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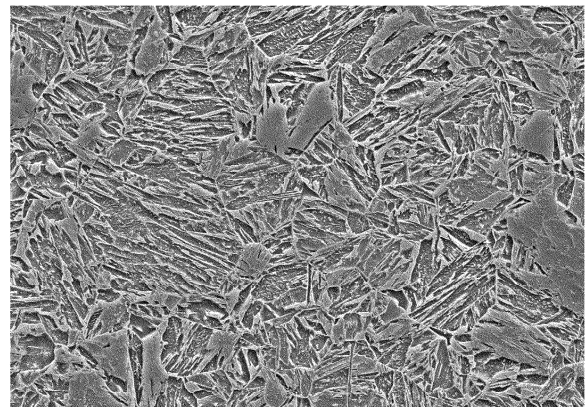
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- (71) Applicant: **POSCO Co., Ltd**
Gyeongsangbuk-do 37859 (KR)

- (72) Inventors:
• **JUNG, Ki-Taek**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **CHO, Hang-Sik**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **CHO, Won-Tae**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **SEO, Chang-Hyo**
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 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. Another aspect of the present invention is to provide an ultra high strength cold rolled steel sheet having excellent hydrogen embrittlement resistance, and a method for manufacturing same.

[Fig. 1]



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Description

Technical Field

5 **[0001]** The present disclosure relates to a cold rolled steel sheet and a method for manufacturing the same.

Background Art

10 **[0002]** Recently, due to various environmental and energy usage regulations, there is a growing demand for steel sheets having higher degrees of strength to improve fuel efficiency and durability. In particular, with the recent expansion of regulations on the impact stability of automobiles, high-strength steel with excellent yield strength is being adopted for use in structural members such as members, seat rails, pillars and the like to enhance the impact resistance of the vehicle body. Structural members have a characteristic that is advantageous for impact energy absorption capacity when the yield strength relative to tensile strength, that is, when the yield ratio (yield strength/tensile strength) is high. However, as the strength of the steel sheet generally increases, elongation decreases, leading to a problem of reduced formability, and therefore, there is a need for the development of materials that may compensate for this.

15 **[0003]** Typically, methods for strengthening steel include solid solution strengthening, precipitation strengthening, strengthening by grain refinement, transformation strengthening, and the like. However, among these methods, strengthening through solid solution strengthening and grain refinement has the disadvantage that it is very difficult to manufacture high-strength steel with a tensile strength of 490 MPa or higher.

20 **[0004]** On the other hand, precipitation-strengthened high-strength steel is a technology securing strength by strengthening steel sheets through the precipitation of carbides and nitrides by adding carbide- and nitride-forming elements such as Cu, Nb, Ti, V and the like, or by refining grains through the inhibition of grain growth by fine precipitates. This technology has the advantage of easily obtaining high strength relative to low manufacturing costs. However, it has the disadvantage that high-temperature annealing should be performed to ensure ductility by inducing sufficient recrystallization, as the recrystallization temperature rises rapidly due to fine precipitates. Furthermore, precipitation-strengthened steel, which is strengthened by precipitating carbides and nitrides in a ferrite matrix, faces the problem that it is difficult to obtain high strength of 600 MPa or higher.

25 **[0005]** Meanwhile, various types of transformation-strengthened high-strength steels have been developed, including dual-phase steels with a ferrite-martensite structure incorporating hard martensite into a ferrite matrix, Transformation Induced Plasticity (TRIP) steels utilizing transformation-induced plasticity of retained austenite, Complexed Phase (CP) steels comprised of ferrite and hard bainite or martensite structures, or the like. However, while these advanced high-strength steels may obtain high strength, the elongation limit is approximately 8% when the tensile strength reaches 1500 MPa. Furthermore, for application as structural members to ensure collision safety, Hot Press Forming steel, which secures final strength through rapid cooling via direct contact with a water-cooling die after forming at high temperatures, is gaining attention, however, application thereof has not expanded significantly due to high equipment investment costs and high heat treatment and processing costs.

30 **[0006]** Recently, to further enhance passenger safety during collisions, the high strength and lightening of vehicle seat components are being pursued simultaneously. These parts are manufactured using a roll forming method and a press forming method. Seat components are parts that connect passengers to the vehicle body and should be supported with high stress to prevent passengers from being ejected during a collision. To this end, high yield strength and yield ratio are required. Additionally, as most processed parts require stretch flangeability, the application of steel with an excellent hole expansion ratio is required.

35 **[0007]** Patent Document 1 discloses a high-strength cold rolled steel sheet having a tensile strength of 880-1170 MPa and a microstructure of a single-phase martensite structure by controlling the alloy composition and heat treatment conditions. Patent Document 2 discloses a method for manufacturing a high-strength steel sheet, in which a steel sheet in which the volume fraction of a low-temperature transformation phase such as martensite or bainite accounts for 90% or more of the total microstructure, is heated and maintained in a two-phase region to control the structure to a fine ferrite and austenite structure that inherits the laths of the low-temperature transformation phase, and subsequently, through cooling, a microstructure in which the ferrite and the low-temperature transformation phase are finely dispersed in a lath shape is obtained. These patents claim that high yield strength may be obtained through the fine dispersion of the low-temperature transformation phase, but there are disadvantages such as the difference in hardness between phases increasing due to the increase in the fraction of the low-temperature transformation phase generated by cooling after heating in the two-phase region, and in that consequently, the stretch flangeability may be reduced.

40 **[0008]** Meanwhile, as disclosed in Non-Patent Literature 1, as the steel sheet undergoes ultra-high strengthening, the likelihood of hydrogen embrittlement occurring increases. In the case in which hydrogen penetrates into the steel

sheet, the hydrogen is trapped in the austenite-ferrite interface, inclusions, retained austenite, and the like, and therefore, as the fraction thereof increases, the fraction of hydrogen concentration increases, and the likelihood of hydrogen embrittlement occurring increases. In the case of TRIP steel, retained austenite is utilized to obtain high elongation, but stability decreases as the size of the retained austenite increases, and during part forming, the retained austenite transforms into martensite or the like, and the amount of retained austenite decreases. Consequently, as hydrogen cannot be stably trapped, the hydrogen that diffuses out causes hydrogen embrittlement. In addition, as the distance between retained austenite grains becomes shorter, the content of local hydrogen trapped in the retained austenite and the hydrogen concentration increase, and consequently, the likelihood of hydrogen embrittlement occurring after strain-induced transformation into martensite increases.

[0009] Therefore, there is a need to develop a technology that may reduce the sensitivity to hydrogen embrittlement by appropriately controlling the stability of retained austenite and the distance between the retained austenite grains.

[Prior Art]

[Patent Literature]

[0010]

(Patent Literature 1) Japanese Registered Patent Publication No. 3729108

(Patent Literature 2) Japanese Patent Publication No. JP 2005-272954

[Non-Patent Literature]

[0011] (Non-Patent Literature 1) Hojo T, Kobayashi J, Kajiyama T, Sugimoto KI, Count A, "Effects of alloying elements on impact properties of ultra-high strength TRIP-aided bainitic ferrite steels", 2010, Vol. 52, pp. 9-16

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] Another aspect of the present disclosure is to provide an ultra-high strength cold rolled steel sheet having excellent hydrogen embrittlement resistance and a method for manufacturing the same.

Solution to Problem

[0014] According to an aspect of the present disclosure, a cold rolled steel sheet includes, in weight%, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Ti: 0.010-0.20%, Mo: 0.0010-0.50%, B: 0.0010-0.0050%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol.Al: 0.010-1.50%, N: 0.010% or less (excluding 0%), with a balance of Fe and unavoidable impurities, wherein a microstructure thereof includes, in area %, a sum of tempered martensite and bainite: 70-95%, retained austenite: 3-15%, fresh martensite: 10% or less (including 0%), and ferrite: 5% or less (including 0%), and satisfies the following Relationship 2,

$$\text{[Relationship 2]} \quad a/b \leq 0.30$$

[0015] (In Relationship 2, a represents an average size (μm) of the retained austenite, and b represents an average closest distance (μm) between retained austenite grains.)

[0016] The cold rolled steel sheet may further include, in weight%, one or more of Cr: 1.20% or less and Nb: 0.10% or less.

[0017] The cold rolled steel sheet may satisfy the following Relationship 1.

$$\text{[Relationship 1]} \quad 2.40 \leq X \leq 3.0$$

[0018] (In Relationship 1, X is $7C + (1.3\text{Si} + \text{Mn})/6 + (\text{Cr} + 1.2\text{Mo})/5 + 100\text{B}$ and a content of each alloying element is in weight%.)

[0019] The tempered martensite may have an average size of a lath minor axis of $3\mu\text{m}$ or less (excluding $0\mu\text{m}$).

[0020] The cold rolled steel sheet may have a tensile strength of 1470 MPa or more, an elongation of 10% or more, and a hole expansion ratio (HER) of 25% or more.

[0021] According to another aspect of the present disclosure, a method for manufacturing a cold rolled steel sheet includes an operation of heating a slab containing, in weight%, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Ti: 0.010-0.20%, Mo: 0.0010-0.50%, B: 0.0010-0.0050%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol.Al: 0.010-1.50%, N: 0.010% or less (excluding 0%), with a balance of Fe and unavoidable impurities; an operation of finishing hot-rolling the heated slab so that an exit temperature of a finishing rolling mill becomes Ar3 or higher to obtain a hot-rolled steel sheet; an operation of coiling the hot-rolled steel sheet at 450-750°C; an operation of obtaining a cold rolled steel sheet by pickling and cold-rolling the coiled hot-rolled steel sheet; an operation of continuously annealing the cold rolled steel sheet at A1-900°C; an operation of first cooling the continuously annealed cold rolled steel sheet to 550-700°C at a cooling rate of 1-10°C/s; an operation of second cooling the first-cooled cold rolled steel sheet to 150-500°C at a cooling rate of 5-100°C/s; and an operation of reheating and overaging the second-cooled cold rolled steel sheet at 150-500°C, wherein the following Relationship 3 is satisfied.

$$175 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52X \leq 216, \quad [\text{Relationship 3}]$$

[0022] (In Relationship 3, SS represents a continuous annealing temperature, A1 represents a eutectoid transformation temperature, Ms represents a martensite transformation start temperature, Tq represents a second cooling end temperature, Tp represents a reheating and overaging heat treatment temperature, $A1 = 723 - 10.7Mn - 16.9Ni + 29.1Si + 16.9Cr$, $Ms = 539 - 423C - 30.4Mn - 12.1Cr - 7.5Mo$, and X refers to $7C + (1.3Si + Mn)/6 + (Cr + 1.2Mo)/5 + 100B$.)

[0023] The slab may further include, in weight%, one or more of Cr: 1.20% or less and Nb: 0.10% or less.

[0024] The slab may satisfy the following Relationship 1.

$$[\text{Relationship 1}] \quad 2.40 \leq X \leq 3.0$$

[0025] (In Relationship 1, X is $7C + (1.3Si + Mn)/6 + (Cr + 1.2Mo)/5 + 100B$ and a content of each alloying element is in weight%.)

[0026] A heating temperature of the slab may be 1000-1350°C.

[0027] A reduction rate during the cold rolling may be 20-90%.

[0028] The method for manufacturing a cold rolled steel sheet may further include an operation of temper rolling the cold rolled steel sheet at an elongation of 0.10-1.0% after the reheating and overaging heat treatment.

Advantageous Effects of Invention

[0029] According to an aspect of the present disclosure, a cold rolled steel sheet and a method for manufacturing the same are provided.

[0030] According to another aspect of the present disclosure, an ultra-high strength cold rolled steel sheet having excellent hydrogen embrittlement resistance and a method for manufacturing the same are provided.

Brief Description of Drawings

[0031] 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

[0032] The technical terms used herein are intended merely to refer to specific embodiments and are not intended to limit the present disclosure. The singular forms used herein include plural forms unless phrases clearly indicate otherwise. The meaning of "including" as used in the specification specifies a particular characteristic, area, integer, step, operation, element, and/or component, and does not exclude the presence or addition of other particular characteristic, area, integer, step, operation, element, component, and/or group.

[0033] Unless otherwise defined, all terms used herein, including technical and scientific terms, have the same meaning as generally understood by a person of ordinary skill in the art to which the present disclosure belongs. Terms defined in commonly used dictionaries are further interpreted to have meanings consistent with relevant technical literature and the present disclosure, and are not interpreted in an ideal or highly formal sense unless otherwise defined.

[0034] Hereafter, a cold rolled steel sheet according to an embodiment of the present disclosure is described. First, the alloy composition of the present disclosure is described. However, unless otherwise noted, the content of the alloy composition described below refers to weight%.

C: 0.10-0.30%

[0035] Carbon (C) is a very important element added to strengthen the transformation structure. C promotes high strength and facilitates the formation of martensite in the transformed structure steel. As the C content increases, the amount of martensite increases. However, if the C content exceeds 0.30%, although the strength of the martensite increases, the strength difference with ferrite having a low carbon concentration becomes large. Since this strength difference easily induces fracture at the interphase interface when stress is applied, the elongation flangeability decreases. In addition, weldability decreases, leading to welding defects during part processing at the customer. On the other hand, if the C content is less than 0.10%, it is very difficult to secure the martensite strength intended in the present disclosure. Therefore, it is desirable for the C content to have a range of 0.10-0.30%. A lower limit of 0.130% for the C content is more advantageous, and 0.150% is even more advantageous. It is more advantageous for the upper limit of the C content to be 0.270%.

Si: 2.50% or less (excluding 0%)

[0036] Silicon (Si) promotes ferrite transformation and increases the carbon content in untransformed austenite, forming a complex structure of ferrite and martensite, which hinders the increase in strength of martensite. Furthermore, regarding surface characteristics, it is desirable to limit addition thereof as much as possible because it not only causes surface scale defects but also reduces chemical treatment properties. Accordingly, in the present disclosure, it is desirable to limit the Si content to 2.50% or less. It is more advantageous for the Si content to be 2.30% or less.

Mn: 1.0-3.0%

[0037] Manganese (Mn) is an element that refines grains without compromising ductility and completely precipitates sulfur in the steel as MnS to prevent hot brittleness caused by the formation of FeS and strengthen the steel. In addition, it plays a role in lowering the critical cooling rate at which the martensite phase is obtained, thereby 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%, there is a high possibility that problems such as weldability, hot rolling performance and the like will occur. Therefore, it is desirable for the Mn content to be in the range of 1.0-3.0%. A lower limit of 1.20% for the Mn content is more advantageous, 1.50% is more advantageous, and 1.70% is the most advantageous. An upper limit of 2.70% for the Mn content is more advantageous.

Ti: 0.010-0.20%

[0038] Titanium (Ti) is an element effective for increasing the strength of steel sheets and for grain refinement by precipitating nano-precipitates through bonding with carbon. These nano-precipitates also play a role in strengthening the matrix structure and 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 0.20%, there may be disadvantages such as castability being impaired due to excessive formation of TiN inclusions, and the structure uniformity being compromised due to delayed recrystallization caused by local grain fixation. Therefore, it is desirable for the Ti content to be in the range of 0.010-0.20%. Regarding the upper limit of the Ti content, 0.170% is more advantageous, 0.150% is even more advantageous, and 0.10% is the most advantageous.

Mo: 0.0010-0.50%

[0039] Molybdenum (Mo) is an element advantageous for stabilizing Fe carbides. If the Mo content is less than 0.0010%, it may be difficult to secure sufficient effects. If the Mo content exceeds 0.50%, phase transformation is suppressed, making it difficult to introduce a bainite structure, and as an expensive element, there may be a disadvantage of poor economic efficiency of the steel sheet. Therefore, it is desirable for the Mo content to be in the range of 0.0010-0.50%. The lower limit of the Mo content is more advantageous at 0.010%, even more advantageous at 0.050%, and most advantageous at 0.070%. The upper limit of the Mo content is more advantageous at 0.450%, even more advantageous at 0.40%, and most advantageous at 0.350%.

B: 0.0010-0.0050%

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

P: 0.0010-0.10%

[0041] Phosphorus (P) is a substitutional alloying element with the greatest solid solution strengthening effect, playing a role in improving in-plane anisotropy and enhancing strength. If the P content is less than 0.0010%, it may be difficult to secure sufficient effects, and it may also cause problems with manufacturing costs. If the P content exceeds 0.10%, press formability decreases, and brittleness of the steel may occur. Therefore, it is desirable for the P content to be in the range of 0.0010-0.10%. The lower limit of the P content is more advantageous at 0.0050%, even more advantageous at 0.0080%, and most advantageous at 0.010%. The upper limit of the P content is more advantageous at 0.080%, even more advantageous at 0.060%, and most advantageous at 0.040%.

S: 0.010% or less (excluding 0%)

[0042] Sulfur (S) is an impurity element in steel, which impairs the ductility and weldability of steel sheets. Since there is a high likelihood that the ductility and weldability of steel sheets will be impaired when the S content exceeds 0.010%, it is desirable in the present disclosure to limit the S content to 0.010% or less. The S content is more advantageous at 0.0050% or less, even more advantageous at 0.0010% or less, and most advantageous at 0.0009% or less.

Sol.Al: 0.010-1.50%

[0043] Soluble aluminum (Sol.Al) is an effective element that not only performs deoxidation by combining with oxygen in steel but also improves the hardenability of martensite by distributing carbon within 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 1.50%, the effect described above is not only saturated, but manufacturing costs may also increase. Therefore, it is desirable for the Sol.Al content to be in the range of 0.010-1.50%. It is more advantageous for the lower limit of the Sol.Al content to be 0.0150%, and even more advantageous to be 0.020%. The upper limit of the Sol.Al content is more advantageous at 1.30%, even more advantageous at 1.0%, and most advantageous at 0.80%.

N: 0.010% or less (excluding 0%)

[0044] Nitrogen (N) is included in steel as an impurity, and it is advantageous to control its content to be as low as possible. If the N content exceeds 0.010%, the risk of cracking during continuous casting may significantly increase due to AlN formation, or the like. Therefore, it is desirable for the N content to be in the range of 0.010% or less (excluding 0%). It is more advantageous for the N content to be 0.0080% or less, even more advantageous for 0.0050% or less, and most advantageous for 0.0030% or less.

[0045] The remaining component is iron (Fe). However, unintended impurities from raw materials or the surrounding environment may inevitably be incorporated during the ordinary manufacturing process, and thus, cannot be excluded. Since these impurities are known to any person skilled in the ordinary manufacturing process, all details thereof are not specifically mentioned in this specification.

[0046] Meanwhile, the cold rolled steel sheet of the present disclosure may additionally contain one or more of Cr: 1.20% or less and Nb: 0.10% or less by weight%.

Cr: 1.20% or less

[0047] Chromium (Cr) is a component added to improve the hardenability of steel and ensure high strength, and is an effective element for forming martensite, a low-temperature transformation phase. However, if the Cr content exceeds 1.20%, the effect is not only saturated, but cold rolling performance may decrease as the strength of the hot-rolled steel sheet increases excessively. Therefore, it is desirable for the Cr content to be in the range of 1.20% or less.

It is more advantageous for the Cr content to be 1.0% or less, even more advantageous for 0.80% or less, and most advantageous for 0.70% or less.

Nb: 0.10% or less

[0048] Niobium (Nb) is an element effective for increasing the strength of steel sheets and for grain refinement by precipitating nano-precipitates through bonding with carbon. These nano-precipitates also play a role in reducing the hardness difference between phases by strengthening the matrix structure. If the Nb content exceeds 0.10%, there may be a disadvantage in that recrystallization is delayed due to local grain fixation, thereby impairing the uniformity of the microstructure. Therefore, it is desirable for the Nb content to be in the range of 0.10% or less. The Nb content is more advantageous at 0.080% or less, even more advantageous at 0.050% or less, and most advantageous at 0.040% or less.

[0049] The cold rolled steel sheet of the present disclosure may satisfy the aforementioned alloy composition and simultaneously satisfy the following Relationship 1.

$$[\text{Relationship 1}] \quad 2.40 \leq X \leq 3.0$$

[0050] (In Relationship 1, X is $7C + (1.3Si + Mn)/6 + (Cr + 1.2Mo)/5 + 100B$ and a content of each alloying element is in weight%.)

[0051] Relationship 1 above is intended to secure the hole expansion ratio (HER) and elongation while ensuring the high strength targeted by the present disclosure. If the value of X is less than 2.40, the tensile strength targeted by the present disclosure cannot be obtained. If the value of X exceeds 3.0, neither the tensile strength nor the elongation targeted by the present disclosure can be obtained. Therefore, it is desirable for the value of X to have a range of 2.40-3.0. The lower limit of the X value is more advantageous at 2.420, even more advantageous at 2.440, and most advantageous at 2.460. The upper limit of the X value is more advantageous at 2.90, even more advantageous at 2.80, and most advantageous at 2.70.

[0052] The microstructure of the cold rolled steel sheet of the present disclosure preferably comprises, in area %, a sum of tempered martensite and bainite: 70-95%, retained austenite: 3-15%, fresh martensite: 10% or less (including 0%), and ferrite: 5% or less (including 0%).

[0053] The tempered martensite and bainite are structures advantageous for securing tensile strength. If the total fraction of the tempered martensite and bainite is less than 70%, the tensile strength targeted by the present disclosure cannot be obtained. If the total fraction of the tempered martensite and bainite exceeds 95%, the tensile strength may become excessively high. Meanwhile, an average minor axis size of the laths of the tempered martensite may be 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 ferrite fraction exceeds 5%, the hole expansion ratio may be reduced by increasing the interphase hardness difference.

[0054] The cold rolled steel sheet of the present disclosure preferably satisfies the following Relationship 2.

$$[\text{Relationship 2}] \quad a/b \leq 0.30$$

[0055] (In Relationship 2, a represents the average size (μm) of retained austenite, and b represents the average nearest-neighbor distance between retained austenite grains (μm).)

[0056] The cold rolled steel sheet of the present disclosure is an ultra-high-strength steel sheet having a tensile strength of 1470 MPa or more, and due to this high strength, the possibility of hydrogen embrittlement occurring increases. In addition, when hydrogen penetrates into the steel sheet, the hydrogen is trapped in the austenite-ferrite interface, inclusions, retained austenite, and the like, and thus as the fraction thereof increases, the fraction of hydrogen concentration increases, and the possibility of hydrogen embrittlement occurring increases. In the case of TRIP steel, retained austenite is utilized to obtain high elongation, however, stability decreases as the size of the retained austenite increases, and during part forming, the retained austenite transforms into martensite or the like, reducing the amount of retained austenite. Consequently, hydrogen is unable to be stably trapped, leading to hydrogen embrittlement caused by diffused hydrogen. Furthermore, the closer the distance between retained austenite grains, the higher the content of local hydrogen trapped within the retained austenite and the greater the hydrogen concentration, there-

by increasing the likelihood of hydrogen embrittlement occurring after strain-induced transformation into martensite. Therefore, the sensitivity to hydrogen embrittlement may be reduced by increasing the stability of the retained austenite and appropriately controlling the distance between the retained austenite grains. If the value of Relationship 2 above exceeds 0.30, the stability of the retained austenite decreases, and the nearest-neighbor distance between retained austenite grains becomes close, which may lead to increased local hydrogen content and hydrogen concentration, potentially resulting in hydrogen embrittlement. Meanwhile, a and b mentioned in Relationship 2 may each be measured using the average size and average distance of the 10 nearest retained austenite grains, starting from one arbitrary retained austenite grain. Additionally, the nearest-neighbor distance between the retained austenite grains may refer to the distance between the centers of the austenite grains. However, for ease of measuring the average size and average distance, a minimum size of the retained austenite to be measured may be 0.2 μm .

[0057] As described above, the cold rolled steel sheet of the present disclosure may have 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 tensile strength, elongation, and hole expansion ratio are not particularly limited, but for example, 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 expansion ratio may be 40%. Furthermore, the cold rolled steel sheet of the present disclosure does not crack or fracture within 96 hours when a load is applied according to ASTM G39 standards and it is immersed in a 0.1 N HCl solution, thereby exhibiting excellent hydrogen embrittlement resistance.

[0058] Hereinafter, a cold rolled steel sheet according to an embodiment of the present disclosure will be described. First, the alloy composition in the present disclosure will be described.

[0059] First, a slab satisfying the aforementioned alloy composition and Relationship 1 is heated. The heating temperature of the slab may be 1000-1350°C. If the heating temperature of the slab is less than 1000°C, there is a possibility that it may be hot-rolled in a region below the finishing 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 steel and melt. Therefore, the heating temperature of the slab may be 1000-1350°C. Regarding the lower limit of the heating temperature of the slab, 1100°C is more advantageous, 1130°C is even more advantageous, and 1150°C is most advantageous. Regarding the upper limit of the heating temperature of the slab, 1280°C is more advantageous, 1260°C is even more advantageous, and 1250°C is most advantageous.

[0060] Subsequently, the heated slab is finish hot-rolled to obtain a hot-rolled steel sheet such that the exit temperature of the finishing rolling mill is Ar3 or higher. If the exit temperature of the finishing rolling mill during the finishing hot-rolling is lower than Ar3, there is a high possibility that the resistance to hot deformation will increase rapidly. Additionally, after coiling, the top, tail, and edges of the hot-rolled coil may become single-phase regions, increasing in-plane anisotropy and reducing formability. Therefore, it is desirable that the exit temperature of the finishing rolling mill during the finishing hot-rolling be Ar3 or higher. Regarding the lower limit of the exit temperature of the finishing rolling mill during the finishing hot-rolling, 800°C is more advantageous, 850°C is even more advantageous, and 870°C is most advantageous. Meanwhile, in the present disclosure, the upper limit of the exit temperature of the finishing rolling mill during the finishing hot-rolling is not particularly limited. However, as an example, the exit temperature of the finishing rolling mill during the finishing hot-rolling may be 1000°C or lower. The upper limit of the exit temperature of the finishing rolling mill during the finishing hot-rolling is more advantageous at 980°C, even more advantageous at 970°C, and most advantageous at 960°C. Meanwhile, the Ar3 may be calculated using the following [Equation 1].

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

[0061] Subsequently, the hot-rolled steel sheet is coiled at 450-750°C. If the coiling temperature is lower than 450°C, excessive martensite or bainite is formed, leading to 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, pickling performance may be reduced due to an increase in surface scale. Therefore, it is desirable for the coiling temperature to be in the range of 450-750°C. The lower limit of the coiling temperature is more advantageous at 465°C, even more advantageous at 480°C, and most advantageous at 500°C. The upper limit of the coiling temperature is more advantageous at 700°C, even more advantageous at 650°C, and most advantageous at 600°C.

[0062] Subsequently, the coiled hot-rolled steel sheet is pickled and cold rolled to obtain a cold rolled steel sheet. The present disclosure does not specifically limit the conditions for the pickling and cold-rolling, and any conditions used in the relevant technical field may be used. However, as an example, a reduction rate during cold rolling may be 20-90%. If the cold reduction rate is less than 20%, it may be difficult to secure the target thickness precision, and it may also be difficult to correct the shape of the steel sheet. If the cold reduction rate exceeds 90%, cracks may occur at the edges of the steel sheet, and the cold-rolling load may become excessively large in terms of productivity. Therefore, the cold reduction rate may be 20-90%. The lower limit of the cold reduction rate is more advantageous at

23%, even more advantageous at 25%, and most advantageous at 30%. The upper limit of the cold reduction rate is more advantageous at 80%, even more advantageous at 70%, and most advantageous at 50%.

[0063] Subsequently, the cold rolled steel sheet is continuously annealed at A1-900°C. If the continuous annealing temperature is below A1, a large amount of ferrite is generated, making it difficult to obtain the yield strength and tensile strength intended in the present disclosure. If the continuous annealing temperature exceeds 900°C, the grain size of austenite increases, and the packet size of martensite formed upon cooling increases, making it difficult to obtain a fine grain size. Therefore, it is desirable for the continuous annealing temperature to have a range of A1-900°C. The lower limit of the continuous annealing temperature is more advantageous at 790°C, even more advantageous at 800°C, and most advantageous at 820°C. The upper limit of the continuous annealing temperature is more advantageous at 890°C, even more advantageous at 880°C, and most advantageous at 870°C.

[0064] Subsequently, the continuously annealed cold rolled steel sheet is first cooled to 550-700°C at a cooling rate of 1-10°C/s. The first cooling is intended to suppress ferrite transformation such that most of the austenite transforms into martensite during second cooling. If the first cooling end temperature is below 550°C or exceeds 700°C, productivity may decrease. Therefore, it is desirable for the first cooling end temperature to be in the range of 550-700°C. The lower limit of the first cooling end temperature is more advantageous at 570°C, even more advantageous at 590°C, and most advantageous at 610°C. The upper limit of the first cooling end temperature is more advantageous at 680°C, even more advantageous at 670°C, and most advantageous at 650°C. If the first cooling rate is less than 1°C/s, a ferrite phase is formed during cooling, making it difficult to secure high strength. If the first cooling rate exceeds 10°C/s, the amount of cooling in the second cooling increases, which may have the disadvantage of increasing the final temperature deviation and material deviation. Therefore, it is desirable for the first cooling rate to be in the range of 1-10°C/s. The lower limit of the first cooling rate is more advantageous at 2°C/s, even more advantageous at 3°C/s, and most advantageous at 4°C/s. The upper limit of the first cooling rate is more advantageous at 8°C/s, even more advantageous at 7°C/s, and most advantageous at 6°C/s.

[0065] Subsequently, the first cooled cold rolled steel sheet is subjected to second cooling to 150-500°C at a cooling rate of 5-100°C/s. This second cooling is intended to secure the shape of the coil in both the width and length directions, as well as to ensure a high yield ratio and hole expansion ratio. If the second cooling end temperature is below 150°C, the yield strength and tensile strength may increase simultaneously and ductility may significantly decrease due to an excessive increase in the amount of martensite during over-aging heat treatment. In particular, shape deterioration caused by rapid cooling is expected to result in reduced workability during the machining of automotive parts. If the second cooling end temperature exceeds 500°C, the austenite generated during annealing fails to transform into martensite, and bainite, granular bainite and the like, which are high-temperature transformation phases, are formed, thereby leading to a rapid decrease in yield strength. The occurrence of such a structure may cause a decrease in the hole expansion ratio along with a decrease in the yield ratio. Therefore, it is desirable for the second cooling end temperature to have a range of 150-500°C. The lower limit of the second cooling end temperature is more advantageous at 170°C, even more advantageous at 190°C, and most advantageous at 200°C. The upper limit of the second cooling end temperature is more advantageous at 480°C, even more advantageous at 450°C, and most advantageous at 430°C. If the second cooling rate is less than 5°C/s, high-temperature phases such as upper bainite are incorporated during cooling, and thus the target tempered martensite fraction and high strength may not be obtained. Meanwhile, although the present disclosure does not specifically limit the upper limit of the second cooling rate, it is difficult to exceed 100°C/s due to equipment or process limitations. Therefore, it is desirable for the second cooling rate to have a range of 5-100°C/s. The lower limit of the second cooling rate is more advantageous at 6°C/s, even more advantageous at 7°C/s, and most advantageous at 10°C/s. The upper limit of the second cooling rate is more advantageous at 50°C/s, even more advantageous at 30°C/s, and most advantageous at 20°C/s.

[0066] Subsequently, the second cooled cold rolled steel sheet is reheated and overaged at 150-500°C. The reheating and overaging heat treatment is intended for interphase carbon distribution and additional bainite phase transformation necessary for the stabilization of retained austenite. If the reheating and overaging heat treatment temperature is less than 150°C, there may be disadvantages such as excessively high strength and poor formability. If the reheating and overaging heat treatment temperature exceeds 500°C, it is difficult to obtain the strength intended in the present disclosure. Therefore, it is desirable for the reheating and overaging heat treatment temperature to have a range of 150-500°C. The lower limit of the reheating and overaging heat treatment temperature is more advantageous at 170°C, even more advantageous at 190°C, and most advantageous at 200°C. The upper limit of the reheating and overaging heat treatment temperature is more advantageous at 480°C, even more advantageous at 460°C, and most advantageous at 450°C.

[0067] A manufacturing method in the present disclosure preferably satisfies Relationship 3 below.

$$175 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52X \leq 216$$

[Relationship 3]

[0068] (In Relationship 3, SS represents the continuous annealing temperature, A1 represents the eutectoid transformation temperature, Ms represents the martensite transformation start temperature, Tq represents the second cooling end temperature, Tp represents the reheating and overaging heat treatment temperature, $A1 = 723 - 10.7\text{Mn} - 16.9\text{Ni} + 29.1\text{Si} + 16.9\text{Cr}$, $Ms = 539 - 423\text{C} - 30.4\text{Mn} - 12.1\text{Cr} - 7.5\text{Mo}$, and X refers to $7\text{C} + (1.3\text{Si} + \text{Mn})/6 + (\text{Cr} + 1.2\text{Mo})/5 + 100\text{B}$)

[0069] Relationship 3 is intended to simultaneously secure strength, elongation, and hole expansion ratio. If the value of Relationship 3 is less than 175, the target tensile strength cannot be obtained. If the value of Relationship 3 exceeds 216, the target elongation cannot be obtained. Therefore, it is desirable for the value of Relationship 3 to be in the range of 175-216. Regarding the lower limit of the value of Relationship 3, 176 is more advantageous, 177 is even more advantageous, and 180 is the most advantageous. Regarding the upper limit of the value of Relationship 3, 215 is more advantageous, 210 is even more advantageous, and 208 is the most advantageous.

[0070] Meanwhile, after the overaging heat treatment, an additional operation of temper rolling the cold rolled steel sheet to an elongation of 0.10-1.0% may be included. Typically, when temper rolling a transformed structure steel, an increase in yield strength of 50 MPa or more occurs with almost no increase in tensile strength. If the elongation during temper rolling is less than 0.10%, shape control may become very difficult in ultra-high strength steels as in the present disclosure. If the elongation during temper rolling exceeds 1.0%, workability may become significantly unstable due to high elongation operations.

Mode for the Invention

[0071] Hereinafter, the present disclosure is to be explained in more detail through the following examples. However, it should be noted that the following examples are intended merely to illustrate and explain the present disclosure in more detail, and are not intended to limit the scope of the rights of the present disclosure. This is because the scope of the rights of the present disclosure is determined by the matters described in the patent claims and matters reasonably inferred therefrom.

(Example)

[0072] A cold rolled steel sheet was manufactured by heating a slab having the alloy composition described in Table 1 below at 1200°C for 1 hour, and then performing hot rolling, coiling, pickling/cold rolling, first cooling, second cooling, and overaging heat treatment using the conditions described in Table 2 below. At this time, the reduction rate during cold rolling was 40%. Subsequently, the cold rolled steel sheet was temper-rolled with an elongation of 0.2%.

[0073] The microstructure and mechanical properties of the cold rolled steel sheet manufactured in this manner were measured, and the results are shown in Table 3 below.

[0074] The types and fractions of the microstructure were measured using the point counting method based on an image observed with a Scanning Electron Microscope (SEM), and in particular, the fraction of retained austenite was measured using X-ray Diffraction (XRD).

[0075] The average size and distance of retained austenite, and the average size of the lath minor axis of tempered martensite, were measured using electron backscatter diffraction pattern analysis (EBSD). At this time, the average size and average distance of retained austenite were determined by starting from one arbitrary retained austenite grain and measuring the average value for the 10 nearest retained austenite grains therefrom. At this time, the nearest-neighbor distance between the retained austenite grains is a distance between the centers of the austenite grains, and the measurement target of the retained austenite had a minimum size of 0.2 μm.

[0076] Yield strength (YS), tensile strength (TS), and elongation (EI) were measured by fabricating JIS No. 5 tensile specimens and then performing tensile tests.

[0077] The hole expansion ratio (HER) was measured by forming a 10 mmØ punched hole (die inner diameter 10.3 mm, clearance 12.5%) by applying a conical punch with a 60° apex angle to the punched hole at a pressure of 20 mm/min in a direction where the burr of the punched hole faces outward.

$$\text{Hole Expansion Ratio (HER) (\%)} = \{(D - D_0)/D_0\} \times 100$$

[0078] (Where D: hole diameter (mm) when the crack penetrates the steel plate, D0: Initial hole diameter (mm).)

[0079] Hydrogen embrittlement resistance was evaluated by applying a load according to ASTM G39 standards, immersing the sample in a 0.1 N HCl solution, and then measuring the presence or absence of cracks after 96 hours. It was evaluated as poor if cracks occurred and good if no cracks occurred.

[Table 1]

Steel Grade No.	Alloy Composition (weight%)												
	C	Si	Mn	Cr	Ti	Nb	Mo	B	Sol. Al	P	S	N	X
1	0.245	0.61	2.48	0.32	0.015	0.040	0.048	0.0014	0.021	0.009	0.003	0.004	2.48
2	0.222	1.12	2.68	0.63	0.10	40.05	0.090	0.0021	0.021	0.011	0.004	0.005	2.60
3	0.252	1.48	2.40	0.05	20.00	0.020	0.100	0.0018	0.018	0.011	0.004	0.005	2.70
4	0.331	0.38	2.69	0.53	0.017	0.050	0.120	0.0022	0.025	0.011	0.003	0.005	3.20
5	0.180	0.65	2.45	0.21	0.022	0.001	0.07	0.0017	0.025	0.012	0.003	0.005	2.04
6	0.345	1.95	2.43	0.03	0.016	0.043	0.001	0	0.025	0.011	0.004	0.005	3.25
X = 7C + (1.3Si+Mn)/6 + (Cr+1.2Mo)/5 + 100B													

[Table 2]

Classification	Steel Grade No.	Ar3 (°C)	Finishing Rolling Mill Exit Temperature (°C)	Coiling Temperature (°C)	A1 (°C)	Continuous Annealing Temperature (SS) (°C)	First Cooling End Temperature (°C)	First Cooling Rate (°C/s)	Second Cooling End Temperature (Tq) (°C)	Second Cooling Rate (°C/s)	Reheating / Over aging Heat Treatment Temperature (Tp)(°C)	Ms (°C)	Relationship 3
Inventive Example 1	1	760	903	521	720	851	611	4.5	202	41.2	279	356	205
Inventive Example 2	1	760	924	518	720	849	601	4.6	201	40.3	302	356	176
Comparative Example 1	1	760	911	504	720	852	626	4.2	212	41.7	358	356	113
Comparative Example 2	1	760	887	506	720	853	630	4.1	198	43.5	413	356	41
Inventive Example 3	1	760	876	513	720	846	658	3.5	247	41.4	302	356	192
Comparative Example 3	1	760	916	509	720	850	646	3.8	250	39.9	358	356	126
Comparative Example 4	1	760	914	511	720	853	618	4.4	156	46.6	253	356	221
Comparative Example 5	1	760	901	517	720	853	622	4.3	149	47.7	349	356	101
Inventive Example 4	2	780	910	520	738	851	636	4.0	204	43.5	299	355	182
Inventive Example 5	2	780	900	534	738	853	639	4.0	244	39.8	305	355	190
Comparative Example 6	2	780	921	559	738	856	628	4.2	249	38.2	353	355	134
Inventive Example 6	3	805	889	522	741	851	608	4.5	200	41.1	300	358	186
Inventive Example 7	3	805	906	573	741	850	640	3.9	250	39.3	300	358	204

(continued)

Classification	Steel Grade No.	Ar3 (°C)	Finishing Rolling Mill Exit Temperature (°C)	Coiling Temperature (°C)	A1 (°C)	Continuous Annealing Temperature (SS) (°C)	First Cooling End Temperature (°C)	First Cooling Rate (°C/s)	Second Cooling End Temperature (Tq) (°C)	Second Cooling Rate (°C/s)	Reheating / Over aging Heat Treatment Temperature (Tp)(°C)	Ms (°C)	Relationship 3
Inventive Example 8	3	805	891	545	741	847	601	4.6	248	35.6	315	358	184
Comparative Example 7	3	805	917	575	741	856	647	3.9	247	40.3	411	358	69
Comparative Example 8	3	805	906	508	741	853	635	4.1	150	48.9	312	358	161
Comparative Example 9	4	727	894	512	714	845	628	4.0	200	43.1	300	310	177
Comparative Example 10	5	779	886	529	719	857	645	3.9	200	44.8	350	385	59
Comparative Example 11	6	805	893	551	754	847	628	4.1	250	38.1	300	319	199
Comparative Example 12	6	805	916	528	754	852	619	4.3	150	47.3	300	319	163
Comparative Example 13	6	805	893	507	754	853	628	4.2	195	43.6	307	319	234
Comparative Example 14	6	805	902	524	754	873	646	4.2	202	44.7	394	319	70
[Relationship 3] $0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52$ [Relationship 1]													

[Table 3]

Classification	Microstructure							Mechanical Properties				
	TM+B (area %)	Retained γ (area %)	FM (area %)	TM Lath minor-Axis Average Size (μm)	a (μm)	b (μm)	a/b	YS (MPa)	TS (MPa)	EI (%)	HE R (%)	Hydrogen Embrittlement Resistance
Inventive Example 1	92.4	4.3	3.3	0.17	0.34	2.7	0.13	1141	1531	103	32	Good
Inventive Example 2	94.3	3.1	2.6	0.46	0.34	3.3	0.10	1192	1493	10.6	35	Good
Comparative Example 1	92.1	5.8	2.1	0.66	0.31	0.94	0.33	1221	1421	9.7	38	Poor
Comparative Example 2 Examp	90.6	7.2	2.2	0.25	0.37	1.19	0.31	1221	1348	12.3	34	Poor
Inventive Example 3	94.2	3.6	2.2	0.41	0.27	1.50	0.18	1151	1510	10.7	34	Good
Comparative Example 3	90.1	7.3	2.6	0.53	0.53	1.71	0.31	1211	1434	10.6	29	Poor
Comparative Example 4	89.8	4.9	5.3	0.62	0.25	0.57	0.44	1224	1524	8.0	26	Poor
Comparative Example 5	91.5	6.5	2.0	0.33	0.41	1.17	0.35	1283	1435	8.2	36	Poor
Inventive Example 4	95.0	3.9	1.1	0.26	0.20	1.05	0.19	1182	1511	10.4	31	Good
Inventive Example 5	94.5	3.4	2.1	0.45	0.44	2.66	0.17	1142	1493	10.6	34	Good
Comparative Example 6	91.1	8.0	0.9	0.22	0.34	1.10	0.31	1235	1421	8.9	29	Poor
Inventive Example 6	94.3	4.1	1.6	0.19	0.27	1.33	0.20	1186	1506	11.2	36	Good
Inventive Example 7	93.7	3.7	2.6	0.46	0.44	6.93	0.06	1127	1523	11.8	32	Good
Inventive Example 8	93.4	4.9	1.7	0.33	0.24	2.73	0.09	1154	1501	11.1	29	Good
Comparative Example 7	92.9	5.7	1.4	0.27	0.37	1.17	0.32	1185	1389	12.5	36	Poor
Comparative Example 8	92.5	4.5	3.0	0.34	0.31	0.90	0.34	1285	1578	8.1	29	Poor
Comparative Example 9	93.4	5.3	1.3	0.84	0.33	0.78	0.42	1241	1532	8.9	23	Poor
Comparative Example 10	90.7	6.6	2.7	0.59	0.35	1.13	0.31	1282	1455	9.5	32	Poor
Comparative Example 11	79.6	14.9	5.5	0.54	0.81	2.61	0.31	1185	1532	9.6	28	Poor
Comparative Example 12	80.4	16.8	2.8	0.79	0.36	1.05	0.34	1221	1511	9.5	21	Poor
ComparativeExample 13	79.6	15.5	4.9	0.66	0.94	2.94	0.32	1052	1435	11.2	36	Poor
ComparativeExample 14	79.2	15.4	5.4	0.87	0.93	2.06	0.45	1180	1539	17.1	9.9	Poor

TM: Tempered Martensite, B: Bainite, γ : Austenite, FM: Fresh Martensite, F: Ferrite, a: Average size of retained γ , b: nearest neighbor distance between retained γ s

TM: Tempered Martensite, B: Bainite, γ : Austenite, FM: Fresh Martensite, F: Ferrite, a: Average size of retained γ , b is nearest neighbor distance between retained γ s

[0080] As can be seen from Tables 1 to 3, in the case of Inventive Examples 1 to 8, which satisfy the conditions proposed by the present disclosure, the hydrogen embrittlement resistance is not only good, but other mechanical properties are also excellent.

[0081] On the other hand, in the case of Comparative Examples 1 to 14, which do not satisfy the conditions proposed by the present disclosure, the hydrogen embrittlement resistance is not only poor, but other mechanical properties are also at a low level.

[0082] FIG. 1 is an image 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 a microstructure formed that is the target of the present disclosure.

Claims

1. A cold rolled steel sheet comprising:

in weight%, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Ti: 0.010-0.20%, Mo: 0.0010-0.50%, B: 0.0010-0.0050%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol.Al: 0.010-1.50%, N: 0.010% or less (excluding 0%), with a balance of Fe and unavoidable impurities, and a microstructure,

wherein the microstructure comprises, in area %, a sum of tempered martensite and bainite: 70-95%, retained austenite: 3-15%, fresh martensite: 10% or less (including 0%), and ferrite: 5% or less (including 0%), and the microstructure satisfies the following Relationship 2,

$$[\text{Relationship 2}] \quad a/b \leq 0.30,$$

wherein in Relationship 2, a represents an average size (μm) of the retained austenite, and b represents an average nearest-neighbor distance (μm) between retained austenite grains.

2. The cold rolled steel sheet of claim 1, wherein the cold rolled steel sheet further comprises, in weight%, one or more of Cr: 1.20% or less and Nb: 0.10% or less.

3. The cold rolled steel sheet of claim 1, wherein the cold rolled steel sheet satisfies the following Relationship 1,

$$[\text{Relationship 1}] \quad 2.40 \leq X \leq 3.0$$

wherein in Relationship 1, X is $7C + (1.3\text{Si} + \text{Mn})/6 + (\text{Cr} + 1.2\text{Mo})/5 + 100\text{B}$ and a content of each alloying element is in weight%.

4. The cold rolled steel sheet of claim 1, wherein the tempered martensite has an average size of a lath minor axis of $3\mu\text{m}$ or less (excluding $0\mu\text{m}$).

5. The cold rolled steel sheet of claim 1, wherein the cold rolled steel sheet has a tensile strength of 1470 MPa or more, an elongation of 10% or more, and a hole expansion ratio (HER) of 25% or more.

6. A method for manufacturing a cold rolled steel sheet, comprising:

an operation of heating a slab containing, in weight%, C: 0.10-0.30%, Si: 2.50% or less (excluding 0%), Mn: 1.0-3.0%, Ti: 0.010-0.20%, Mo: 0.0010-0.50%, B: 0.0010-0.0050%, P: 0.0010-0.10%, S: 0.010% or less (excluding 0%), Sol.Al: 0.010-1.50%, N: 0.010% or less (excluding 0%), with a balance of Fe and unavoidable impurities;

an operation of finishing hot-rolling the heated slab so that an exit temperature of a finishing rolling mill becomes Ar3 or higher to obtain a hot-rolled steel sheet;

an operation of coiling the hot-rolled steel sheet at 450-750°C;

an operation of obtaining a cold rolled steel sheet by pickling and cold-rolling the coiled hot-rolled steel sheet;

an operation of continuously annealing the cold rolled steel sheet at A1-900°C;

an operation of first cooling the continuously annealed cold rolled steel sheet to 550-700°C at a cooling rate of 1-10°C/s;

an operation of second cooling the first-cooled cold rolled steel sheet to 150-500°C at a cooling rate of 5-100°C/s; and
an operation of reheating and overaging the second-cooled cold rolled steel sheet at 150-500°C,
wherein the following Relationship 3 is satisfied,

$$175 \leq 0.3(SS-A1) + 0.85(Ms-Tq) - 1.22(Tp-Tq) + 52X \leq 216, \quad [\text{Relationship 3}]$$

wherein in Relationship 3, SS represents a continuous annealing temperature, A1 represents a eutectoid transformation temperature, Ms represents a martensite transformation start temperature, Tq represents a second cooling end temperature, Tp represents a reheating and overaging heat treatment temperature, $A1 = 723 - 10.7Mn - 16.9Ni + 29.1Si + 16.9Cr$, $Ms = 539 - 423C - 30.4Mn - 12.1Cr - 7.5Mo$, and $X = 7C + (1.3Si + Mn)/6 + (Cr + 1.2Mo)/5 + 100B$.

7. The method for manufacturing a cold rolled steel sheet of claim 6, wherein the slab further comprises, in weight%, one or more of Cr: 1.20% or less and Nb: 0.10% or less.

8. The method for manufacturing a cold rolled steel sheet of claim 6, wherein the slab satisfies the following Relationship 1,

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

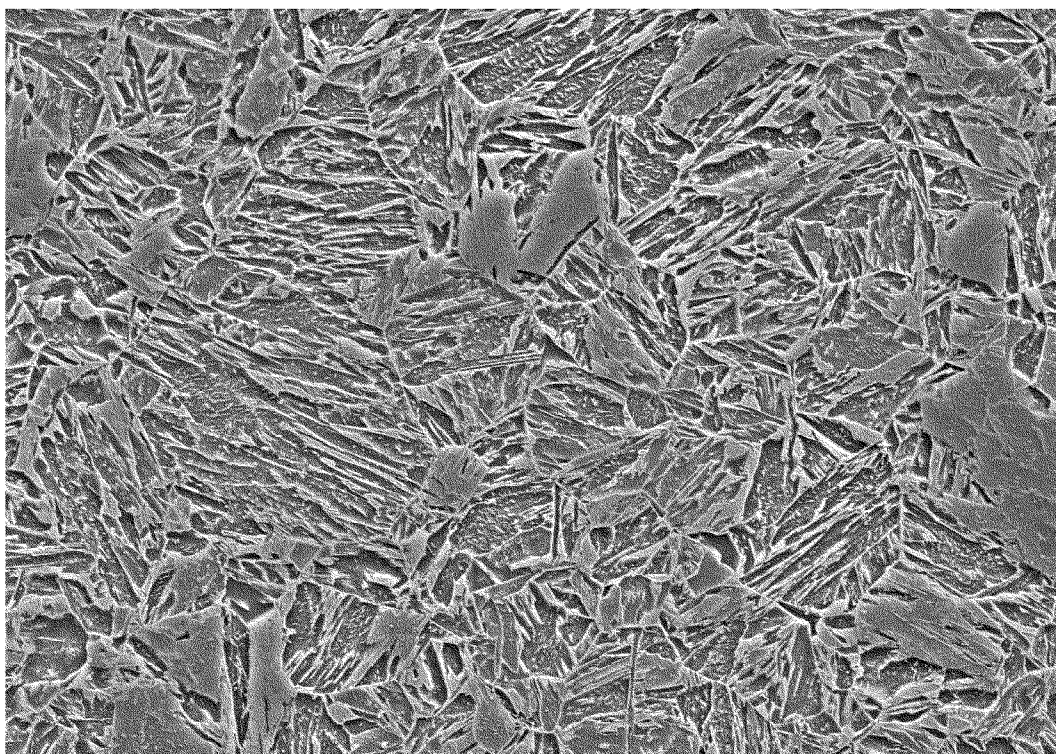
wherein in Relationship 1, a content of each alloying element is in weight%.

9. The method for manufacturing a cold rolled steel sheet of claim 6, wherein a heating temperature of the slab is 1000-1350°C.

10. The method for manufacturing a cold rolled steel sheet of claim 6, wherein a reduction rate during the cold rolling is 20-90%.

11. The method for manufacturing a cold rolled steel sheet of claim 6, further comprising an operation of temper rolling the cold rolled steel sheet at an elongation of 0.10-1.0% after the reheating and overaging heat treatment.

[Fig. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019687

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; C22C 38/02(2006.01)i; C22C 38/14(2006.01)i; C22C 38/12(2006.01)i; C22C 38/06(2006.01)i;
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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/04(2006.01); C21D 1/18(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/06(2006.01);
C22C 38/38(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: 내수소취성(Hydrogen embrittlement resistance), 초고강도(Ultra-high strength),
냉각속도(Cooling rate), 냉연강판(Cold rolled steel sheet), 템퍼드 마르텐사이트(Tempered martensite), 베이나이트
(Bainite), 잔류오스테나이트(Retained austenite), 프레쉬 마르텐사이트(Fresh martensite), 페라이트(Ferrite), 래스
(Lath), 인장강도(Tensile strength)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2022-0078173 A (POSCO) 10 June 2022 (2022-06-10) See claims 1-3 and 5-10 and table 4.	1-4,6-11
Y		5
Y	KR 10-2023-0087773 A (POSCO) 19 June 2023 (2023-06-19) See claims 3-5.	5
X	KR 10-2022-0019867 A (POSCO) 18 February 2022 (2022-02-18) See claims 1 and 9 and table 4.	1-4,6-11
A	JP 2010-275608 A (KOBE STEEL LTD. et al.) 09 December 2010 (2010-12-09) See paragraph [0077] and claim 1.	1-11

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

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“&” document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 March 2025	06 March 2025
Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208	
Facsimile No. +82-42-481-8578	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019687

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2250333 B1 (HYUNDAI STEEL COMPANY) 10 May 2021 (2021-05-10) See claims 1 and 6.	1-11

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/019687

5	Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
10	KR 10-2022-0078173 A	10 June 2022	CN 116547400 A	04 August 2023
			EP 4257720 A1	11 October 2023
			JP 2023-551501 A	08 December 2023
			JP 7576704 B2	31 October 2024
			KR 10-2440757 B1	08 September 2022
			US 2024-0002968 A1	04 January 2024
			WO 2022-119253 A1	09 June 2022
15	KR 10-2023-0087773 A	19 June 2023	None	
	KR 10-2022-0019867 A	18 February 2022	KR 10-2412400 B1	24 June 2022
20	JP 2010-275608 A	09 December 2010	CN 102449180 A	09 May 2012
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25			US 2012-0132327 A1	31 May 2012
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			JP 2022-531275 A	06 July 2022
			JP 7357691 B2	06 October 2023
			US 2022-0205059 A1	30 June 2022
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2005272954 A [0010]

Non-patent literature cited in the description

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