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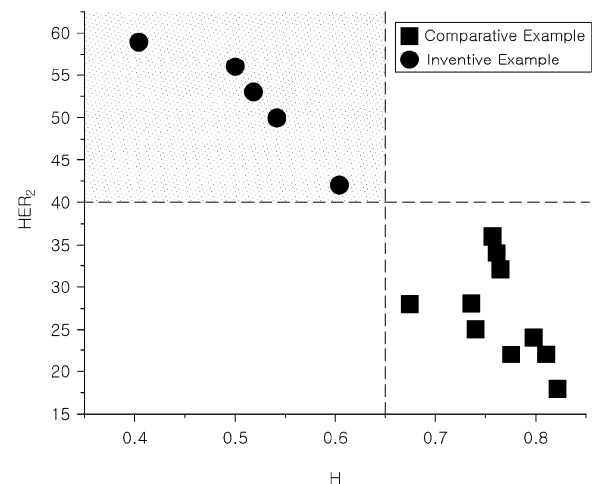
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(54) **STEEL PLATE AND METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to a steel plate and a manufacturing method and, more specifically, to an ultra-high strength composite structure hot-rolled steel plate having excellent punching resistance, and a method for manufacturing same.

[FIG. 1]



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Description

Technical Field

5 **[0001]** The present disclosure relates to a steel plate and a method for manufacturing the same, and more particularly, to an ultra-high strength composite structure hot-rolled steel plate having excellent punching resistance, and a method for manufacturing the same.

Background Art

10 **[0002]** High-strength hot-rolled steel plates used for chassis and frames of a conventional vehicle are required to have excellent formability in consideration of shapes of components, while being highly thinned to achieve lightening, and demand for yield strength is increasing to maximize durability of the components. In particular, in a process of developing a platform of an electric vehicle, thinning of a steel material for offsetting an increase in weight due to
15 usage of a battery is becoming more important than in the past. However, since local formability (typically hole expansion ratio) may deteriorate as the steel material is strengthened, a microstructure and an alloy design, which may have an ultra-high strength and an excellent hole expansion ratio, may be very important.

[0003] Patent Document 1 relates to a method of manufacturing composite structure steel having a microstructure of 10 to 55% of ferrite, and 45 to 90% of a sum of bainite and martensite, that is, 90% or higher of ferrite, bainite, and
20 martensite in total, and a tensile strength of 950 MPa or more.

[0004] However, only the bainite and martensite composite structure was considered as a main phase, and it is judged that it may be difficult to guarantee high collision resistance performance because there is no mention of yield strength.

[0005] Patent Document 2 discloses hot-rolled composite structure steel including, by area, bainitic ferrite: 55% or
25 higher, a martensite/austenite composite phase (MA): 10% or higher, a sum of bainitic ferrite and a martensite/austenite composite phase (MA): 95% or higher, and less than 5% of a remainder of granular ferrite, residual austenite, and a carbide in total. In addition, a method for manufacturing hot-rolled composite structure steel, characterized in that a microstructure in which an area fraction of bainitic ferrite having an intragrain orientation difference of 1.5° or more and 10.5° or less is 55% or more of a total area of the bainitic ferrite, an average grain size of a martensite/austenite
30 composite phase (MA) is 2.0 μm or less, and an average spacing is 0.3 μm or more, and having mechanical properties such as a yield strength of 750 MPa or more, a tensile strength of 950 MPa or more, an elongation of 8% or more, and a hole expansion ratio of 25% or more.

[0006] However, the patent does not describe the manufacturing method or development concept for securing an ultra-high strength of 1180 MPa or more and a hole expansion ratio of 30% or higher at the same time.

35 (Patent Document 1) Korean Patent Publication No. 10-2020-0011475

(Patent Document 2) Korean Patent Publication No. 10-2022-0039946

Disclosure of Invention

40 **[0007]** An embodiment of the present disclosure is to provide a steel plate and a method for manufacturing the same.

[0008] An embodiment of the present disclosure is to provide an ultra-high strength composite structure hot-rolled steel plate having excellent punching resistance and a method of manufacturing the same.

[0009] An object of the present disclosure is not limited to the above descriptions. One of ordinary skill in the art will have no difficulty in understanding the additional object of the present disclosure from the overall content of the present specification.

50 **[0010]** An embodiment of the present disclosure relates to a steel plate including, by weight, C: 0.13 to 0.25%, Si: 0.01 to 1.00%, Mn: 1.8 to 2.5%, Al: 0.010 to 0.100%, Cr: 0.005 to 0.500%, Mo: 0.005 to 0.300%, P: 0.001 to 0.050%, S: 0.001 to 0.010%, N: 0.001 to 0.010%, a remainder of Fe, and inevitable impurities,

wherein a microstructure of a surface layer may include 30 to 70% of ferrite, by area, and

wherein a microstructure of a central portion excluding the surface layer may include 95% or higher, by area, of a

sum of tempered martensite and lower bainite.

[0011] The steel plate may further include 0.05% or less of at least one of V, Nb, Ti, or B.

[0012] The microstructure of the central portion may include 5% or less of at least one of granular bainite, fresh martensite, an MA phase, or perlite as a remaining structure.

[0013] A yield strength may be 950 MPa or more, a tensile strength may be 1180 MPa or more, an elongation may be 5% or higher, and a hole expansion ratio (HER) may be 40% or higher.

[0014] An H value defined in Relational Expression 1 below may be 0.65 or less:

[Relational Expression 1]

$$H = (HER_1 - HER_2) / HER_1$$

[0015] (In the Relational Expression 1, HER_1 may be a hole expansion ratio value punched and measured through discharge processing during hole processing for a hole expansion ratio test (HER test), and HER_2 may be a hole expansion ratio value punched and measured through punching during the hole processing for the hole expansion ratio test (HER test))

[0016] An embodiment of the present disclosure relates to a method for manufacturing a steel plate, including reheating a steel slab including, by weight, C: 0.13 to 0.25%, Si: 0.01 to 1.00%, Mn: 1.8 to 2.5%, Al: 0.010 to 0.100%, Cr: 0.005 to 0.500%, Mo: 0.005 to 0.300%, P: 0.001 to 0.050%, S: 0.001 to 0.010%, N: 0.001 to 0.010%, a remainder of Fe, and inevitable impurities;

rough-rolling the reheated steel slab;

descaling the rough-rolled steel plate 3 to 6 times;

finish-rolling the descaled steel plate in a temperature range of 850°C or higher;

cooling and coiling the finish-rolled steel plate to a temperature range of Ms-120°C to Ms-30°C at an average cooling rate of 50°C/s or higher; and

cooling the coiled steel plate to a temperature range of 150°C or less at an average cooling rate of 0.1 to 25°C/h.

[0017] The steel slab may further include 0.05% or less of at least one of V, Nb, Ti, or B in total.

[0018] The reheating may be performed in a temperature range of 1150 to 1350°C,

the rough-rolling may be performed in a temperature range of 900 to 1150°C, and

the descaling may be performed at a water pressure of 170 bar or more.

[0019] Pickling and oiling the cooled steel plate may be further included.

[0020] Heating the cooled steel plate to a temperature range of 450 to 740°C and then hot-dip galvanizing the heated steel plate may be further included.

Advantageous Effects of Invention

[0021] According to an embodiment of the present disclosure, a steel plate and a method for manufacturing the same may be provided.

[0022] According to an embodiment of the present disclosure, an ultra-high strength composite structure hot-rolled steel plate having excellent punching resistance and a method of manufacturing the same may be provided.

[0023] According to an embodiment of the present disclosure, a composite structure hot-rolled steel plate that may be used for members of a chassis component of a vehicle, and components used in a lower arm, a reinforcing material, a connector, and a frame due to excellent strength while having excellent formability and a hole expansion ratio.

[0024] Various advantages and effects of the present disclosure are not limited to the above description, and can be more easily understood in a process of explaining the specific embodiment of the present disclosure.

Brief Description of Drawings

[0025] FIG. 1 shows a HER_2 value (a hole expansion ratio value punched and measured through punching during hole processing for a hole expansion ratio test (HER test)) according to an H value of Relational Expression 1 according to an embodiment of the present disclosure.

Best Mode for the Invention

[0026] Hereinafter, preferred embodiments of the present disclosure will be described. Embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as being limited to embodiments described below. The present embodiments may be provided to explain the present disclosure in more detail to those skilled in the art to which the present disclosure pertains.

[0027] Hereinafter, the present disclosure will be described in detail.

[0028] Hereinafter, a steel composition of the present disclosure will be described in detail.

[0029] Unless otherwise stated in the present disclosure, % indicating the content of each element is based on weight.

[0030] A steel plate according to an embodiment of the present disclosure may include, by weight, C: 0.13 to 0.25%, Si: 0.01 to 1.00%, Mn: 1.8 to 2.5%, Al: 0.010 to 0.100%, Cr: 0.005 to 0.500%, Mo: 0.005 to 0.300%, P: 0.001 to 0.050%, S: 0.001 to 0.010%, and N: 0.001 to 0.010%.

Carbon (C): 0.13 to 0.25%

[0031] Carbon (C) may be the most economical and effective element for reinforcing steel, and when an addition amount thereof increases, a precipitation reinforcement effect or a low-temperature phase fraction may increase, thereby increasing a tensile strength. When the content is less than 0.13%, sufficient curing capacity may not be secured, and thus it may be difficult to secure a target strength due to difficulty in forming a low-temperature phase. According to an embodiment of the present disclosure, it may be 0.14% or higher. On the other hand, when the content exceeds 0.25%, strength may too increase, a carbide may be excessively formed, and formability may be deteriorated, and weldability may be generally deteriorated by increasing carbon equivalent. In addition, when an excessive amount of carbon (C) is added, deterioration of the low-temperature phase and additional excess carbides may be formed during additional heat treatment after hot-rolling according to characteristics of the generated micro-structure, and thus there may be room for a significant decrease in tensile strength after heat treatment. According to an embodiment of the present disclosure, it may be 0.24% or less.

Silicon (Si): 0.01 to 1.00%

[0032] Silicon (Si) may be advantageous in improving formability by deoxidizing molten steel and enhancing solid solution, and delaying formation of a coarse carbide. In addition, there may be an effect of suppressing formation of a carbide during heat treatment at 300 to 600°C. However, when the content is less than 0.01%, an effect of delaying formation of a carbide may be small, and thus it may be difficult to improve formability and may be almost insignificant in improving strength. According to an embodiment of the present disclosure, it may be 0.30% or higher. According to an embodiment of the present disclosure, it may be 0.40% or higher. On the other hand, when the content exceeds 1.00%, a red scale may be formed by Si on a surface of a steel plate during hot-rolling, and not only surface quality of the steel plate may be very poor, but also ductility and weldability may be deteriorated. According to an embodiment of the present disclosure, it may be 0.90% or less.

Manganese (Mn): 1.8 to 2.5%

[0033] Manganese (Mn), like Si, may be an effective element in strengthening solid solution of steel, and further improves curing capacity of the steel, thereby delaying ferrite transformation at the same cooling rate and facilitating formation of a low-temperature phase such as bainite, martensite, or the like. However, when the content is less than 1.8%, there may be a problem that an effect of enhancing solid solution and improving curing capacity may be small, and thus an effect of increasing strength as desired may not be obtained. According to an embodiment of the present disclosure, it may be 1.9% or higher. On the other hand, when it exceeds 2.5%, curing capacity may greatly increase, and a martensite fraction may exceed the intended purpose, and a segregation portion may be greatly developed in a thickness central portion during slab casting in a performance process, resulting in poor formability and poor welding quality. According to an embodiment of the present disclosure, it may be 2.2% or less.

Aluminum (Al): 0.010 to 0.100%

[0034] Aluminum (Al) may be a component mainly added for deoxidation, and when the content is less than 0.01%, an addition effect may be insufficient. According to an embodiment of the present disclosure, it may be 0.027% or higher. According to an embodiment of the present disclosure, it may be 0.031% or higher. On the other hand, when the content exceeds 0.100%, AlN may be formed by combining with nitrogen, and corner cracks may be likely to occur

in a slab during performance and casting, and defects due to formation of inclusions may be likely to occur. According to an embodiment of the present disclosure, it may be 0.090% or less.

Chromium (Cr): 0.005 to 0.500%

[0035] Chromium (Cr) may strengthen solid solution of steel, and may play a role in helping to form bainite by delaying ferrite phase transformation during cooling. However, when the content is less than 0.005%, there may be a problem that an effect according to addition may not be obtained. According to an embodiment of the present disclosure, it may be 0.200% or higher. On the other hand, when the content exceeds 0.500%, ferrite transformation may be excessively delayed and elongation may be deteriorated due to formation of a martensite phase. In addition, similar to Mn, a segregation portion in a thickness central portion may be greatly developed, and elongation flangeability may be deteriorated by making a microstructure in a thickness direction uneven. In addition, when the chromium (Cr) content is too high, corrosion resistance of a material may be deteriorated. Therefore, according to an embodiment of the present disclosure, it may be 0.400% or less.

Molybdenum (Mo): 0.005 to 0.300%

[0036] Molybdenum (Mo) may increase curing ability of steel to facilitate formation of a bainite structure. However, when it is less than 0.005%, an effect according to addition may not be obtained. According to an embodiment of the present disclosure, it may be 0.100% or higher. On the other hand, when the content exceeds 0.300%, a martensite phase may be formed due to an excessive increase in particle size, and thus formability may be rapidly deteriorated. In addition, it may be economically disadvantageous and may be harmful to weldability. According to an embodiment of the present disclosure, it may be 0.200% or less.

Phosphorus (P): 0.001 to 0.050%

[0037] Like Si, phosphorus (P) may have an effect of strengthening solid solution and promoting ferrite transformation at the same time. However, to manufacture the content to be less than 0.001%, manufacturing costs may be required, and thus it may be economically disadvantageous and insufficient to obtain strength. However, when the content exceeds 0.050%, brittleness occurs due to grain boundary segregation, and fine cracks may be likely to occur during molding, and ductility and impact resistance properties may be greatly deteriorated.

Sulfur (S): 0.001 to 0.010%

[0038] Sulfur (S) may be an impurity present in steel, and to manufacture the content to be less than 0.001%, it may take a lot of time during steelmaking operation, and there may be a concern that productivity may decrease. On the other hand, when the content exceeds 0.010%, it combines with Mn to form a non-metal interposition, and accordingly, minute cracks may be likely to occur during steel cutting processing.

Nitrogen (N): 0.001 to 0.010%

[0039] Nitrogen (N) may be a representative solid solution reinforcing element, together with C, and may form a coarse precipitate together with Ti, Al, or the like. In general, a solid solution reinforcing effect of nitrogen (N) may be superior to carbon, but there may be a problem in that toughness greatly decreases as an amount of N in steel increases. Accordingly, according to an embodiment of the present disclosure, an upper limit of the nitrogen (N) content is limited to 0.010%. Meanwhile, to manufacture the content to be less than 0.001%, it may take a lot of time during a steelmaking operation, and thus productivity may be deteriorated.

[0040] A steel material of the present disclosure may include remaining iron (Fe) and inevitable impurities in addition to the composition. Since inevitable impurities may be unintentionally mixed in a conventional manufacturing process, it may not be excluded. Since these impurities may be known to anyone skilled in the art in steel manufacturing, all of the contents may not be specifically mentioned in the specification.

[0041] A steel plate according to an embodiment of the present disclosure may further include 0.05% or less of at least one of V, Nb, Ti, or B.

[0042] Vanadium (V), niobium (Nb), titanium (Ti), and boron (B) may be characterized by segregation or precipitation of a carbide or a nitride. When an amount of the carbide or nitride excessively increases, desired breaking resistance of the present disclosure may be deteriorated. Accordingly, in the present disclosure, a sum thereof may be controlled to be 0.05% or less.

[0043] Hereinafter, a steel microstructure of the present disclosure will be described in detail.

[0044] Unless otherwise stated in the present disclosure, a percentage indicating a fraction of the microstructure may be based on an area.

[0045] According to an embodiment of the present disclosure, the steel plate may secure strength and punching resistance at the same time by forming ferrite in a certain region from a surface of the steel plate in terms of strength improvement.

[0046] Accordingly, according to an embodiment of the present disclosure, a surface layer having a predetermined thickness, and a central portion, which may be a remaining region except for the surface layer, may be divided based on a thickness direction of the steel plate, and the microstructure may be controlled for each region.

[0047] According to an embodiment of the present disclosure, the remaining region except for the surface layer may be divided into the central portion. According to an embodiment of the present disclosure, the surface layer of the steel plate may mean a depth up to a point where the ferrite fraction decreases. According to an embodiment of the present disclosure, the surface layer of the steel plate may mean a depth up to a point where the ferrite fraction rapidly decreases. According to an embodiment of the present disclosure, it may appear as a depth level, which may be 7% of a thickness of the steel plate, in a direction from the surface of the steel plate to the thickness central portion. That is, although an interface between the surface layer and the center portion is not clear, if a fraction of a hard phase (tempered martensite and lower bainite) increases and is 95% or higher, it may be defined as the central portion. Meanwhile, according to an embodiment of the present disclosure, a region (thickness) of the surface layer may be changed according to a thickness of the steel plate to be manufactured.

[0048] A microstructure of the surface layer of the steel plate according to an embodiment of the present disclosure may include 30 to 70% ferrite, by area.

[0049] When the ferrite fraction of the surface layer is less than 30%, resistance to break due to ferrite may decrease during a hole expansion test. On the other hand, when the fraction exceeds 70%, overall strength of the steel material decreases, and thus it is not possible to secure a target tensile property. Although the surface layer is not particularly limited to a microstructure other than ferrite, according to an embodiment of the present disclosure, upper and lower bainite, martensite, or the like may be included as a microstructure other than ferrite.

[0050] According to an embodiment of the present disclosure, the microstructure of the central portion excluding the surface layer of the steel plate may include 95% or higher of tempered martensite and lower bainite in total, and may include 5% or less of at least one of granular bainite, fresh martensite, an MA phase, or perlite as a remaining structure.

[0051] According to an embodiment of the present disclosure, the microstructure of the central portion may be measured at a quarter point in a thickness center direction from the surface of the steel plate.

[0052] In the present disclosure, to secure an excellent hole expansion ratio and ultra-high strength properties at the same time, 95% or higher of tempered martensite and lower bainite may be included. When a sum of the fractions is less than 95%, there may be a problem that the hole expansion ratio and strength may be deteriorated at the same time. The hole expansion ratio of the steel may be greatly influenced by a composition of the microstructure. This may be because when several phases with different strengths exist at the same time, the hole expansion ratio may be deteriorated due to a difference in hardness between phases. In addition, in ultra-high strength steel of giga-grade or higher, it may be very important to secure strength by martensite and lower bainite phase fractions, and strength may be easily lowered by introduction of other upper bainite and ferrite. According to an embodiment of the present disclosure, tempered martensite and lower bainite may be 100%.

[0053] A steel plate according to an embodiment of the present disclosure may have a yield strength of 950 MPa or more, a tensile strength of 1180 MPa or more, an elongation of 5% or higher, a hole expansion ratio (HER) of 40% or higher, and an H value defined in the following Relational Expression 1 may be 0.65 or less.

[0054] In addition, the steel plate according to an embodiment of the present disclosure may maintain the mechanical properties even after heat treatment at 300 to 600°C, so it may be easy to use when manufacturing a plated hot-rolled steel plate using hot-rolled zinc.

[Relational Expression 1]

$$H = (HER_1 - HER_2) / HER_1$$

[0055] (In the Relational Expression 1, HER_1 is a hole expansion ratio value punched and measured through discharge processing during hole processing for a hole expansion ratio test (HER test), and HER_2 is a hole expansion ratio value punched and measured through punching during the hole processing for the hole expansion ratio test (HER test))

[0056] Main factors related to HER may be largely divided into an intrinsic factor related to unique characteristics of the material, and an extrinsic factor that occur around the hole during punching, and the intrinsic factor may be defined as HER_1 , and the extrinsic factor ΔHER may be defined as $(HER_1 - HER_2)$.

[0057] The intrinsic factor may be a hole expansion ratio caused by the inherent microstructure/mechanical properties of the material, and the extrinsic factor may be a hole expansion ratio value considering a drop caused by external factors such as a hole punching process for the hole expansion test, punching clearance, an abrasion state of a punch, or the like, in addition to unique properties of the material.

[0058] Therefore, the intrinsic factor may be implemented by making a hole by discharge processing in place of a general punching method while minimizing damage to the hole during punching. In this manner, a hole expansion ratio value when external damage is minimized through discharge processing was defined as HER_1 . A hole expansion ratio value obtained through the punching process was defined as HER_2 . An average value of results of evaluating three times at room temperature was described as the hole expansion ratio.

[0059] When the H value defined in Relational Expression 1 exceeds 0.65, it means that a difference between HER_1 and HER_2 is large, and it means that a hole expansion ratio that decreases when punching is performed is large. Therefore, according to an embodiment of the present disclosure, the H value is limited to 0.65 or less to secure excellent punching surface quality and to secure a steel material with a small hole expansion capacity reduction even by external factors.

[0060] FIG. 1 shows a HER_2 value (a hole expansion ratio value punched and measured through punching during hole processing for a hole expansion ratio test (HER test)) according to an H value of Relational Expression 1 according to an embodiment of the present disclosure. As shown in FIG. 1, when the H value has a value of 0.65 or less, HER_2 may have a suggested level of the hole expansion ratio.

[0061] Hereinafter, a steel manufacturing method of the present disclosure will be described in detail.

[0062] The steel plate according to an embodiment of the present disclosure may be manufactured by reheating, hot-rolling, cooling, coiling, and cooling a steel slab satisfying the alloy composition.

Reheating

[0063] A steel slab satisfying an alloy composition according to an embodiment of the present disclosure may be reheated in a temperature range of 1150 to 1350°C.

[0064] When a reheating temperature is less than 1150°C, a hot-rolling entry temperature may be lowered, and surface quality may be deteriorated. On the other hand, when the temperature exceeds 1350°C, there may be a concern that strength may decrease due to coarsening of austenitic grains.

Rough-rolling

[0065] According to an embodiment of the present disclosure, a process in which a continuous casting and a hot-rolled process are directly connected may be applied.

[0066] The reheated steel slab may be crudely rolled in a temperature range of 900 to 1150°C.

[0067] During rough-rolling, conditions are not particularly limited, and may be conditions applicable to the same technical field. According to an embodiment of the present disclosure, the rough-rolling may be performed in a temperature range of 900 to 1150°C. During the rough-rolling, when rolling is started at a temperature exceeding 1150°C, a temperature of a steel plate may increase, to coarsen a grain size, and increase oxide generation on a surface of the steel plate, resulting in poor quality.

Descaling

[0068] The rough-rolled steel plate may be descaled 3 to 6 times.

[0069] A hot-rolling process may include rough-rolling and finish-rolling, and according to an embodiment of the present disclosure, descaling may be performed after the rough-rolling and before the finish-rolling.

[0070] According to an embodiment of the present disclosure, after the rough-rolling, the steel plate may be subjected to descaling with a full width of the steel plate 3 to 6 times at a hydraulic pressure of 170 bar or more.

[0071] The descaling causes a difference in temperature between a surface layer and other portions of the steel plate by performing surface cooling, and as a result, a temperature of the surface layer may be momentarily lowered below a ferrite phase transformation temperature to introduce a certain amount of ferrite in the surface layer. When testing a hole expansion ratio due to ferrite introduced into the surface layer, resistance of a polar surface layer to the hole expansion ratio may be greatly improved.

[0072] When the descaling is less than 3 times, surface cooling may not be sufficient, and ferrite formation may be insufficient, and the hole expansion ratio may thus be inferior. When the descaling exceeds 6 times, ferrite may be excessively formed, and desired strength may not be secured.

Finish-rolling

[0073] The descaled steel plate may be finish-rolled in a temperature range of 850°C or higher.

[0074] During finish-rolling, when the temperature is less than 850°C, development of stretched crystal grains due to excessive recrystallization delay may intensify anisotropy, and may deteriorate formability.

[0075] During the finish-roll, an upper limit of the temperature is not particularly limited, but may be 1150°C or less according to an embodiment of the present disclosure.

coiling

[0076] The hot-rolled steel plate may be cooled and coiled up to a temperature range of Ms-120°C to Ms-30°C at an average cooling rate of 50°C/s or more.

[0077] To simultaneously ensure ultra-high strength and an excellent hole expansion ratio, proposed by the present disclosure, a desired microstructure may be ensured by controlling cooling and coiling temperatures.

[0078] During cooling, when an end temperature is less than Ms-120°C, since a final microstructure configuration may be mainly configured, strength relative to a target may excessively increase and formability may be deteriorated. According to an embodiment of the present disclosure, it may be Ms-100°C or higher. On the other hand, when the end temperature exceeds Ms-30°C, a fraction of tempered martensite may decrease during the final microstructure configuration, and strength may be deteriorated due to generation of granular or upper bainite with low strength due to double heat during coiling. According to an embodiment of the present disclosure, it may be Ms-50°C or less.

[0079] During cooling, when an average cooling rate is less than 50°C/s, ferrite and upper bainite may be introduced, which may be disadvantageous in securing strength and may deteriorate a hole expansion ratio. According to an embodiment of the present disclosure, it may be 58°C/s or more. In the present disclosure, an upper limit of an average cooling rate is not particularly limited, but may be 73°C/s or less.

[Equation]

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

(In the Equation, [C], [Mn], [Cr], and [Mo] may be a weight percent of each element.)

Cooling

[0080] The coiled steel plate may be cooled to a temperature range of 150°C or less at an average cooling rate of 0.1 to 25°C/h.

[0081] When the average cooling rate exceeds 25°C/h, a tempering of martensite in the steel may become insufficient, and thus yield strength of the steel may decrease and elongation flangeability may be deteriorated. According to an embodiment of the present disclosure, it may be 10°C/h or less. On the other hand, to control the average cooling rate to be less than 0.1°C/h, a separate heating facility or the like may be required, and thus it may be economically disadvantageous. According to an embodiment of the present disclosure, it may be 1°C/h or more.

[0082] According to an embodiment of the present disclosure, it may further include oiling the cooled steel plate after acid treatment, as necessary. In addition, according to an embodiment of the present disclosure, it may further include manufacturing a plated steel plate by plating a cooled steel plate, as needed.

[0083] Plating conditions are not particularly limited, but conventional plating conditions may be applied, and according to an embodiment of the present disclosure, hot-dip galvanizing may be performed. According to an embodiment of the present disclosure, after heating the cooled steel plate in a temperature range of 450 to 750°C, hot-dip galvanizing may be performed using a plating bath including Mg: 0.01 to 30%, Al: 0.01 to 50%, and a remainder of Zn.

Mode for the Invention

[0084] Hereinafter, the present disclosure will be described in more detail through embodiments. However, it may be important to note that the following embodiments may be intended to illustrate the present disclosure in more detail and may not be intended to limit the scope of the present disclosure.

(Example)

[0085] After preparing a steel slab having a composition of Table 1 below, a hot-rolled steel plate having a thickness of 2.5 mm was manufactured under manufacturing conditions shown in Table 2 below. In this case, a reheating

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temperature was within a temperature range of 1150 to 1350°C, and rough-rolling was equally applied within a temperature range of 1050°C. In addition, during descaling, it was performed at a water pressure of 180 bar.

[Table 1]

Steel	Alloy Composition (wt%)								
	C	Si	Mn	Al	P	S	N	Cr	Mo
A	0.09	0.60	1.6	0.031	0.007	0.001	0.003	0.200	0.100
B	0.02	0.50	2.3	0.032	0.009	0.002	0.004	0.400	0.200
C	0.17	0.50	1.1	0.025	0.011	0.003	0.004	0.200	0.200
D	0.29	0.40	2.2	0.027	0.011	0.001	0.003	0.100	0.300
E	0.16	0.70	3.5	0.035	0.014	0.002	0.003	0.200	0.200
F	0.14	0.70	2.2	0.028	0.009	0.001	0.004	0.200	0.100
G	0.16	0.90	1.9	0.027	0.012	0.002	0.003	0.400	0.200
H	0.19	0.80	2.2	0.029	0.011	0.002	0.003	0.300	0.200
I	0.21	0.40	2.1	0.031	0.013	0.001	0.004	0.100	0.100
J	0.24	0.50	1.9	0.028	0.008	0.002	0.003	0.300	0.100

[Table 2]

Specimen	Steel	Descaling	Finish-Rolling	Ms (°C)	coiling		Cooling	
		Running No. (EA)	Temp. (°C)		Temp. (°C)	Average Cooling Rate (°C/s)	End Temp. (°C)	Average Cooling Rate (°C/h)
1	A	3	912	449	412	65	52	12
2	B	3	905	454	402	70	46	5
3	C	3	922	430	376	62	48	8
4	D	5	885	346	268	56	35	8
5	E	6	879	361	287	73	28	16
6	F	3	911	410	363	59	25	22
7	G	3	898	407	322	70	29	14
8	H	4	880	387	309	73	36	3
9	I	5	912	384	267	58	31	9
10	J	3	905	375	295	65	42	16
11	F	4	889	410	550	76	44	20
12	G	5	866	407	395	15	39	20
13	H	6	725	387	329	65	27	14
14	I	3	905	384	39	72	22	15
15	J	4	907	375	301	4	34	9
16	F	1	910	410	372	62	29	19
17	F	8	912	410	365	65	32	14

$$[Equation] \quad Ms = 539 - 423 [C] - 30.4 [Mn] - 12.1 [Cr] - 7.5 [Mo]$$

(In the Equation, [C], [Mn], [Cr], and [Mo] may be the weight percent of each element.)

[0086] After measuring the microstructure and properties of the prepared steel plate, it was shown in Table 3 below.

[0087] A central portion microstructure fraction was observed at a quarter point in a thickness center direction from a surface of the manufactured steel plate and measured from results of analysis at x4000 and x8000 magnification using an SEM. After Nital and LePera etching, analysis was performed at x1000 magnification using an optical microscope and an image analyzer for reading tempered martensite and fresh martensite. In this case, lower bainite and tempered martensite may have very similar properties microstructure, so they may be classified only by local analysis in very small areas such as TEM analysis. However, since it may be difficult to calculate a representative fraction of the steel with results, lower bainite and tempered martensite combined and calculated fractions together.

[0088] In addition, the surface layer microstructure was observed in a region from the surface of the steel plate to a depth of 7% of the thickness of the steel plate in the thickness center direction, and the average value was measured through random observation of 3 sites using the SEM using the x1000 magnification image. As the surface microstructure, upper and lower bainite, martensite, or the like, in addition to ferrite, were observed.

[0089] In addition, results of hole expansion ratio related to yield strength (YS), tensile strength (TS), elongation (EI) and Relational Expression 1 of the prepared steel plate were shown. The tensile material was a result of collecting and testing a specimen in a direction, perpendicular to a rolling direction, and testing of the tensile material was measured at room temperature.

[0090] The hole expansion ratio (HER) test was performed by applying a punching clearance (cl) of 12%, and results were performed based on the JFST 1001-1996 standard. The HER_1 and HER_2 evaluation values were expressed as average values after three times. In addition, H values of Relational Expression 1 were calculated and shown through the obtained values.

[Table 3]

Specimen	Steel	Microstructure (area%)				Mechanical Properties							Example
		Central Portion			Surface Layer	YS (MPa)	TS (MPa)	EI (%)	HER ₁	HER ₂	ΔHER (%)	Relational Expression 1 (H)	
		TM+LB	GB+UB	FM+MA	F								
1	A	71	23	6	45	863	1092	11	98	22	76	0.78	Comparative Ex. 1
2	B	42	41	17	35	654	826	17	136	32	104	0.76	Comparative Ex. 2
3	C	52	36	12	39	921	1132	11	106	28	78	0.74	Comparative Ex. 3
4	D	98	1	1	51	1426	1698	4	86	28	58	0.67	Comparative Ex. 4
5	E	97	1	2	61	1322	1565	5	96	25	71	0.74	Comparative Ex. 5
6	F	96	2	2	62	982	1221	7	112	56	56	0.50	Inventive Ex. 1
7	G	97	2	1	53	1002	1253	7	110	53	57	0.52	Inventive Ex. 2
8	H	97	1	2	49	1153	1298	6	106	42	64	0.60	Inventive Ex. 3
9	I	96	2	2	46	1235	1356	6	109	50	59	0.54	Inventive Ex. 4
10	J	99	0	1	52	1296	1427	7	99	59	40	0.40	Inventive Ex. 5
11	F	6	81	13	60	611	829	18	148	36	112	0.76	Comparative Ex. 6
12	G	4	86	10	55	652	889	16	142	34	108	0.76	Comparative Ex. 7
13	H	76	10	14	45	861	1275	8	119	24	95	0.80	Comparative Ex. 8
14	I	12	2	86	62	1269	1429	5	101	18	83	0.82	Comparative Ex. 9
15	J	2	94	4	59	825	1189	6	116	22	94	0.81	Comparative Ex. 10
16	F	10	88	2	1	994	1287	7	110	20	90	0.82	Comparative Ex. 11
17	F	91	5	4	75	765	1122	8	115	45	70	0.61	Comparative Ex. 12
* TM: tempered martensite, LB: lower bainite, GB: granular bainite, UB: upper bainite, FM: fresh martensite, MA: MA phase, F: ferrite. [Relational Expression 1]													

$$H = (HER_1 - HER_2) / HER_1$$

(In the Relational Expression 1, HER_1 is a hole expansion ratio value punched and measured through discharge processing during hole processing for a hole expansion ratio test (HER test), and HER_2 is a hole expansion ratio value punched and measured through punching during the hole processing for the hole expansion ratio test (HER test))

[0091] As shown in Table 3, in Inventive Examples satisfying the alloy composition and manufacturing conditions of the present disclosure, microstructure characteristics proposed in the present disclosure were satisfied, and desired properties of the present disclosure were also secured.

[0092] On the other hand, Comparative Examples 1 to 5 may be examples outside the alloy composition range proposed by the present disclosure. In Comparative Examples 1 and 2, the carbon content was insufficient, and thus the tempered martensite and the lower bainite fraction proposed by the present disclosure were not satisfied, and strength was also inferior. In Comparative Example 3, the manganese content was insufficient, and thus desired strength could not be secured. In Comparative Example 4, the carbon content was excessively high, and thus elongation and hole expansion ratio were deteriorated. In Comparative Example 5, as the manganese content exceeded the scope of the present disclosure, elongation and hole expansion ratio were deteriorated.

[0093] In Comparative Examples 6 to 10, composition ranges of the present disclosure were satisfied, but manufacturing conditions were examples outside the scope of the present disclosure. In Comparative Example 6, since a coiling temperature was higher than an M_s temperature, fractions of the upper bainite and granular bainite were too high, and accordingly, strength may be greatly reduced. Even with the same bainite structure, upper and lower bainites may bring about a great difference in generation temperature and strength, and even when they contain a large amount of fresh martensite, tensile strength may be greatly improved even when they were not tempered martensite, but since yield strength was not as high as that of tempered martensite structure, it can be confirmed that a high yield ratio steel material could not be manufactured and the hole expansion ratio was deteriorated. In Comparative Examples 7 and 10, average cooling rates to coiling temperatures after hot-rolling was low, so that fractions of upper bainite and granular bainite were excessively high. Accordingly, as in Comparative Example 6, strength may be significantly less than a level targeted by the present disclosure. In Comparative Example 8, when a hot-rolling temperature was operated lower than a target range, it can be confirmed that a desired microstructure fraction was not secured. In Comparative Example 9, a target fraction of a microstructure was satisfied, but target elongation and hole expansion ratio were significantly lowered. In a coiling temperature, fresh martensite was produced at a temperature below M_f (martensite transformation end temperature) of the steel, and then tempered at low temperatures to form a tempered martensite structure, but it can be seen that the ΔHER related to Relational Expression 1 may be very large.

[0094] Comparative Example 11 and Comparative Example 12 were examples that do not satisfy a descaling condition proposed by the present disclosure. In Comparative Example 11, formation of ferrite in a surface layer was insufficient due to the insufficient number of descaling times, and as a result, strength was excessively high, and the hole expansion ratio was deteriorated. In Comparative Example 12, the number of descaling times was excessive, and thus ferrite in the surface layer was excessively formed. As a result, desired strength could not be secured.

[0095] Although the present disclosure has been described in detail through embodiments, other forms of embodiments may be also possible. Therefore, the technical idea and scope of the claims described below may not be limited to embodiments.

Claims

1. A steel plate comprising:

by weight, C: 0.13 to 0.25%, Si: 0.01 to 1.00%, Mn: 1.8 to 2.5%, Al: 0.010 to 0.100%, Cr: 0.005 to 0.500%, Mo: 0.005 to 0.300%, P: 0.001 to 0.050%, S: 0.001 to 0.010%, N: 0.001 to 0.010%, a remainder of Fe, and inevitable impurities,

wherein a microstructure of a surface layer comprises 30 to 70% of ferrite, by area, and

wherein a microstructure of a central portion excluding the surface layer comprises 95% or higher, by area, of a sum of tempered martensite and lower bainite.

2. The steel plate of claim 1, further comprising 0.05% or less of at least one of V, Nb, Ti, or B.

3. The steel plate of claim 1, wherein the microstructure of the central portion comprises 5% or less of at least one of granular bainite, fresh martensite, an MA phase, or perlite as a remaining structure.

4. The steel plate of claim 1, wherein a yield strength is 950 MPa or more, a tensile strength is 1180 MPa or more, an

elongation is 5% or higher, and a hole expansion ratio (HER) is 40% or higher.

5. The steel plate of claim 1, wherein an H value defined in Relational Expression 1 below is 0.65 or less:

[Relational Expression 1]

$$H = (HER_1 - HER_2) / HER_1$$

(In the Relational Expression 1, HER_1 is a hole expansion ratio value punched and measured through discharge processing during hole processing for a hole expansion ratio test (HER test), and HER_2 is a hole expansion ratio value punched and measured through punching during the hole processing for the hole expansion ratio test (HER test))

6. A method for manufacturing a steel plate, comprising:

reheating a steel slab comprising, by weight, C: 0.13 to 0.25%, Si: 0.01 to 1.00%, Mn: 1.8 to 2.5%, Al: 0.010 to 0.100%, Cr: 0.005 to 0.500%, Mo: 0.005 to 0.300%, P: 0.001 to 0.050%, S: 0.001 to 0.010%, N: 0.001 to 0.010%, a remainder of Fe, and inevitable impurities;

rough-rolling the reheated steel slab;

descaling the rough-rolled steel plate 3 to 6 times;

finish-rolling the descaled steel plate in a temperature range of 850°C or higher;

cooling and coiling the finish-rolled steel plate to a temperature range of Ms-120°C to Ms-30°C at an average cooling rate of 50°C/s or higher; and

cooling the coiled steel plate to a temperature range of 150°C or less at an average cooling rate of 0.1 to 25°C/h.

7. The method of claim 6, wherein the steel slab further comprises 0.05% or less of at least one of V, Nb, Ti, or B in total.

8. The method of claim 6, wherein the reheating is performed in a temperature range of 1150 to 1350°C,

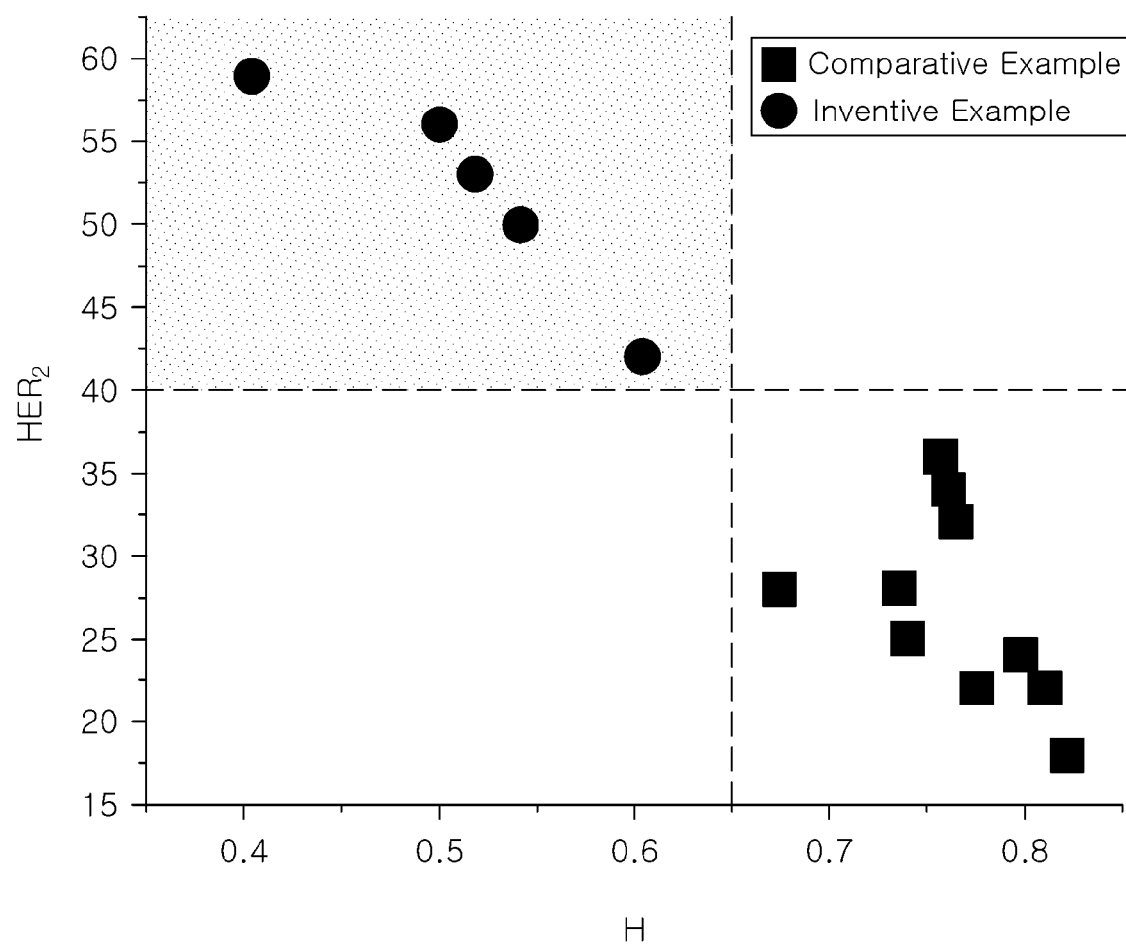
wherein the rough-rolling is performed in a temperature range of 900 to 1150°C, and

wherein the descaling is performed at a water pressure of 170 bar or more.

9. The method of claim 6, further comprising pickling and oiling the cooled steel plate.

10. The method of claim 6, further comprising heating the cooled steel plate to a temperature range of 450 to 740°C and then hot-dip galvanizing the heated steel plate.

[FIG. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020387

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/22**(2006.01)i; **C22C 38/00**(2006.01)i; **C21D 8/02**(2006.01)i; **C21D 9/46**(2006.01)i;
C23G 1/08(2006.01)i; **C23C 2/06**(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); B21B 1/26(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 18/00(2006.01);
 C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/14(2006.01); C23C 2/28(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: 열연강판(hot rolled steel sheet), 페라이트(ferrite), 템퍼드 마르텐사이트(tempered martensite), 베이나이트(hainite), 조압연(rough rolling), 디스케일링(descaling), 냉각(cooling), 크롬(chromium), 몰리브덴(molybdenum)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2021-0024135 A (JFE STEEL CORPORATION) 04 March 2021 (2021-03-04) See paragraphs [0091], [0112]-[0113] and [0144], claims 1-3 and 7 and tables 2-1, 2-2 and 3-1.	1-10
A	KR 10-2075642 B1 (POSCO) 10 February 2020 (2020-02-10) See paragraph [0100] and claims 1-2.	1-10
A	JP 2015-078394 A (NIPPON STEEL & SUMITOMO METAL) 23 April 2015 (2015-04-23) See paragraphs [0077]-[0078] and claims 1-3.	1-10
A	US 2019-0085427 A1 (JFE STEEL CORPORATION) 21 March 2019 (2019-03-21) See paragraphs [0090] and [0135].	1-10

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

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

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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 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020387

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020387

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