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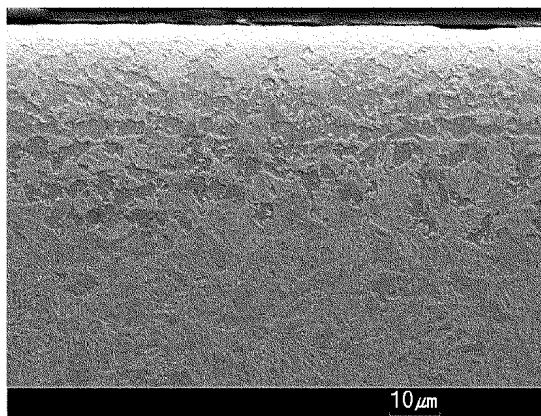
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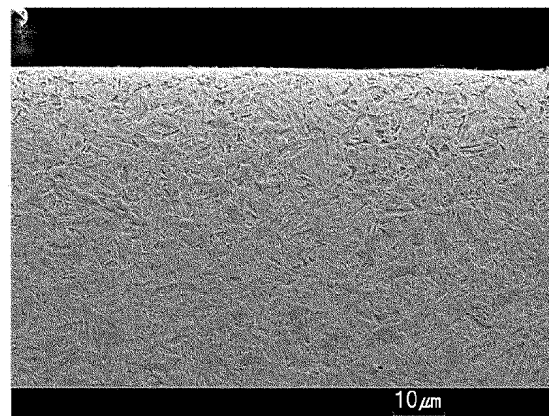
(54) **ULTRA-HIGH STRENGTH STEEL SHEET HAVING EXCELLENT BENDABILITY, AND MANUFACTURING METHOD THEREFOR**

(57) The present invention relates to a steel sheet suitable for automobile chassis members, etc., and, more particularly, to an ultra-high strength steel sheet having excellent bendability, and a manufacturing method therefor.

[FIG. 1]



SURFACE LAYER IN INVENTIVE EXAMPLE 1



SURFACE LAYER IN COMPARATIVE EXAMPLE 1

Description

Technical Field

5 **[0001]** The present invention relates to a steel sheet suitable for automobile chassis members, etc., and, more particularly, to an ultra-high strength steel sheet having excellent bendability, and a manufacturing method therefor.

Background Art

10 **[0002]** Recently, in the automobile field, research to reduce the weight of a vehicle body is being actively conducted in developed countries, including Europe, due to fuel efficiency regulations and performance improvement. Specifically, in the case of the steel field, efforts are being made to produce a high strength steel further reduce the thickness of the steel sheet in the same grade compared to competitive materials (Mg, Al, CFRP (carbon fiber reinforced plastic), etc.) in order to meet the demand for weight reduction of automakers. In other words, in addition to weight reduction, stability and high strength of vehicle body materials are also required due to the strengthening of safety regulations for automobile passengers and pedestrians.

15 **[0003]** On the other hand, in order to improve the stability and collision characteristics of the vehicle body, the use of high-strength steel with excellent yield strength in Body-In-White (BIW) structural members is increasing, and these structural members have the characteristic that as the yield strength compared to the tensile strength, that is, a yield ratio (yield strength/tensile strength, YR) increases, this is advantageous for absorbing impact energy.

20 **[0004]** Thus, as a representative method to increase the yield strength of steel, a method using water cooling during continuous annealing is mainly used. Specifically, the representative method may include a method of manufacturing ultra-high strength steel through processes such as tempering after annealing a cold-rolled steel sheet with a two-phase region or a single-phase region and quenching to approximately room temperature.

25 **[0005]** However, while ultra-high strength steel produced thereby has a very high yield ratio, there may be a problem that a shape quality of a coil may deteriorate due to a temperature deviation in a width direction and a length direction, and further, problems such as poor material and deterioration of workability depending to components may occur during component processing due to roll forming or the like. In addition, in general, as the strength of the steel increases, the elongation decreases, which may cause a decrease in molding processability.

30 **[0006]** To overcome these problems, a hot press forming (HPF) method has been developed and applied to secure strength through water cooling between a die and a material after molding a material at a high temperature at which molding may be relatively easily performed (see Patent Document 1).

[0007] When the HPF method is applied, high strength compared to the same thickness may be secured, and components using the HPF method are being developed in Europe.

35 **[0008]** However, the HPF method requires excessive facility investment costs and problems such as increased process costs are emerging, and accordingly, the development of materials for cold stamping is required.

[0009] In other words, it is necessary to develop a steel sheet that is suitable for use as a cold stamping material, has high strength and a high yield ratio to secure collision performance characteristics, and has excellent formability.

[0010] (Patent Document 1) International Publication No. WO 2021/084303

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Summary of Invention

Technical Problem

45 **[0011]** An aspect of the present invention is to provide a steel sheet suitable for automobile chassis members while being suitable for cold stamping, and particularly, to a steel sheet having excellent bendability, and a manufacturing method therefor.

50 **[0012]** An object of the present invention is not limited to the description above. An object of the present invention may be understood from the overall contents of the present specification, and it may be understood by those of ordinary skill in the art that there would be no difficulty in understanding the additional problems of the present invention.

Solution to Problem

55 **[0013]** According to an aspect of the present invention, provided is an ultra-high strength steel sheet having excellent bendability, including: by wt%, carbon (C): 0.1 to 0.3%, manganese (Mn): 1.0 to 2.3%, silicon (Si): 0.05 to 1.0%, phosphorus (P): 0.1% or less (excluding 0%), sulfur (S) : 0.03% or less (excluding 0%), aluminum (Al) : 0.01 to 0.5%, two or more types of chromium (Cr): 0.01 to 0.2%, molybdenum (Mo): 0.01 to 0.2% and boron (B): 0.005% or less, one or more types of titanium (Ti): 0.1% or less and niobium (Nb): 0.1% or less, and a balance of Fe and unavoidable impurity

elements, and satisfying the following relational expression 1, wherein a microstructure comprises, in area fraction, 99% or more of martensite and/or tempered martensite phases.

<Relational Expression 1>

$$0.12 \leq \frac{Ceq1^2 + Ceq2^2}{2} \leq 0.28$$

(where $Ceq1 = C + (Mn/20) + (Si/30) + (2P) + (4S)$, and $Ceq2 = C + (Mn/6) + (Si/30) + (Cr+Mo+V+Nb)/5 + (Cu+Ni)/15$).

[0014] According to an aspect of the present invention, provided is a manufacturing method for an ultra-high strength steel sheet having excellent bendability, including: heating a steel slab including, by wt%, carbon (C): 0.1 to 0.3%, manganese (Mn): 1.0 to 2.3%, silicon (Si): 0.05 to 1.0%, phosphorus (P): 0.1% or less (excluding 0%), sulfur (S): 0.03% or less (excluding 0%), aluminum (Al): 0.01 to 0.5%, two or more types of chromium (Cr): 0.01 to 0.2%, molybdenum (Mo): 0.01 to 0.2% and boron (B): 0.005% or less, one or more types of titanium (Ti): 0.1% or less and niobium (Nb): 0.1% or less, and a balance of Fe and unavoidable impurity elements, and satisfying the following relational expression 1 in a temperature range of 1100 to 1300°C; manufacturing a hot-rolled steel sheet by finish hot rolling the reheated steel slab at Ar3 or higher; coiling the hot-rolled steel sheet at a temperature of 700°C or less; manufacturing a cold-rolled steel sheet by cold rolling the coiled hot-rolled steel sheet with a total reduction ratio of 30 to 80%; continuously annealing the cold-rolled steel sheet for 30 seconds or more at Ac3 or higher; performing primary cooling at an average cooling rate of 1 to 10°C/s to a temperature range of 550 to 750°C after the continuous annealing; performing secondary cooling at an average cooling rate of 20 to 80°C/s to a temperature of Ms-190°C or less after the performing primary; and performing reheating after the secondary cooling and then performing an over-aging treatment,

[0015] wherein the reheating and over-aging include heating to a temperature range that satisfies the following relational expression 3.

<Relational Expression 3>

$$CT2 + 30^{\circ}\text{C} \leq A \leq 270^{\circ}\text{C}$$

(where CT2 denotes a secondary cooling end temperature (°C), and A means a reheating and over-aging temperature (°C)).

Advantageous Effects of Invention

[0016] According to the present invention, a steel sheet with improved processability may be provided by achieving a high yield ratio in addition to ultra-high strength. In particular, a steel sheet of the present invention is not only a material that may be suitably applied to automobile chassis members, but is also advantageously applicable to processing such as cold stamping.

Brief Description of Drawings

[0017]

FIG. 1 illustrates an image of a microstructure of a surface layer of an embodiment of an inventive example and a comparative example, according to an embodiment of the present invention.

FIG. 2 illustrates an image of a microstructure of a 1/4t region of an inventive example and a comparative example, according to an embodiment of the present invention.

Best Mode for Invention

[0018] The inventors of the present invention conducted in-depth research to provide a steel sheet that is suitable for automobile chassis members and is advantageous for processing such as cold stamping. Accordingly, the inventors have confirmed that it was possible to provide a steel sheet with a desired structure, physical properties, etc. by optimizing an alloy composition and manufacturing conditions, and have completed the present invention.

[0019] Hereinafter, the present invention will be described in detail.

[0020] An ultra-high strength steel sheet according to an aspect of the present invention may include, by wt%, carbon

(C): 0.1 to 0.3%, manganese (Mn): 1.0 to 2.3%, silicon (Si): 0.05 to 1.0%, phosphorus (P): 0.1% or less (excluding 0%), sulfur (S): 0.03% or less (excluding 0%), and aluminum (Al): 0.01 to 0.5%.

[0021] Hereinafter, the reason for limiting the alloy composition of the ultra-high strength steel sheet provided by the present invention as described above will be explained in detail.

[0022] Meanwhile, in the present invention, unless specifically stated, the content of each element is based on weight, and the ratio of a structure is based on area.

Carbon (C): 0.1 to 0.3%

[0023] Carbon (C) is an interstitial solid solution element and is the most effective and important element in improving the strength of steel. Specifically, in martensitic steel, Carbon (C) is an element that must be added to secure strength.

[0024] In order to obtain a steel sheet with a target strength, yield ratio, and the like, in the present invention, Carbon (C) may be added in an amount of 0.1% or more. However, when the content thereof exceeds 0.3%, the martensite strength increases, but during a continuous annealing process, carbides may be easily generated and coarsening may be facilitated, which causes not only reduced ductility but also poor bendability. Additionally, an excessive increase in carbon content has the problem of deteriorating weldability.

[0025] Therefore, in the present invention, Carbon (C) may be included in an amount of 0.1 to 0.3%, and more advantageously, 0.12% or more and 0.28% or less.

Manganese (Mn): 1.0 to 2.3%

[0026] Manganese (Mn) is an element that suppresses the formation of ferrite in composite steel and promotes the formation of austenite, making it easy to ultimately secure a martensite phase.

[0027] When the Mn content exceeds 2.3%, Mn is segregated in a thickness direction of steel and a manganese band is easily formed in the slab, which increases an occurrence of defects during rolling as well as continuous casting cracks. On the other hand, when the content thereof is less than 1.0%, a target level of strength may not be secured.

[0028] Accordingly, in the present invention, Manganese (Mn) may be included in an amount of 1.0 to 2.3%, and may be included in an amount of, more advantageously, 1.2% or more and 2.1% or less. Manganese (Mn) may be included in an amount of, more advantageously, 1.4% or more.

Silicon (Si): 0.05 to 1.0%

[0029] Silicon (Si) serve to suppress the formation of carbides and controlling the size of carbides in reheating and over-aging treatment steps performed after continuous annealing and cooling during a process of manufacturing a steel sheet to be obtained in the present invention.

[0030] In order to sufficiently obtain the above-described effect, Si may be included in an amount of 0.05% or more. However, when the content exceeds 1.0%, there is a risk that ferrite may be generated during cooling in a continuous annealing furnace, which may weaken the strength of the steel. Furthermore, Si-based oxides are generated during reheating and over-aging after cooling, which may cause surface oxidation problems in the steel.

[0031] Accordingly, in the present invention, Si may be included in an amount of 0.05 to 1.0%, and may be included in an amount of, more advantageously, 0.09% or more and 0.8% or less. Si may be included in an amount of even more advantageously, 0.6% or less.

Phosphorus (P): 0.1% or less (excluding 0%)

[0032] Phosphorus (P) is an impurity element contained in steel, and when a content thereof exceeds 0.1%, the weldability of the steel may deteriorate and brittleness may occur. Accordingly, Phosphorus (P) is limited to 0.1% or less, and the amount of 0% may be excluded in consideration of a level of unavoidable inclusion during the steel manufacturing process. More advantageously, Phosphorus (P) may be included in an amount of 0.05% or less, and even more advantageously, 0.03% or less.

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

[0033] Sulfur (S), similar to Phosphorus (P), is an impurity inevitably contained in steel and is an element that impairs the ductility and weldability of steel, and it may be advantageous to keep a content thereof as low as possible. In the present invention, there is no difficulty in securing target physical properties even if Sulfur (S) is contained at a maximum of 0.03%, and thus, an upper limit thereof may be limited to 0.03%, and the amount of 0% may be excluded in consideration of a level of unavoidable inclusion during the steel manufacturing process.

[0034] Meanwhile, in order to more advantageously secure the bendability targeted in the present invention, the content of S may be limited to 0.01% or less, and even more advantageously, 0.005% or less.

Aluminum (Al): 0.01 to 0.5%

[0035] Aluminum (Al) may be added to remove oxygen in molten steel and, similarly to Si, Aluminum (Al) is an element that stabilizes ferrite. Furthermore, Al is an element that improves the hardenability of final martensitic steel by increasing the carbon content in austenite.

[0036] In order to sufficiently obtain the above-described effect, Al may be contained in an amount of 0.01% or more. However, when the content exceeds 0.5%, there is a risk that ferrite may be formed during cooling in a continuous annealing furnace, thereby weakening the strength. Furthermore, there may be a risk of causing cast piece cracks by combining with N, which is inevitably present as an impurity element in the steel, to form AlN, and there may be a problem of impairing hot rolling properties.

[0037] Therefore, in the present invention, Al may be included in an amount of 0.01 to 0.5%.

[0038] Meanwhile, the steel sheet of the present invention may further include elements advantageous for securing the physical properties of steel in addition to the alloy composition described above. Specifically, the steel sheet of the present invention may further include two or more types selected from chromium (Cr), molybdenum (Mo), and boron (B), and one or more types of titanium (Ti) and niobium (Nb).

Chromium (Cr): 0.01 to 0.2%

[0039] Chromium (Cr) may be added to improve the hardenability of steel and ensure high strength. Specifically, it is useful for manufacturing an ultra-high strength steel sheet including pure martensite phase by suppressing the formation of bainite during cooling in a continuous annealing furnace.

[0040] In order to fully obtain the above-mentioned effect, Cr may be added in an amount of 0.01% or more, but when the content thereof exceeds 0.2%, the cost of ferroalloy increases, which may become economically disadvantageous.

[0041] Therefore, when adding Cr, Cr may be added in an amount of 0.01 to 0.2%.

Molybdenum (Mo): 0.01 to 0.2%

[0042] Molybdenum (Mo), similar to Cr, is an element that improves the hardenability of steel.

[0043] In order to obtain sufficient hardening effect, Mo may be added in an amount of 0.01% or more, but when the content exceeds 0.2%, an alloy input amount becomes excessive, which may cause a problem in that costs of iron alloy may increase.

[0044] Therefore, when adding Mo, Mo may be added in an amount of 0.01 to 0.2%.

Boron (B): 0.005% or less

[0045] Boron (B) is an element that suppresses the transformation of austenite into ferrite during the continuous annealing process, and is an element that is effective in improving hardenability, like Cr and Mo, even when Boron (B) is added in very small amounts. However, when the content thereof exceeds 0.005%, as $\text{Fe}_{23}(\text{B},\text{C})_6$ precipitated phase precipitates at an austenite grain boundary, there may be a risk that Boron (B) may act to promote the formation of ferrite.

[0046] Therefore, when adding B, B may be added in an amount of 0.005% or less.

Titanium (Ti): 0.1% or less

[0047] Titanium (Ti) is an element that forms fine carbides and contributes to securing yield strength and tensile strength. Furthermore, Ti is an element that performs scavenging by precipitating N which is inevitably present at an impurity level in steel, as TiN, and Ti may be added in an amount of $48/(14 \times \text{N})$ or more based on chemical equivalent

[0048] When the content of Ti exceeds 0.1%, there may be a problem in that coarse carbides are precipitated and the strength and elongation are lowered as the amount of carbon in the steel decreases. Furthermore, since Ti may cause nozzle clogging in a continuous casting process, Ti may be added in an amount of 0.1% or less.

[0049] Meanwhile, in order to maximize the effect of addition of B, it may be advantageous to add Ti together.

Niobium (Nb): 0.1% or less

[0050] Niobium (Nb) is an element that segregates at austenite grain boundaries, suppresses coarsening of austenite grains during the continuous annealing process, and forms fine carbides, thus contributing to strength improvement.

[0051] When the content of Nb exceeds 0.1%, precipitation of coarse carbonitrides increases, and there is a risk that the strength and elongation may be lowered due to a decrease in the amount of carbon in steel. In addition, there is a problem that the processability of a base material decreases and the manufacturing costs increases.

[0052] Accordingly, when adding Nb, Nb may be added in an amount of 0.1% or less.

[0053] As a remainder of the present invention, Fe may be included. Unintended impurities may inevitably be introduced from raw materials or the surrounding environment during a normal manufacturing process, which may not be excluded. Since these impurities may be known to anyone skilled in the art during the manufacturing process, all of them are not specifically mentioned in this specification.

[0054] In the steel sheet of the present invention that satisfies the above-described alloy composition, a content relationship of specific elements satisfies the following relational expression 1.

<Relational Expression 1>

$$0.12 \leq \frac{Ceq1^2 + Ceq2^2}{2} \leq 0.28$$

(where $Ceq1 = C + (Mn/20) + (Si/30) + (2P) + (4S)$, $Ceq2 = C + (Mn/6) + (Si/30) + (Cr+Mo+V+Nb)/5 + (Cu+Ni)/15$.)

[0055] Relation Expression 1 is a complex relational expression of Ceq1 and Ceq2 for the effect of the content of alloy elements added in steel on welding characteristics, and when a range thereof satisfies 0.12 to 0.28, the basic welding characteristics may be satisfied and the desired properties of the present invention may be advantageously secured.

[0056] Specifically, when a value of Relational Expression 1 is less than 0.12, the strength targeted by the present invention may not be secured, but when the value exceeds 0.28, physical properties, especially welding characteristics, may be significantly deteriorated.

[0057] The value of Relational Expression 1 may be, more preferably, 0.15 or more and 0.27 or less, and, even more preferably, 0.17 or more.

[0058] In the steel sheet of the present invention that satisfies the above-described alloy composition and Relational Expression 1, a microstructure includes a martensite phase as a main phase.

[0059] Specifically, the steel sheet may include a martensite phase and/or a tempered martensite phase in an area fraction of 99% or more. In this case, the fraction may be 100%.

[0060] When the fraction of the martensite phase and/or the tempered martensite phase is 99%, the remaining 1% may be a ferrite phase and/or a bainite phase.

[0061] As will be described below, the steel sheet of the present invention has a surface layer in a specific region, and a main structure in a remaining region (for example, a central region) excluding the surface layer is a martensite phase and/or a tempered martensite phase.

[0062] Meanwhile, in a steel sheet of the present invention, a region ranging from a minimum of 50 μm to a maximum of 70 μm in a thickness direction from a surface may be determined as a surface layer, and the surface layer includes a soft phase.

[0063] The surface layer may include a tempered martensite phase in an area fraction of 70% or less, and may include, as a remaining structure, one or more kind of ferrite and bainite, which have softer properties than the tempered martensite. In this manner, by softening the surface layer of the steel sheet, the effect of further improving the bendability may be obtained.

[0064] Furthermore, the surface layer including a certain soft phase has the characteristic of including a decarburization layer containing C at a lower content than the C content contained in the steel sheet.

[0065] Specifically, a C content ratio in region A of 1 to 3 μm in a surface reference thickness direction as compared to the C content of the steel sheet of the present invention may be 0.6 or less. Here, the C content ratio of region A denotes [average C content of region A / C content of steel sheet].

[0066] Additionally, a C content ratio of region B of 0.2 to 30 μm in the surface reference thickness direction as compared to the C content of the steel sheet may be 0.9 or less. Here, the C content ratio of region B denote [average C content of region B / C content of steel sheet].

[0067] The decarburization layer in the surface layer may be advantageous for improving the bendability of the steel sheet, and when the carbon (C) content ratio of specific regions A and B in the surface layer exceeds 0.6 and 0.9, respectively, desired bendability may not be achieved.

[0068] Here, the decarburization layer may be formed by a thickness corresponding to the surface layer, and may be formed to be thinner than the thickness of the surface layer.

[0069] In the present invention, the decarburization layer may be formed by controlling a continuous annealing process during a steel sheet manufacturing process, and this will be explained in detail below.

[0070] As described above, while the microstructure is formed of a hard phase, the steel sheet of the present invention,

which includes a decarburization layer in the surface layer, may have ultra-high strength with a tensile strength of 1300 MPa or more, and a high yield ratio of 0.72 or more, as well as the bending properties (R/t) of 3 or less.

[0071] Furthermore, the steel sheet of the present invention has a relationship between tensile strength and bendability, specifically, a relationship between tensile strength (TS), which is a basic tensile property, and a maximum bending angle after a three-point bending test according to the VDA238-100 standard, which may satisfy Relational Expression 2 below.

[0072]

<Relational Expression 2>

(Tensile strength (TS)/maximum bending angle) $\leq$ 25

[0073] When a value of Relational Expression 2 is 25 or less, excellent bendability may be secured in ultra-high strength steel with tensile strength of 1300 MPa or more, but when the value thereof exceeds 25, the strength is high but the bendability deteriorates.

[0074] Hereinafter, a method for manufacturing an ultra-high strength steel sheet with excellent bendability according to another aspect of the present invention will be described in detail.

[0075] Briefly, the present invention may manufacture the desired steel sheet through the following processes [steel slab heating - hot rolling - coiling - cold rolling - continuous annealing], and each process is described in detail below. Meanwhile, the continuous annealing process includes a cooling process as well as a reheating and over-aging process, which means that the processes are performed simultaneously in a continuous annealing line.

[Heating Steel Slab]

[0076] First, after preparing a steel slab satisfying the above-described alloy composition, the steel slab may be heated.

[0077] This process is performed to smoothly perform a subsequent hot rolling process and obtain sufficient physical properties of a target steel sheet. In the present invention, the conditions of this heating process are not particularly limited, and normal conditions may be used. As an example, a heating process may be performed in a temperature range of 1100 to 1300°C. When the heating temperature is less than 1100°C, there may be a problem that the load increases rapidly during subsequent hot rolling, but when the temperature exceeds 1300°C, the amount of surface scale increases and a yield of a material decreases.

[Hot Rolling]

[0078] The steel slab heated according to the above-described above may be hot-rolled to manufacture a hot-rolled steel sheet, and in this case, final hot rolling may be performed in a temperature range of Ar3 or higher.

[0079] When a temperature during the finishing hot rolling is less than Ar3, a mixed structure may be formed by rolling the two-phase region of ferrite+austenite or ferrite region, and there may be a risk of malfunction due to fluctuations in hot rolling load.

[0080] More specifically, the finishing hot rolling may be performed in a temperature range of 800 to 1000°C.

[Coiling]

[0081] The hot-rolled steel sheet manufactured according to the above-described process may be coiled into a coil shape.

[0082] The coiling may be performed in a temperature range of 700°C or lower. When a coiling temperature exceeds 700°C, an excessive oxide film may be generated on a surface of the steel sheet, which may cause defects.

[0083] On the other hand, as the coiling temperature decreases, the strength of the hot-rolled steel sheet increases, and thus, there may be a disadvantage in that the rolling load increases in a subsequent cold rolling process. Accordingly, a lower limit of the coiling temperature may be limited to 100°C.

[Cold rolling]

[0084] The hot-rolled steel sheet coiled according to the above-described process may be cold-rolled to manufacture a cold-rolled steel sheet, and in the present invention, the cold rolling may be performed at a cold rolling reduction rate of 30 to 80%.

[0085] When the cold rolling reduction rate during cold rolling is less than 30%, not only may it not be possible to

secure a targeted thickness, but there is also a concern that hot rolling grains may remain, which may affect the generation of austenite and securing final physical properties during the subsequent continuous annealing process. On the other hand, when the cold rolling reduction rate exceeds 80%, the amount of reduction rolled in length and width directions from processing hardening that occurs during cold rolling becomes non-uniform, which may result in a material deviation of the final steel sheet. Additionally, it may be difficult to secure the targeted thickness due to the rolling load.

[0086] Meanwhile, prior to the cold rolling, a pickling process may be additionally performed for the purpose of removing an oxide layer formed on a surface of the hot-rolled steel sheet obtained by hot rolling. There are no particular limitations on the conditions of the pickling process, and the pickling process may be performed under commonly used conditions.

[Continuous Annealing]

[0087] The cold-rolled steel sheet manufactured according to the above-described above may be subject to continuous annealing. For example, the continuous annealing treatment may be performed in a continuous annealing furnace (CAL).

[0088] The continuous annealing treatment may be performed as a heat treatment process at a temperature of Ac3 or higher for 30 seconds or more. This is to secure the austenite fraction at 100% through austenite single phase region annealing.

[0089] Here, Ac3 may be calculated from the equation below.

$$Ac3 = 910 - 203\sqrt{C} - 15.2Ni + 44.7Si + 104V + 31.5Mo + 13.1W \quad \text{<Equation>}$$

(where each element is a weight content thereof.)

[0090] In the present invention, a dew point temperature in the annealing furnace may be controlled to be 0 to 20°C during the continuous annealing under the above-described conditions, and by controlling the dew point temperature in this manner, a decarburization layer may be formed on the surface of steel during the continuous annealing process.

[0091] Typically, the dew point in a continuous annealing furnace is around -50°C, and when moist nitrogen (N₂+H₂O) is added to increase the dew point temperature by 0°C or more, oxygen partial pressure increases, and carbon (C) in the steel meets oxygen (O) in the annealing furnace and is released as CO gas, which causes decarburization in the surface layer.

[0092] If the dew point temperature in the annealing furnace is less than 0°C, a decarburization layer is not sufficiently formed on the steel surface, and on the other hand, when the temperature exceeds 20°C, there may be a problem of reduced equipment lifespan and productivity.

[0093] In this manner, by forming a decarburization layer on a surface of steel during the continuous annealing process and softening only the surface layer, the present invention has the effect of further improving the bendability of steel with ultra-high strength.

[Stepwise Cooling]

[0094] As described earlier, a targeted structure may be formed by cooling a cold-rolled steel sheet that has been continuously annealed according to the above-described process, and in this case, cooling is performed stepwise.

[0095] In the present invention, the stepwise cooling may be accomplished by primary cooling - secondary cooling, and specifically, after the continuous annealing, the primary cooling may be performed at an average cooling rate of 1 to 10°C/s to a temperature range of 550 to 750°C, and the secondary cooling may be performed at an average cooling rate of 20 to 80°C/s to the temperature range equal to or less than Ms-190°C.

[0096] When an end temperature during the primary cooling is less than 550°C, there may be a risk that strength may decrease due to the formation of phases such as ferrite and bainite, but when the temperature thereof exceeds 750°C, not only is the annealing furnace's durability lifespan shortened, but excessive cooling is required during the subsequent secondary cooling, which may cause problems in an actual production line, such as poor sheet shape and difficulty controlling meandering.

[0097] Furthermore, when the average cooling rate during the primary cooling is less than 1°C/s, a ferrite phase is formed during cooling, making it impossible to secure a target level of strength, but when the average cooling rate exceeds 10°C/s, the average cooling rate during the subsequent secondary cooling decreases, and the fraction of low-temperature transformation phases other than martensite increases, ultimately making it impossible to secure the target level of strength.

[0098] After the primary cooling is completed as described above, rapid cooling (secondary cooling) may be performed at an average cooling rate of a certain level or higher.

[0099] Specifically, in the present invention, in order to secure a martensite phase and/or a tempered martensite phase

as the main structure, during the secondary cooling, it is advantageous to cool quickly the steel sheet to a temperature equal to or less than M_f (martensite transformation end temperature).

[0100] Specifically, by performing cooling to a temperature of $M_s-190^\circ\text{C}$ or lower, a sufficiently hard martensite structure may be formed, and during a subsequent reheating (tempering) process, a yield strength increase effect may be obtained by carbide precipitation. When the temperature at which the cooling ends exceeds $M_s-190^\circ\text{C}$, it may be difficult to secure the level of strength targeted in the present invention, and there is a risk that the subsequent reheating temperature may be excessively high, and in this case, there is a risk that the bendability of the steel may become poor. Additionally, the fraction of an intended structure (martensite and/or tempered martensite) may not be sufficiently secured.

[0101] Accordingly, in the present invention, by limiting the end temperature during the secondary cooling, it may be possible to sufficiently induce a tempering effect and secure bendability without excessively increasing the subsequent reheating temperature.

[0102] There is no particular limitation on a lower limit of the temperature at which the secondary cooling ends, but in consideration of facility characteristics, the temperature thereof may be limited to around 50°C .

[0103] Here, M_s (martensite transformation onset temperature) may be calculated from the equation below.

$$M_s = 539 - 423C - 30.4Mn - 7.5Si + 30Al - 17.7Ni - 12.1Cr - 7.5Mo \quad [\text{Equation}]$$

(where each element is a weight content.)

[0104] When the average cooling rate during the secondary cooling is less than 20°C/s , there is a risk that some bainite structure may be generated during the secondary cooling process, but when the average cooling rate exceeds 80°C/s , there is a problem that a surface shape of the steel sheet deteriorates due to a rapid martensite transformation rate at the time of the secondary cooling, and material deviation in a width direction occurs.

[Reheating and Over-aging]

[0105] In the present invention, the toughness of steel may be improved by changing hard martensite phase having a high dislocation density formed during secondary cooling into tempered martensite through a reheating and over-aging treatment.

[0106] Specifically, the reheating and over-aging treatment may be a process of heating the cold-rolled steel sheet cooled in a stepwise manner according to the above-described process to a temperature range satisfying the following Relational Expression 3, and then maintaining the heated steel sheet at that temperature for 1 to 20 minutes.

<Relational Expression 3>

$$CT_2 + 30^\circ\text{C} \leq A \leq 270^\circ\text{C}$$

(where CT_2 refers to a secondary cooling end temperature ($^\circ\text{C}$), and A refers to a reheating and over-aging temperature ($^\circ\text{C}$).)

[0107] In other words, in order to sufficiently secure the tempering effect, a lower limit of the reheating temperature is limited to a temperature of 30°C or higher compared to the secondary cooling end temperature (CT_2). Yield strength of steel increases due to fine carbides formed during the reheating process of the present invention, and in this case, when the temperature in this case is less than $CT_2 + 30^\circ\text{C}$, the tempering effect becomes insignificant. On the other hand, when the temperature exceeds 270°C , there is a problem that the carbide becomes coarse to deteriorate the bendability.

[0108] In addition, when the maintaining time during the over-aging treatment after reheating to the above-described temperature range is less than 1 minute, it may be difficult to obtain a targeted tempering effect because martensite is not sufficiently transformed into tempered martensite. On the other hand, when the maintaining time exceeds 20 minutes, carbide generated through over-aging may become coarse, which may reduce bendability and adversely affect the mechanical property of a material.

[0109] The steel sheet of the present invention manufactured as described above has a microstructure comprised of martensite and/or tempered martensite, so that the steel sheet may ultra-high tensile strength of 1300MPa or more, and may also secure an excellent yield ratio by controlling a temperature during a continuous annealing process, a cooling process, and a reheating process thereof. Moreover, excellent bendability may be achieved by forming a decarburization layer on the surface layer during the continuous annealing process.

Mode for Invention

[0110] Hereinafter, the present invention will be described in more detail through embodiments. However, the description of this embodiment is only for illustrating an embodiment of the present invention, and the present invention is not limited by the description of this embodiment. This is because the scope of the present invention is determined by the matters described in the claims and matters reasonably inferred therefrom.

<Embodiment>

[0111] A steel slab having an alloy composition shown in Table 1 below was heated at 1100 to 1300°C, and was subjected to final hot rolling at 850 to 950°C, a temperature of Ar3 or higher, thus manufacturing a hot-rolled steel sheet. Then, each hot rolled steel sheet was coiled at 300 to 700°C, and was cold-rolled at a cold rolling reduction rate of 45 to 65%, thus manufacturing a cold-rolled steel sheet.

[0112] After continuously annealing each cold-rolled steel sheet manufactured according to the above-described process for 100 to 400 seconds at a temperature range of 800 to 900°C, stepwise cooling was performed under the conditions shown in Table 2 below. Then, a final steel sheet was manufactured through reheating and over-aging treatments under the conditions shown in Table 2 below. A dew point temperature in the annealing furnace during the continuous annealing treatment is also shown in Table 2 below.

[0113] Then, the C content in the surface layer of the manufactured steel sheet was measured using GDS, and the physical properties were measured through material evaluation. In this case, yield strength, tensile strength, a yield ratio, total elongation, and uniform elongation were measured by processing each steel sheet into JIS standards (gauge length width × length: 25 × 50 mm, total specimen length: 200 to 260 mm) and conducting a tensile test under the condition of a test rate of 28 mm/min.

[0114] Additionally, the bending properties (R/t) were measured by processing the same steel sheet into a specimen of 100 mm in width × 30 mm in length and then conducting a 90° bending test under the condition of a test rate of 100 mm/min. Then, cracks in a bending portion were confirmed using a microscope, and a R/t value was obtained by dividing a minimum bending radius (R value of a mold) at which no cracks occurred by a thickness of a test piece (t, mm). A maximum bending angle for a three-point bending test was measured by processing the same steel sheet into a specimen of 60 mm in width × 30 mm in length and the conducting a test according to the VDA238-100 standard at a test rate of 20 mm/min and a punching radius of 0.4R, and accordingly, a maximum bending angle at a maximum load at which cracks occurred was measured.

[0115] Then, the microstructure of each steel sheet was observed using SEM, and each fraction was measured.

[Table 1]

Steel Type	Alloy composition (wt%)											Relational Expression 1			
	C	Si	Mn	P	S	Cr	Mo	Al	Ti	V	B	Nb	Ceq 1	Ceq 2	Calculated Value
Inventive Steel 1	0.24	0.10	1.9	0.01	0.003	0.10	0.05	0.025	0.025	0	0.002	0.03	0.370	0.596	0.25
Inventive Steel 2	0.17	0.10	1.9	0.01	0.003	0	0.05	0.025	0.025	0	0.002	0.04	0.300	0.508	0.17
Comparative Steel 1	0.18	0.05	3.6	0.01	0.003	0.05	0	0.025	0.020	0.004	0.002	0.04	0.394	0.800	0.40
Comparative Steel 2	0.17	1.50	2.5	0.01	0.003	0	0.05	0.025	0.025	0	0.002	0.04	0.377	0.655	0.29
Comparative Steel 3	0.22	0.10	0.6	0.01	0.003	0.05	0	0.025	0.025	0.005	0.002	0	0.285	0.334	0.10

[Table 2]

Steel Type	Continuous Annealing		Stepwise Cooling				Reheating and Over-aging		Division
	Annealing Temperature (°C)	Dew Point Temperature (°C)	Primary Cooling End Temperature (°C)	Primary Cooling Rate (°C/s)	Secondary Cooling End Temperature (°C)	Secondary Cooling Rate (°C/s)	Reheating Temperature (°C)	Over-aging Time (minute)	
Inventive Steel 2	850	-50	700	2	100	47	210	10	Comparative Example 1
Inventive Steel 2	850	-50	700	2	130	44	210	10	Comparative Example 2
Inventive Steel 2	850	-50	700	2	150	43	210	10	Comparative Example 3
Inventive Steel 2	850	-50	700	2	100	47	230	10	Comparative Example 4
Inventive Steel 2	850	-50	700	2	130	44	230	10	Comparative Example 5
Inventive Steel 2	850	-50	700	2	150	43	230	10	Comparative Example 6
Inventive Steel 2	850	-50	700	2	100	47	180	10	Comparative Example 7
Inventive Steel 2	850	-50	700	2	100	47	270	10	Comparative Example 8
Inventive Steel 2	850	-50	700	2	150	43	270	10	Comparative Example 9
Inventive Steel 2	850	-50	700	2	150	43	300	10	Comparative Example 10
Inventive Steel 2	850	-50	700	2	220	37	270	10	Comparative Example 11
Inventive Steel 2	850	5	700	2	200	39	210	10	Comparative Example 12
Inventive Steel 1	850	-50	700	2	100	47	210	10	Comparative Example 13
Inventive Steel 1	850	-50	700	2	150	43	210	10	Comparative Example 14
Inventive Steel 1	850	5	700	2	100	47	210	10	Inventive Example 1
Inventive Steel 1	850	5	700	2	150	43	210	10	Inventive Example 2
Inventive Steel 2	850	5	700	2	100	47	210	10	Inventive Example 3
Inventive Steel 1	850	5	700	2	200	39	210	10	Comparative Example 15

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(continued)

Steel Type	Continuous Annealing		Stepwise Cooling				Reheating and Over-aging		Division
	Annealing Temperature (°C)	Dew Point Temperature (°C)	Primary Cooling End Temperature (°C)	Primary Cooling Rate (°C/s)	Secondary Cooling End Temperature (°C)	Secondary Cooling Rate (°C/s)	Reheating Temperature (°C)	Over-aging Time (minute)	
Comparative Steel 1	850	5	700	2	150	43	210	10	Comparative Example 16
Comparative Steel 2	850	5	700	2	150	43	210	10	Comparative Example 17
Comparative Steel 3	850	5	700	2	150	43	210	10	Comparative Example 18

[Table 3]

Division	Surface layer (up to 50 μm in thickness direction from a surface)							Excluding Surface layer	
	Decarburiza tion layer depth (μm)	Regio n A Avera ge C Conte nt	Regio n A C Conte nt Ratio	Regio n B Avera ge C Conte nt	Regio n B C Conte nt Ratio	F and/or B (Area %)	T-M (Area %)	M / T- M (Area %)	Balan ce
Comparative Example 1	-	0.183	1.076	0.174	1.024	5	95	99	1
Comparative Example 2	-	0.175	1.029	0.194	1.141	5	95	99	1
Comparative Example 3	-	0.189	1.112	0.185	1.088	5	95	99	1
Comparative Example 4	-	0.211	1.241	0.196	1.153	5	95	99	1
Comparative Example 5	-	0.164	0.965	0.205	1.206	5	95	99	1
Comparative Example 6	-	0.232	1.365	0.186	1.094	5	95	99	1
Comparative Example 7	-	0.178	1.047	0.193	1.135	5	95	99	1
Comparative Example 8	-	0.190	1.118	0.235	1.382	5	95	99	1
Comparative Example 9	-	0.225	1.324	0.173	1.018	5	95	99	1
Comparative Example 10	-	0.198	1.165	0.169	0.994	5	95	99	1

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(continued)

Division	Surface layer (up to 50 μm in thickness direction from a surface)							Excluding Surface layer	
	Decarburization layer depth (μm)	Region A Average C Content	Region A C Content Ratio	Region B Average C Content	Region B C Content Ratio	F and/or B (Area %)	T-M (Area %)	M / T-M (Area %)	Balance
Comparative Example 11	-	0.167	0.982	0.227	1.335	5	95	99	1
Comparative Example 12	40	0.088	0.518	0.122	0.718	65	35	99	1
Comparative Example 13	-	0.313	1.304	0.274	1.142	5	95	99	1
Comparative Example 14	-	0.345	1.438	0.283	1.179	5	95	99	1
Inventive Example 1	50	0.047	0.196	0.142	0.592	53	47	99	1
Inventive Example 2	50	0.099	0.413	0.169	0.704	47	53	99	1
Inventive Example 3	40	0.097	0.571	0.127	0.747	54	46	99	1
Comparative Example 15	50	0.094	0.392	0.151	0.629	51	49	99	1
Comparative Example 16	40	0.097	0.539	0.139	0.772	58	42	95	5
Comparative Example 17	50	0.037	0.218	0.095	0.559	75	25	80	20
Comparative Example 18	40	0.065	0.295	0.156	0.709	99	1	1	99

[0116] (In Table 3, the decarburization layer depth refers to a depth measured in the thickness direction from the surface.)

[Table 4]

Division	Yield Strength (MPa)	Tensile Strength (MPa)	Yield Ratio	Uniform Elongation (%)	Total Elongation (%)	Bendability (R/t)	Maximum Bending Angle	Relational Expression 2
Comparative Example 1	1079	1345	0.80	4.5	7.5	3<	74	18
Comparative Example 2	1072	1344	0.80	4.3	7.4	3<	76	18
Comparative Example 3	1060	1335	0.79	4.7	8.4	3<	78	17
Comparative Example 4	1112	1349	0.82	4.5	7.5	3<	75	18
Comparative Example 5	1105	1347	0.82	4.4	7.7	3<	77	17

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(continued)

Division	Yield Strength (MPa)	Tensile Strength (MPa)	Yield Ratio	Uniform Elongation (%)	Total Elongation (%)	Bendability (R/t)	Maximum Bending Angle	Relation al Expressi on 2
Comparat ive Example 6	1098	1345	0.82	4.1	7.2	3<	78	17
Comparative Example 7	1061	1364	0.78	4.3	7.0	3<	73	19
Comparat ive Example 8	1188	1325	0.90	2.5	4.7	4<	79	17
Comparat ive Example 9	1174	1319	0.89	2.7	5.8	4<	78	17
Comparat ive Example 10	1203	1288	0.93	2.2	4.7	4<	80	16
Comparat ive Example 11	1017	1271	0.80	4.1	7.3	4<	78	16
Comparat ive Example 12	936	1284	0.73	5.9	9.8	<2.5	101	13
Comparat ive Example 13	1208	1556	0.78	4.5	7.9	<4	55	28
Comparat ive Example 14	1191	1557	0.76	4.6	8.1	<4	57	27
Inventiv e Example 1	1156	1516	0.76	4.5	8.5	<2.5	84	18
Inventi ve Example 2	1125	1508	0.75	4.5	8.1	<2.5	80	19
Inventiv e Example 3	1013	1318	0.77	4.8	8.6	<2.5	103	13
Comparat ive Example 15	1067	1495	0.71	4.8	8.7	<2.5	88	17
Comparat ive Example 16	1005	1514	0.66	4.4	7.8	<2.5	99	15
Comparat ive Example 17	926	1174	0.79	8.5	11.4	<2.5	115	10
Comparat ive Example 18	331	588	0.56	15.5	27.3	<2.5	140	4

[0117] As shown in Tables 1 to 4 above, Inventive Examples 1 to 3, which satisfy all of the alloy composition and manufacturing conditions proposed in the present invention, had a sufficient decarburization layer in the surface layer, and thus had excellent bendability. In addition, it may be confirmed that the steel sheet had ultra-high strength because a main structure thereof was formed of martensite/tempered martensite.

[0118] On the other hand, Comparative Examples 1 to 11, which satisfy the alloy composition of the present invention, but do not satisfy the present invention in the manufacturing conditions, especially annealing conditions or reheating conditions, had inferior bendability because the decarburization layer in the surface layer was not formed.

[0119] Comparative Example 12 had a decarburization layer formed, but had an insufficient tempering effect, because a secondary cooling end temperature was high during cooling after continuous annealing, and the temperature was not sufficiently increased during reheating, resulting in low yield strength and low tensile strength.

[0120] Although Comparative Examples 13 and 14 satisfied all of the alloy compositions of the present invention, the annealing conditions (dew point temperature conditions) did not satisfy the present invention, and thus, a decarburization

layer was not formed in the surface layer, and further, it may be confirmed that the bendability was inferior to approximately 4, and a maximum angle during a bending test was not sufficient, thus deviating from Relational Expression 2.

[0121] In Comparative Example 15, when cooling after continuous annealing, the secondary cooling end temperature was high, and the temperature was not sufficiently increased during reheating, so that a decarburization layer was formed, but as the tempering effect was insufficient, the yield strength was low and the yield ratio was inferior.

[0122] Comparative Example 16 was an example that did not satisfy the alloy composition of the present invention, so that the yield strength and yield ratio were inferior.

[0123] Comparative Example 17 was also an example that did not satisfy the alloy composition of the present invention, so that due to an insufficient martensite (+ tempered martensite) phase as a steel sheet microstructure, both yield strength and tensile strength were inferior.

[0124] Comparative Example 18 was an example deviating from Relational Expression 1 of the present invention, and even though the annealing conditions of the present invention were applied, the martensite (+ tempered martensite) phase was hardly formed not only in the surface layer but also in the center, so that the strength was significantly inferior.

[0125] FIG. 1 illustrates an image obtained by measuring, by SEM, a microstructure of a cross-section of a surface layer (approximately up to 80 μm in the thickness direction) of Inventive Example 1 and Comparative Example 1.

[0126] As illustrated in FIG. 1, in the case of Inventive Example 1, it may be seen that a decarburization layer including a soft phase was formed in the surface layer, but in Comparative Example 1, it may be seen that a hard phase was formed densely.

[0127] FIG. 2 illustrates an image obtained by measuring, by SEM, a cross-sectional microstructure of the 1/4t region (t: steel sheet thickness (mm), based on 1.4 mm) of Inventive Example 1 and Comparative Example 1.

[0128] As illustrated in FIG. 2, it may be confirmed that martensite (or tempered martensite) phase was formed as a main structure in both Inventive Example 1 and Comparative Example 1.

Claims

1. An ultra-high strength steel sheet having excellent bendability, comprising: by wt%, carbon (C): 0.1 to 0.3%, manganese (Mn): 1.0 to 2.3%, silicon (Si): 0.05 to 1.0%, phosphorus (P): 0.1% or less (excluding 0%), sulfur (S): 0.03% or less (excluding 0%), aluminum (Al): 0.01 to 0.5%, two or more types of chromium (Cr): 0.01 to 0.2%, molybdenum (Mo): 0.01 to 0.2% and boron (B): 0.005% or less, one or more types of titanium (Ti): 0.1% or less and niobium (Nb): 0.1% or less, and a balance of Fe and unavoidable impurity elements, and satisfying the following relational expression 1,

wherein a microstructure comprises, in area fraction, 99% or more of martensite and/or tempered martensite phases,

<Relational Expression 1>

$$0.12 \leq \frac{Ceq1^2 + Ceq2^2}{2} \leq 0.28$$

where $Ceq1 = C + (Mn/20) + (Si/30) + (2P) + (4S)$, and $Ceq2 = C + (Mn/6) + (Si/30) + (Cr+Mo+V+Nb)/5 + (Cu+Ni)/15$.

2. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein the steel sheet has a C content ratio (average C content of region A / C content of steel sheet) of 0.6 or less in region A of 1 to 3 μm in a surface reference thickness direction as compared to the C content.
3. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein the steel sheet has a C content ratio (average C content of region B / C content of steel sheet) of 0.9 or less in region B of 0.2 to 30 μm in a surface reference thickness direction as compared to the C content.
4. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein the steel sheet includes 1% or less (including 0%) of a ferrite phase and/or a bainite phase.
5. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein in the steel sheet, a microstructure of a surface layer, a region ranging from a minimum of 50 μm to a maximum of 70 μm in a thickness direction from

a surface thereof, comprises tempered martensite with an area fraction of 70% or less (excluding 0%) and one or more types of ferrite and bainite as a balance.

6. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein the steel sheet has tensile strength of 1300 MPa or more, a yield ratio of 0.72 or more, and a bending property (R/t) of 3 or less.
7. The ultra-high strength steel sheet having excellent bendability of claim 1, wherein the steel sheet satisfies the following relational expression 2,

<Relational expression 2>

$$(\text{Tensile Strength (TS)}/\text{Maximum Bending Angle}) \leq 25.$$

8. A manufacturing method for an ultra-high strength steel sheet having excellent bendability, comprising:

heating a steel slab including, by wt%, carbon (C): 0.1 to 0.3%, manganese (Mn): 1.0 to 2.3%, silicon (Si): 0.05 to 1.0%, phosphorus (P): 0.1% or less (excluding 0%), sulfur (S): 0.03% or less (excluding 0%), aluminum (Al): 0.01 to 0.5%, two or more types of chromium (Cr): 0.01 to 0.2%, molybdenum (Mo): 0.01 to 0.2% and boron (B): 0.005% or less, one or more types of titanium (Ti): 0.1% or less and niobium (Nb): 0.1% or less, and a balance of Fe and unavoidable impurity elements, and satisfying the following relational expression 1, in a temperature range of 1100 to 1300°C;

manufacturing a hot-rolled steel sheet by finish hot rolling the reheated steel slab at Ar3 or higher;

coiling the hot-rolled steel sheet at a temperature of 700°C or less;

manufacturing a cold-rolled steel sheet by cold rolling the coiled hot-rolled steel sheet with a total reduction ratio of 30 to 80%;

continuously annealing the cold-rolled steel sheet for 30 seconds or more at Ac3 or higher;

performing primary cooling at an average cooling rate of 1 to 10°C/s to a temperature range of 550 to 750°C after the continuous annealing;

performing secondary cooling at an average cooling rate of 20 to 80°C/s to a temperature of Ms-190°C or less after the performing primary cooling; and

performing reheating after the secondary cooling and then performing an over-aging treatment,

wherein the reheating and over-aging include heating to a temperature range that satisfies the following relational expression 3,

<Relational Expression 1>

$$0.12 \leq \frac{Ceq1^2 + Ceq2^2}{2} \leq 0.28$$

(where $Ceq1 = C + (Mn/20) + (Si/30) + (2P) + (4S)$, $Ceq2 = C + (Mn/6) + (Si/30) + (Cr+Mo+V+Nb)/5 + (Cu+Ni)/15$)

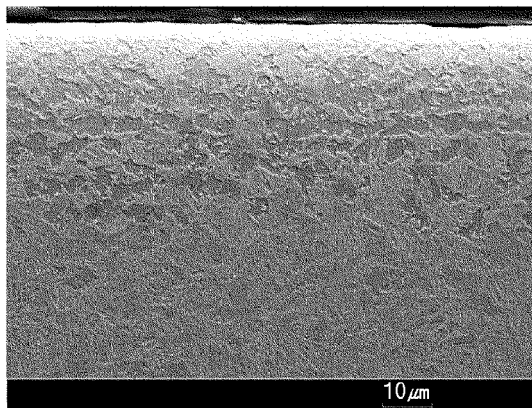
<Relational Expression 3>

$$CT2 + 30^\circ\text{C} \leq A \leq 270^\circ\text{C}$$

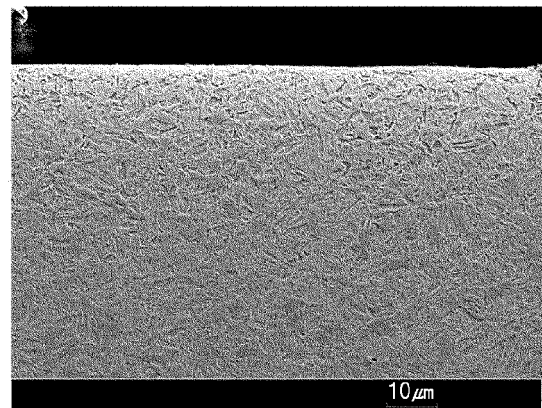
where CT2 denotes a secondary cooling end temperature (°C), and A means a reheating and over-aging temperature (°C).

9. The manufacturing method for an ultra-high strength steel sheet having excellent bendability of claim 8, wherein the continuous annealing is performed in a continuous annealing furnace with a dew point temperature of 0 to 20°C.
10. The manufacturing method for an ultra-high strength steel sheet having excellent bendability of claim 8, wherein the over-aging treatment is performed for 1 to 20 minutes.

[FIG. 1]

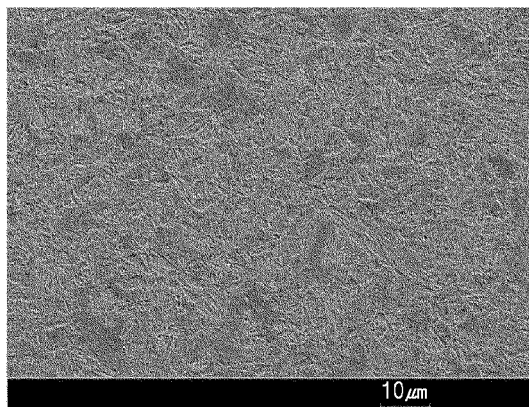


SURFACE LAYER IN INVENTIVE EXAMPLE 1

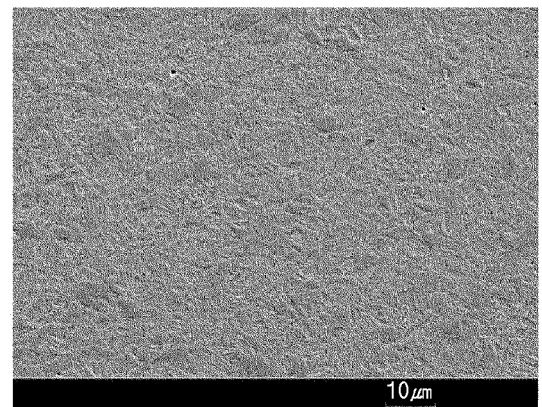


SURFACE LAYER IN COMPARATIVE EXAMPLE 1

[FIG. 2]



1/4t IN INVENTIVE EXAMPLE 1



1/4t IN COMPARATIVE EXAMPLE 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2022/020030

A. CLASSIFICATION OF SUBJECT MATTER C22C 38/38(2006.01)i; C22C 38/22(2006.01)i; C22C 38/32(2006.01)i; C22C 38/28(2006.01)i; C22C 38/26(2006.01)i; C21D 8/02(2006.01)i; B21C 47/02(2006.01)i; C21D 9/46(2006.01)i According to International Patent Classification (IPC) or to both national classification and IPC																					
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C22C 38/38(2006.01); C21D 1/18(2006.01); C21D 1/30(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/60(2006.01) Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models: IPC as above Japanese utility models and applications for utility models: IPC as above Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS (KIPO internal) & keywords: 강판(steel sheet), 강도(strength), 마르텐사이트(martensite), 템퍼드(tempered), 크롬(Cr), 몰리브덴(Mo), 보론(B), 티타늄(Ti), 니오븀(Nb), 냉각(cooling), 냉간압연(cold rolled)																					
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>KR 10-2021-0149841 A (JFE STEEL CORPORATION) 09 December 2021 (2021-12-09) See paragraphs [0110], [0112] and [0149]-[0161] and claims 2, 4-5 and 7.</td> <td>1,4,8,10</td> </tr> <tr> <td>Y</td> <td></td> <td>2-3,5-7,9</td> </tr> <tr> <td>Y</td> <td>KR 10-2018-0070940 A (POSCO) 27 June 2018 (2018-06-27) See paragraphs [0072]-[0073], [0090] and [0115], claims 1 and 9 and table 2.</td> <td>2-3,5-7,9</td> </tr> <tr> <td>A</td> <td>WO 2021-149676 A1 (NIPPON STEEL CORPORATION) 29 July 2021 (2021-07-29) See claims 1 and 4.</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>JP 2009-203549 A (JFE STEEL CORP.) 10 September 2009 (2009-09-10) See paragraph [0024] and claims 1-3 and 5.</td> <td>1-10</td> </tr> <tr> <td>A</td> <td>KR 10-2019-0049294 A (POSCO) 09 May 2019 (2019-05-09) See paragraph [0020] and claims 1-4.</td> <td>1-10</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	KR 10-2021-0149841 A (JFE STEEL CORPORATION) 09 December 2021 (2021-12-09) See paragraphs [0110], [0112] and [0149]-[0161] and claims 2, 4-5 and 7.	1,4,8,10	Y		2-3,5-7,9	Y	KR 10-2018-0070940 A (POSCO) 27 June 2018 (2018-06-27) See paragraphs [0072]-[0073], [0090] and [0115], claims 1 and 9 and table 2.	2-3,5-7,9	A	WO 2021-149676 A1 (NIPPON STEEL CORPORATION) 29 July 2021 (2021-07-29) See claims 1 and 4.	1-10	A	JP 2009-203549 A (JFE STEEL CORP.) 10 September 2009 (2009-09-10) See paragraph [0024] and claims 1-3 and 5.	1-10	A	KR 10-2019-0049294 A (POSCO) 09 May 2019 (2019-05-09) See paragraph [0020] and claims 1-4.	1-10
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<table border="0"> <tr> <td style="vertical-align: top;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family																			
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<table border="1"> <tr> <td>Date of the actual completion of the international search 13 March 2023</td> <td>Date of mailing of the international search report 14 March 2023</td> </tr> </table>	Date of the actual completion of the international search 13 March 2023	Date of mailing of the international search report 14 March 2023																			
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<table border="1"> <tr> <td> 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 </td> <td> Authorized officer Telephone No. </td> </tr> </table>	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
Information on patent family members

International application No.

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