second cooling rate may be 15 to 25°C/sec.

[0099] Next, in the first holding stage (M_1), it is maintained for 30 seconds or more within a range of the second cooling temperature (T_2) $\pm$ 10°C. If the holding time of the first holding stage (M_1) is too short, a problem may occur in terms of insufficient growth of fine grains. More specifically, the holding time may be 30 to 600 seconds. More specifically, it may be 60 to 300 seconds.

[0100] After the first holding stage (M_1), the strip may be cooled to room temperature; however, additional cooling and heat-holding may be performed when cooling to room temperature in order to prevent strip breakage caused by material deviation in the transverse and longitudinal directions and shape defects.

[0101] The method may further comprise a third cooling stage (C_3) of cooling to a third cooling temperature (T_3) after the first holding stage.

[0102] The third cooling temperature (T_3) may be 90 to 220°C. If the third cooling temperature (T_3) is too low, problems may occur in terms of shape deformation due to rapid cooling. If the third cooling temperature (T_3) is too high, problems may occur in terms of poor coating quality as coating is performed at a high temperature. More specifically, the third cooling temperature (T_3) may be 100 to 200°C.

[0103] The average cooling rate of the third cooling may be 30 to 50°C/sec. If the third cooling rate is too slow, productivity may decrease. If the third cooling rate is too fast, problems may occur in terms of material deviation and shape defects due to deviation in the transverse and longitudinal directions. More specifically, the third cooling rate may be 35 to 45°C/sec.

[0104] The above-described annealing before cold rolling may be performed in a vertical continuous annealing line or a horizontal continuous annealing line. In performing the annealing, a pickling process may be performed using sulfuric acid, hydrochloric acid, or nitric acid to remove an oxidation layer that may exist on the steel sheet before the annealing, or alternatively, an oxidation layer remaining on the surface may be removed by performing pickling after the annealing.

[0105] Returning to the description of the method for manufacturing a non-oriented electrical steel sheet, a cold-rolled sheet is manufactured by cold rolling the annealed steel sheet. In this process, the steel sheet may be cold rolled at a reduction ratio of 30 to 80%. If the reduction ratio is too low, the strain energy accumulated in the rolled steel sheet is small, making recrystallization difficult in a subsequent annealing process, so that the rolled structure remains, which may cause problems in the improvement of magnetic flux density and iron loss. Conversely, if the reduction ratio is too high, recrystallization of <111>//ND oriented grains is promoted and the grains become fine in the subsequent annealing process, which may cause problems in which magnetic flux density is inferior and iron loss increases. More specifically, the reduction ratio may be 40 to 70%. The thickness may be 0.1 mm to 0.5 mm. More specifically, it may be 0.15 to 0.35 mm. For the cold rolling, a tandem cold rolling mill may be used to continuously cold roll the steel sheet using a plurality of rolling stands, or a reverse rolling mill may be used to discontinuously cold roll the sheet using a rolling mill with 12 or more rolls.

[0106] Next, the step of annealing the cold-rolled sheet may be performed in a temperature range of 600 to 1200°C. If the annealing temperature is too low, recrystallization of <111>//ND oriented grains is promoted and the grains become fine, so that excellent magnetic flux density characteristics may not be secured. If the annealing temperature is too high, the grains grow coarsely to increase iron loss, and an oxidation layer or a nitride layer may be generated on the surface of the steel sheet due to an annealing atmosphere gas, which may also cause a problem of increasing iron loss. More specifically, the cold-rolled sheet may be annealed at 750 to 1100°C.

[0107] After the cold-rolled sheet annealing, a step of forming an insulation coating to secure insulation and corrosion resistance on the steel sheet may be further included. Since insulation coating is widely known, a specific description thereof will be omitted.

[0108] Preferred examples and comparative examples of the present invention are described below. However, the following examples are merely preferred embodiments of the present invention, and the present invention is not limited to the following examples.

Example 1

[0109] A slab having a composition as shown in Table 1 below was manufactured, with the balance being Fe. The slab was heated to 1150°C, subjected to hot finishing rolling at 920°C, and coiled at 650°C to produce a hot-rolled sheet with a thickness of 2.3 mm. Subsequently, the hot-rolled sheet was subjected to preliminary cold rolling to a thickness of 1.4 mm. Then, soaking was performed at 1100°C for 30 seconds, followed by primary cooling to 600°C at a cooling rate of 10°C/sec, secondary cooling to 350°C at a cooling rate of 15°C/sec, and annealing while maintaining the temperature at 350°C for 240 seconds. Subsequently, the sheet was cooled to 150°C at a cooling rate of 40°C/sec, maintained at 150°C for 60 seconds, and then cooled to room temperature. Subsequently, final cold rolling was performed to a thickness of 0.25 mm using a reverse rolling mill, followed by annealing at 900°C for 100 seconds and an insulation coating treatment.

[0110] The grain diameter of the steel sheet was measured by EBSD and analyzed using a GS (diameter) chart in OIM software, thereby determining a ratio ($GS_{\geq 25\%}/GS_{\leq 75\%}$) of an average grain diameter of coarse grains to an average grain diameter of fine grains.

[0111] The carbides of the steel sheet were measured using TEM and EDS, and the results are summarized in Table 2 below.

[0112] The magnetic properties were measured by preparing Epstein specimens for each angle using an Epstein tester, and are expressed as an average value of the rolling direction and the transverse direction.

[Table 1]

(wt%)	Si	Al	Mn	C(ppm)	S(ppm)	N(ppm)	Ti(ppm)	Mo(ppm)	V(ppm)	Nb(ppm)
A1	2.7	1.6	0.7	70	14	16	16	15	50	12
A2	2.7	1.6	0.7	32	15	55	15	20	12	15
A3	2.7	1.6	0.7	28	20	21	20	15	351	35
A4	2.7	1.6	0.7	16	62	32	29	40	125	50
A5	2.7	1.6	0.7	20	23	26	31	50	107	20

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(continued)

(wt%)	Si	Al	Mn	C(ppm)	S(ppm)	N(ppm)	Ti(ppm)	Mo(ppm)	V(ppm)	Nb(ppm)
A6	2.7	1.6	0.7	25	10	17	24	30	154	15
A7	2.7	1.6	0.7	20	23	26	31	5	5	5

[Table 2]

	Grain diameter ratio	Average grain diameter (μm)	Carbide density($\text{ea}/\mu\text{m}^2$)	B50(Tesla)
A1	6.8	89	3.25	1.58
A2	6.7	80	2.42	1.59
A3	4.5	32	3.70	1.57
A4	2.8	35	2.80	1.58
A5	5.9	68	2.31	1.63
A6	4.8	75	2.45	1.62
A7	6.6	80	2.62	1.59

[0113] As shown in Table 1 and Table 2, it may be confirmed that when the steel composition is not appropriately included, the grain diameter ratio is not appropriately formed, and the magnetic flux density is inferior.

Example 2

[0114] A slab having the composition shown in Table 3 below was manufactured. The process was carried out in the same manner as in Example 1, except that the thermal conditions for the annealing before cold rolling were changed as shown in Table 4 below.

[Table 3]

(wt%)	Si	Al	Mn	C(ppm)	S(ppm)	N(ppm)	Ti(ppm)	Mo(ppm)	V(ppm)	Nb(ppm)
B1	3.45	0.7	1.2	56	16	32	58	85	-	-
B2	3.45	0.7	1.2	28	22	28	26	-	-	70
B3	3.45	0.7	1.2	26	16	23	14	-	125	-
B4	3.45	0.7	1.2	20	15	27	22	-	100	40
B5	3.45	0.7	1.2	30	23	26	23	10	-	80
B6	3.45	0.7	1.2	45	15	20	32	70	20	-

[Table 4]

Remarks	Steel grade	Soaking temperature (°C)	First cooling temperature (°C)	First cooling rate (°C/sec)	Second cooling temperature (°C)	Second cooling rate (°C/sec)	First isothermal holding time (sec)	Third cooling temperature (°C)	Second isothermal holding time (sec)
C1	B1	1000	600	10	350	15	300	150	60
C2	B2	1000	600	25	350	15	300	150	60
C3	B3	900	550	10	350	15	300	150	60
C4	B4	1000	800	10	320	15	300	150	60
C5	B5	900	600	10	320	15	300	150	60
C6	B6	1000	600	15	320	15	300	150	60
C7	B2	750	600	10	350	15	60	150	35
C8	B3	850	600	10	350	15	300	150	60
C9	B4	1000	600	10	350	15	300	150	60
C10	B5	1100	600	10	350	15	300	150	60
C11	B6	1150	600	25	350	15	300	150	60
C13	B3	1000	700	10	350	15	300	150	60
C14	B4	1000	650	10	350	15	300	150	60
C16	B6	1000	600	15	450	25	300	150	60
C17	B2	1000	600	15	360	25	60	150	60
C18	B3	1000	600	15	320	25	300	150	60
C19	B4	1000	600	15	250	25	60	150	60
C20	B5	1000	600	15	320	35	60	150	60
C21	B6	1000	600	15	320	25	20	150	30
C22	B2	1000	600	15	320	25	60	250	30
C23	B3	1000	600	15	320	25	60	150	120
C14	B4	1000	600	15	320	25	60	80	60
C16	B6	1000	600	15	320	25	60	100	20

[Table 5]

	Remarks	Grain diameter ratio	Average grain diameter (μm)	Carbide density ($\text{ea}/\mu\text{m}^2$)	B50(Tesla)	Occurrence of shape defects
5	C1	5.8	36	3.81	1.57	X
	C2	3.9	31	4.24	1.58	X
	C3	4.5	38	3.78	1.58	X
10	C4	6.9	93	2.32	1.58	X
	C5	4.7	73	2.38	1.61	X
	C6	4.3	62	2.82	1.58	X
	C7	5.8	35	3.61	1.57	X
15	C8	4.7	46	2.35	1.63	X
	C9	5.1	64	2.41	1.61	X
	C10	4.9	103	2.43	1.61	X
	C11	6.8	115	3.12	1.59	X
20	C13	4.8	72	2.31	1.62	X
	C14	4.7	61	2.15	1.61	X
	C16	6.8	37	3.08	1.58	X
25	C17	5.3	79	2.41	1.61	X
	C18	4.9	75	2.28	1.62	X
	C19	5.7	83	2.81	1.58	X
	C20	6.9	81	2.42	1.59	O
30	C21	6.7	85	2.68	1.59	X
	C22	6.8	85	2.75	1.59	X
	C23	4.2	81	2.45	1.61	X
35	C14	4.9	84	2.63	1.58	O
	C16	5.2	83	2.55	1.59	X

[0115] As may be seen from Tables 3 to 5, it may be confirmed that when the cooling pattern is appropriately controlled during the annealing before cold rolling process, the grain diameter ratio and carbide density are appropriately adjusted, so that the magnetic property is excellent. On the other hand, when the cooling pattern is not appropriately controlled, it may be confirmed that the grain diameter is not appropriately formed and carbides are generated in large numbers, resulting in inferior magnetic properties.

[0116] The present invention is not limited to the above embodiments but may be manufactured in various different forms, and those of ordinary skill in the art to which the present invention belongs may understand that the present invention may be implemented in other specific forms without changing the technical spirit or essential features of the present invention. Therefore, it should be understood that the embodiments described above are exemplary in all respects and not restrictive.

Claims

1. A non-oriented electrical steel sheet comprising, in weight%:

Si: 1.5 to 4.5%, Al: 0.1 to 2.0%, Mn: 0.1 to 2.0%, and one or more types of Mo, V, and Nb in an amount of 0.002 to 0.03%, and a balance of Fe and unavoidable impurities, wherein, in descending order of grain diameter, a ratio of the average grain diameter of coarse grains in range of 0 to 25% to the average grain diameter of fine grains in range of 75 to 100% is 6.5 or less.

2. The non-oriented electrical steel sheet according to claim 1,
wherein a density of carbides is $2.5\text{ea}/\mu\text{m}^2$ or less.
3. The non-oriented electrical steel sheet according to claim 1,
wherein average grain diameter in the steel sheet is from 40 to 150 μm .
4. The non-oriented electrical steel sheet according to claim 1,
further comprising one or more of: P: 0.1% or less (excluding 0%), C: 0.005% or less (excluding 0%), S: 0.005% or less (excluding 0%), Ti: 0.005% or less (excluding 0%), and N: 0.005% or less (excluding 0%).
5. The non-oriented electrical steel sheet according to claim 1,
further comprising one or two or more types of Sn, Sb, Bi, Pb, Ge, and As in an amount of 0.005 to 0.200 wt% each or in total.
6. The non-oriented electrical steel sheet according to 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%), and Zn: 0.01 wt% or less (excluding 0%).
7. The non-oriented electrical steel sheet according to claim 1,
further comprising one or more of B: 0.0050 wt% or less (excluding 0%), Ca: 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 according to claim 1, satisfying the following Equation 1.

[Equation 1]

$$(B50_L + B50_C) / 2 \geq 1.60$$

(Wherein, in Equation 1, $B50_L$ represents a magnetic flux density measured in the rolling direction (B50, Tesla), and $B50_C$ represents a magnetic flux density measured in the transverse direction (B50, Tesla).)

9. A method of manufacturing a non-oriented electrical steel sheet comprising:
hot rolling a slab to manufacture a hot-rolled steel sheet, the slab comprising, in weight%, Si: 1.5 to 4.0%, Al: 0.1 to 2.0%, Mn: 0.2 to 2.0%, and at least one of Mo, V, and Nb: 0.002 to 0.03%, and the balance Fe and inevitable impurities;
annealing before cold rolling for annealing the steel sheet;
cold rolling the annealed steel sheet to manufacture a cold-rolled sheet; and
cold-rolled sheet annealing for annealing the cold-rolled sheet,
wherein the annealing before cold rolling comprises
soaking the steel sheet;
a first cooling of cooling the steel sheet to a first cooling temperature at a first cooling rate;
a second cooling of cooling the steel sheet to a second cooling temperature at a second cooling rate that is 3 to 17°C/sec higher than the first cooling rate; and
a first holding of maintaining the steel sheet for 30 seconds or more within a range of the second cooling temperature $\pm 10^\circ\text{C}$.
10. The method of manufacturing a non-oriented electrical steel sheet according to claim 9,
wherein the first cooling temperature is 580 to 770°C.
11. The method of manufacturing a non-oriented electrical steel sheet according to claim 9,
wherein the second cooling temperature is 280 to 370°C.
12. The method of manufacturing a non-oriented electrical steel sheet according to claim 9,
wherein the first cooling rate is 5 to 20°C/sec, and the second cooling rate is 10 to 30°C/sec.

13. The method of manufacturing a non-oriented electrical steel sheet according to claim 9,
wherein the annealing before cold rolling further comprises a third cooling of cooling to a third cooling temperature
after the first holding.

5 14. The method of manufacturing a non-oriented electrical steel sheet according to claim 13,
wherein the annealing before cold rolling further comprises a second holding of maintaining for 30 seconds or
more within a range of a third cooling temperature $\pm 10^{\circ}\text{C}$ after the third cooling.

10 15. The method of manufacturing a non-oriented electrical steel sheet according to claim 13,
wherein the third cooling temperature is 90 to 220°C .

16. The method of manufacturing a non-oriented electrical steel sheet according to claim 13,
wherein the third cooling has an average cooling rate of 30 to 50°C/sec .

15 17. 18. The method of manufacturing a non-oriented electrical steel sheet according to claim 9,
further comprising a preliminary cold rolling of the hot-rolled steel sheet before the annealing before cold rolling.

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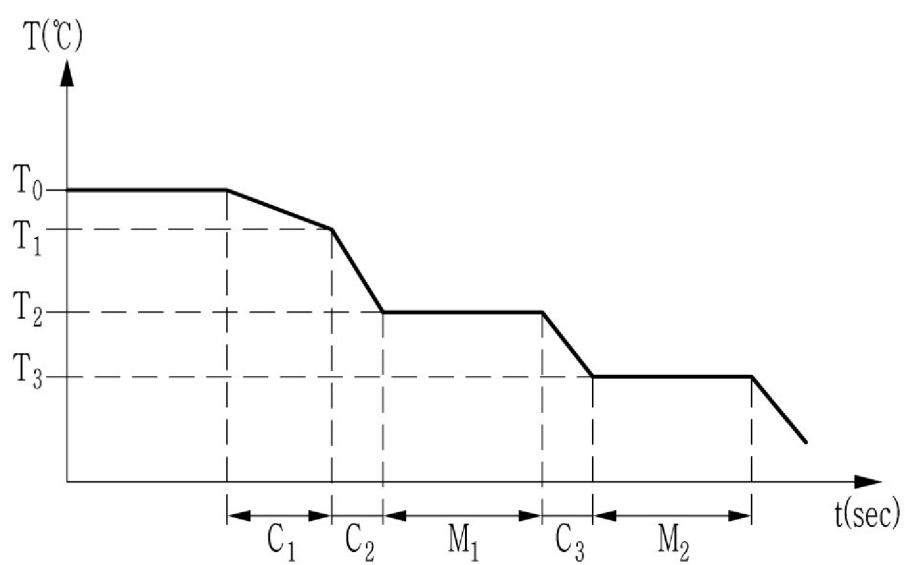
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FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063294

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/02(2006.01)i; C22C 38/06(2006.01)i; C22C 38/04(2006.01)i; C22C 38/12(2006.01)i; C22C 38/14(2006.01)i;
C22C 38/00(2006.01)i; C22C 38/42(2006.01)i; C22C 38/58(2006.01)i; C22C 38/52(2006.01)i; 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); B21B 1/24(2006.01); C21D 8/12(2006.01); C22C 38/00(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), 몰리브덴(Mo), 바나듐
(V), 니오븀(Nb), 냉각속도(cooling velocity)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2012-0086367 A (BAOSHAN IRON & STEEL CO., LTD.) 02 August 2012 (2012-08-02) See claims 1 and 12.	1-17
A	KR 10-2017-0002605 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 06 January 2017 (2017-01-06) See claims 1 and 3.	1-17
A	KR 10-2023-0023103 A (POSCO CO., LTD.) 17 February 2023 (2023-02-17) See claims 1, 3-4 and 7.	1-17
A	KR 10-2278897 B1 (POSCO) 16 July 2021 (2021-07-16) See claims 1 and 10.	1-17
A	KR 10-2271303 B1 (POSCO) 29 June 2021 (2021-06-29) See claims 1, 11 and 13.	1-17

☐ 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

“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

14 April 2025

Date of mailing of the international search report

15 April 2025

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
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Authorized officer

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IB2024/063294

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