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(54) STEEL SHEET AND MANUFACTURING METHOD THEREFOR

(57) The present invention relates to a high-strength steel sheet having excellent formability and a high yield ratio, and a manufacturing method therefor, and, more particularly, to a high-strength steel sheet having excellent formability and a high yield ratio, and a manufacturing method therefor, the steel sheet having various uses such as that of vehicle parts.

Description

Technical Field

[0001] The present disclosure relates to a high-strength steel sheet having excellent formability and a high yield ratio and a manufacturing method therefor, and more particularly, to a high strength steel sheet having excellent formability and a high yield ratio that can be used for various purposes, including automobile parts, and a manufacturing method therefor.

Background Art

[0002] Recently, the automobile industry has been receiving a lot of encouragement to ensure passenger safety and improve vehicle fuel efficiency. For this reason, a high-strength steel sheet is increasingly applied to a material of vehicle bodies.

[0003] In order to improve collision performance of a vehicle body, when a yield strength of a steel material is increased, collision energy may be efficiently adsorbed even at a low deformation amount. As a method of increasing the yield strength, there is solid solution strengthening steel and precipitation strengthening steel.

[0004] Solid solution strengthening steel is a steel sheet in which solid solution strengthening elements are dissolved in a ferrite phase having excellent formability, so that yield strength is increased. However, Si or Cr are elements which easily form oxides on a surface of the steel sheet in a continuous annealing line or continuous hot dip galvanizing line. In addition, Mn is an element which promotes the formation of a low-temperature transformation phase (bainite or martensite), which has the characteristic of lowering yield strength. Therefore, solid solution strengthening steel with a large amount of Mn, Si, and Cr added is not an appropriate method to increase a yield ratio of high-strength steel sheet with a tensile strength of 610 MPa or more.

[0005] Meanwhile, precipitation strengthening steel using Nb, Ti, V, and the like is a steel sheet which improves yield strength by precipitating fine carbides in ferrite. Precipitation strengthening steel increases yield ratio without deteriorating workability, so it is a strengthening mechanism suitable for a high-strength steel sheet with a tensile strength of 610 MPa or more having excellent collision performance and workability.

[0006] As a technology for improving the formability and yield ratio of a steel sheet, Patent Documents 1 and 2 disclose a method using introduction of unrecrystallized ferrite and addition of Ti or Nb. Precipitation strengthening and unrecrystallized ferrite using Ti or Nb are effective in increasing yield strength without significantly increasing tensile strength by directly strengthening ferrite.

[0007] However, Patent Documents 1 and 2 have the disadvantage that it is difficult to simultaneously secure excellent strength, elongation, formability, and a high yield ratio by including a large amount of unrecrystallized ferrite. Patent Document 3 is a technology using unrecrystallized ferrite instead of a transformed hard phase (martensite, bainite, and the like) of existing dual phase (DP) steel, and that is, has the disadvantage in that it is difficult to simultaneously secure excellent strength, elongation, formability, and a high yield ratio by including only a ferrite structure. Patent Document 4 has the disadvantage that it is difficult to simultaneously secure excellent strength, elongation, formability, and high yield ratio by including Mn in a content range of 0.15 to 0.45%.

[Prior art document]

[0008]

(Patent Document 1) Japanese Patent Laid-Open No. 2009-114523

(Patent Document 2) Japanese Patent Publication No. 2017-002333

(Patent Document 3) Japanese Patent Laid-Open No. 2017-002332

(Patent Document 4) Japanese Patent Laid-Open No. 2015-147965

Summary of Invention

Technical Problem

[0009] An aspect of the present disclosure is to provide a high-strength steel sheet having excellent formability and a high yield ratio and a manufacturing method therefor.

Solution to Problem

[0010] According to an aspect of the present disclosure, provided is a high-strength steel sheet having excellent formability and a high yield ratio, the high-strength steel sheet including, by weight: 0.05 to 0.25% of C, 0.7% or less (excluding 0%) of Si, 0.46 to 1.8% of Mn, 0.7% or less (excluding 0%) of Al, 0.05% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.03% or less (excluding 0%) of N, a total amount of at least one of Ti, Nb, and V of 0.22% or less, with a remainder of Fe and other unavoidable impurities, wherein a microstructure includes, by area: 1 to 13% of unrecrystallized ferrite, 67 to 98% of recrystallized ferrite, and 1 to 20% of cementite.

[0011] According to another aspect of the present disclosure, provided a manufacturing method for a high-strength steel sheet having excellent formability and a high yield ratio, the manufacturing method including: heating a steel ingot or slab including by weight: 0.05 to 0.25% of C, 0.7% or less (excluding 0%) of Si, 0.46 to 1.8% of Mn, 0.7% or less (excluding 0%) of Al, 0.05% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.03% or less (excluding 0%) of N, a total amount of at least one of Ti, Nb, and V of 0.22% or less, with a remainder of Fe and other unavoidable impurities, at a temperature within a range of 1000 to 1350°C; hot rolling the heated steel ingot or slab at a finish rolling temperature of 800 to 1000°C to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet at a temperature within a range of 300 to 600°C; heat treating the coiled hot-rolled steel sheet at a temperature within a range of 650 to 800°C for 600 to 1700 seconds; cold rolling the heat treated hot-rolled steel sheet at a cold rolling reduction rate of 30 to 90% to obtain a cold-rolled steel sheet; reheating the cold-rolled steel sheet at a temperature within a range of 720 to 860°C and maintained for 50 seconds or more; primarily cooling the reheated and maintained cold-rolled steel sheet to a temperature within a range of 600 to 760°C at an average cooling rate of 1°C/s or more; secondarily cooling the primarily cooled cold-rolled steel sheet to a temperature within a range of 450 to 550°C at an average cooling rate of 2°C/s or more and maintained for 50 seconds or more; and tertiarily cooling the secondarily cooled and maintained cold-rolled steel sheet to room temperature.

Advantageous Effects of Invention

[0012] As set forth above, according to an aspect of the present disclosure, a high-strength steel sheet having excellent formability and a high yield ratio and a manufacturing method therefor may be provided.

Best Mode for Invention

[0013] Hereinafter, a high-strength steel sheet having excellent formability and a high yield ratio according to an embodiment of the present disclosure will be described. First, an alloy composition of the present disclosure will be described. A content of the alloy composition described below refers to % by weight.

Carbon (C): 0.05 to 0.25%

[0014] Carbon (C) is an element forming precipitates with Ti, Nb, or V in a ferrite phase to provide strength to a steel sheet. If the C content is less than 0.05%, it is difficult to secure a tensile strength of 610 MPa or more. On the other hand, if the C content exceeds 0.25%, it is difficult to secure sufficient strength in a weld zone. Therefore, the C content is preferably in the range of 0.05 to 0.25%. A lower limit of the C content is more preferably 0.06%, and even more preferably 0.07%. An upper limit of the C content is more preferably 0.24%, and even more preferably 0.23%.

Silicon (Si): 0.7% or less (excluding 0%)

[0015] Silicon (Si) is an element having the effect of improving strength through solid solution strengthening, and is an element which strengthens ferrite, uniformize a microstructure, and improves workability. In addition, Si is an element necessary for deoxidation during steelmaking. If the Si content exceeds 0.7, plating defect problems such as non-plating in the plating process may occur and weldability of the steel sheet may deteriorate. Therefore, the Si content is preferably in the range of 0.7% or less. A lower limit of the Si content is more preferably 0.001%, and even more preferably 0.002%. An upper limit of the Si content is more preferably 0.69%, and even more preferably 0.68%.

Manganese (Mn): 0.46 to 1.8%

[0016] Manganese (Mn) is a useful element for increasing both strength and ductility. If the Mn content is less than 0.46%, it is difficult to sufficiently obtain the above-described effect, and if the Mn content exceeds 1.8%, the formation of a low-temperature transformation phase such as martensite or bainite in austenite is promoted, thereby lowering a yield ratio of the steel sheet. Therefore, the Mn content is preferably in the range of 0.46 to 1.8%. A lower limit of the

Mn content is more preferably 0.47%, and even more preferably 0.48%. An upper limit of the Mn content is more preferably 1.79%, and even more preferably 1.78%.

Aluminum (Al): 0.7% or less (excluding 0%)

[0017] Aluminum (Al) is an element which is combined with oxygen in steel to deoxidize. In addition, like Si, Al is an element which strengthens ferrite, uniformize the microstructure, and improves workability. If the Al content exceeds 0.7%, plating defect problems such as non-plating may occur during the plating process and weldability of the steel sheet may deteriorate. Therefore, the Si content is preferably in the range of 0.7% or less. A lower limit of the Al content is more preferably 0.001%, and even more preferably 0.002%. An upper limit of the Al content is more preferably 0.69%, and even more preferably 0.68%.

Phosphorus (P): 0.05% or less (excluding 0%)

[0018] Phosphorus (P) is an element which is contained as an impurity and deteriorates impact toughness. Therefore, the P content is preferably controlled to be 0.05% or less. The P content is more preferably 0.04% or less, and even more preferably 0.03% or less.

Sulfur (S): 0.03% or less (excluding 0%)

[0019] Sulfur (S) is an element which is contained as an impurity and creates MnS in a steel sheet and deteriorates ductility. Therefore, the S content is preferably controlled to be 0.03% or less. The S content is more preferably 0.02% or less, and even more preferably 0.01% or less.

Nitrogen (N): 0.03% or less (excluding 0%)

[0020] Nitrogen (N)is an element which is contained as an impurity and creates nitride during continuous casting, causing cracks in a slab. Therefore, the N content is preferably controlled to be 0.03% or less. The N content is more preferably 0.02% or less, and even more preferably 0.01% or less.

Total amount of at least one Ti, Nb, and V: 0.22% or less

[0021] Ti, Nb, and V are important elements forming precipitates in a steel sheet. Ti, Nb, and V may be included to improve strength and impact toughness of the steel sheet. If the total amount of one or more of the Ti, Nb, and V exceeds 0.22%, a fraction of unrecrystallized ferrite may exceed 13% due to the excessive formation of precipitates, which may not only be difficult to obtain the physical properties desired by the present disclosure, but also cause an increase in manufacturing costs. Therefore, the total amount of at least one of Ti, Nb, and V is in preferably the range of 0.22% or less. A lower limit of the total amount of at least one of Ti, Nb, and V is more preferably 0.03%, and even more preferably 0.05%. An upper limit of the total amount of at least one of Ti, Nb, and V is more preferably 0.21%, and even more preferably 0.20%.

[0022] The remaining components of the present disclosure are iron (Fe) and inevitable impurities. However, since in the common manufacturing process, unintended impurities may be inevitably incorporated from raw materials or the surrounding environment, the component may not be excluded. Since these impurities are known to any person skilled in the common manufacturing process, the entire contents thereof are not particularly mentioned in the present specification.

[0023] Meanwhile, the steel sheet of the present disclosure may further include 0.8% or less of a total amount of at least one of Cr and Mo.

[0024] Cr and Mo are elements suppressing austenite decomposition during an alloying treatment and, like Mn, stabilizing austenite. If the total amount of at least one of Cr and Mo exceeds 0.8%, the formation of a low-temperature transformation phase such as martensite or bainite may be promoted, thereby lowering a yield ratio of the steel sheet. Therefore, the total amount of at least one of Cr and Mo is preferably in the range of 0.8% or less. A lower limit of the total amount of at least one of Cr and Mo is more preferably 0.0001%, and even more preferably 0.001%. An upper limit of the total amount of at least one of Cr and Mo is more preferably 0.7%, more preferably 0.6%, and most preferably 0.53%.

[0025] In addition, the steel sheet of the present disclosure may further include a total amount of at least one of Cu and Ni of 0.8% or less.

[0026] Cu and Ni are elements stabilizing austenite and inhibiting corrosion. In addition, Cu and Ni are concentrated on a surface of the steel sheet and prevent hydrogen intrusion into the steel sheet, thereby suppressing delayed hydrogen destruction. If the total amount of at least one of Cu and Ni exceeds 0.8%, it may be not only difficult to obtain the physical properties desired by the present disclosure, but it may also cause an increase in manufacturing costs. Therefore, the total amount of at least one of Cu and Ni is preferably in the range of 0.8% or less. A lower limit of the total amount of at least one of Cu and Ni is more preferably 0.0001%, and even more preferably 0.001%. An upper limit of the total amount of at least one of Cu and Ni is more preferably 0.7%, even more preferably 0.6%, and most preferably 0.54%.

[0027] In addition, the steel sheet of the present disclosure may further include 0.005% or less of B.

[0028] B is an element which improves hardenability, increases strength, and suppresses nucleation at grain boundaries. If the content of B exceeds 0.005%, it may not only be difficult to obtain the physical properties desired by the present disclosure, but also cause an increase in manufacturing costs. Therefore, the content of B is preferably in the range of 0.005% or less. A lower limit of the B content is more preferably 0.0001%, and even more preferably 0.0003%. An upper limit of the B content is more preferably 0.0045%, and even more preferably 0.004%.

[0029] In addition, the steel sheet of the present disclosure may further include a total amount of at least one of Ca, REM (excluding Y), and Mg of 0.05% or less.

[0030] Ca, Mg, and REM (excluding Y) are elements which improves the ductility of a steel sheet by spheroidizing sulfides. If the total amount of at least one of Ca, REM (excluding Y), and Mg exceeds 0.05%, not only may it be difficult to obtain the physical properties desired by the present disclosure, but it may also cause an increase in manufacturing costs. Therefore, the total amount of one or more of Ca, REM (excluding Y), and Mg is preferably in the range of 0.05% or less. A lower limit of the total amount of at least one of Ca, REM (excluding Y), and Mg is more preferably 0.0001%, and even more preferably 0.0003%. An upper limit of the total amount of at least one of Ca, REM (excluding Y), and Mg is more preferably 0.04%, more preferably 0.03%, and most preferably 0.02%. Meanwhile, REM refers to 17 elements including Sc, Y, and lanthanoid.

[0031] In addition, the steel sheet of the present disclosure may further include a total amount of at least one of W and Zr of 0.5% or less.

[0032] W and Zr are elements increasing the strength of a steel sheets by improving hardenability. If the total amount of at least one of W and Zr exceeds 0.5%, not only may it be difficult to obtain the physical properties desired by the present disclosure, but it may also cause an increase in manufacturing costs. Therefore, the total amount of at least one of W and Zr is preferably in the range of 0.5% or less. A lower limit of the total amount of at least one of W and Zr is more preferably 0.0001%, even more preferably 0.001%, and most preferably 0.01%. An upper limit of the total amount of at least one of W and Zr is more preferably 0.4%, more preferably 0.35%, and most preferably 0.3%.

[0033] In addition, the steel sheet of the present disclosure may further include a total amount of at least one of Sb and Sn of 0.5% or less.

[0034] Sb and Sn are elements improving plating wettability and plating adhesion of a steel sheet. If the total amount of at least one of Sb and Sn exceeds 0.5%, brittleness of the steel sheet may increase and cracks may occur during hot working or cold working. The total amount of at least one of Sb and Sn is within the range of 0.5% or less. A lower limit of the total amount of at least one of Sb and Sn is more preferably 0.0001%, even more preferably 0.001%, and most preferably 0.005%. An upper limit of the total amount of at least one of Sb and Sn is more preferably 0.4%, more preferably 0.3%, and most preferably 0.2%.

[0035] In addition, the steel sheet of the present disclosure may further include a total amount of at least one of Y and Hf of 0.2% or less.

[0036] Y and Hf are elements improving corrosion resistance of a steel sheet. If the total amount of at least one of Y and Hf exceeds 0.2%, ductility of the steel sheet may deteriorate. Therefore, the total amount of at least one of Y and Hf is preferably in the range of 0.2% or less. A lower limit of the total amount of at least one of Y and Hf is more preferably 0.0001%, even more preferably 0.001%, and most preferably 0.005%. An upper limit of the total amount of at least one of Y and Hf is more preferably 0.15%, more preferably 0.12%, and most preferably 0.1%.

[0037] Hereinafter, a microstructure will be described. A fraction of the microstructure described below refers to % by area.

Unrecrystallized ferrite: 1 to 13%

[0038] In general, unrecrystallized ferrite includes many dislocations and exhibits low ductility and hole expandability. However, the present inventors confirmed that when a fraction of uncrystallized ferrite is 1 to 13%, a high yield ratio may be secured without deteriorating an elongation and a hole expansion rate. When the fraction of unrecrystallized ferrite is less than 1% or exceeds 13%, the yield ratio, elongation, or hole expansion rate decreases. Meanwhile, the unrecrystallized ferrite may be defined as ferrite formed by cooling ferrite processed in a cold rolling process that cannot be transformed into austenite during annealing. The unrecrystallized ferrite has a form elongated in a direction of cold rolling.

Recrystallized ferrite: 67 to 98%

[0039] Recrystallized ferrite may be defined as ferrite in which ferrite processed in a cold rolling process is transformed into austenite during annealing and then transformed during cooling and has effects such as improving the ductility and hole expandability of the steel sheet. When the fraction of recrystallized ferrite is less than 67% or more than 98%, the yield ratio, elongation, or hole expansion rate may decrease. Recrystallized ferrite is common polygonal ferrite.

Cementite: 1 to 20%

[0040] Cementite exhibits an effect of increasing strength and hardness of a steel sheet. If the fraction of cementite is less than 1%, it may be difficult to secure the strength. On the other hand, if the fraction of cementite exceeds 20%, precipitation of Ti, Nb, or V carbides may be suppressed, and the fraction of ferrite desired by the present disclosure cannot be secured, making it difficult to secure mechanical properties.

[0041] The steel sheet of the present disclosure provided as described above has a tensile strength (TS) of 610 MPa or more, a yield ratio (YR) of 0.8 to 0.95, a tensile strength $(TS)^2 \times \sqrt{}$ elongation (EL) of 1.8×10^6 to 2.3×10^6 $MPa^2\%^{0.5}$, and a tensile strength $(TS)^2 \times \sqrt{}$hole expandability(HER): 2.5×10^6 to 3.8×10^6 $MPa^2\%^{0.5}$, which has excellent strength and high yield ratio.

[0042] Meanwhile, the steel sheet of the present disclosure may be a cold-rolled steel sheet or a plated steel sheet, and the plated steel sheet may be a hot-dip galvanized steel sheet, an electro-galvanized steel sheet, or a hot-dip aluminum plated steel sheet.

[0043] Hereinafter, a method of manufacturing a high-strength steel sheet having excellent formability and a high yield ratio according to an embodiment of the present disclosure will be described.

[0044] First, a steel ingot or slab satisfying the above-described alloy composition is heated at a temperature within a range of 1000 to 1350°C. If the heating temperature is lower than 1000°C, hot rolling may be performed outside a finish rolling temperature range. On the other hand, if the heating temperature is higher than 1350°C, it may reach a melting point of the steel and may be melted. A lower limit of the steel ingot or slab heating temperature is more preferably 1025°C, and even more preferably 1050°C. An upper limit of the steel ingot or slab heating temperature is more preferably 1325°C, and even more preferably 1300°C.

[0045] Thereafter, the heated steel ingot or slab is hot rolled at a finish rolling temperature within a range of 800 to 1000°C to obtain a hot-rolled steel sheet. If the finish rolling temperature is lower than 800°C, it may place an excessive burden on a hot rolling mill due to the high strength of the steel. On the other hand, if the finish rolling temperature is higher than 1350°C, grains of the steel sheet after hot rolling may be coarse, so that mechanical properties may deteriorate. A lower limit of the steel ingot or slab heating temperature is more preferably 1025°C, and even more preferably 1050°C. An upper limit of the steel ingot or slab heating temperature is more preferably 1325°C, and even more preferably 1300°C.

[0046] Meanwhile, after the finish rolling, the hot-rolled steel sheet may be cooled to the following coiling temperature at an average cooling rate of 10°C/s or more. The cooling is performed for refining the grains, and if the average cooling rate is less than 10°C/s, it may be difficult to sufficiently obtain the grain refinement effect. Since the faster the average cooling rate, the more advantageous it is, in the present disclosure, an upper limit of the average cooling rate is not particularly limited, but considering limitations in facility, or the like, it is difficult that the average cooling rate exceeds 500°C/s.

[0047] Thereafter, the hot-rolled steel sheet is coiled at a temperature within a range of 300 to 600°C. If the coiling temperature is lower than 300°C, a main phase of the hot-rolled steel sheet may comprise a high-strength low-temperature transformation phase, so that coiling may not be performed easily. On the other hand, if the coiling temperature is higher than 600°C, scale generated on the surface of the hot-rolled steel sheet may be formed deep inside the steel sheet, so that pickling may be difficult to perform. A lower limit of the coiling temperature is more preferably 315°C, and even more preferably 330°C. An upper limit of the coiling temperature is more preferably 585°C, and even more preferably 570°C.

[0048] Thereafter, the coiled hot-rolled steel sheet is heat treated at 650 to 800°C for 600 to 1,700 seconds. The heat treatment is performed to improve a yield ratio of a final product by promoting formation of precipitates in the hot-rolled steel sheet. If the heat treatment temperature is lower than 650°C or the heat treatment time is less than 600 seconds, it may not be easy to optimize the precipitates of the annealed hot-rolled steel sheet. On the other hand, when the heat treatment temperature is higher than 800°C or the heat treatment time exceeds 1700 seconds, it may not be easy to form precipitates in the annealed hot-rolled steel sheet. A lower limit of the heat treatment temperature is more preferably 660°C, and even more preferably 670°C. An upper limit of the heat treatment temperature is more preferably 790°C, and even more preferably 780°C. A lower limit of the heat treatment time is more preferably 700 seconds, and even more preferably 800 seconds. An upper limit of the heat treatment time is more preferably 1600 seconds, and even more preferably 1500 seconds.

[0049] Meanwhile, after the heat treatment, a pickling process to remove scale formed on a surface of the steel sheet may be further performed. In the present disclosure, the pickling process is not specifically limited, and all pickling processes used in the technical field may be applied.

[0050] Thereafter, the heat-treated hot-rolled steel sheet is cold rolled at a cold rolling reduction ratio of 30 to 90% to obtain a cold-rolled steel sheet. If the cold rolling reduction ratio is less than 30%, there is a disadvantage in that it is difficult to secure an appropriate shape of the cold-rolled steel sheet, and if the cold rolling reduction ratio exceeds 90%, it may be difficult to perform cold rolling within a short period of time due to the high strength of the steel sheet. A lower limit of the cold rolling reduction ratio is more preferably 31%, and even more preferably 32%. An upper limit of the cold rolling reduction ratio is more preferably 89%, and even more preferably 88%.

[0051] Thereafter, the cold-rolled steel sheet is reheated at a temperature within a range of 720 to 860°C and maintained for more than 50 seconds. If the reheating temperature is lower than 720°C, a fraction of unrecrystallized ferrite may exceed 13%, so that it may be difficult to obtain mechanical properties desired by the present disclosure. When the reheating temperature is higher than 860°C, the fraction of unrecrystallized ferrite is not formed in an amount of 1% or more, so that it may be difficult to obtain the mechanical properties desired by the present disclosure. If the holding time is less than 50 seconds, it may be difficult to obtain the mechanical properties desired by the present disclosure due to an insufficient heat treatment time. A lower limit of the reheating temperature is more preferably 730°C, and even more preferably 740°C. An upper limit of the reheating temperature is more preferably 850°C, and even more preferably 840°C. The holding time is more preferably 55 seconds or more, and even more preferably 60 seconds or more. Meanwhile, in the present disclosure, the longer the holding time, the more advantageous it is, so the upper limit thereof is not particularly limited. However, in terms of productivity, the holding time may be 600 seconds or less. In addition, an average temperature increase rate during the reheating is not particularly limited, and may be, for example, 1 to 100°C/s.

[0052] Thereafter, the reheated and maintained cold-rolled steel sheet is primarily cooled to a temperature within a range of 600 to 760°C at an average cooling rate of 1°C/s or more. If the primary cooling stop temperature is lower than 600°C, a fraction of cementite may exceed 20%, so that it may be difficult to obtain the mechanical properties desired by the present disclosure. If the primary cooling stop temperature is higher than 760°C, a cooling stop temperature may be high, so that it may be difficult to obtain the mechanical properties desired by the present disclosure. A lower limit of the primary cooling stop temperature is more preferably 610°C, and even more preferably 620°C. An upper limit of the primary cooling stop temperature is more preferably 750°C, and even more preferably 740°C. The primary average cooling rate is more preferably 1.5°C/s. Meanwhile, in the present disclosure, an upper limit of the primary average cooling rate is particularly limited.

[0053] Thereafter, the primary cooled cold-rolled steel sheet is secondarily cooled to a temperature within a range of 450 to 550°C at an average cooling rate of 2°C/s or more and maintained for 50 seconds or more. If the secondary cooling stop temperature is lower than 450°C, it may be difficult to obtain the mechanical properties desired by the present disclosure due to a low heat-treatment temperature. On the other hand, if the secondary cooling stop temperature is higher than 550°C, the fraction of unrecrystallized ferrite may exceed 13%, so that it may be difficult to obtain the mechanical properties desired by the present disclosure. If the secondary cooling rate is less than 2°C/s, the fraction of cementite may exceed 20%, so that it may be difficult to obtain the mechanical properties desired by the present disclosure. If the holding time is less than 50 seconds, it is difficult to obtain the mechanical properties desired by the present disclosure due to an insufficient holding time. A lower limit of the secondary cooling stop temperature is more preferably 460°C, and even more preferably 470°C. An upper limit of the secondary cooling stop temperature is more preferably 540°C, and even more preferably 530°C. The secondary average cooling rate is more preferably 3°C/or more. Meanwhile, in the present disclosure, an upper limit of the secondary average cooling rate is particularly limited. In addition, in the present disclosure, the longer the holding time, the more advantageous it is, the upper limit thereof is not particularly limited. However, in terms of productivity, the holding time may be 1800 seconds or less.

[0054] Thereafter, the secondarily cooled and maintained cold-rolled steel sheet is tertiarily cooled to room temperature. The average cooling rate during the tertiary cooling may be 0.5 to 50°C/s.

[0055] Meanwhile, after the tertiary cooling, a plating process can be further performed. In the present disclosure, the plating process is not particularly limited, and all common processes used in the technical field can be used.

Mode for Invention

[0056] Hereinafter, the present disclosure will be specifically described through the following Examples. However, it should be noted that the following examples are only for describing the present disclosure by illustration, and not intended to limit the right scope of the present disclosure. The reason is that the right scope of the present disclosure is determined by the matters described in the claims and reasonably inferred therefrom.

(Example)

[0057] A slab having a thickness of 100 mm having the alloy composition shown in Table 1 below was prepared and then heated at a temperature of 1200°C, and was subjected to hot rolling at a finish rolling temperature of 900°C to manufacture a hot-rolled steel sheet having a thickness of 3 mm. The hot-rolled steel sheet was cooled to the coiling temperature shown in Table 2 below at an average cooling rate of 30°C/s, and then coiled. Thereafter, the coiled hot-rolled steel sheet was heat treated under the conditions shown in Table 2, pickled, and then cold rolled to manufacture a cold-rolled steel sheet having a thickness of 1.5 mm. Thereafter, reheating, primary cooling, secondary cooling, and tertiary cooling were performed under the conditions shown in Tables 2 and 3 below.

[0058] A microstructure and mechanical properties of the cold-rolled steel sheet manufactured in this manner were measured, and the results thereof were shown in Table 4 below.

[0059] The microstructure was observed through SEM after polishing and nital etching of a cross-section of a specimen collected from a cold-rolled steel sheet. After nital etching, a structure without irregularities on the surface of the specimen was determined to be ferrite, and a structure with a spherical or lamellar structure was determined to be cementite. In unrecrystallized ferrite containing many dislocations, a difference in crystal orientation occurs within grains. Therefore, after measuring the crystal orientation of ferrite using FESEM-EBSD, unrecrystallized ferrite and recrystallized ferrite were distinguished from ferrite using a Kernel Average Misorientation (KAM) method and a fraction thereof was measured.

[0060] The mechanical properties were measured by a tensile test and a hole expansion test. The tensile test is performed using test specimens collected in accordance with JIS No. 5 standards based on a 0° direction with respect to a rolling direction of the cold-rolled steel sheet. The hole expansion test was measured by forming a cone punch with an apex angle of 60° in a 10 mm Ø punching hole (die inner diameter 10.3 mm, clearance 12.5%) by pressing and expanding the same at 20 mm/min in a direction in which burrs of the punching hole become outward.

$$\text{Hole expansion rate: HER (\%)} = \{(D - D_0)/D_0\} \times 100$$

D: Hole diameter when a crack penetrates a steel sheet (mm)

D_0: Initial hole diameter (mm)

[Table 1]

Steel type	Alloy composition (weight %)											
	C	Si	Mn	P	S	Al	N	Ti	Nb	V	Ti+Nb+V	Others
A	0.14	0.45	1.34	0.009	0.0011	0.28	0.0032	0.15	0.01	0.02	0.18	
B	0.12	0.38	1.25	0.010	0.0010	0.24	0.0029	0.01	0.12	0.01	0.14	
C	0.17	0.34	1.27	0.008	0.0008	0.29	0.0025	0.02	0.03	0.11	0.16	
D	0.16	0.39	1.19	0.012	0.0010	0.31	0.0028	0.08	0.07	0.05	0.20	
E	0.15	0.43	1.31	0.008	0.0007	0.27	0.0030	0.11	0.06	0.01	0.18	Cr: 0.43
F	0.07	0.68	1.77	0.007	0.0011	0.66	0.0031	0.09	0.02	0.08	0.19	Mo: 0.38
G	0.23	0.64	0.47	0.010	0.0013	0.62	0.0027	0.01	0.09	0.07	0.17	Ni: 0.35
H	0.14	0.42	1.18	0.011	0.0012	0.23	0.0036	0.10	0.01	0.02	0.13	Cu: 0.44
I	0.16	0.39	1.22	0.009	0.0009	0.25	0.0039	0.04	0.01	0	0.05	B: 0.0021
J	0.12	0.37	1.28	0.008	0.0010	0.28	0.0028	0.09	0.02	0.01	0.12	Ca: 0.003
K	0.20	0.61	0.50	0.011	0.0011	0.59	0.0027	0.11	0.01	0.02	0.14	REM(excludi ng Y): 0.001

(continued)

Steel type	Alloy composition (weight %)											
	C	Si	Mn	P	S	Al	N	Ti	Nb	V	Ti+Nb+V	Others
L	0.15	0.36	1.32	0.009	0.0009	0.33	0.0032	0.01	0.08	0.02	0.11	Mg: 0.002
M	0.16	0.43	1.31	0.007	0.0011	0.30	0.0028	0.01	0.04	0	0.05	W: 0.16
N	0.13	0.41	1.35	0.011	0.0008	0.32	0.0025	0.02	0.11	0.01	0.14	Zr: 0.14
O	0.21	0.58	0.49	0.010	0.0007	0.60	0.0032	0.01	0.09	0.02	0.12	Sb: 0.11
P	0.14	0.37	1.28	0.009	0.0009	0.27	0.0030	0.02	0.01	0.11	0.14	Sn: 0.08
Q	0.15	0.34	1.25	0.011	0.0012	0.25	0.0031	0.01	0.01	0.12	0.14	Y: 0.03
R	0.17	0.40	1.27	0.007	0.0010	0.29	0.0028	0.01	0.02	0.08	0.11	Hf: 0.04
XA	0.03	0.36	1.16	0.011	0.0009	0.33	0.0026	0.12	0.01	0.01	0.14	
XB	0.28	0.39	1.19	0.009	0.0010	0.31	0.0032	0.15	0.01	0.02	0.18	
XC	0.11	0.74	1.28	0.010	0.0012	0.25	0.0035	0.13	0.02	0.01	0.16	
XD	0.13	0.42	0.45	0.012	0.0008	0.27	0.0028	0.14	0.02	0.01	0.17	
XE	0.14	0.41	1.82	0.008	0.0007	0.28	0.0025	0.02	0.11	0.02	0.15	
XF	0.12	0.37	1.33	0.007	0.0011	0.73	0.0027	0.01	0.13	0.01	0.15	
XG	0.15	0.35	1.30	0.011	0.0010	0.31	0.0031	0.24	0.01	0.01	0.26	
XH	0.13	0.46	1.34	0.009	0.0008	0.33	0.0028	0.02	0.23	0.02	0.27	
XI	0.12	0.43	1.26	0.008	0.0010	0.26	0.0032	0.01	0.01	0.25	0.27	
XJ	0.14	0.34	1.27	0.012	0.0009	0.32	0.0034	0.06	0.09	0.08	0.23	

[Table 2]

Division	Steel type	Hot-rolled steel sheet coiling temperat ure (°C)	Hot-rolled steel sheet heattreatmen t temperat ure (°C)	Hotrolle d steel sheet coili ng time (sec)	Temperat ure increase rate of cold-rolled steel sheet (°C/s)	Cold-rolled steel sheet reheating temperature (°C)	Cold-rolled steel sheet reheati ng holding time (sec)
Inventiv e Example 1	A	550	700	1200	10	750	120
Comparat ive Example 1	A	500	830	1300	10	750	120
Comparat ive Example 2	A	500	620	1500	10	780	90
Comparat ive Example 3	A	550	750	1800	10	780	120
Comparat ive Example 4	A	450	750	500	10	780	90
Comparat ive Example 5	A	400	700	1100	10	880	120
Comparat ive Example 6	A	400	750	900	10	700	100
Comparat ive Example 7	A	500	700	1200	10	830	30
Comparat ive Example 8	A	450	750	1000	10	830	120
Comparat ive Example 9	A	400	750	1400	10	750	120
Comparat ive Example 10	A	450	700	1200	10	750	120
Comparat ive Example 11	A	550	750	1100	10	750	90
Comparat ive Example 12	A	550	700	1400	10	750	120

(continued)

Division	Steel type	Hot-rolled steel sheet coiling temperat ure (°C)	Hot-rolled steel sheet heattreatmen t temperat ure (°C)	Hotrolle d steel sheet coili ng time (sec)	Temperat ure increase rate of cold-rolled steel sheet (°C/s)	Cold-rolled steel sheet reheating temperature (°C)	Cold-rolled steel sheet reheati ng holding time (sec)
Comparat ive Example 13	A	450	700	1200	10	750	100
Inventiv e Example 2	B	500	680	1400	10	750	100
Inventiv e Example 3	C	350	700	1600	10	750	120
Inventiv e Example 4	D	550	770	700	10	750	90
Inventiv e Example 5	E	350	700	1100	10	750	90
Inventiv e Example 6	F	450	780	1000	10	750	100
Inventiv e Example 7	G	400	670	1300	10	840	120
Inventiv e Example 8	H	500	700	1300	10	750	120
Inventiv e Example 9	I	550	750	1500	10	750	90
Inventiv e Example 10	J	550	750	1600	10	800	100
Inventiv e Example 11	K	550	700	1100	10	750	90
Inventiv e Example 12	L	450	700	1300	10	820	120
Inventiv e Example 13	M	400	700	700	10	750	100
Inventiv e Example 14	N	400	750	1200	10	750	90
Inventiv e Example 15	O	500	750	1100	10	840	90
Inventiv e Example 16	P	500	700	1300	10	750	120

(continued)

Division	Steel type	Hot-rolled steel sheet coiling temperat ure (°C)	Hot-rolled steel sheet heattreatmen t temperat ure (°C)	Hotrolle d steel sheet coili ng time (sec)	Temperat ure increase rate of cold-rolled steel sheet (°C/s)	Cold-rolled steel sheet reheating temperature (°C)	Cold-rolled steel sheet reheati ng holding time (sec)
Inventiv e Example 17	Q	450	750	1400	10	740	120
Inventiv e Example 18	R	450	700	1200	10	750	100
Comparat ive Example 14	XA	450	750	15000	10	780	100
Comparat ive Example 15	XB	500	750	1200	10	780	90
Comparat ive Example 16	XC	550	700	1200	10	780	120
Comparat ive Example 17	XD	550	700	1300	10	750	90
Comparat ive Example 18	XE	550	700	1000	10	750	120
Comparat ive Example 19	XF	550	750	1200	10	780	100
Comparat ive Example 20	XG	500	750	1400	10	750	120
Comparat ive Example 21	XH	500	700	1100	10	780	100
Comparat ive Example 22	XI	500	700	1200	10	750	90

(continued)

Division	Steel type	Hot-rolled steel sheet coiling temperat ure (°C)	Hot-rolled steel sheet heattreatmen t temperat ure (°C)	Hotrolle d steel sheet coili ng time (sec)	Temperat ure increase rate of cold-rolled steel sheet (°C/s)	Cold-rolled steel sheet reheating temperature (°C)	Cold-rolled steel sheet reheati ng holding time (sec)
Comparat ive Example 23	XJ	450	700	1300	10	750	120

[Table 3]

Division	Steel type	Averag e Primar y coolin g rate (°C/s)	Primary cooling stop temperatur e (°C)	Average Secondar y cooling rate (°C/s)	Secondary cooling stop temperatur e (°C)	Secondar y holding time (°C)	Average Tertiar y cooling rate (°C/s)
Inventive Example 1	A	10	700	20	500	200	10
Comparativ e Example 1	A	10	650	20	500	200	10
Comparativ e Example 2	A	10	650	20	500	150	10
Comparativ e Example 3	A	10	700	20	500	200	10
Comparativ e Example 4	A	10	650	20	500	100	10
Comparativ e Example 5	A	10	700	20	500	200	10
Comparativ e Example 6	A	10	650	20	500	150	10
Comparativ e Example 7	A	10	700	20	500	100	10
Comparativ e Example 8	A	10	780	20	500	200	10
Comparativ e Example 9	A	10	580	20	500	150	10
Comparativ e Example 10	A	10	700	0.5	500	200	10
Comparativ e Example 11	A	10	700	20	570	200	10
Comparativ e Example 12	A	10	650	20	430	200	10

(continued)

Division	Steel type	Averag e Primar y coolin g rate (°C/s)	Primary cooling stop temperatur e (°C)	Average Secondar y cooling rate (°C/s)	Secondary cooling stop temperatur e (°C)	Secondar y holding time (°C)	Average Tertiar y cooling rate (°C/s)
Comparativ e Example 13	A	10	650	20	500	30	10
Inventive Example 2	B	10	700	20	500	100	10
Inventive Example 3	C	10	650	20	500	200	10
Inventive Example 4	D	10	740	20	500	200	10
Inventive Example 5	E	10	700	20	500	150	10
Inventive Example 6	F	10	740	20	500	200	10
Inventive Example 7	G	10	700	20	530	100	10
Inventive Example 8	H	10	620	20	500	200	10
Inventive Example 9	I	10	700	20	500	150	10
Inventive Example 10	J	10	650	20	530	200	10
Inventive Example 11	K	10	630	20	500	100	10
Inventive Example 12	L	10	700	20	500	200	10
Inventive Example 13	M	10	650	20	480	150	10
Inventive Example 14	N	10	700	20	480	200	10
Inventive Example 15	O	10	700	20	500	200	10
Inventive Example 16	P	10	650	20	500	100	10
Inventive Example 17	Q	10	700	20	500	100	10
Inventive Example 18	R	10	700	20	500	200	10
Comparativ e Example 14	XA	10	700	20	500	150	10
Comparativ e Example 15	XB	10	650	20	500	200	10

(continued)

Division	Steel type	Averag e Primar y coolin g rate (°C/s)	Primary cooling stop temperatur e (°C)	Average Secondar y cooling rate (°C/s)	Secondary cooling stop temperatur e (°C)	Secondar y holding time (°C)	Average Tertiar y cooling rate (°C/s)
Comparativ e Example 16	XC	10	650	20	500	200	10
Comparativ e Example 17	XD	10	700	20	500	200	10
Comparativ e Example 18	XE	10	700	20	500	150	10
Comparativ e Example 19	XF	10	650	20	500	200	10
Comparativ e Example 20	XG	10	700	20	500	200	10
Comparativ e Example 21	XH	10	700	20	500	100	10
Comparativ e Example 22	XI	10	650	20	500	200	10
Comparativ e Example 23	XJ	10	700	20	500	200	10

[Table 4]

Division	Microstructure(area %)			Mechanical properties		
	Recrystalliz ed ferrite	Unrecrystalliz ed ferrite	Cementit e	YR	$TS^2\times\sqrt{EL}$ ($MPa^2\%^{0.5}$)	$TS^2\times\sqrt{HER}$ ($MPa^2\%^{0.5}$)
Inventive Example 1	81	7	12	0.8 7	2,135,08 4	3,024,32 5
Comparativ e Example 1	82.5	0.5	17	0.8 2	1,724,63 4	2,406,50 1
Comparativ e Example 2	83.7	0.3	16	0.8 4	1,588,12 5	2,274,84 2
Comparativ e Example 3	84.3	0.7	15	0.8 3	1,608,53 2	2,387,63 8
Comparativ e Example 4	85.4	0.6	14	0.8 2	1,713,22 8	2,269,00 6
Comparativ e Example 5	83	0	17	0.7 9	1,671,53 9	2,445,21 9

(continued)

Division	Microstructure(area %)			Mechanical properties		
	Recrystallized ferrite	Unrecrystallized ferrite	Cementite	YR	$TS^2 \times \sqrt{EL}$ ($MPa^2\%^{0.5}$)	$TS^2 \times \sqrt{HER}$ ($MPa^2\%^{0.5}$)
Comparative Example 6	75	14	11	0.96	2,430,054	3,926,502
Comparative Example 7	74	17	9	0.97	2,536,248	3, 835,426
Comparative Example 8	86.4	0.6	13	0.83	1,730,150	2,323,005
Comparative Example 9	70	8	22	0.81	1,554,426	2,268,514
Comparative Example 10	72	5	23	0.82	1,696,522	2,434,269
Comparative Example 11	74	15	11	0.97	2,638,145	4,053,387
Comparative Example 12	85.7	0.3	14	0.83	1,569,897	2,332,060
Comparative Example 13	87.2	0.8	12	0.82	1,756,458	2,455,831
Inventive Example 2	80	9	11	0.85	2,037,548	3,196,147
Inventive Example 3	81	6	13	0.94	2,294,432	3,785,165
Inventive Example 4	97	2	1	0.89	2,183,055	3,432,584
Inventive Example 5	84	7	9	0.81	1,811,246	2,520,614
Inventive Example 6	68	12	20	0.86	1,902,750	3,048,620
Inventive Example 7	95	3	2	0.90	2,063,284	2,601,423
Inventive Example 8	86	6	8	0.82	2,139,551	3,174,562
Inventive Example 9	70	11	19	0.84	2,288,405	3,724,357
Inventive Example 10	81	7	12	0.87	1,936,524	2,836,520
Inventive Example 11	76	10	14	0.89	1,923,658	2,912,548
Inventive Example 12	82	8	10	0.93	1,823,042	2,528,027
Inventive Example 13	72	10	18	0.85	2,046,954	3,703,248

(continued)

Division	Microstructure(area %)			Mechanical properties		
	Recrystallized ferrite	Unrecrystallized ferrite	Cementite	YR	$TS^2\times\sqrt{EL}$ ($MPa^2\%^{0.5}$)	$TS^2\times\sqrt{HER}$ ($MPa^2\%^{0.5}$)
Inventive Example 14	82	6	12	0.88	2,135,745	3,203,865
Inventive Example 15	85	7	8	0.92	2,065,483	3,095,684
Inventive Example 16	80	9	11	0.90	2,126,841	3,186,405
Inventive Example 17	83	8	9	0.87	1,935,687	2,889,421
Inventive Example 18	73	10	17	0.86	2,025,342	2,932,586
Comparative Example 14	94	2	4	0.76	1,452,301	2,096,328
Comparative Example 15	70	16	14	0.94	2,769,523	4,256,214
Comparative Example 16	81	7	12	0.89	1,635,204	2,352,735
Comparative Example 17	83	9	8	0.83	1,535,218	2,464,524
Comparative Example 18	74	15	11	0.92	2,589,245	4,095,168
Comparative Example 19	79	8	13	0.88	1,762,147	2,230,650
Comparative Example 20	73	15	12	0.96	2,466,325	3,968,057
Comparative Example 21	74	16	10	0.97	2,623,024	4,146,885
Comparative Example 22	70	19	11	0.96	2,500,362	3,813,402
Comparative Example 23	72	20	8	0.96	2,714,268	4,035,964

[0061] As can be seen from Tables 1 to 4, in the case of Invention Examples 1 to 18 satisfying the alloy composition and manufacturing conditions proposed by the present disclosure, an appropriate microstructure was secured, and thereby, it can be seen that excellent strength and formability and a high yield ratio were achieved.

[0062] On the other hand, in the case of Comparative Examples 1 to 23 not satisfying the alloy composition and manufacturing conditions proposed by the present disclosure, an appropriate microstructure was not secured, and as a result, it can be seen that the mechanical properties were inferior.

Claims

1. A steel sheet, comprising by weight: 0.05 to 0.25% of C, 0.7% or less (excluding 0%) of Si, 0.46 to 1.8% of Mn, 0.7% or less (excluding 0%) of Al, 0.05% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.03% or

less (excluding 0%) of N, 0.22% or less of a total amount of at least one of Ti, Nb, and V, with a remainder of Fe and other unavoidable impurities,
wherein a microstructure includes, by area: 1 to 13% of unrecrystallized ferrite, 67 to 98% of recrystallized ferrite, and 1 to 20% of cementite.

2. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of Cr and Mo of 0.8% or less.

3. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of Cu and Ni of 0.8% or less.

4. The steel sheet of claim 1, wherein the steel sheet further comprises 0.005% or less of B.

5. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of Ca, REM (excluding Y), and Mg of 0.05% or less.

6. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of W and Zr of 0.5% or less.

7. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of Sb and Sn of 0.5% or less.

8. The steel sheet of claim 1, wherein the steel sheet further comprises a total amount of at least one of Y and Hf of 0.2% or less.

9. The steel sheet of claim 1, wherein the steel sheet has a tensile strength (TS)of 610 MPa or more, a yield ratio (YR)of 0.8 to 0.95, a tensile strength $(TS)^2 \times \sqrt{}$ elongation (EL)of 1.8×10^6 to 2.3×10^6 $MPa^2\%^{0.5}$, and a tensile strength $(TS)^2 \times \sqrt{}$ Hole expandability (HER) of 2.5×10^6 to 3.8×10^6 $MPa^2\%^{0.5}$.

10. A manufacturing method for a steel sheet, comprising:

heating a steel ingot or slab, including by weight: 0.05 to 0.25% of C, 0.7% or less (excluding 0%) of Si, 0.46 to 1.8% of Mn, 0.7% or less (excluding 0%) of Al, 0.05% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.03% or less (excluding 0%) of N, 0.22% or less of a total amount of at least one of Ti, Nb, and V, with a remainder of Fe and other unavoidable impurities, at a temperature within a range of 1000 to 1350°C;
hot rolling the heated steel ingot or slab at a finish rolling temperature of 800 to 1000°C to obtain a hot-rolled steel sheet;
coiling the hot-rolled steel sheet at a temperature within a range of 300 to 600°C;
heat treating the coiled hot-rolled steel sheet at a temperature within a range of 650 to 800°C for 600 to 1700 seconds;
cold rolling the heat treated hot-rolled steel sheet at a cold rolling reduction rate of 30 to 90% to obtain a cold-rolled steel sheet;
reheating the cold-rolled steel sheet at a temperature within a range of 720 to 860°C and maintained for 50 seconds or more;
primarily cooling the reheated and maintained cold-rolled steel sheet to a temperature within a range of 600 to 760°C at an average cooling rate of 1°C/s or more;
secondarily cooling the primarily cooled cold-rolled steel sheet to a temperature within a range of 450 to 550°C at an average cooling rate of 2°C/s or more and maintained for 50 seconds or more; and
tertiarily cooling the secondarily cooled and maintained cold-rolled steel sheet to room temperature.

11. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of Cr and Mo of 0.8% or less.

12. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of Cu and Ni of 0.8% or less.

13. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises 0.005% or less of B.

14. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of Ca, REM (excluding Y), and Mg of 0.05% or less.

15. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of W and Zr of 0.5% or less.

16. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of Sb and Sn of 0.5% or less.

17. The manufacturing method for a steel sheet of claim 10, wherein the steel ingot or slab further comprises a total amount of at least one of Y and Hf of 0.2% or less.

18. The manufacturing method for a steel sheet of claim 10, further comprising, after the finish rolling:
cooling the hot-rolled steel sheet to a coiling temperature at an average cooling rate of 10°C/s or more.

INTERNATIONAL SEARCH REPORT

International application No. **PCT/KR2022/020302**

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; **C22C 38/02**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/14**(2006.01)i; **C22C 38/12**(2006.01)i; **C22C 38/38**(2006.01)i; **C22C 38/22**(2006.01)i; **C22C 38/08**(2006.01)i; **C21D 9/46**(2006.01)i; **C21D 8/02**(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 38/04(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/12(2006.01); C22C 38/14(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: 강판(steel sheet), 페라이트(ferrite), 시멘타이트(cementite), 냉각(cooling), 미재결정(non-recrystallized), 티타늄(Ti), 니오븀(Nb), 바나듐(V)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021-141006 A1 (NIPPON STEEL CORPORATION) 15 July 2021 (2021-07-15) See paragraphs [0037], [0041]-[0045], [0086], [0097]-[0098] and [0111] and claims 1 and 7.	1-18
A	KR 10-2017-0118929 A (JFE STEEL CORPORATION) 25 October 2017 (2017-10-25) See paragraph [0085] and claims 1-2 and 5.	1-18
A	JP 2013-253268 A (KOBE STEEL LTD.) 19 December 2013 (2013-12-19) See paragraphs [0070]-[0072] and claims 1 and 3-4.	1-18
A	KR 10-2013-0047757 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 08 May 2013 (2013-05-08) See paragraphs [0086]-[0087] and claims 1-5.	1-18

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

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

International application No. **PCT/KR2022/020302**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 113718166 A (SHANGHAI MEISHAN IRON & STEEL CO., LTD.) 30 November 2021 (2021-11-30) See claims 1 and 4.	1-18

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2022/020302

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2021-141006 A1	15 July 2021	CN 114667360 A	24 June 2022
		EP 4089192 A1	16 November 2022
		JP 7216933 B2	02 February 2023
		KR 10-2022-0079609 A	13 June 2022
		US 2022-0389531 A1	08 December 2022
KR 10-2017-0118929 A	25 October 2017	CN 107429355 A	01 December 2017
		CN 107429355 B	21 January 2020
		EP 3255167 A1	13 December 2017
		EP 3255167 B1	25 September 2019
		JP 6075516 B1	08 February 2017
		JP WO2016-152135 A1	27 April 2017
		MX 2017012196 A	15 December 2017
		US 10655194 B2	19 May 2020
		US 2018-0080099 A1	22 March 2018
		WO 2016-152135 A1	29 September 2016
JP 2013-253268 A	19 December 2013	JP 5829977 B2	09 December 2015
KR 10-2013-0047757 A	08 May 2013	BR 112013004195 A2	10 May 2016
		BR 112013004195 B1	12 June 2018
		CN 103180468 A	26 June 2013
		CN 103180468 B	01 July 2015
		EA 022435 B1	30 December 2015
		EA 201390277 A1	28 June 2013
		EP 2610357 A1	03 July 2013
		EP 2610357 B1	18 December 2019
		ES 2765674 T3	10 June 2020
		JP 4941619 B2	30 May 2012
		JP WO2012-026419 A1	28 October 2013
		KR 10-1498398 B1	03 March 2015
		PL 2610357 T3	18 May 2020
		TW 201221657 A	01 June 2012
		TW I449797 B	21 August 2014
		US 2014-0144553 A1	29 May 2014
		US 9435013 B2	06 September 2016
		WO 2012-026419 A1	01 March 2012
CN 113718166 A	30 November 2021	CN 113718166 B	06 December 2022

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009114523 A **[0008]**
- JP 2017002333 A **[0008]**
- JP 2017002332 A **[0008]**
- JP 2015147965 A **[0008]**