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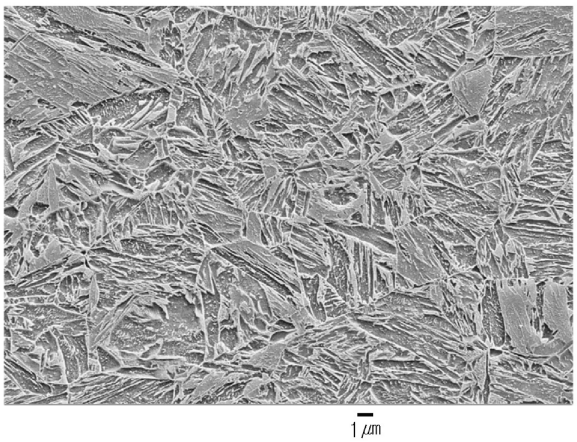
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(54) COLD-ROLLED STEEL SHEET AND METHOD FOR MANUFACTURING SAME

(57) One aspect of the present invention is to provide a cold-rolled steel sheet and a method for manufacturing same. A preferred aspect of the present invention is to provide an ultra-high strength cold-rolled steel sheet having excellent LME resistance and formability, and a method for manufacturing same.

[Fig. 1]



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a cold-rolled steel sheet and a method for manufacturing the same, and more particularly, to a cold-rolled steel sheet and a method for manufacturing the same that are advantageously applicable to automobile collision and structural members.

BACKGROUND ART

[0002] Recently, due to various environmental and energy consumption regulations, steel sheets for automobiles are required to have higher strength to improve fuel efficiency and durability. In particular, as impact safety regulations for automobiles have recently become more widespread, high-strength steel with excellent yield strength has been adopted for structural members such as members, seat rails, and pillars to enhance the impact resistance of the vehicle body. The higher the yield strength relative to the tensile strength of the structural member, that is, the higher the yield ratio (yield strength/tensile strength), the more advantageous it is for shock energy absorption. However, as the strength of the steel sheet generally increases, the elongation decreases, leading to a problem of reduced formability, and thus the development of materials that can compensate for this is required.

[0003] Typically, methods for strengthening steel include solid-solution strengthening, precipitation strengthening, strengthening by grain refinement, and transformation strengthening. However, among these methods, strengthening by solid-solution strengthening and grain refinement has the disadvantage of making it very difficult to manufacture high-strength steel with a tensile strength of 490 MPa or more.

[0004] Precipitation-strengthened high-strength steel is a technology that secures strength by adding carbide- and nitride-forming elements such as Cu, Nb, Ti, and V to precipitate carbides and nitrides to strengthen the steel sheet, or by refining grains through the suppression of grain growth by fine precipitates. This technology has the advantage of easily obtaining high strength at a low manufacturing cost, but it has the disadvantage that high-temperature annealing must be performed to secure ductility by causing sufficient recrystallization, as the recrystallization temperature rises sharply due to fine precipitates. Furthermore, it is problematic that precipitation-strengthened steel, which is strengthened by precipitating carbides and nitrides in a ferrite matrix, has difficulty achieving a high strength of 600 MPa or more.

[0005] Various types of transformation-strengthened high-strength steels have been developed, such as Dual Phase (DP) steel with a two-phase structure of ferrite-martensite, which includes hard martensite in a ferrite matrix, Transformation Induced Plasticity (TRIP) steel, which utilizes the transformation-induced plasticity of retained austenite, or Complex Phase (CP) steel, which consists of ferrite and a hard bainite or martensite structure. However, for such Advanced High Strength Steels, when the achievable tensile strength is 1500 MPa, the elongation is limited to a level of about 8%. In addition, for application as structural members to ensure crash safety, Hot Press Forming steel, which secures final strength by quenching through direct contact with a die that is water-cooled after forming at high temperature, is gaining attention, but its application has not been widely expanded due to excessive facility investment costs and high heat treatment and processing costs.

[0006] Recently, to further improve passenger safety during a collision, high-strengthening and weight reduction of vehicle seat components are being pursued simultaneously. These components are manufactured by two methods: roll forming and press forming. As a component connecting the passenger and the vehicle body, the seat component must provide support with high stress to prevent the passenger from being ejected outward during a collision. For this purpose, high yield strength and a high yield ratio are necessary. Furthermore, since most of the processed components require stretch-flangeability, the application of steel materials with excellent hole expandability is required.

[0007] Meanwhile, Patent Document 1 discloses a high-tensile-strength cold-rolled steel sheet with a tensile strength of 880-1170 MPa, controlled to have a single-phase martensite structure by optimizing the alloy composition and heat treatment conditions. Patent Document 2 discloses a method for manufacturing a high-tensile-strength steel sheet by heating and holding a steel sheet, in which the volume fraction of a low-temperature transformation phase composed of martensite and retained austenite accounts for 90% or more of the total metal structure, in a two-phase region, thereby controlling the structure to be a fine ferrite and austenite structure including laths of the low-temperature transformation phase, and then finally forming a metal structure in which ferrite and the low-temperature transformation phase are finely dispersed in a lath-like form through subsequent cooling.

[0008] However, although Patent Documents 1 and 2 claim that high yield strength can be obtained without water cooling treatment, they have disadvantages such as very low ductility or low stretch-flangeability due to the large amount of austenite generated in the steel.

[0009] Meanwhile, alloying elements added to manufacture ultra-high-strength cold-rolled steel sheets with a tensile strength of 1470 MPa or more are typically Mn, Si, Cr, B, etc. However, since these elements have a high tendency to

oxidize, they diffuse to the surface to combine with oxygen during annealing, forming surface oxides. These surface oxides, however, cause a deterioration in properties such as chemical conversion treatability and platability by reducing the surface reactivity of the steel sheet. Furthermore, as the strength of the steel material increases, there is a problem of cracking in the weld heat-affected zone due to Liquid Metal Embrittlement (LME) during spot welding.

[0010] Therefore, there is a need for the development of an ultra-high-strength cold-rolled steel sheet with excellent LME resistance and formability.

[Prior Art Document]

[0011]

(Patent Document 1) Japanese Patent Publication No. 3729108
(Patent Document 2) Japanese Patent Application Laid-Open No. 2005-272954

Disclosure of Invention

Technical Problem

[0012] An aspect of the present disclosure is to provide a cold-rolled steel sheet and a method for manufacturing the same.

[0013] A preferred aspect of the present disclosure is to provide an ultra-high-strength cold-rolled steel sheet with excellent LME resistance and formability, and a method for manufacturing the same.

Solution to Problem

[0014] An embodiment of the present disclosure provides a cold-rolled steel sheet comprising, by weight %, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Cr: 0.010-1.20%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol. Al: 0.010-0.10%, N: 0.0010-0.010%, Mo: 0.020-0.20%, B: 0.0010-0.0050%, Ti: 0.010-0.120%, and Nb: 0.010-0.050%, with the balance being Fe and other unavoidable impurities, satisfying the following Relational Expression 1, wherein the microstructure comprises, by area %, tempered martensite: 70-95% and retained austenite: 3-15%, the tempered martensite has an average minor axis size of laths of 3 μm or less, and a decarburization depth from the surface in the thickness direction is 30-100 μm.

$$2.40 \leq 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B \leq 3.0 \quad \text{[Relational Expression 1]}$$

(wherein the content of each alloying element in Relational Expression 1 is in weight %.)

[0015] The microstructure may further include one or more of fresh martensite: 10% or less and ferrite: 5% or less.

[0016] The cold-rolled steel sheet may have a microstructure in a region within 5 μm from the surface in the thickness direction, comprising, by area %, ferrite: 20-99% and a sum of one or more of fresh martensite and tempered martensite: 1-80%.

[0017] The cold-rolled steel sheet may have a yield strength of 1100 MPa or more, a tensile strength of 1470 MPa or more, an elongation of 10% or more, and a Hole Expansion Ratio (HER) of 25% or more.

[0018] Another embodiment of the present disclosure provides a method for manufacturing a cold-rolled steel sheet, the method comprising: heating a slab that comprises, by weight %, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Cr: 0.010-1.20%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol. Al: 0.010-0.10%, N: 0.0010-0.010%, Mo: 0.020-0.20%, B: 0.0010-0.0050%, Ti: 0.010-0.120%, and Nb: 0.010-0.050%, with the balance being Fe and other unavoidable impurities, and satisfies the following Relational Expression 1; finish hot rolling the heated slab to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet at 450-750°C; pickling and cold rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet; continuously annealing the cold-rolled steel sheet at 750-900°C with a dew point of 0-15°C; primarily cooling the continuously annealed cold-rolled steel sheet to 550-750°C at a cooling rate of 1-10°C/s; secondarily cooling the primarily cooled cold-rolled steel sheet to 150-320°C at a cooling rate of 5-60°C/s; and reheating and over-aging the secondarily cooled cold-rolled steel sheet at 200-400°C, wherein the following Relational Expression 2 is satisfied.

$$2.40 \leq 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B \leq 3.0 \quad \text{[Relational Expression 1]}$$

$$180 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52\text{[Relational Expression 1]} \leq 216 \quad \text{[Relational Expression 2]}$$

(wherein the content of each alloying element in Relational Expression 1 is in weight %, and in Relational Expression 2, SS denotes a continuous annealing temperature, A1 denotes an eutectoid transformation temperature, Ms denotes a martensite transformation start temperature, Tq denotes a secondary cooling finish temperature, and Tp denotes a reheating and over-aging treatment temperature, and wherein A1 = 723 - 10.7Mn - 16.9Ni + 29.1Si + 16.9Cr, and Ms = 539 - 423C - 30.4Mn - 12.1Cr - 7.5Mo.)

[0019] The slab heating may be performed at 1000-1350°C.

[0020] The finish hot rolling may be performed at Ar3-1000°C.

[0021] The cold rolling may be performed with a cold reduction ratio of 20-90%.

[0022] The method may further comprise skin pass rolling the cold-rolled steel sheet at an elongation of 0.010-1.0% after the reheating and over-aging treatment.

Advantageous Effects of Invention

[0023] According to an aspect of the present disclosure, a cold-rolled steel sheet and a method for manufacturing the same can be provided.

[0024] According to a preferred aspect of the present disclosure, it is possible to provide an ultra-high-strength cold-rolled steel sheet with excellent LME resistance and formability, and a method for manufacturing the same.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a photograph of Inventive Example 1 according to an embodiment of the present disclosure, observed using a scanning electron microscope (SEM).

Best Mode for the Invention

[0026] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. The singular forms used herein include the plural forms as well, unless the context clearly indicates otherwise. The meaning of "comprising" as used in the specification specifies the presence of stated features, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0027] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Terms defined in commonly used dictionaries are to be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0028] Hereinafter, a cold-rolled steel sheet according to an embodiment of the present disclosure will be described. First, the alloy composition of the present disclosure will be described. However, the content of the alloy composition described below means % by weight unless otherwise specified.

C: 0.10-0.30%

[0029] Carbon (C) is a very important element added to strengthen the transformation structure. C promotes high strength and the formation of martensite in transformation-structured steel. As the C content increases, the amount of martensite in the steel increases. However, if the C content exceeds 0.30%, the strength of martensite increases, but the strength difference with ferrite, which has a low carbon concentration, becomes large, and this strength difference easily causes fracture at the interphase interface when stress is applied, thereby deteriorating stretch-flangeability. In addition, weldability deteriorates, causing welding defects during component processing by customers. On the other hand, if the C content is less than 0.10%, it is very difficult to secure the strength of martensite desired in the present disclosure. Therefore, it is desirable that the C content be in the range of 0.10-0.30%.

[0030] The lower limit of the C content is more preferably 0.130%, and even more preferably 0.150%. The upper limit of the C content is more preferably 0.290%, and even more preferably 0.270%.

Si: 2.50% or less (excluding 0%)

[0031] Silicon (Si) promotes ferrite transformation and increases the carbon content in untransformed austenite, forming a composite structure of ferrite and martensite, which hinders the strength increase of martensite. In addition, in relation to surface properties, it is desirable to limit its addition as much as possible because it not only causes

surface scale defects but also deteriorates chemical conversion treatability. Accordingly, in the present disclosure, it is desirable to limit the Si content to 2.50% or less. The Si content is more preferably 2.30% or less, even more preferably 2.10% or less, and most preferably 2.0% or less. Meanwhile, although the lower limit of the Si content is not particularly limited in the present disclosure, as an example, the lower limit may be 0.0010%.

Mn: 1.0-3.0%

[0032] Manganese (Mn) is an element that refines grains without impairing ductility and strengthens the steel by completely precipitating sulfur in the steel as MnS, thereby preventing hot shortness caused by the formation of FeS. In addition, it lowers the critical cooling rate at which the martensite phase is obtained, making it easier to form martensite. If the Mn content is less than 1.0%, it may be difficult to sufficiently secure the aforementioned effects. If the Mn content exceeds 3.0%, problems such as weldability and hot rollability are likely to occur. Therefore, it is desirable that the Mn content be in the range of 1.0-3.0%. The lower limit of the Mn content is more preferably 1.20%, even more preferably 1.50%, and most preferably 1.70%. The upper limit of the Mn content is more preferably 2.90%, even more preferably 2.70%, and most preferably 2.50%.

Cr: 0.010-1.20%

[0033] Chromium (Cr) is a component added to improve the hardenability of steel and secure high strength, and it is an effective element for forming martensite, a low-temperature transformation phase. If the Cr content is less than 0.010%, it is difficult to sufficiently obtain the aforementioned effects. If the Cr content exceeds 1.20%, the effect is saturated, and cold rollability may be deteriorated as the strength of the hot-rolled steel sheet excessively increases. Therefore, it is desirable that the Cr content be in the range of 0.010-1.20%.

[0034] The lower limit of the Cr content is more preferably 0.050%, even more preferably 0.10%, and most preferably 0.30%. The upper limit of the Cr content is more preferably 1.0%, even more preferably 0.80%, and most preferably 0.70%.

P: 0.0010-0.10%

[0035] Phosphorus (P) is a substitutional alloying element with the greatest solid-solution strengthening effect, and it serves to improve in-plane anisotropy and enhance strength. If the P content is less than 0.0010%, it may be difficult to sufficiently secure the effect, and it may also cause a problem of manufacturing cost. If the P content exceeds 0.10%, press formability is deteriorated, and embrittlement of the steel may occur. Therefore, it is desirable that the P content be in the range of 0.0010-0.10%. The lower limit of the P content is more preferably 0.0050%, even more preferably 0.0080%, and most preferably 0.010%. The upper limit of the P content is more preferably 0.080%, even more preferably 0.060%, and most preferably 0.040%.

S: 0.010% or less (excluding 0%)

[0036] Sulfur (S) is an impurity element in steel that impairs the ductility and weldability of the steel sheet. If the S content exceeds 0.010%, it is highly likely to impair the ductility and weldability of the steel sheet, so in the present disclosure, it is desirable to limit the S content to 0.010% or less. The S content is more preferably 0.0050% or less, even more preferably 0.0010% or less, and most preferably 0.0009% or less.

Sol. Al: 0.010-0.10%

[0037] Soluble aluminum (Sol. Al) is an effective element not only for deoxidation by combining with oxygen in the steel but also for improving the hardenability of martensite by partitioning carbon in ferrite to austenite. If the Sol. Al content is less than 0.010%, it may be difficult to sufficiently secure the effect. If the Sol. Al content exceeds 0.10%, the effect is saturated, and the manufacturing cost may increase. Therefore, it is desirable that the Sol. Al content be in the range of 0.010-0.10%. The lower limit of the Sol. Al content is more preferably 0.0150%, and even more preferably 0.020%. The upper limit of the Sol. Al content is more preferably 0.090%, even more preferably 0.080%, and most preferably 0.070%.

N: 0.0010-0.010%

[0038] Nitrogen (N) is a component that has an effective action in stabilizing austenite. If the N content is less than 0.0010%, it is difficult to sufficiently obtain the aforementioned effect. If the N content exceeds 0.010%, the risk of

cracking during continuous casting increases significantly due to the formation of AlN and the like. Therefore, it is desirable that the N content be in the range of 0.0010-0.010%. The lower limit of the N content is more preferably 0.0020%, and even more preferably 0.0030%. The upper limit of the N content is more preferably 0.0090%, even more preferably 0.0080%, and most preferably 0.0070%.

Mo: 0.020-0.20%

[0039] Molybdenum (Mo) is an element advantageous for securing strength through improvement of hardenability and formation of Mo-based precipitates. If the Mo content is less than 0.020%, it may be difficult to sufficiently secure the effect. If the Mo content exceeds 0.20%, coarse carbides may form, which can lead to a decrease in elongation. Therefore, it is desirable that the Mo content be in the range of 0.020-0.20%. The lower limit of the Mo content is more preferably 0.030%, even more preferably 0.040%, and most preferably 0.050%. The upper limit of the Mo content is more preferably 0.190%, even more preferably 0.180%, and most preferably 0.170%.

B: 0.0010-0.0050%

[0040] Boron (B) is an element that delays the transformation of austenite to pearlite during cooling after annealing, and it is an element that suppresses ferrite formation and promotes martensite formation. If the B content is less than 0.0010%, it may be difficult to sufficiently secure the effect. If the B content exceeds 0.0050%, there may be a disadvantage of increased manufacturing costs due to excessive ferroalloy. Therefore, it is desirable that the B content be in the range of 0.0010-0.0050%. The lower limit of the B content is more preferably 0.00120%, even more preferably 0.00140%, and most preferably 0.00150%. The upper limit of the B content is more preferably 0.00450%, even more preferably 0.0040%, and most preferably 0.00350%.

Ti: 0.010-0.120%

[0041] Titanium (Ti) is an element effective for grain refinement by increasing the strength of the steel sheet and precipitating nano-precipitates through bonding with carbon. These nano-precipitates also strengthen the matrix structure, reducing the hardness difference between phases. If the Ti content is less than 0.010%, it may be difficult to sufficiently secure the effect. If the Ti content exceeds 0.120%, ductility may be deteriorated due to the formation of coarse precipitates. Therefore, it is desirable that the Ti content be in the range of 0.010-0.120%. The lower limit of the Ti content is more preferably 0.020%, and even more preferably 0.030%. The upper limit of the Ti content is more preferably 0.110%, and even more preferably 0.10%.

Nb: 0.010-0.050%

[0042] Niobium (Nb) is an element effective for grain refinement by increasing the strength of the steel sheet and precipitating nano-precipitates through bonding with carbon. These nano-precipitates also strengthen the matrix structure, reducing the hardness difference between phases. If the Nb content is less than 0.010%, it may be difficult to sufficiently secure the effect. If the Nb content exceeds 0.050%, ductility may be deteriorated due to the formation of coarse precipitates. Therefore, it is desirable that the Nb content be in the range of 0.010-0.050%. The lower limit of the Nb content is more preferably 0.0150%, and even more preferably 0.020%. The upper limit of the Nb content is more preferably 0.0450%, and even more preferably 0.040%.

[0043] The remaining component is iron (Fe). However, in a normal manufacturing process, unintended impurities from raw materials or the surrounding environment may be inevitably incorporated, so these cannot be excluded. Since these impurities are known to any person skilled in the art of the normal manufacturing process, all of their contents are not particularly mentioned in this specification.

[0044] It is desirable that the cold-rolled steel sheet of the present disclosure satisfies the aforementioned alloy composition and, at the same time, satisfies the following Relational Expression 1.

$$2.40 \leq 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B \leq 3.0 \quad \text{[Relational Expression 1]}$$

(wherein the content of each alloying element in Relational Expression 1 is in weight %.)

[0045] The Relational Expression 1 is for securing the high strength targeted in the present disclosure while also securing the Hole Expansion Ratio (HER) and elongation. If the value of Relational Expression 1 is less than 2.40, the tensile strength targeted by the present disclosure cannot be obtained. If the value of Relational Expression 1 exceeds 3.0, not only the tensile strength targeted by the present disclosure but also the elongation cannot be obtained. Therefore, it is desirable that the value of Relational Expression 1 be in the range of 2.40-3.0. The lower limit of the

value of Relational Expression 1 is more preferably 2.420, even more preferably 2.440, and most preferably 2.460. The upper limit of the value of Relational Expression 1 is more preferably 2.90, even more preferably 2.80, and most preferably 2.70.

[0046] It is desirable that the microstructure of the cold-rolled steel sheet of the present disclosure comprises, by area %, tempered martensite: 70-95% and retained austenite: 3-15%. In addition, the microstructure may further include one or more of fresh martensite: 10% or less and ferrite: 5% or less.

[0047] The tempered martensite is a structure advantageous for securing tensile strength. If the fraction of the tempered martensite is less than 70%, the tensile strength targeted by the present disclosure cannot be obtained. If the fraction of the tempered martensite exceeds 95%, the tensile strength may become excessively high. The tempered martensite may have an average minor axis size of laths of 3 μm or less (excluding 0 μm). If the average size of the tempered martensite exceeds 3 μm, it may be disadvantageous for securing formability. The retained austenite is a structure advantageous for securing elongation. If the fraction of the retained austenite is less than 3%, the elongation targeted by the present disclosure cannot be obtained. If the fraction of the retained austenite exceeds 15%, the tensile strength targeted by the present disclosure cannot be obtained. The fresh martensite is a structure disadvantageous for securing formability. If the fraction of the fresh martensite exceeds 10%, the tensile strength may become excessively high. The ferrite is a structure disadvantageous for securing formability. If the fraction of the ferrite exceeds 5%, the interphase hardness difference may be increased, thereby reducing hole expandability.

[0048] It is desirable that the cold-rolled steel sheet of the present disclosure has a decarburization depth of 30-100 μm from the surface in the thickness direction. If the decarburization depth is less than 30 μm, LME cracks may occur during welding. If the decarburization depth exceeds 100 μm, the material properties may deteriorate. Therefore, it is desirable that the decarburization depth be 30-100 μm. The lower limit of the decarburization depth is more preferably 35 μm, even more preferably 40 μm, and most preferably 50 μm. The upper limit of the decarburization depth is more preferably 90 μm, even more preferably 80 μm, and most preferably 70 μm. Meanwhile, the decarburization can be based on a reduction of 10% or more compared to the C content of the base material.

[0049] The cold-rolled steel sheet of the present disclosure may have a microstructure in a region within 5 μm from the surface in the thickness direction, comprising, by area %, ferrite: 20-99% and a sum of one or more of fresh martensite and tempered martensite: 1-80%. In the cold-rolled steel sheet of the present disclosure, the ferrite fraction in the surface layer portion is increased by the aforementioned decarburization. Accordingly, the cold-rolled steel sheet of the present disclosure may include 20-99% of ferrite in the microstructure in a region within 5 μm from the surface in the thickness direction.

[0050] The cold-rolled steel sheet of the present disclosure provided as described above may have a yield strength of 1100 MPa or more, a tensile strength of 1470 MPa or more, an elongation of 10% or more, and a Hole Expansion Ratio (HER) of 25% or more. Meanwhile, in the present disclosure, the upper limits of the yield strength, tensile strength, elongation, and hole expandability are not particularly limited, but for example, the upper limit of the yield strength may be 1470 MPa, the upper limit of the tensile strength may be 1700 MPa, the upper limit of the elongation may be 20%, and the upper limit of the hole expandability may be 40%. In addition, the cold-rolled steel sheet of the present disclosure may not generate B-type LME cracks after spot welding according to the SEP 1220-2 standard.

[0051] Hereinafter, a cold-rolled steel sheet according to an embodiment of the present disclosure will be described. First, the alloy composition of the present disclosure will be described.

[0052] First, a slab satisfying the aforementioned alloy composition and Relational Expression 1 is heated. The slab heating may be performed at 1000-1350°C. If the heating temperature of the slab is less than 1000°C, there is a possibility that it will be hot-rolled in a region below the finish hot rolling temperature range. If the heating temperature of the slab exceeds 1350°C, there is a possibility that it will reach the melting point of the steel and melt. Therefore, the slab heating may be performed at 1000-1350°C. The lower limit of the heating temperature of the slab is more preferably 1100°C, even more preferably 1130°C, and most preferably 1150°C. The upper limit of the heating temperature of the slab is more preferably 1280°C, even more preferably 1260°C, and most preferably 1250°C.

[0053] Thereafter, the heated slab is finish hot rolled to obtain a hot-rolled steel sheet. The finish hot rolling may be performed at Ar3-1000°C. If the finish hot rolling temperature is less than Ar3, the hot deformation resistance is likely to increase sharply, and problems in the manufacturing process may occur. If the finish hot rolling temperature exceeds 1000°C, not only may an excessively thick oxide scale be generated, but the microstructure of the steel sheet is also likely to become coarse. Therefore, the finish hot rolling may be performed at Ar3-1000°C. The lower limit of the finish hot rolling temperature is more preferably 800°C, even more preferably 850°C, and most preferably 870°C. The upper limit of the exit side temperature of the finishing mill during the finish hot rolling is more preferably 980°C, even more preferably 970°C, and most preferably 960°C. Meanwhile, the Ar3 can be obtained through the following [Equation 1].

$$Ar3(°C) = 910 - 203\sqrt{C} - 30Mn + 44.7Si - 11Cr + 31.5Mo - 15.2Ni \quad \text{[Equation 1]}$$

[0054] Thereafter, the hot-rolled steel sheet is coiled at 450-750°C. If the coiling temperature is less than 450°C, excessive martensite or bainite is generated, causing an excessive increase in the strength of the hot-rolled steel sheet, which may cause problems such as shape defects due to the load during cold rolling. If the coiling temperature exceeds 750°C, the pickling property may be deteriorated due to an increase in surface scale. Therefore, it is desirable that the coiling temperature be in the range of 450-750°C. The lower limit of the coiling temperature is more preferably 465°C, even more preferably 480°C, and most preferably 495°C. The upper limit of the coiling temperature is more preferably 700°C, even more preferably 650°C, and most preferably 600°C.

[0055] Thereafter, the coiled hot-rolled steel sheet is pickled and cold-rolled to obtain a cold-rolled steel sheet. In the present disclosure, the pickling and cold rolling conditions are not particularly limited, and all conditions used in the art can be used. However, as an example, the cold rolling may be performed with a cold reduction ratio of 20-90%. If the cold reduction ratio is less than 20%, it is difficult to secure the target thickness precision, and shape correction of the steel sheet may become difficult. If the cold reduction ratio exceeds 90%, cracks may occur at the edge of the steel sheet, and the cold rolling load may become excessively large in terms of productivity. Therefore, the cold reduction ratio may be 20-90%. The lower limit of the cold reduction ratio is more preferably 23%, even more preferably 25%, and most preferably 30%. The upper limit of the cold reduction ratio is more preferably 80%, even more preferably 70%, and most preferably 50%.

[0056] Thereafter, the cold-rolled steel sheet is continuously annealed at 750-900°C with a dew point of 0-15°C. If the dew point is less than 0°C, it is difficult to secure the decarburized layer depth desired in the present disclosure, and LME cracks may occur. If the dew point exceeds 15°C, the strength may be deteriorated by excessive decarburization. Therefore, it is desirable that the dew point be in the range of 0-15°C. The lower limit of the dew point is more preferably 1°C, even more preferably 2°C, and most preferably 3°C. The upper limit of the dew point is more preferably 14°C, even more preferably 13°C, and most preferably 12°C. If the continuous annealing temperature is less than 750°C, a large amount of ferrite is generated, making it difficult to secure the yield strength and tensile strength targeted by the present disclosure. If the continuous annealing temperature exceeds 900°C, the grain size of austenite increases, and the packet size of martensite formed during cooling may increase. Therefore, it is desirable that the continuous annealing temperature be in the range of 750-900°C. The lower limit of the continuous annealing temperature is more preferably 760°C, even more preferably 770°C, and most preferably 780°C. The upper limit of the continuous annealing temperature is more preferably 890°C, even more preferably 880°C, and most preferably 870°C.

[0057] Thereafter, the continuously annealed cold-rolled steel sheet is primarily cooled to 550-700°C at a cooling rate of 1-10°C/s. The primary cooling is to suppress ferrite transformation and transform most of the austenite into martensite during the secondary cooling. If the primary cooling finish temperature is less than 550°C or exceeds 700°C, productivity may be deteriorated. Therefore, it is desirable that the primary cooling finish temperature be in the range of 550-700°C. The lower limit of the primary cooling finish temperature is more preferably 575°C, and even more preferably 600°C. The upper limit of the primary cooling finish temperature is more preferably 690°C, and even more preferably 680°C. If the primary cooling rate is less than 1°C/s, a ferrite phase is formed during cooling, making it difficult to secure high strength. If the primary cooling rate exceeds 10°C/s, the amount of cooling in the secondary cooling increases, which may lead to an increase in the final temperature deviation and material property deviation. Therefore, it is desirable that the primary cooling rate be in the range of 1-10°C/s. The lower limit of the primary cooling rate is more preferably 2°C/s, even more preferably 3°C/s, and most preferably 4°C/s. The upper limit of the primary cooling rate is more preferably 8°C/s, even more preferably 7°C/s, and most preferably 6°C/s.

[0058] Thereafter, the primarily cooled cold-rolled steel sheet is secondarily cooled to 150-320°C at a cooling rate of 5-60°C/s. The secondary cooling is for securing the shape of the coil in the width and length directions, as well as for securing a high yield ratio and hole expandability. If the secondary cooling finish temperature is less than 150°C, the yield strength and tensile strength may simultaneously increase and the ductility may be severely deteriorated due to an excessive increase of martensite during the over-aging heat treatment. In particular, shape deterioration due to rapid cooling is expected, leading to workability deterioration during automobile parts processing. If the secondary cooling finish temperature exceeds 320°C, the austenite formed during annealing may not transform into martensite, and high-temperature transformation phases such as bainite and granular bainite may be formed, leading to a sharp decrease in yield strength. The occurrence of such a structure can cause a decrease in the yield ratio as well as a decrease in hole expandability. Therefore, it is desirable that the secondary cooling finish temperature be in the range of 150-320°C. The lower limit of the secondary cooling finish temperature is more preferably 170°C, even more preferably 190°C, and most preferably 200°C. The upper limit of the secondary cooling finish temperature is more preferably 310°C, even more preferably 300°C, and most preferably 290°C. If the secondary cooling rate is less than 5°C/s, a high-temperature phase such as upper bainite is mixed in during cooling, making it impossible to obtain the target tempered martensite fraction and high strength. If the secondary cooling rate exceeds 60°C/s, there may be a disadvantage that the shape of the product is thermally degraded. Therefore, it is desirable that the secondary cooling rate be in the range of 5-60°C/s. The lower limit of the secondary cooling rate is more preferably 6°C/s, even more

preferably 7°C/s, and most preferably 10°C/s. The upper limit of the secondary cooling rate is more preferably 50°C/s, even more preferably 40°C/s, and most preferably 30°C/s.

[0059] Thereafter, the secondarily cooled cold-rolled steel sheet is reheated and over-aged at 200-400°C. The reheating and over-aging treatment is for interphase carbon partitioning necessary for stabilization of retained austenite and for additional bainitic phase transformation. If the reheating and over-aging treatment temperature is less than 200°C, there may be a disadvantage that the strength becomes excessively high and the formability deteriorates. If the reheating and over-aging treatment temperature exceeds 400°C, it is difficult to obtain the strength desired in the present disclosure. Therefore, it is desirable that the reheating and over-aging treatment temperature be in the range of 200-400°C. The lower limit of the reheating and over-aging treatment temperature is more preferably 210°C, even more preferably 230°C, and most preferably 250°C. The upper limit of the reheating and over-aging treatment temperature is more preferably 390°C, even more preferably 380°C, and most preferably 370°C.

[0060] Meanwhile, it is desirable that the manufacturing method of the present disclosure satisfies the following Relational Expression 2.

$$180 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52[\text{Relational Expression 1}] \leq 216 \quad [\text{Relational Expression 2}]$$

(wherein in Relational Expression 2, SS denotes a continuous annealing temperature, A1 denotes an eutectoid transformation temperature, Ms denotes a martensite transformation start temperature, Tq denotes a secondary cooling finish temperature, and Tp denotes a reheating and over-aging treatment temperature, and wherein A1 = 723 - 10.7Mn - 16.9Ni + 29.1Si + 16.9Cr, and Ms = 539 - 423C - 30.4Mn - 12.1Cr - 7.5Mo.)

[0061] The Relational Expression 2 is for simultaneously securing strength, elongation, and hole expandability. If the value of Relational Expression 2 is less than 180, the target tensile strength cannot be obtained. If the value of Relational Expression 2 exceeds 216, the target elongation cannot be obtained. Therefore, it is desirable that the value of Relational Expression 2 be in the range of 180-216. The lower limit of the value of Relational Expression 2 is more preferably 181, even more preferably 183, and most preferably 185. The upper limit of the value of Relational Expression 2 is more preferably 215, even more preferably 210, and most preferably 208.

[0062] Meanwhile, the method may further comprise skin pass rolling the cold-rolled steel sheet at an elongation of 0.010-1.0% after the reheating and over-aging heat treatment. Typically, when a transformation-structured steel is skin pass rolled, the yield strength increases by 50 MPa or more with almost no increase in tensile strength. If the elongation is less than 0.010%, it can be very difficult to control the shape of an ultra-high-strength steel such as that of the present disclosure. If the elongation exceeds 1.0%, the operability may become very unstable due to the high elongation work.

Mode for the Invention

[0063] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are for illustrating the present disclosure in more detail and are not intended to limit the scope of rights of the present disclosure. This is because the scope of rights of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

(Examples)

[0064] A slab having the alloy composition shown in Table 1 below was heated at 1200°C for 1 hour, and then hot-rolled, coiled, pickled/cold-rolled, primarily cooled, secondarily cooled, and over-aged under the conditions shown in Table 2 below to manufacture a cold-rolled steel sheet. At this time, the reduction ratio during cold rolling was 40%. Thereafter, the cold-rolled steel sheet was skin pass rolled at an elongation of 0.2%.

[0065] The microstructure, decarburization depth, and mechanical properties of the cold-rolled steel sheet thus manufactured were measured, and the results are shown in Tables 3 and 4 below.

[0066] The type and fraction of the microstructure were measured by the Point Counting method from a photograph observed using a scanning electron microscope (SEM).

[0067] The average minor axis size of the tempered martensite laths was measured using electron backscatter diffraction (EBSD) analysis.

[0068] The decarburization depth was measured using GDS (Glow Discharge Spectrometry) equipment and SEM.

[0069] Yield strength (YS), tensile strength (TS), and elongation (El) were measured by preparing a JIS No. 5 tensile test specimen and performing a tensile test.

[0070] The hole expansion ratio (HER) was measured by punching a 10 mmØ hole (die inner diameter 10.3 mm, clearance 12.5%) and then expanding the hole by pressing a 60° conical punch at a speed of 20 mm/min with the burr of the punched hole facing outward.

$$\text{Hole Expansion Ratio (HER) (\%)} = \{(D - D0)/D0\} \times 100$$

(wherein, D: hole diameter (mm) when a crack penetrates the steel sheet, D0: initial hole diameter (mm).)

[0071] The LME property was evaluated by spot welding according to the SEP 1220-2 standard and then measuring the presence or absence of B-type LME cracks. It was rated as 'Good' if no B-type LME cracks occurred and 'Poor' if they occurred.

[Table 1]

Steel Type No.	Alloy Composition (wt%)												
	C	Si	Mn	Cr	Ti	Nb	Mo	B	Sol. Al	P	S	N	Relational Expression 1
1	0.222	1.12	2.68	0.63	0.04	0.02	0.09	0.0021	0.021	0.011	0.004	0.005	2.6
2	0.252	1.48	2.40	0.05	0.11	0.03	0.10	0.0018	0.018	0.011	0.004	0.005	2.7
3	0.311	0.38	2.69	0.53	0.05	0.04	0.12	0.0022	0.050	0.011	0.003	0.005	3.2
[Relational Expression 1] 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B													

[Table 2]

Category	Steel Type No.	Ar3 (°C)	Finish Rolling Temperature (°C)	Coiling Temperature (°C)	Continuous Annealing Temperature (SS) (°C)	Dew Point Temperature (°C)	1st Cooling Finish Temperature (°C)	1st Cooling Rate (°C/s)	2nd Cooling Finish Temperature (Tq) (°C)	2nd Cooling Rate (°C/s)	Reheating /Overaging Temperature (Tp) (°C)	Ms (°C)	Relational Expression 2
Inventive Example 1	1	780	912	512	851	5.2	612	3	204	32	299	355	182
Comparative Example 1	1	780	899	523	851	-5	632	3	204	33	299	355	182
Comparative Example 2	1	780	918	505	848	-40	711	2	201	39	348	355	120
Inventive Example 2	1	780	902	521	853	2.6	692	2	244	35	305	355	190
Comparative Example 3	1	780	923	503	856	-38	682	2	249	34	353	355	134
Inventive Example 3	2	805	915	506	851	8.6	693	2	200	38	300	358	186
Inventive Example 4	2	805	897	506	850	7.5	642	3	250	30	300	358	204
Comparative Example 4	2	805	912	543	856	5.8	662	3	247	30	411	358	69
Comparative Example 5	2	805	913	532	856	-42	632	3	247	30	411	358	69
Comparative Example 6	2	727	915	521	853	-42	672	3	150	40	300	358	168
Comparative Example 7	3	727	916	526	845	6.5	612	3	200	32	300	310	177
Comparative Example 8	3	727	918	562	845	-42	690	3	200	38	300	310	177
Comparative Example 9	3	727	906	577	852	-49	670	3	150	39	300	310	161
[Relational Expression 2] 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52[Relational Expression 1]													

[Table 3]

Category	Microstructure					Decarburization Depth (μm)	Microstructure in region within 5μm from surface in thickness direction			
	TM (area%)	Retained γ (area%)	FM (area%)	F (area%)	Average minor axis size of TM laths (μm)		TM (area %)	Retained γ (area %)	FM (area %)	F (area %)
Inventive Example 1	88	8	2	2	1.4	45	51	0	0	49
Compa rativ e Examp le 1	88	7	3	2	1.3	2	85	8	5	2
Compa rativ e Examp le 2	88	7	2	3	1.3	1	87	6	6	1
Inven tive Examp le 2	87	8	3	2	2.1	54	46	0	0	54
Compa rativ e Example 3	87	8	3	2	1.6	2	82	6	10	2
Inventive Example 3	87	8.8	3	1.2	1.2	63	37	0	0	63
Inventive Example 4	86	10.1	1.6	2.3	1.6	59	41	0	0	59
Comparative Example 4	84	11.1	1.6	3.3	3.4	62	38	0	0	62
Comparative Example 5	84	11	3	2	3.6	2	82	11.1	4.9	2
Comparative Example 6	95	2	2	1	1.1	2	95	2	1	2
Comparative Example 7	90	6	2	2	1.7	57	43	0	0	57
Compa rative Example 8	90	6	2	2	2.1	2	89	6	3	2
Comparative Example 9	91	7	1	1	1.3	1	92	6	1	1
TM: Tempered Martensite, γ: Austenite, FM: Fresh Martensite, F: Ferrite										

[Table 4]

Category	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Hole Expansion Ratio (%)	LME Property
Inventive Example 1	1152	1502	10.2	34	Good
Comparative Example 1	1182	1511	10.4	31	Poor
Comparative Example 2	1221	1432	9.8	29	Poor
Inventive Example 2	1142	1493	10.6	34	Good
Comparative Example 3	1235	1421	8.9	29	Poor
Inventive Example 3	1186	1506	11.2	36	Good
Inventive Example 4	1127	1523	11.8	32	Good
Comparative Example 4	1168	1374	12.9	38	Good
Comparative Example 5	1185	1389	12.5	36	Poor
Comparative Example 6	1285	1578	8.1	29	Poor
Comparative Example 7	1235	1512	9.8	24	Good
Comparative Example 8	1241	1532	8.9	23	Poor
Comparative Example 9	1241	1511	9.5	21	Poor

[0072] As can be seen from Tables 1 to 4, in the case of Inventive Examples 1 to 4, which satisfy the alloy composition and manufacturing conditions of the present disclosure, it can be confirmed that not only the mechanical properties but also the LME resistance are excellent by securing the target steel sheet microstructure, decarburization depth, and surface layer microstructure.

[0073] In the case of Comparative Example 1, which does not satisfy the dew point temperature, it can be seen that the LME resistance is insufficient because the target decarburization depth and surface layer microstructure are not secured.

[0074] In the case of Comparative Examples 2 and 3, which do not satisfy the dew point temperature and Relational Expression 2, it can be seen that the tensile strength and elongation are low and the LME resistance is insufficient because the target decarburization depth and surface layer microstructure are not secured.

[0075] In the case of Comparative Example 4, which does not satisfy Tp and Relational Expression 2, it can be seen that the tensile strength is low because the target average minor axis size of the TM laths is not secured.

[0076] In the case of Comparative Example 5, which does not satisfy the dew point temperature, Tp, and Relational Expression 2, it can be seen that the tensile strength is low and the LME resistance is insufficient because the target average minor axis size of the TM laths, decarburization depth, and surface layer microstructure are not secured.

[0077] In the case of Comparative Example 6, which does not satisfy the dew point temperature and Relational Expression 2, it can be seen that the elongation is low and the LME resistance is insufficient because the target steel sheet microstructure, average minor axis size of the TM laths, decarburization depth, and surface layer microstructure are not secured.

[0078] In the case of Comparative Example 7, which does not satisfy the C content, Relational Expression 1, and Relational Expression 2, it can be seen that the elongation and hole expandability are low.

[0079] In the case of Comparative Examples 8 and 9, which do not satisfy the C content, Relational Expression 1, the dew point temperature, and Relational Expression 2, it can be seen that the elongation and hole expandability are low and the LME resistance is insufficient because the decarburization depth and surface layer microstructure are not secured.

[0080] FIG. 1 is a photograph of Inventive Example 1 of the present disclosure observed using a scanning electron microscope (SEM). As can be seen from FIG. 1, it can be confirmed that Inventive Example 1 has the microstructure targeted by the present disclosure.

Claims

1. A cold-rolled steel sheet, comprising:

by weight%, C: 0.10 to 0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0 to 3.0%, Cr: 0.010 to 1.20%, P:

0.0010 to 0.10%, S: 0.010% or less (excluding 0%), Sol. Al: 0.010 to 0.10%, N: 0.0010 to 0.010%, Mo: 0.020 to 0.20%, B: 0.0010 to 0.0050%, Ti: 0.010 to 0.120%, and Nb: 0.010 to 0.050%, with a balance being Fe and other unavoidable impurities;
wherein the following Relational Expression 1 is satisfied, a microstructure comprising, by area%, tempered martensite of 70 to 95% and retained austenite of 3 to 15%;
wherein the tempered martensite has an average minor axis size of laths of 3 μm or less; and
wherein a decarburization depth from a surface in a thickness direction is 30 to 100 μm,

$$2.40 \leq 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B \leq 3.0 \quad \text{[Relational Expression 1]}$$

(wherein the content of each alloying element in Relational Expression 1 is in weight %).

2. The cold-rolled steel sheet of claim 1, wherein the microstructure further comprises at least one of fresh martensite of 10% or less and ferrite of 5% or less.

3. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a microstructure in a region within 5 μm from a surface in a thickness direction, the microstructure comprising, by area%, ferrite of 20 to 99% and a sum of at least one of fresh martensite and tempered martensite of 1 to 80%.

4. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield strength of 1100 MPa or more, a tensile strength of 1470 MPa or more, an elongation of 10% or more, and a Hole Expansion Ratio (HER) of 25% or more.

5. A method for manufacturing a cold-rolled steel sheet, the method comprising:

heating a slab that comprises, by weight%, C: 0.10 to 0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0 to 3.0%, Cr: 0.010 to 1.20%, P: 0.0010 to 0.10%, S: 0.010% or less (excluding 0%), Sol. Al: 0.010 to 0.10%, N: 0.0010 to 0.010%, Mo: 0.020 to 0.20%, B: 0.0010 to 0.0050%, Ti: 0.010 to 0.120%, and Nb: 0.010 to 0.050%, with a balance being Fe and other unavoidable impurities, and satisfies Relational Expression finish hot rolling the heated slab to obtain a hot-rolled steel sheet;
coiling the hot-rolled steel sheet at 450 to 750°C;
pickling and cold rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet;
continuously annealing the cold-rolled steel sheet at 750 to 900°C with a dew point of 0 to 15°C;
primarily cooling the continuously annealed cold-rolled steel sheet to 550 to 750°C at a cooling rate of 1 to 10°C/s;
secondarily cooling the primarily cooled cold-rolled steel sheet to 150 to 320°C at a cooling rate of 5 to 60°C/s; and
reheating and over-aging the secondarily cooled cold-rolled steel sheet at 200 to 400°C;
wherein the following Relational Expression 2 is satisfied,

$$2.40 \leq 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B \leq 3.0, \text{ and} \quad \text{[Relational Expression 1]}$$

$$180 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52[\text{Relational Expression 1}] \leq 216 \quad \text{[Relational Expression 2]}$$

(wherein, the content of each alloying element in Relational Expression 1 is in weight %, and in Relational Expression 2, SS denotes a continuous annealing temperature, A1 denotes an eutectoid transformation temperature, Ms denotes a martensite transformation start temperature, Tq denotes a secondary cooling finish temperature, and Tp denotes a reheating and over-aging treatment temperature, and wherein A1 = 723-10.7Mn-16.9Ni+29.1Si+16.9Cr, and Ms= 539-423C-30.4Mn-12.1Cr-7.5Mo).

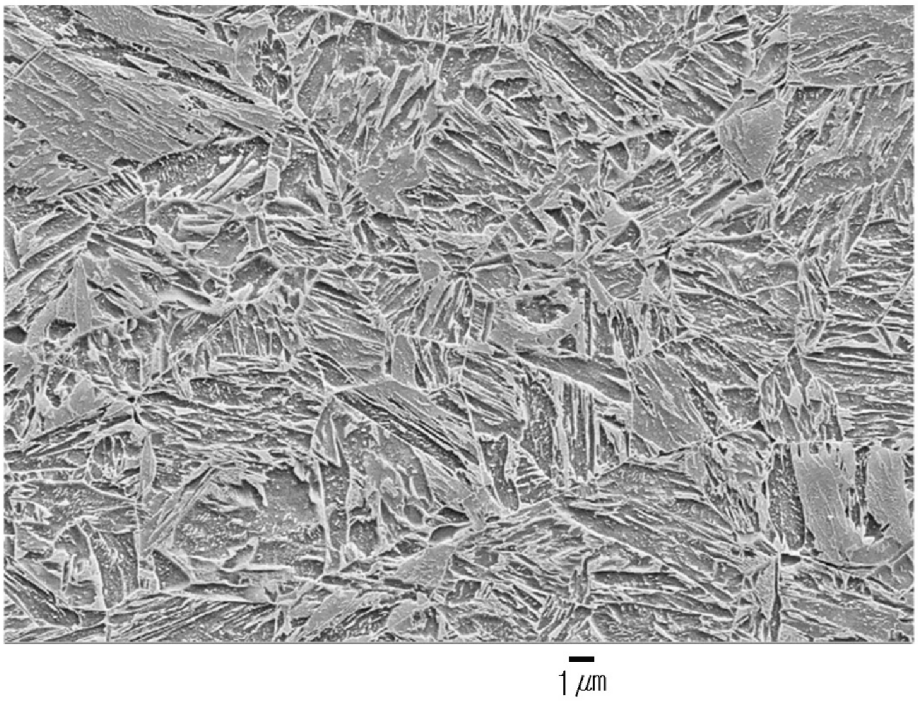
6. The method of claim 5, wherein the heating of the slab is performed at 1000 to 1350°C.

7. The method of claim 5, wherein the finish hot rolling is performed at Ar3 to 1000°C.

8. The method of claim 5, wherein the cold rolling is performed with a cold reduction ratio of 20 to 90%.

9. The method of claim 5, further comprising skin pass rolling the cold-rolled steel sheet at an elongation of 0.010 to 1.0% after the reheating and over-aging treatment.

[Fig. 1]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/020438

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/34**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/22**(2006.01)i; **C22C 38/28**(2006.01)i; **C22C 38/26**(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 38/38(2006.01); B21C 47/02(2006.01); C21D 1/18(2006.01); C21D 8/02(2006.01); C21D 8/04(2006.01); C21D 9/46(2006.01); C22C 38/04(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: 템퍼드 마르텐사이트(tempered martensite), 구멍확장성(hole expansion ratio, HER), 이슬점온도(dew point temperature), 냉각속도(cooling rate), 규소(Si), 망간(Mn)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2023-0087773 A (POSCO) 19 June 2023 (2023-06-19) See paragraphs [0137]-[0149] and [0201]-[0202], claims 1-6 and tables 2 and 3.	1-9
Y	KR 10-2023-0089785 A (POSCO) 21 June 2023 (2023-06-21) See claims 8-9 and table 2.	1-9
A	KR 10-2019-0091304 A (JFE STEEL CORPORATION) 05 August 2019 (2019-08-05) See claims 1-9.	1-9
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A	JP 05-171286 A (KOBE STEEL LTD.) 09 July 1993 (1993-07-09) See paragraphs [0025]-[0033] and claim 1.	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"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	Date of mailing of the international search report
18 March 2025	**19 March 2025**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/020438

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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