



(11)

EP 4 826 072 A1

(12)

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

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

(21) Application number: **24904144.3**

(22) Date of filing: **03.12.2024**

(51) International Patent Classification (IPC):
C22C 38/38 ^(2006.01) **C22C 38/22** ^(2006.01)
C22C 38/28 ^(2006.01) **C22C 38/06** ^(2006.01)
C22C 38/00 ^(2006.01) **C22C 38/26** ^(2006.01)
C22C 38/32 ^(2006.01) **C21D 8/02** ^(2026.01)
C21D 9/46 ^(2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/02; C21D 9/46; C22C 38/00; C22C 38/06;
C22C 38/22; C22C 38/26; C22C 38/28;
C22C 38/32; C22C 38/38

(86) International application number:
PCT/KR2024/019589

(87) International publication number:
WO 2025/127579 (19.06.2025 Gazette 2025/25)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **15.12.2023 KR 20230183048**

(71) Applicant: **POSCO Co., Ltd**
Gyeongsangbuk-do 37859 (KR)

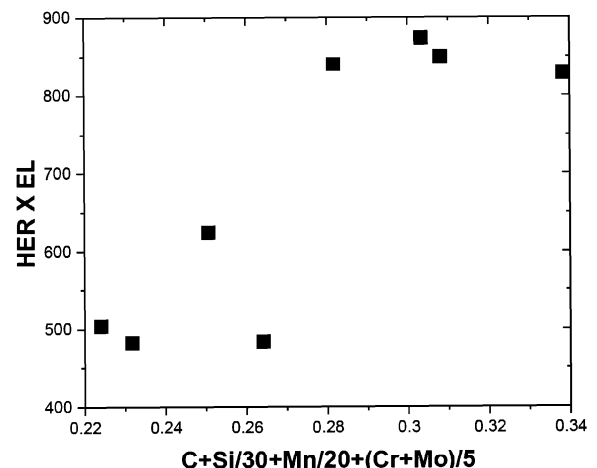
(72) Inventors:
• **CHOI, Kang-Hyun**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **AHN, Yeon-Sang**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **HYUN, Cheol-Seung**
Gwangyang-si, Jeollanam-do 57807 (KR)

(74) Representative: **Meissner Bolte Partnerschaft**
mbB
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

(54) **COLD-ROLLED STEEL SHEET AND MANUFACTURING METHOD THEREOF**

(57) The present invention relates to a cold-rolled steel sheet and a manufacturing method thereof and, more specifically, to a high-strength cold-rolled steel sheet having excellent ductility and workability, and a manufacturing method thereof.

[FIG. 1]



EP 4 826 072 A1

Description

Technical Field

5 **[0001]** The present disclosure relates to a cold-rolled steel sheet and a manufacturing method thereof and, more specifically, to a high-strength cold-rolled steel sheet having excellent ductility and workability, and a manufacturing method thereof.

Background Art

10 **[0002]** Recently, regulations for preserving the global environment have become increasingly stringent in the automotive industry. Accordingly, regulations on carbon reduction and fuel efficiency are becoming stricter, and the use of high-strength steel is increasing in order to ensure occupant's safety in the event of accidents such as collisions. In addition, the high-strength steels having excellent yield strength are being applied to structural members such as members, seat rails, and pillars to improve the impact resistance of vehicle bodies.

15 **[0003]** However, increasing the strength of the steel sheets may lead to the deterioration in ductility and formability.

[0004] To address this issue, there is a growing demand for the development of materials that simultaneously satisfy both high strength and high formability. In general, as the strength of the steel sheet increases, elongation decreases, resulting in reduced workability; therefore, there is a need to develop materials capable of compensating for this drawback. Typically, methods for strengthening steel have been researched, including solid solution strengthening, precipitation strengthening, grain refinement strengthening, and transformation strengthening. However, among these methods, steels strengthened by solid solution strengthening and grain refinement have a limitation in that it is very difficult to produce high-strength steels having a tensile strength of 490 MPa or more.

25 **[0005]** Meanwhile, precipitation-strengthened high-strength steel is a technology that secures strength by adding carbonitride-forming elements such as Nb, Ti, and V to form carbonitrides, thereby achieving grain refinement through the suppression of grain growth by fine precipitates. While this technology has the advantage of readily attaining high strength at relatively low manufacturing costs, it has a drawback in that the recrystallization temperature increases significantly due to fine precipitates, and therefore high-temperature annealing should be performed to ensure sufficient recrystallization and adequate ductility. In addition, the precipitation-strengthened steels in which carbonitrides are precipitated in a ferrite matrix have a limitation in that it is difficult to obtain high-strength steels having a strength of 600 MPa or more.

30 **[0006]** Various types of transformation-strengthened high-strength steels have been developed, including dual phase (DP) steel, which is composed of a soft ferrite matrix and a hard martensite phase; transformation induced plasticity (TRIP) steel, which achieves high ductility by utilizing transformation-induced plasticity of retained austenite; and complex phase (CP) steel, which has a composite microstructure composed of ferrite and hard bainite or martensite.

35 **[0007]** Recently, there has been an increasing demand for higher-strength steel sheets for automotive applications in order to improve fuel efficiency and durability. In addition, the demand for ultra-high-strength steel sheets with a tensile strength of 1180 MPa or more has been growing for use in vehicle body structures and reinforcing members to ensure crash safety and passenger protection.

40 **[0008]** Among these, the DP steel is the most widely used automotive steel sheet due to its excellent ductility; however, it has drawbacks such as a low yield ratio (YR) and inferior formability and workability. Furthermore, as steel sheets continue to become increasingly high-strength, cracks or wrinkles may occur during press forming of automotive components, thereby making it difficult to manufacture complex-shaped components.

45 **[0009]** Among the ultra-high-strength steels, the TRIP and XF steels exhibit higher ductility and an excellent yield ratio compared to the conventional DP steel, resulting in good workability, but the TRIP and XF steels have a drawback in that weldability is deteriorated due to the addition of a large amount of Si and Al required to secure high elongation.

50 **[0010]** To overcome these limitations of conventional ultra-high-strength steels, a steel composition with improved weldability is designed by reducing Si and Al contents, while still satisfying a predetermined level of yield ratio, thereby enabling the application of ultra-high-strength steels to more complex components. This may be achieved by utilizing quenching and partitioning (Q&P) heat treatment, which is an advanced process capable of effectively securing retained austenite.

55 **[0011]** The invention disclosed in Patent Document 1 relates to a technology for simultaneously securing ductility and workability of the above-described high-strength steel. In this technology in Patent Document 1, it is necessary to carefully select the heat treatment temperature in order to form retained austenite through precise control of slow cooling and rapid cooling conditions, thereby achieving high elongation.

[0012] The invention disclosed in Patent Document 2 is characterized by manufacturing a steel sheet having a high

yield ratio through a Q&P process followed by a coating treatment.

[0013] The invention disclosed in Patent Document 3 provides a manufacturing method of a high-strength cold-rolled steel sheet with a high fraction of bainite by cooling into the bainite region. However, this method exhibits inferior elongation compared to the Q&P process due to a reduced carbon partitioning effect.

(Patent Document 1) Korean Patent Laid-Open Publication No. 10-2020-0076795

(Patent Document 2) Japanese Patent Laid-Open Publication No. 2010-090432

(Patent Document 3) Japanese Patent Laid-Open Publication No. 2016-216808

Summary of Invention

Technical Problem

[0014] An aspect of the present disclosure is to provide a cold-rolled steel sheet and a manufacturing method thereof.

[0015] Another aspect of the present disclosure is to provide a high-strength cold-rolled steel sheet having excellent ductility and formability, and a manufacturing method thereof.

[0016] The objects of the present disclosure are not limited to those described above. A person skilled in the art will have no difficulty in understanding the further subject matter of the present disclosure from the general content of this specification.

Solution to Problem

[0017] According to an aspect of the present disclosure, a cold-rolled steel sheet includes: by wt%, carbon (C): 0.08 to 0.16%, silicon (Si): 1.00% or less, manganese (Mn): 1.60 to 3.00%, molybdenum (Mo): 0.40% or less, chromium (Cr): 1.0% or less, phosphorus (P): 0.10% or less, sulfur (S): 0.020% or less, aluminum (sol.Al): 0.60% or less, titanium (Ti): 0.001 to 0.040%, niobium (Nb): 0.001 to 0.040%, nitrogen (N): 0.01% or less, boron (B): 0.010% or less, antimony (Sb): 0.05% or less, the balance being iron (Fe) and unavoidable impurities,

in which an R value defined in the following Relational Equation 1 is 0.270 or more, and a microstructure includes, in area %, a total of 30 to 70% bainite and tempered martensite, 50% or less ferrite, 5% or less retained austenite, and the balance being fresh martensite.

[Relational Equation 1]

$$R = [C] + [Si] / 30 + [Mn] / 20 + ([Cr] + [Mo]) / 5$$

(In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

[0018] The microstructure may include, in area %, a total of 30 to 50% bainite and tempered martensite, 20 to 50% ferrite, 2 to 5% retained austenite, and the balance being fresh martensite.

[0019] The cold-rolled steel sheet may have a yield ratio of 0.60 or more, a hole expansion ratio (HER) of 30% or more, and a product (HER*EL) of hole expansion ratio (HER) and elongation ratio (EL) of 800 or more.

[0020] According to another aspect of the present disclosure, a manufacturing method of a cold-rolled steel sheet includes: reheating a steel slab including, by wt%, carbon (C): 0.08 to 0.16%, silicon (Si): 1.00% or less, manganese (Mn): 1.60 to 3.00%, molybdenum (Mo): 0.40% or less, chromium (Cr): 1.0% or less, phosphorus (P): 0.10% or less, sulfur (S): 0.020% or less, aluminum (sol.Al): 0.60% or less, titanium (Ti): 0.001 to 0.040%, niobium (Nb): 0.001 to 0.040%, nitrogen (N): 0.01% or less, boron (B): 0.010% or less, antimony (Sb): 0.05% or less, the balance being iron (Fe) and unavoidable impurities, and having an R value defined in the following Relational Equation 1 of 0.270 or more;

hot rolling the reheated steel slab;

coiling the hot-rolled steel sheet;

cold rolling the coiled steel sheet;

continuously annealing the cold-rolled steel sheet in a temperature range of 790 to 830°C;

primarily cooling the continuously annealed steel sheet to a temperature range of 630 to 680°C;

secondarily cooling the primarily cooled steel sheet to a temperature range of 320 to 360°C;

reheating and holding the secondarily cooled steel sheet to a temperature range of Ms or higher; and thirdly cooling the reheated and held steel sheet to a temperature range of 150°C or lower.

[Relational Equation 1]

$$R = [C] + [Si] / 30 + [Mn] / 20 + ([Cr] + [Mo]) / 5$$

[0021] (In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

[0022] The reheating may be performed in a temperature range of 1100 to 1300°C,

the hot rolling may be performed at a finish rolling temperature of Ar3 to Ar3+50°C,
the coiling may be performed by coiling in a temperature range of 400 to 650°C and then cooling to room temperature at an average cooling rate of 0.1°C/s or lower,
the cold rolling may be performed at a reduction ratio of 40 to 70%,
in the primarily cooling, the cooling may be performed at an average cooling rate of 10.0°C/s or lower,
in the secondarily cooling, the cooling may be performed at an average cooling rate of 5°C/s or higher,
the reheating and holding may be held for 60 seconds or longer after reheating, and
in the thirdly cooling, the cooling may be performed at an average cooling rate of 5°C/s or higher.

[0023] The manufacturing method may further include temper rolling the thirdly cooled steel sheet to less than 1%.

Advantageous Effects of Invention

[0024] According to an aspect of the present disclosure, it is possible to provide a cold-rolled steel sheet and a manufacturing method thereof.

[0025] According to an aspect of the present disclosure, it is possible to provide a high-strength cold-rolled steel sheet having excellent ductility and workability, and a manufacturing method thereof.

[0026] According to an aspect of the present disclosure, it is possible to provide a high-strength cold-rolled steel sheet, which can be used for automotive structural members having complex shapes requiring high formability, and which exhibits excellent ductility and hole expansion ratio while improving workability by increasing the yield ratio, and a manufacturing method thereof.

[0027] Various and beneficial advantages and effects in the present disclosure are not limited to the above description, and may be more easily understood in the course of describing the specific example embodiments in the present disclosure.

Brief Description of Drawings

[0028]

FIG. 1 is a graph showing the change in the product of hole expansion ratio (HER) and elongation (EL) according to Relational Equation 1 according to an example embodiment of the present disclosure.

FIG. 2 is a graph showing the change in the hole expansion ratio (HER) according to Relational Equation 1 according to an embodiment of the present disclosure.

FIG. 3 is a graph showing the change in the yield ratio according to Relational Equation 1 according to an embodiment of the present disclosure.

Best Mode for Invention

[0029] Hereinafter, example embodiments in the present disclosure will be described. Implementation embodiments of the present disclosure may be modified into several forms, and it is not to be interpreted that the scope of the present disclosure is limited to exemplary embodiments described in detail below. These example embodiments are provided to explain the present disclosure in more detail to those skilled in the art to which the present disclosure pertains.

[0030] Hereinafter, the present disclosure will be described in detail.

[0031] Hereinafter, a steel composition of the present disclosure will be described in detail.

[0032] In the present disclosure, unless otherwise specified, % indicating the respective contents of elements is based on weight.

[0033] According to an aspect of the present disclosure, a cold-rolled steel sheet includes: by wt%, carbon (C): 0.08

to 0.16%, silicon (Si): 1.00% or less, manganese (Mn): 1.60 to 3.00%, molybdenum (Mo): 0.40% or less, chromium (Cr): 1.0% or less, phosphorus (P): 0.10% or less, sulfur (S): 0.020% or less, aluminum (sol.Al): 0.60% or less, titanium (Ti): 0.001 to 0.040%, niobium (Nb): 0.001 to 0.040%, nitrogen (N): 0.01% or less, boron (B): 0.010% or less, and antimony (Sb): 0.05% or less.

Carbon (C): 0.08 to 0.16%

[0034] Carbon (C) is a very important element added to strengthen a transformation structure. Carbon (C) promotes the formation of hard martensite in complex phase steel, thereby improving strength. When the carbon (C) content increases, the amount of martensite increases. However, when the content exceeds 0.16%, the strength of the martensite increases, but the strength difference with ferrite, which has a low carbon concentration, becomes large. Due to this difference in strength, fracture easily occurs at the interphase interface during plastic deformation, which may lead to a decrease in ductility and work hardening rate. In addition, weldability is inferior, which may result in welding defects during component processing. Therefore, according to an embodiment of the present disclosure, the upper limit may be limited to 0.16%. According to an example embodiment of the present disclosure, the C content may be 0.15% or less. On the other hand, when the carbon (C) content is less than 0.08%, it may be difficult to secure the desired strength. Therefore, according to an embodiment of the present disclosure, the lower limit may be limited to 0.08%. According to an example embodiment of the present disclosure, the C content may be 0.09% or more.

Silicon (Si): 1.00% or less

[0035] Silicon (Si) is a ferrite-stabilizing element that promotes ferrite transformation and contributes to the formation of retained austenite by encouraging carbon concentration in untransformed austenite during the Q&P process. Furthermore, it effectively increases the strength of ferrite through solid solution strengthening, thereby reducing the hardness difference between phases, and serves as a useful element capable of securing strength without deteriorating the ductility of the steel sheet. However, when the Si content exceeds 1.00%, it may cause surface scale defects and adversely affect surface quality. Additionally, it may reduce weldability and chemical conversion treatability. Therefore, according to an example embodiment of the present disclosure, the upper limit may be limited to 1.00%. According to an example embodiment of the present disclosure, the Si content may be 0.90% or less.

Manganese (Mn): 1.60 to 3.00%

[0036] Manganese (Mn) is an element that refines grains without reducing ductility and completely precipitates S in steel as MnS, thereby preventing hot brittleness caused by the formation of FeS and strengthening the steel. At the same time, in the complex phase steel, it plays a role in lowering the critical cooling rate at which martensite is obtained, making the formation of martensite easier. When the manganese (Mn) content is less than 1.60%, it may be difficult to secure the strength targeted in the present disclosure. According to an example embodiment of the present disclosure, the Mn content may be 2.00% or more. On the other hand, when the content exceeds 3.00%, there is a high possibility that problems such as weldability and hot rolling performance may occur, and issues such as material instability due to excessive formation of martensite, and increased risk of processing cracks and plate fracture due to the formation of Mn-band (band of Mn oxide) within the structure may arise. In addition, there may be a problem in which Mn oxide leaches out onto the surface during annealing, significantly impairing surface quality. According to an example embodiment of the present disclosure, the Mn may be 2.60% or less.

Molybdenum (Mo): 0.40% or less

[0037] Molybdenum (Mo) is an element useful for delaying the transformation of austenite into pearlite, while simultaneously refining ferrite and improving strength. This molybdenum (Mo) improves the hardenability of steel and has the advantage of enabling yield ratio control by finely forming martensite at grain boundaries. However, since Mo is an expensive element, an increase in Mo content leads to an increase in manufacturing costs, which is disadvantageous in terms of cost. Therefore, it is preferable to appropriately control the content thereof. To obtain the above-described effects, the molybdenum (Mo) may be added at 0.40% or less. When the molybdenum (Mo) content exceeds 0.40%, it leads to a sharp increase in alloy costs, resulting in reduced economic feasibility. Furthermore, due to excessive grain refinement and solid solution strengthening effects, there is a problem in that the ductility of the steel is actually reduced. According to an example embodiment of the present disclosure, the Mo content may be 0.30% or less. In the present disclosure, 0% is excluded in consideration of an amount inevitably added during manufacturing.

Chromium (Cr): 1.0% or less

[0038] Chromium (Cr) is a component added to improve the hardenability of steel and secure high strength. As an element that plays a very important role in the formation of martensite, it may be advantageous for manufacturing complex phase steel with high ductility by minimizing the decrease in elongation relative to the increase in strength. In particular, chromium (Cr) forms Cr-based carbides such as Cr_{23}C_6 during hot rolling. During the annealing process, a portion of these carbides is dissolved while the remainder remains undissolved, thereby enabling control of the dissolved carbon content in martensite below an appropriate level after cooling. This suppresses yield point elongation and is thus advantageous for manufacturing complex phase steel having a low yield ratio. However, when the content exceeds 1.0%, not only is the effect saturated, but there may also be a problem of inferior cold rolling performance due to an excessive increase in hot-rolled strength. Furthermore, as the fraction of Cr-based carbides increases and they become coarsened, the martensite phase is also coarsened after annealing, which may result in a decrease in elongation. According to an example embodiment of the present disclosure, the Cr may be 0.8% or less.

Phosphorus (P): 0.10% or less

[0039] Phosphorus (P) is a substitutional element exhibiting the strongest solid solution strengthening effect. It is highly effective for increasing strength without significantly deteriorating formability, and it also contributes to the improvement of in-plane anisotropy. However, excessive addition may significantly increase the likelihood of brittle fracture, potentially causing problems such as the possibility of slab breakage during hot rolling and acting as an element that impairs plating surface characteristics. Therefore, according to an example embodiment of the present disclosure, the upper limit of the phosphorous (P) may be limited to 0.10%. However, considering the inevitably added amount, 0% is excluded.

Sulfur (S): 0.020% or less

[0040] Sulfur (S) is an impurity element that is unavoidably present in steel and is known to deteriorate ductility and weldability. Therefore, it is important to control its content as low as possible. In particular, as it increases the likelihood of red-hot brittleness, its content may be controlled to 0.020% or less. However, considering the inevitably introduced amount during the manufacturing process, 0% is excluded.

Aluminum (sol.Al): 0.60% or less

[0041] Acid-soluble aluminum (sol.Al) is an element added for grain refinement and deoxidation of steel. Similar to Si, it is a ferrite-stabilizing element that distributes carbon within ferrite to austenite, thereby improving martensite hardenability and forming residual austenite. Furthermore, when maintained in the bainite region during annealing, it is a useful element that may improve the ductility of steel sheets by effectively suppressing the precipitation of carbides within the bainite. However, when its content exceeds 0.60%, although it is advantageous for increasing strength due to the grain refinement effect, it may cause an increase in manufacturing costs and a higher risk of surface defects in plated steel sheets due to excessive formation of inclusions during continuous casting in steelmaking. According to an example embodiment of the present disclosure, the acid-soluble aluminum may be 0.30% or less. However, considering the inevitably introduced amount during the manufacturing process, 0% is excluded.

Titanium (Ti): 0.001 to 0.040%

[0042] Titanium (Ti) is an element effective for increasing the strength of steel sheets and for refining grain size through the formation of nano-precipitates. When this element is added, the titanium binds with carbon to form very fine nano-precipitates. These nano-precipitates strengthen the matrix structure and play a role in reducing the hardness difference between phases. When the titanium (Ti) content is less than 0.001%, it may be difficult to secure such effects. On the other hand, when the content exceeds 0.040%, manufacturing costs may increase and ductility may be significantly reduced due to excessive precipitates. According to an example embodiment of the present disclosure, the Ti content may be 0.030% or less. However, considering the inevitably introduced amount during the manufacturing process, 0% is excluded.

Niobium (Nb): 0.001 to 0.040%

[0043] Niobium (Nb) is an element effective for increasing the strength of steel sheets and for refining grain size through the formation of nano-precipitates. When this element is added, the niobium (Nb) binds with carbon to form

very fine nano-precipitates. These nano-precipitates strengthen the matrix structure and play a role in reducing the hardness difference between phases. When the niobium (Nb) content is less than 0.001%, it may be difficult to secure such effects. On the other hand, when the content exceeds 0.040%, manufacturing costs may increase and ductility may be significantly reduced due to excessive precipitates. According to an example embodiment of the present disclosure, the Nb content may be 0.030% or less. However, considering the inevitably introduced amount during the manufacturing process, 0% is excluded.

Nitrogen (N): 0.01% or less

[0044] Nitrogen (N) is an element that effectively stabilizes austenite; however, when its content exceeds 0.01%, steel refining costs increase sharply, and the risk of cracking during continuous casting may be significantly increased due to the formation of AlN. However, considering the inevitably added amount, 0% is excluded.

Boron (B): 0.010% or less

[0045] Boron (B) is an element that delays the transformation of austenite into pearlite during cooling in the annealing process. It suppresses ferrite formation and promotes martensite formation, thereby acting as a hardenability-enhancing element. However, when the content exceeds 0.010%, excessive boron (B) may become concentrated on the surface, potentially leading to a deterioration in plating adhesion. According to an example embodiment of the present disclosure, the B content may be 0.008% or less.

Antimony (Sb): 0.05% or less

[0046] Antimony (Sb) is distributed at grain boundaries and suppresses surface enrichment of oxides by retarding the diffusion of oxidizing elements such as Mn, Si, and Al. In addition, it exhibits an excellent effect in inhibiting the coarsening of surface-enriched layers caused by temperature increases and variations in the hot rolling process. However, when the content exceeds 0.05%, not only is the effect saturated, but manufacturing costs and workability may also be inferior. According to an example embodiment of the present disclosure, the Sb content may be 0.03% or less.

[0047] The steel material of the present disclosure may include remaining iron (Fe) and unavoidable impurities in addition to the above-described composition. Since the unavoidable impurities may be unintentionally incorporated in the normal manufacturing process, the unavoidable impurities may not be excluded. Since these impurities are known to those skilled in the steel manufacturing field, not all of these impurities are specifically mentioned in this specification.

[0048] The cold-rolled steel sheet according to an embodiment of the present disclosure may have an R value defined in the following Relational Equation 1 of 0.270 or more.

[Relational Equation 1]

$$R = [C] + [Si] / 30 + [Mn] / 20 + ([Cr] + [Mo]) / 5$$

[0049] (In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

[0050] According to an embodiment of the present disclosure, the content of alloying elements at a 1/4 point from the surface of the steel sheet toward the thickness center direction may be controlled.

[0051] According to an embodiment of the present disclosure, the content of C, Si, Al, Cr, and Mo, which are elements related to hardenability, may be controlled. Si and Al are ferrite-stabilizing elements that promote ferrite transformation and contribute to the formation of retained austenite and martensite by promoting carbon enrichment in untransformed austenite. C is also an element that contributes to the formation and fraction adjustment of martensite by encouraging carbon concentration in untransformed austenite. In addition, C, Si, and Al have an adverse effect on weldability, causing cracks on the surface and inside the welded portion. On the other hand, while Mn, Cr, and Mo are elements that contribute to improving hardenability, their effect on C enrichment within austenite is relatively low compared to C, Si, and Al. Therefore, it is very important to properly adjust the ratio of C, Si, Al and other hardenability elements such as Mn, Cr, and Mo.

[0052] When the R value defined in the above Relational Equation 1 is 0.270 or more, the physical properties proposed in the present disclosure may be secured as described above. On the other hand, when the value is less than 0.270, it is difficult to secure the target bainite and residual austenite fractions, and thus the desired hole expansion ratio, elongation, and workability may not be secured. According to an example embodiment of the present disclosure, the value may be 0.280 or more. Although the upper limit of the R value of Relational Equation 1 is not

specifically limited, since weldability may be impaired by an excess of C, Si, and Mn, according to an embodiment of the present disclosure, it may be 0.350 or less.

[0053] Hereinafter, a steel microstructure of the present disclosure will be described in detail.

[0054] In the present disclosure, unless otherwise specified, % indicating the fraction of the microstructure is based on area.

[0055] According to an embodiment of the present disclosure, the microstructure of the cold-rolled steel sheet may include, in area %, a total of 30 to 70% bainite and tempered martensite, 50% or less ferrite, 5% or less retained austenite, and the balance being fresh martensite.

[0056] In the present disclosure, the microstructure may be observed at a 1/4 point from the surface of the steel sheet toward the thickness center direction.

[0057] In the present disclosure, in order to simultaneously secure the high ductility and workability, the fraction between tempered martensite, bainite, and ferrite is strictly controlled.

[0058] In the present disclosure, to appropriately secure the desired strength and ductility, the sum of fractions of bainite and tempered martensite may be 30% or more. When the sum of fractions of the bainite and tempered martensite is less than 30%, the desired strength and workability may not be sufficiently secured. Meanwhile, according to an embodiment of the present disclosure, the upper limit may be limited to 70% to ensure ductility. According to an embodiment of the present disclosure, it may be limited to 50% or less. According to an example embodiment of the present disclosure, it may be 40% or less.

[0059] In the present disclosure, the upper limit of the ferrite fraction may be limited to 50% to ensure ductility. Meanwhile, by performing intercritical annealing, a sufficient ferrite fraction may be obtained, and ductility may be improved by partially forming ferrite even during the slow cooling stage. According to an example embodiment of the present disclosure, the lower limit of the ferrite fraction may be 20%.

[0060] Since the retained austenite may cause the decrease in workability, the upper limit may be limited to 5% in the present disclosure. Meanwhile, according to an embodiment of the present disclosure, the retained austenite may contribute to improving the ductility of the steel sheet by inducing transformation-induced plasticity. Accordingly, according to an embodiment of the present disclosure, the retained austenite may be included in an amount of 2% or more.

[0061] According to an embodiment of the present disclosure, the fresh martensite may be included as the remainder structure. By introducing a small amount of fresh martensite during final cooling, the desired strength may be secured.

[0062] The cold-rolled steel sheet according to an embodiment of the present disclosure may have a yield ratio of 0.60 or more, a hole expansion ratio (HER) of 30% or more, and a product (HER*EL) of hole expansion ratio (HER) and elongation ratio (EL) of 800 or more.

[0063] Hereinafter, a manufacturing method of steel of the present disclosure will be described in detail.

[0064] The cold-rolled steel sheet according to an embodiment of the present disclosure may be manufactured by reheating, hot rolling, coiling, cooling, cold rolling, continuous annealing, primary cooling, secondary cooling, reheating and holding, cooling, and temper rolling a steel slab satisfying the alloy composition described above.

Reheating

[0065] A steel slab satisfying the alloy composition according to an example embodiment of the present disclosure may be reheated to a temperature range of 1100 to 1300°C.

[0066] The slab reheating process may be performed to facilitate the subsequent rolling process and to sufficiently obtain the target physical properties of the steel sheet. The reheating temperature of the present disclosure is not particularly limited and may be a normal reheating condition. According to an example embodiment of the present disclosure, it may be reheated to a temperature range of 1100 to 1300°C.

Hot Rolling

[0067] The reheated steel slab may be hot rolled at a finish rolling temperature of Ar3 to Ar3+50°C.

[0068] In the present disclosure, the hot rolling conditions are not particularly limited and may be performed at a normal hot rolling temperature. According to an example embodiment of the present disclosure, it may be hot rolled at a finish rolling temperature of 800 to 1000°C.

$$\text{Ar3} = 910 - 310[\text{C}] - 80[\text{Mn}] - 55[\text{Ni}] - 15[\text{Ni}] - 15[\text{Cr}] - 80[\text{Mo}] - 20[\text{Cu}] + 0.35(t - 8)$$

[Equation]

(In Equation, [C], [Mn], [Ni], [Cr], [Mo], and [Cu] are wt% of each element, and t is the thickness of the steel sheet

(mm).)

Coiling

- 5 **[0069]** The hot-rolled steel sheet above may be coiled in a temperature range of 400 to 650°C.
- [0070]** By performing the coiling process, a steel sheet in which carbides serving as austenite nucleation sites are finely dispersed may be manufactured. By evenly dispersing fine carbides during the hot rolling process, the carbides dissolve during subsequent annealing to form finely dispersed austenite, thereby allowing for the uniform dispersion of fine martensite after annealing.
- 10 **[0071]** When the coiling temperature is less than 400°C, there may be a problem with the material variation in the width direction of the steel sheet being inferior. On the other hand, when the temperature exceeds 650°C, an excessive amount of oxide may be formed on the surface of the steel sheet, which may result in inferior platability.
- [0072]** According to an example embodiment of the present disclosure, the steel sheet may be cooled to room temperature after coiling. When cooling to room temperature after coiling, the average cooling rate is not specifically
- 15 limited and may be a condition applicable in the same technical field. According to an example embodiment of the present disclosure, air cooling may be performed. According to an example embodiment of the present disclosure, when cooling to room temperature, the average cooling rate may be limited to 0.1°C/s or lower.

Cold Rolling

- 20 **[0073]** The coiled steel sheet may be cold rolled with a reduction rate of 40 to 70%.
- [0074]** When the cold reduction rate is less than 40%, it may be difficult to secure the target thickness, and it may also be difficult to correct the shape of the steel sheet. On the other hand, when it exceeds 70%, there is a high probability of cracks occurring at the edge of the steel sheet, and there are problems associated with cold rolling loads.

Continuous Annealing

- [0075]** The cold-rolled steel sheet may be continuously annealed in a temperature range of 790 to 830°C.
- 30 **[0076]** The continuous annealing process may improve strength and ductility by securing the desired ferrite fraction through annealing in a specific range.
- [0077]** When the continuous annealing temperature is less than 790°C, it is difficult to secure a sufficient austenite fraction, and the ferrite fraction increases excessively after annealing, which may result in an inability to secure sufficient strength. According to an example embodiment of the present disclosure, the continuous annealing may be performed in a temperature range of 795°C or higher. On the other hand, when the temperature exceeds 830°C, the
- 35 excessive austenite is formed, and the ferrite fraction decreases, making it difficult to secure the desired ductility. Furthermore, the surface enrichment by elements that degrade surface quality, such as Si, Mn, and B, becomes severe, which may lead to a deterioration in surface quality. According to an example embodiment of the present disclosure, the continuous annealing may be performed in a temperature range of 820°C or lower.

Primary Cooling

- [0078]** The continuously annealed steel sheet described above may be primarily cooled to a temperature range of 630 to 680°C at an average cooling rate of 10.0°C/s or lower.
- 45 **[0079]** According to an example embodiment of the present disclosure, by controlling the end temperature during the primary cooling, the cooling capacity of the equipment may be taken into account, and a small amount of additional ferrite may be secured.
- [0080]** When the final temperature during the primary cooling is less than 630°C, there may be a problem in that ferrite is not sufficiently formed during the primary cooling. On the other hand, when the end temperature exceeds 680°C, there may be a problem in that the ferrite fraction becomes excessively high.
- 50 **[0081]** When the average cooling rate during the primary cooling exceeds 10.0°C/s, there may be a problem in that the bainite fraction becomes excessively high. According to an example embodiment of the present disclosure, it may be 5.0°C/s or lower. The lower limit of the average cooling rate is not specifically limited, but according to an example embodiment of the present disclosure, it may be 2.0°C/s or more.

Secondary Cooling

- [0082]** The primarily cooled steel sheet may be secondarily cooled at an average cooling rate of 5 °C/s or higher to a temperature range of 320 to 360°C.

[0083] According to an example embodiment of the present disclosure, in a Q&P process in which the material is quenched to a temperature of Ms or lower and then reheated to a temperature of Ms or higher, the end temperature during the primary and secondary cooling may be strictly controlled to form a desired microstructure.

[0084] When the cooling end temperature exceeds 360°C during the secondary cooling, the initial martensite fraction formed is very low or martensite formation is difficult; consequently, it is difficult to form the desired fraction of tempered martensite and bainite during the final cooling, making it impossible to obtain the desired hole expansion ratio. On the other hand, when the temperature is lower than 320°C, the fractions of tempered martensite and bainite become excessive, making it difficult to form a desired fraction of fresh martensite during the final cooling, and thus preventing the desired strength from being obtained.

[0085] During the secondary cooling, when the average cooling rate is less than 5°C/s, the initial martensite fraction may be very low or martensite formation may be difficult, which may result in a problem where the fraction of tempered martensite may not be sufficiently secured during final cooling. According to an example embodiment of the present disclosure, it may be 10°C/s or higher. Meanwhile, although the upper limit is not specifically limited, according to an example embodiment of the present disclosure, it may be 50°C/s or lower.

[0086] During cooling, although the conditions are not specifically limited, according to an example embodiment of the present disclosure, a hydrogen quenching facility using H₂ gas may be used during cooling.

Reheating and Holding

[0087] The secondarily cooled steel sheet may be reheated to a temperature range of Ms or higher and held for 60 seconds or longer.

[0088] According to an example embodiment of the present disclosure, the martensite formed in the secondary cooling process is reheated to a temperature range greater than Ms and held for at least 60 seconds to form the tempered martensite and bainite through the Q&P process, and to concentrate carbon in the surrounding untransformed austenite. Additionally, the fine fresh martensite may be introduced through the above process.

[0089] According to an example embodiment of the present disclosure, the Ms temperature may be determined by the martensite transformation start temperature and the Ms temperature equation applied in the same technical field. According to an example embodiment of the present disclosure, the Ms temperature may be calculated through the following Equation.

[Equation]

$$Ms = 539 - 423 [C] - 30.4 [Mn] - 12.1 [Cr] - 17.7 [Ni] - 7.5 [Mo]$$

[0090] (In Equation, [C], [Mn], [Cr], [Ni], and [Mo] are wt% of each element.)

Thirdly Cooling

[0091] The reheated and held steel sheet may be thirdly cooled to a temperature range of 150°C or lower at an average cooling rate of 5°C/s or higher.

[0092] During thirdly cooling, when the end temperature exceeds 150°C, the phase transformation may not be completed, which may result in a problem where the desired physical properties may not be secured. Additionally, during thirdly cooling, when the average cooling rate is less than 5°C/s, there may be a problem where additional phase transformation occurs.

Temper Rolling

[0093] The thirdly cooled steel sheet may be temper rolled at a reduction ratio of less than 1%.

[0094] In the present disclosure, the temper rolling may be additionally performed to control the plate shape. In the present disclosure, the conditions for the temper rolling are not specifically limited, and may be performed by applying normal conditions.

[0095] Hereinafter, the present disclosure will be described in more detail with reference to Examples. However, it should be noted that the following Examples are only for illustrating the present disclosure in more detail and are not intended to limit the scope of the present disclosure.

Mode for Invention

[0096] After preparing a steel slab having compositions shown in Table 1, the steel slab was reheated to a tempera-

EP 4 826 072 A1

ture range of 1050 to 1250°C, and finish hot rolling was performed in a temperature range of Ar3+50°C to 950°C, which is an Ar3 transformation temperature or higher. Thereafter, the hot-rolled steel sheet was coiled in a temperature range of 400 to 650°C and then cooled at a cooling rate of 0.1°C/s or less, thereby manufacturing the hot-rolled steel sheet. After pickling, the hot-rolled steel sheet was cold-rolled at a reduction ratio of 40 to 70%, followed by continuous annealing and primary and secondary cooling under the conditions disclosed in Table 2. In addition, after the reheating and holding process, thirdly cooling was performed and temper rolling of less than 1% was performed, thereby manufacturing the cold-rolled steel sheet. During the reheating and holding, all specimens were reheated to a temperature higher than or equal to the Ms temperature and held for 60 seconds or longer.

[Table 1]

Steel Grade	Alloy Composition (wt%)											Relationship Equation 1
	C	Si	Mn	P	S	S.Al	Nb	Ti	B	Cr	Mo	R value
A	0.14	0.70	2.00	0.01	0.001	0.03	0.020	0.015	-	0.2	0.01	0.305
B	0.14	0.70	1.90	0.01	0.001	0.05	0.020	0.006	-	0.4	0.02	0.342
C	0.15	0.90	2.00	0.01	0.001	0.04	0.020	0.003	-	0.1	0.04	0.308
D	0.14	0.80	2.10	0.01	0.001	0.04	0.025	0.020	0.0010	-	0.05	0.282
<u>E</u>	<u>0.07</u>	0.45	2.30	0.01	0.001	0.03	0.010	0.020	-	0.1	0.02	<u>0.224</u>
<u>F</u>	0.09	0.50	2.35	0.01	0.001	0.03	0.007	0.006	-	0.2	0.01	<u>0.266</u>
<u>G</u>	0.12	0.65	1.80	0.01	0.001	0.02	0.005	0.030	0.0015	-	0.02	<u>0.236</u>
<u>H</u>	0.10	0.50	2.00	0.01	0.001	0.04	0.020	0.001	-	0.1	0.07	<u>0.251</u>

$$R = [C] + [Si]/30 + [Mn]/20 + ([Cr] + [Mo])/5$$

[Relational Equation 1]

(In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

[Table 2]

Specimen Number	Steel Grade	Continuous Annealing	Primary Cooling		Secondary Cooling		Reheating and Holding
		Temperature (°C)	Temperature (°C)	Rate (°C/s)	Temperature (°C)	Rate (°C/s)	Temperature (°C)
1	A	804	670	2.9	340	24	450
2	A	<u>850</u>	670	3.9	340	24	450
3	A	<u>770</u>	670	2.2	343	24	450
4	A	810	670	3.0	<u>442</u>	16	450
5	A	810	670	3.0	<u>300</u>	27	450
6	B	800	650	3.3	345	22	446
7	C	813	659	3.3	339	23	451
8	D	820	652	3.6	346	22	449
9	<u>E</u>	806	650	3.4	400	18	440
10	<u>F</u>	820	660	3.5	390	20	450
11	<u>G</u>	810	652	3.4	404	18	444
12	<u>H</u>	803	655	3.2	405	18	470

[0097] Microstructural and mechanical properties were evaluated for each of the manufactured steel sheets, and the results were shown in Table 3 below.

[0098] Microstructural fractions were determined by analyzing the matrix structure at a location corresponding to 1/4 of the thickness from the surface toward the center of the annealed steel sheet. Specifically, after Nital etching, the

fractions of bainite, tempered martensite, ferrite, fresh martensite, and retained austenite were measured using FE-SEM and an image analyzer.

[0099] In addition, tensile tests were conducted on each specimen in the C-direction in accordance with JIS standards. Tensile properties, including yield strength (YS), tensile strength (TS), yield ratio (YS/TS), and elongation (EI), were evaluated. The hole expansion ratio (HER) was measured using a hole expansion testing machine.

[Table 3]

Specimen Numb er	Steel Grade	Microstructure				Physical property						Division
		Fraction (area%)				YS (MPa)	TS (MPa)	Yield Ratio	HER (%)	EI (%)	HER* EI	
		B+TM	F	FM	RA							
1	A	30	45	23	2	508	817	0.62	38	23	874	Inventive Ex- ample 1
2	A	<u>76</u>	10	11	3	670	921	0.73	56	13	<u>728</u>	<u>Comparative Example 1</u>
3	A	<u>14</u>	<u>59</u>	25	2	420	803	<u>0.52</u>	<u>25</u>	27	<u>675</u>	<u>Comparative Example 2</u>
4	A	<u>24</u>	<u>52</u>	24	0	437	811	<u>0.54</u>	<u>26</u>	22	<u>572</u>	<u>Comparative Example 3</u>
5	A	35	<u>52</u>	9	4	572	770	0.74	42	21	882	<u>Comparative Example 4</u>
6	B	32	43	23	2	522	826	0.63	36	23	828	Inventive Ex- ample 2
7	C	33	39	25	3	511	818	0.62	34	25	850	Inventive Ex- ample 3
8	D	38	38	22	2	531	819	0.65	40	21	840	Inventive Ex- ample 4
9	<u>E</u>	24	<u>53</u>	23	0	422	824	<u>0.51</u>	<u>24</u>	21	<u>504</u>	<u>Comparative Example 5</u>
10	<u>F</u>	<u>17</u>	<u>55</u>	28	0	410	832	<u>0.49</u>	<u>22</u>	22	<u>484</u>	<u>Comparative Example 6</u>
11	<u>G</u>	<u>13</u>	<u>60</u>	27	0	410	839	<u>0.49</u>	<u>23</u>	21	<u>483</u>	<u>Comparative Example 7</u>
12	<u>H</u>	<u>20</u>	<u>60</u>	20	0	414	821	<u>0.50</u>	<u>26</u>	24	<u>624</u>	<u>Comparative Example 8</u>
* B: Bainite, TM: Tempered Martensite, F: Ferrite, FM: Fresh Martensite, RA: Retained Austenite												

[0100] As shown in Table 3, in the case of the Inventive Examples satisfying the alloy composition and manufacturing conditions of the present disclosure, the microstructural features proposed in the present disclosure were satisfied, and the desired physical properties of the present disclosure were also achieved.

[0101] FIG. 1 is a graph showing the change in the product of hole expansion ratio (HER) and elongation (EI) according to Relational Equation 1 according to an example embodiment of the present disclosure. It can be seen that when the value of Relational Equation 1 is 0.270 or more, the product of hole expansion ratio and elongation targeted in the present disclosure may be secured.

[0102] FIG. 2 is a graph showing the change in the hole expansion ratio (HER) according to Relational Equation 1 according to an example embodiment of the present disclosure. It can be seen that when the value of Relational Equation 1 is 0.27 or more, the hole expansion ratio value targeted in the present disclosure may be secured.

[0103] FIG. 3 is a graph showing the change in the yield ratio according to Relational Equation 1 according to an example embodiment of the present disclosure. It can be seen that when the value of Relational Equation 1 is 0.27 or more, the yield ratio value targeted in the present disclosure may be secured.

[0104] On the other hand, in the case of Comparative Example 1, the temperature during continuous annealing was excessively high, and thus the intended elongation could not be secured.

[0105] In Comparative Example 2, the annealing temperature was below the proposed range, resulting in excessive formation of intercritical ferrite. Accordingly, the target strength could not be obtained.

[0106] In Comparative Example 3, the end temperature during secondary cooling was excessively high, and thus sufficient tempered martensite was not secured. As a result, the intended hole expansion ratio could not be secured.

[0107] In Comparative Example 4, the end temperature during secondary cooling was below the proposed range, resulting in the excessive formation of tempered martensite and bainite, thereby leading to inferior strength.

[0108] Comparative Examples 5 to 8 are examples in which the value of Relational Equation 1 did not fall within the range proposed in the present disclosure. As a result, ferrite was excessively formed, and the formation of bainite and tempered martensite was insufficient. Accordingly, the desired yield ratio and hole expansion ratio could not be secured.

[0109] While example embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A cold-rolled steel sheet, comprising:

by wt%, carbon (C): 0.08 to 0.16%, silicon (Si): 1.00% or less, manganese (Mn): 1.60 to 3.00%, molybdenum (Mo): 0.40% or less, chromium (Cr): 1.0% or less, phosphorus (P): 0.10% or less, sulfur (S): 0.020% or less, aluminum (sol.Al): 0.60% or less, titanium (Ti): 0.001 to 0.040%, niobium (Nb): 0.001 to 0.040%, nitrogen (N): 0.01% or less, boron (B): 0.010% or less, antimony (Sb): 0.05% or less, the balance being iron (Fe) and unavoidable impurities,

wherein an R value defined in the following Relational Equation 1 is 0.270 or more, and a microstructure includes, in area %, a total of 30 to 70% bainite and tempered martensite, 50% or less ferrite, 5% or less retained austenite, and the balance being fresh martensite.

[Relational Equation 1]

$$R = [C] + [Si] / 30 + [Mn] / 20 + ([Cr] + [Mo]) / 5$$

(In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

2. The cold-rolled steel sheet of claim 1, wherein the microstructure includes, in area %, a total of 30 to 50% bainite and tempered martensite, 20 to 50% ferrite, 2 to 5% retained austenite, and the balance being fresh martensite.

3. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield ratio of 0.60 or more, a hole expansion ratio (HER) of 30% or more, and a product (HER*EL) of hole expansion ratio (HER) and elongation ratio (EL) of 800 or more.

4. A manufacturing method of a cold-rolled steel sheet, comprising:

reheating a steel slab comprising, by wt%, carbon (C): 0.08 to 0.16%, silicon (Si): 1.00% or less, manganese (Mn): 1.60 to 3.00%, molybdenum (Mo): 0.40% or less, chromium (Cr): 1.0% or less, phosphorus (P): 0.10% or less, sulfur (S): 0.020% or less, aluminum (sol.Al): 0.60% or less, titanium (Ti): 0.001 to 0.040%, niobium (Nb): 0.001 to 0.040%, nitrogen (N): 0.01% or less, boron (B): 0.010% or less, antimony (Sb): 0.05% or less, the balance being iron (Fe) and unavoidable impurities, and having an R value defined in the following Relational Equation 1 of 0.270 or more;

hot rolling the reheated steel slab;

coiling the hot-rolled steel sheet;

cold rolling the coiled steel sheet;

continuously annealing the cold-rolled steel sheet in a temperature range of 790 to 830°C;

primarily cooling the continuously annealed steel sheet to a temperature range of 630 to 680°C;

secondarily cooling the primarily cooled steel sheet to a temperature range of 320 to 360°C;

reheating and holding the secondarily cooled steel sheet to a temperature range of Ms or higher; and

thirdly cooling the reheated and held steel sheet to a temperature range of 150°C or lower.

[Relational Equation 1]

$$R = [C] + [Si] / 30 + [Mn] / 20 + ([Cr] + [Mo]) / 5$$

5 (In Relational Equation 1, [C], [Si], [Mn], [Cr], and [Mo] are wt% of each element.)

5. The manufacturing method of claim 4, wherein the reheating is performed in a temperature range of 1100 to 1300°C,

10 the hot rolling is performed at a finish rolling temperature of Ar₃ to Ar₃+50°C,
the coiling is performed by coiling in a temperature range of 400 to 650°C and then cooling to room temperature at an average cooling rate of 0.1°C/s or lower,
the cold rolling is performed at a reduction ratio of 40 to 70%,
15 in the primarily cooling, the cooling is performed at an average cooling rate of 10.0°C/s or lower,
in the secondarily cooling, the cooling is performed at an average cooling rate of 5°C/s or higher,
the reheating and holding is held for 60 seconds or longer after reheating, and
in the thirdly cooling, the cooling is performed at an average cooling rate of 5°C/s or higher.

- 20 6. The manufacturing method of claim 4, further comprising:
temper rolling the thirdly cooled steel sheet to less than 1%.

25

30

35

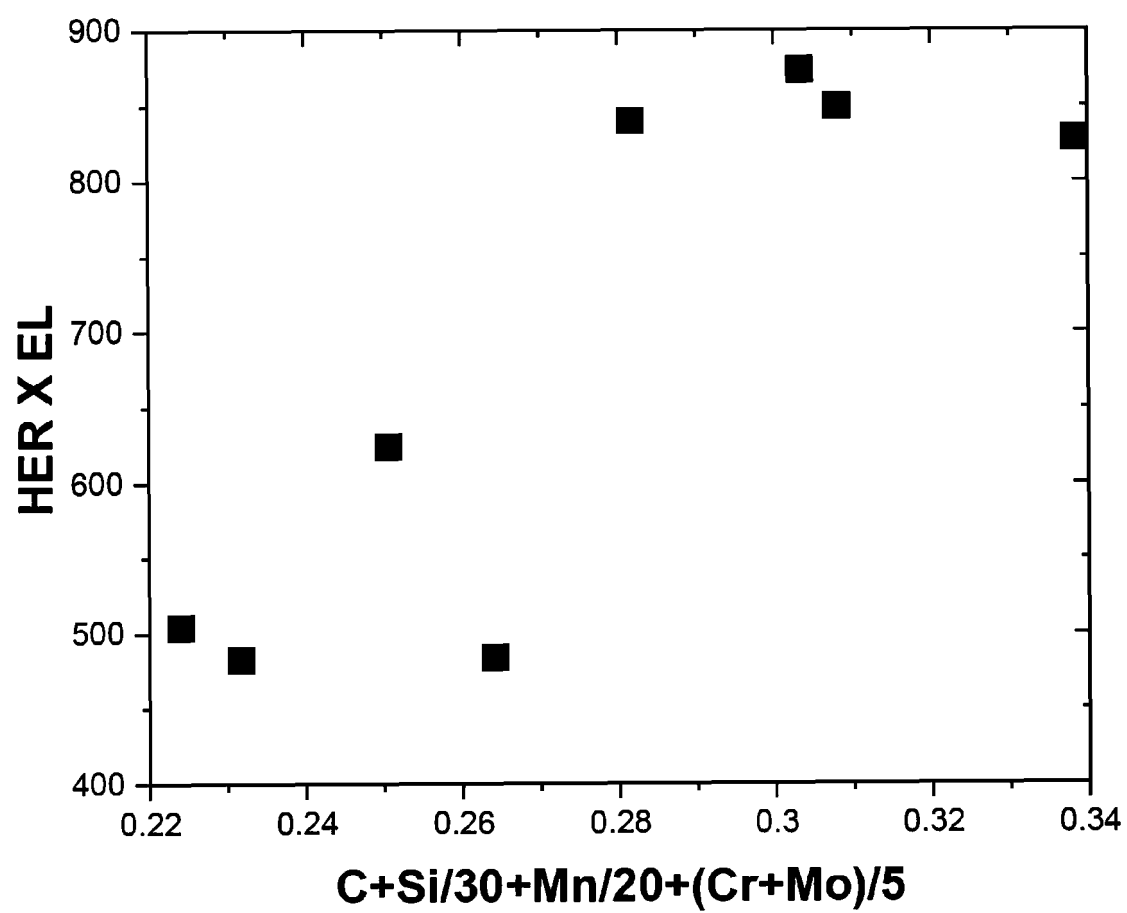
40

45

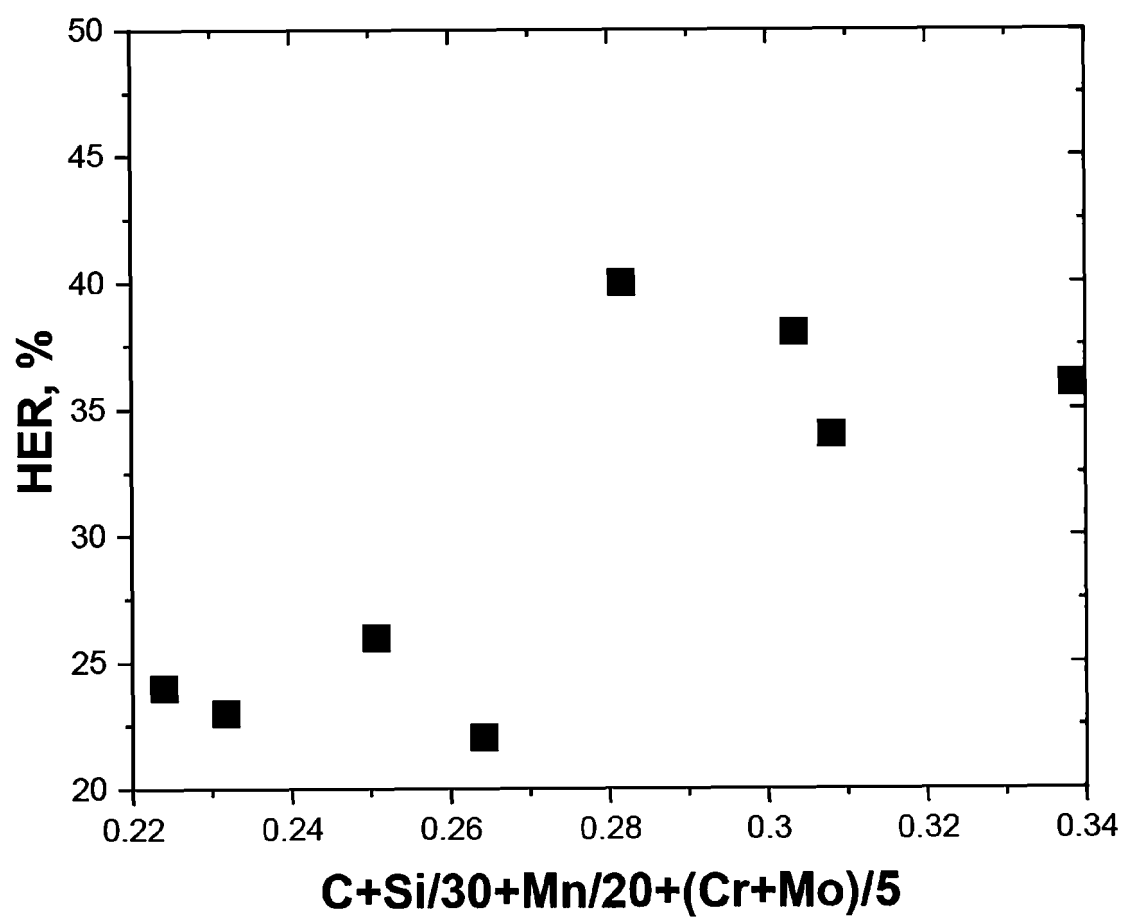
50

55

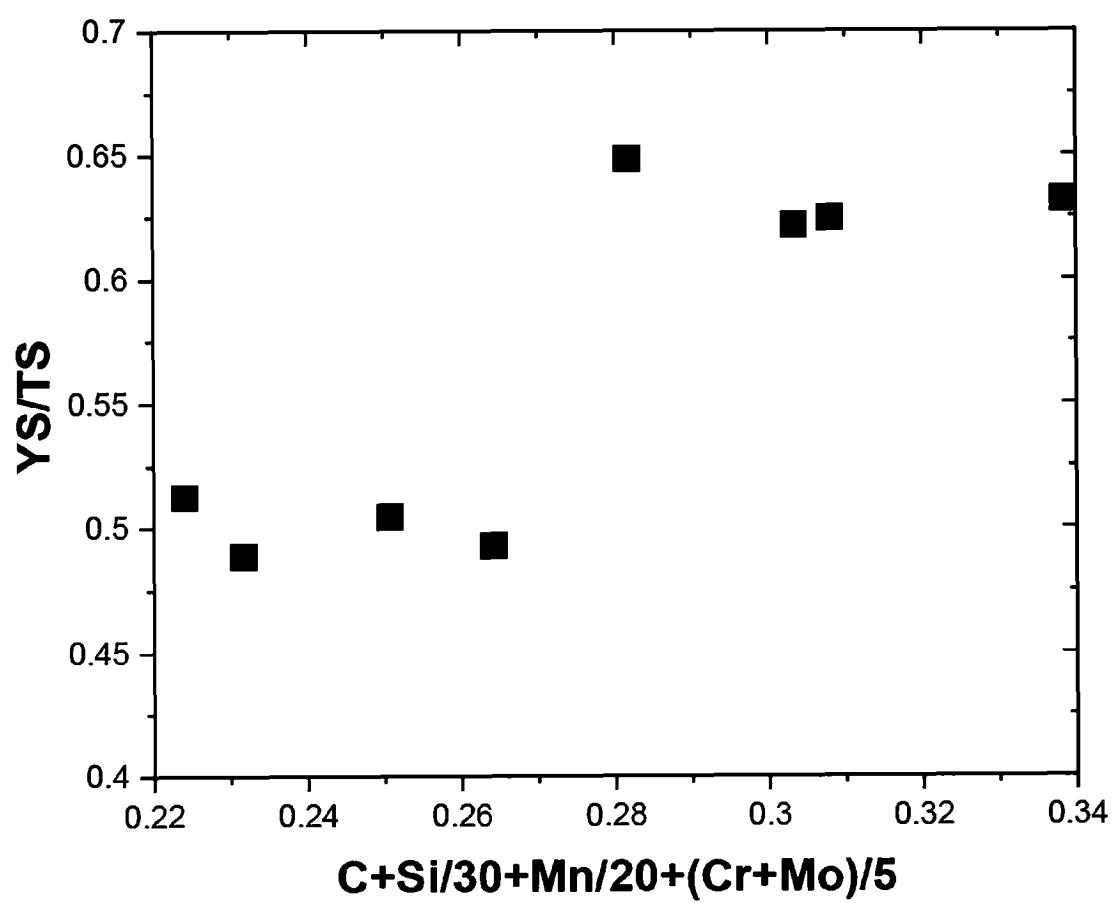
[FIG. 1]



[FIG. 2]



[FIG. 3]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019589

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/22(2006.01)i; C22C 38/28(2006.01)i; C22C 38/06(2006.01)i; C22C 38/00(2006.01)i;
C22C 38/26(2006.01)i; C22C 38/32(2006.01)i; C21D 8/02(2006.01)i; C21D 9/46(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 38/38(2006.01); C21D 8/02(2006.01); C21D 8/04(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01);
C22C 38/02(2006.01); C22C 38/60(2006.01)

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 냉연강판(cold rolling steel sheet), 템퍼드 마르텐사이트(tempered martensite)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2022-0081529 A (POSCO) 16 June 2022 (2022-06-16) See paragraph [0100] and claims 1-3 and 6.	1-6
A	KR 10-2023-0066166 A (POSCO CO., LTD.) 15 May 2023 (2023-05-15) See claims 1 and 7.	1-6
A	KR 10-2468040 B1 (POSCO) 17 November 2022 (2022-11-17) See claims 1 and 3.	1-6
A	WO 2021-200578 A1 (JFE STEEL CORPORATION) 07 October 2021 (2021-10-07) See paragraphs [0066]-[0074] and claim 1.	1-6
A	WO 2022-136683 A1 (VOESTALPINE STAHL GMBH) 30 June 2022 (2022-06-30) See claims 1 and 13-14.	1-6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search 07 March 2025	Date of mailing of the international search report 10 March 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/019589

5	Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
10	KR 10-2022-0081529 A	16 June 2022	CN 116635556 A EP 4261314 A1 JP 2023-554277 A KR 10-2490312 B1 US 2024-0026483 A1 WO 2022-124609 A1	22 August 2023 18 October 2023 27 December 2023 19 January 2023 25 January 2024 16 June 2022
15	KR 10-2023-0066166 A	15 May 2023	CN 118202081 A EP 4428262 A1 JP 2024-541988 A MX 2024005459 A WO 2023-080632 A1	14 June 2024 11 September 2024 13 November 2024 22 May 2024 11 May 2023
20	KR 10-2468040 B1	17 November 2022	KR 10-2022-0048611 A	20 April 2022
25	WO 2021-200578 A1	07 October 2021	CN 115362277 A CN 115362277 B EP 4130325 A1 JP 2022-020866 A JP 2022-023085 A JP 7001203 B1 JP 7044196 B2 KR 10-2022-0144405 A MX 2022012142 A US 12098439 B2 US 2023-0127243 A1 WO 2021-200578 A1	18 November 2022 12 March 2024 08 February 2023 01 February 2022 07 February 2022 03 February 2022 30 March 2022 26 October 2022 18 October 2022 24 September 2024 27 April 2023 07 October 2021
35	WO 2022-136683 A1	30 June 2022	CN 116806275 A CN 116829756 A CN 116867923 A CN 116917525 A EP 4267775 A1 EP 4267776 A1 EP 4267777 A1 EP 4267778 A1 KR 10-2023-0129025 A KR 10-2023-0129177 A KR 10-2023-0129178 A KR 10-2023-0129244 A SE 2051557 A1 SE 2051558 A1 SE 545209 C2 SE 545210 C2 US 2024-0060163 A1 US 2024-0117455 A1 US 2024-0132989 A1 US 2024-0229183 A9 US 2024-0229184 A1 WO 2022-136684 A1 WO 2022-136686 A1 WO 2022-136689 A1	26 September 2023 29 September 2023 10 October 2023 20 October 2023 01 November 2023 01 November 2023 01 November 2023 01 November 2023 05 September 2023 06 September 2023 06 September 2023 07 September 2023 24 June 2022 24 June 2022 23 May 2023 23 May 2023 22 February 2024 11 April 2024 25 April 2024 11 July 2024 11 July 2024 30 June 2022 30 June 2022 30 June 2022

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- KR 1020200076795 [0013]
- JP 2010090432 A [0013]
- JP 2016216808 A [0013]