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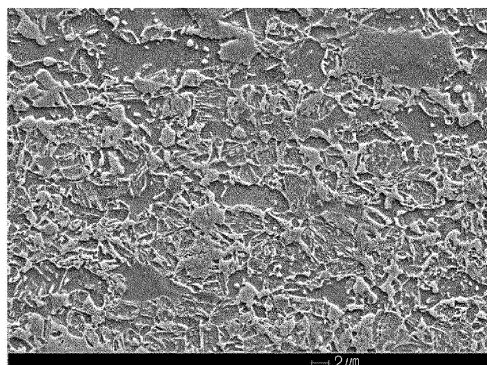
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(54) **ULTRA HIGH STRENGTH STEEL SHEET HAVING EXCELLENT DUCTILITY AND METHOD FOR MANUFACTURING THEREOF**

(57) The present invention relates to a steel sheet suitable for a vehicle material and, more specifically, to an ultra high strength steel sheet having excellent ductility.

【FIG. 1】



Description

[Technical Field]

5 **[0001]** The present disclosure relates to a steel sheet suitable as a vehicle material, and more particularly, to an ultra-high strength steel sheet having excellent ductility.

[Background Art]

10 **[0002]** Recently, in the automobile industry, in order to improve fuel efficiency or durability in accordance with various environmental regulations and energy use regulations, the use of a high-strength steel sheet has been required.

[0003] However, in a case where the strength of the steel sheet is increased, it has been found that the ductility is relatively reduced. Therefore, a lot of studies have been conducted to improve a relationship between the strength and the ductility. As a result, phase-transformation steel using a retained-austenite phase as well as martensite and bainite, which are low-temperature microstructures, has been developed and applied.

15 **[0004]** The phase-transformation steel is classified into ferrite-martensite dual phase (DP) steel in which a hard martensite phase is formed in a ferrite matrix, transformation induced plasticity (TRIP) steel using transformation induced plasticity of retained-austenite, and complexed phase (CP) steel composed of ferrite and a hard bainite or martensite structure. Each type of steel has different mechanical properties, that is, a tensile strength and an elongation, according to a type and fraction of a mother phase and a second phase.

20 **[0005]** In particular, TRIP steel containing a large amount of a retained-austenite phase has the highest tensile strength and elongation balance (TS × EI) value.

[0006] As an example, Patent Document 1 discloses steel that contains about 10% of a retained-austenite phase, in addition to ferrite and martensite, has a product of a tensile strength and an elongation of 21,000 MPa% or more, and may secure a tensile strength of 780 MPa or more. However, since carbon (C) and silicon (Si) are added to the steel in high contents of about 0.2% and about 1.5% or more, respectively, spot weldability and hot-dip galvanizing properties may be deteriorated. In addition, since annealing is performed twice in order to realize high physical properties, there is a problem in that the manufacturing cost of the steel sheet is increased.

25 **[0007]** Meanwhile, Patent Document 2 discloses a technique capable of lowering a content of Si to a level of 1% in order to secure excellent plating properties and spot weldability and securing a tensile strength of 980 MPa or more and an elongation of 15% or more by being composed of martensite, bainite, and ferrite without containing a retained-austenite phase as a microstructure. However, recently, in accordance with strengthening of crashworthiness regulations for vehicles, in order to improve impact resistance of a vehicle body, high-strength steel having an excellent yield strength has been adopted for structural members such as a member, a seat rail, and a pillar, but the steel has a yield strength of 700 MPa or less, and thus has limitations in its applications.

(Patent Document 1) Korean Patent Laid-Open Publication No. 2015-0130612

(Patent Document 2) Korean Patent Laid-Open Publication No. 2013-0106142

40 [Disclosure]

[Technical Problem]

45 **[0008]** An aspect of the present disclosure is to provide a steel sheet, a steel sheet suitable for a vehicle structural member and the like, having an excellent tensile strength and yield strength and improved ductility, and a method for manufacturing the same.

[0009] An object of the present disclosure is not limited to the above description. The object of the present disclosure will be understood from the general contents of the present specification, and those skilled in the art to which the present disclosure pertains will have no difficulties in understanding the additional objects of the present disclosure.

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[Technical Solution]

[0010] According to an aspect of the present disclosure, an ultra-high strength steel sheet having excellent ductility contains, by wt%, 0.1 to 0.2% of carbon (C), 0.1 to 1.0% of silicon (Si), 2.0 to 3.0% of manganese (Mn), 1.0% or less (excluding 0%) of aluminum (Al), 1.0% or less of chromium (Cr), 0.5% or less of molybdenum (Mo), 0.1% or less of titanium (Ti), 0.1% or less of niobium (Nb), 0.1% or less (excluding 0%) of antimony (Sb), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.02% or less of nitrogen (N), and a balance of Fe and unavoidable impurities, wherein the ultra-high strength steel sheet satisfies the following Relational Expressions 1 to 3.

55

[Relational Expression 1]

$$1110[C] + 41.5[Si] + 575[Mn] - 1092[Al] - 3590[Nb] - 5181[Ti] + 258[Cr] + 664[Mo] \geq 1380$$

[Relational Expression 2]

$$2853[C] + 95[Si] + 309[Mn] - 153[Al] + 4661[Nb] - 780[Ti] + 210[Cr] + 457[Mo] \geq 1300$$

[Relational Expression 3]

$$-29[C] + 0.6[Si] - 7.3[Mn] + 7.8[Al] - 145.2[Nb] + 62.6[Ti] - 3.3[Cr] - 2.2[Mo] \geq -24$$

[0011] (In Relational Expressions 1 to 3, each element represents a weight content).

[0012] According to another aspect of the present disclosure, a method for manufacturing an ultra-high strength steel sheet having excellent ductility includes: preparing a steel slab satisfying the alloy composition and Relational Expressions 1 to 3; heating the steel slab to a temperature within a range of 1,050 to 1,300°C; hot rolling the heated steel slab at a temperature within a range of 800 to 1,000°C to manufacture a hot-rolled steel sheet; coiling the hot-rolled steel sheet at a temperature within a range of 400 to 700°C; cold rolling the coiled hot-rolled steel sheet at a total reduction ratio of 20 to 70% to manufacture a cold-rolled steel sheet; annealing the cold-rolled steel sheet at a temperature within a range of 800 to 900°C; cooling the continuously annealed cold-rolled steel sheet to a temperature range of 250 to 400°C; and reheating and maintaining the cooled cold-rolled steel sheet, wherein the reheating and maintaining are performed at a temperature within a range of the cooled temperature + 50°C or higher to the cooled temperature + 200°C or lower for 0.1 to 60 minutes.

[Advantageous Effects]

[0013] As set forth above, according to the present disclosure, a steel sheet having an excellent tensile strength and yield strength and improved ductility may be provided, and the steel sheet of the present disclosure has an advantage of guaranteeing formability and crashworthiness required for a steel sheet for cold forming.

[Description of Drawings]

[0014]

FIG. 1 is a photograph of a microstructure of an inventive steel according to an exemplary embodiment in the present disclosure measured with a scanning electron microscope (SEM).

FIG. 2 is a photograph of a microstructure of a comparative steel according to an exemplary embodiment in the present disclosure measured with an SEM.

[Best Mode for Invention]

[0015] The inventors of the present disclosure have intensively conducted studies to provide a steel sheet as a vehicle material that guarantees formability and crashworthiness because it has an excellent tensile strength and ductility and has an excellent yield strength, and thus is applicable to a structural member required to be processed into a complex shape, and the like.

[0016] As a result, the present inventors have found that a steel sheet having a structure advantageous for securing desired physical properties may be provided by optimizing an alloy composition system and manufacturing conditions, thereby completing the present disclosure.

[0017] In particular, the present disclosure is characterized by providing a steel sheet having a composite structure

in which a soft phase and a hard phase are properly dispersed by controlling a content relationship between specific elements among alloy components and optimizing process conditions of a steel sheet manufactured through a series of processes.

[0018] Hereinafter, the present disclosure will be described in detail.

[0019] An ultra-high strength steel sheet having excellent ductility according to an aspect of the present disclosure may contain, by wt%, 0.1 to 0.2% of carbon (C), 0.1 to 1.0% of silicon (Si), 2.0 to 3.0% of manganese (Mn), 1.0% or less (excluding 0%) of aluminum (Al), 1.0% or less of chromium (Cr), 0.5% or less of molybdenum (Mo), 0.1% or less of titanium (Ti), 0.1% or less of niobium (Nb), 0.1% or less (excluding 0%) of antimony (Sb), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), and 0.02% or less of nitrogen (N).

[0020] Hereinafter, the reason for limiting the alloy composition of the steel sheet provided in the present disclosure as described above will be described in detail.

[0021] Meanwhile, in the present disclosure, a content of each element is based on weight, and a ratio of a structure is based on area, unless specifically stated otherwise.

Carbon (C): 0.1 to 0.2%

[0022] Carbon (C) is an element that significantly contributes to enhancing the strength of the steel sheet. C precipitates in grains of the steel sheet to induce solid solution strengthening and promotes formation of martensite in the steel to strengthen the steel. In addition, C is an austenite stabilizing element and plays an important role in forming retained-austenite. Specifically, as the amount of carbon (C) solid-dissolved in austenite is increased, austenite stability is increased, such that a fraction of austenite in the steel is increased. This induces an increase in fraction of martensite formed due to transformation of austenite, such that an effect of improving the strength of the steel sheet may be obtained, and some austenite remains at room temperature to remain as retained-austenite.

[0023] In order to sufficiently obtain the above effect, C may be added in an amount of 0.1% or more. However, when the content thereof exceeds 0.2%, the fraction of the martensite phase is excessively increased, and a fraction of a ferrite phase having an excellent elongation and impact absorption energy is relatively decreased. This causes a reduction in ductility of the steel sheet and an increase in possibility of occurrence of brittleness.

[0024] Therefore, C may be contained in an amount of 0.1 to 0.2%, and more preferably 0.12% or more and 0.18% or less.

Silicon (Si): 0.1 to 1.0%

[0025] Silicon (Si) is an element contributing to stabilization of retained-austenite by suppressing precipitation of carbides in ferrite and inducing diffusion of carbon in ferrite to austenite.

[0026] In order to obtain the above effect, it is advantageous to contain Si in an amount of 0.1% or more. However, when the content thereof exceeds 1.0%, Si oxide is formed on a steel surface, which may cause deterioration of the effects of hot-dip plating and chemical conversion coating.

[0027] Therefore, Si may be contained in an amount of 0.1 to 1.0%, and more preferably 0.2% or more, and still more preferably 0.40 or more. Meanwhile, still more preferably, Si may be contained in an amount of 0.9% or less.

Manganese (Mn): 2.0 to 3.0%

[0028] Manganese (Mn) may act as an austenite stabilizing element similar to C. Specifically, Mn may contribute to increasing the fraction of martensite in the steel by reducing a critical cooling rate at which martensite is formed in the composite structure steel.

[0029] In order to sufficiently obtain the above effect, it is preferable that Mn is contained in an amount of 2.0% or more. However, when the content thereof exceeds 3.0%, weldability of the steel sheet is deteriorated, which may cause deterioration of hot rolling properties. In addition, Mn forms a striped band called a Mn-Band, which inhibits formability and increases a risk of processing cracks.

[0030] Therefore, Mn may be contained in an amount of 2.0 to 3.0%, and more preferably 2.2% or more and 2.8% or less.

Aluminum (Al): 1.0% or less

[0031] Aluminum (Al) is an element added for deoxidation of the steel, and is a ferrite stabilizing element similar to Si. Al is effective to improve hardenability of martensite by distributing carbon in ferrite into austenite, and is an element useful for improving the ductility of the steel sheet by effectively suppressing precipitation of carbides in bainite when held in a bainite region.

[0032] When a content of Al exceeds 1.0%, continuous casting properties are deteriorated during a steelmaking

continuous casting operation, and inclusions are excessively formed, which increases the possibility of material defects of an annealed material.

[0033] Therefore, Al may be contained in an amount of 1.0% or less, and 0% is excluded. More preferably, Al may be contained in an amount of 0.01% or more.

[0034] In the present disclosure, Al refers to acid-soluble aluminum (Sol.Al).

Chromium (Cr): 1.0% or less

[0035] Chromium (Cr) is an element added to improve the hardenability of steel and secure high strength, and plays an important role in the formation of martensite. In addition, Cr is advantageous in manufacturing a composite structural steel having high ductility by minimizing a decrease in elongation compared to an increase in strength.

[0036] When a content of Cr exceeds 1.0%, the above effect may be saturated, cold rolling properties are deteriorated due to an excessive increase in hot rolling strength, and the fraction of martensite is significantly increased after annealing, which may cause a decrease in elongation.

[0037] Therefore, it should be noted that Cr may be contained in an amount of 1.0% or less, and there is no difficulty in securing intended physical properties even when Cr is not intentionally added.

Molybdenum (Mo): 0.5% or less

[0038] Molybdenum (Mo) is an element that forms carbides in the steel, and may contribute to improving a yield strength and a tensile strength by forming fine carbides in steel through combination with Ti, Nb, and the like, in the steel. When a content of Mo exceeds 0.5%, the elongation of the steel is decreased, and the manufacturing cost is increased.

[0039] Therefore, it should be noted that Mo may be contained in an amount of 0.5% or less, and there is no difficulty in securing intended physical properties even when Mo is not intentionally added.

Titanium (Ti): 0.1% or less

[0040] Titanium (Ti) may contribute to securing the yield strength and the tensile strength of the steel by forming fine carbides in the steel similar to Mo. In addition, Ti forms nitride to precipitate N contained in the steel as TiN, such that it is possible to prevent N from being combined with Al to be precipitated as AlN, which may have an effect of reducing a risk of cracks occurring in a casting process.

[0041] When a content of Ti exceeds 0.1%, coarse carbides are precipitated and C in the steel is reduced, such that the strength of the steel sheet may be decreased. In addition, the coarse carbides may cause clogging of nozzles in the casting process.

[0042] Therefore, it should be noted that Ti may be contained in an amount of 0.1% or less, and there is no difficulty in securing intended physical properties even when Ti is not intentionally added.

Niobium (Nb): 0.1% or less

[0043] Niobium (Nb) is segregated at austenite grain boundaries to suppress coarsening of austenite grains during an annealing heat treatment and to precipitate fine carbides on the grains, thereby contributing to increasing the strength of the steel sheet.

[0044] When a content of Nb exceeds 0.1%, the content of C in the steel is decreased due to formation of coarse carbides, such that the strength and the elongation of the steel sheet are decreased and the manufacturing cost of the steel is increased.

[0045] Therefore, it should be noted that Nb may be contained in an amount of 0.1% or less, and there is no difficulty in securing intended physical properties even when Nb is not intentionally added.

Antimony (Sb): 0.1% or less

[0046] Antimony (Sb) is distributed on grain boundaries to delay diffusion of oxidizing elements such as Mn, Si, and Al in the steel through grain boundaries, such that Sb has an advantageous effect in suppressing a surface concentration of oxides and suppressing coarsening of the surface concentrate depending on a temperature rise and a hot rolling process change.

[0047] When a content of Sb exceeds 0.1%, the workability is deteriorated and the manufacturing cost is increased.

[0048] Therefore, Sb may be contained in an amount of 0.1% or less, and 0% is excluded. More preferably, Sb may be contained in an amount of 0.01% or more.

Phosphorus (P): 0.05% or less

[0049] Phosphorus (P) is segregated at grain boundaries and becomes a major cause of temper brittleness, causing deterioration of the weldability and toughness. Therefore, it is advantageous to control a content of P to be as close to 0% as possible. However, P is inevitably contained in the steel manufacturing process, a process for decreasing the content of P is difficult, and the manufacturing cost is increased due to an additional process, therefore it is effective to manage an upper limit thereof.

[0050] Therefore, the content of P may be limited to 0.05% or less and more preferably may be limited to 0.03% or less. However, it should be noted that 0% may be excluded in consideration of a level that is unavoidably added.

Sulfur (S): 0.02% or less

[0051] Sulfur (S) is an impurity that is unavoidably contained in the steel together with P, and has a problem of inhibiting the ductility and weldability of the steel sheet. Therefore, it is also advantageous to control a content of S as low as possible to be as close to 0% as possible, but in consideration of the cost and time consumed in a process for decreasing the content of S, it is effective to manage an upper limit thereof.

[0052] Therefore, the content of S may be limited to 0.02% or less and more preferably may be limited to 0.01% or less. However, it should be noted that 0% may be excluded in consideration of a level that is unavoidably added.

Nitrogen (N): 0.02% or less

[0053] Nitrogen (N) may be combined with Al in the steel to form an alumina-based non-metallic inclusion of AlN. AlN deteriorates the casting quality and increases the brittleness of the steel sheet, causing an increase in risk of fracture defects.

[0054] Therefore, a content of N may be limited to 0.02% or less and more preferably may be limited to 0.01% or less. However, 0% may be excluded in consideration of a level that is unavoidably added.

[0055] The remaining component of the present disclosure is iron (Fe). However, unintended impurities may be inevitably mixed from raw materials or surrounding environments in a general manufacturing process. Therefore, it is difficult to exclude these impurities. Since these impurities may be recognized in the general manufacturing process by those skilled in the art, all the contents thereof are not particularly described in the present specification.

[0056] In the steel sheet of the present disclosure having the alloy composition described above, it is preferable that a content relationship between specific elements in the steel satisfies all of the following Relational Expressions 1 to 3.

[Relational Expression 1]

$$1110[C] + 41.5[Si] + 575[Mn] - 1092[Al] - 3590[Nb] - 5181[Ti] + 258[Cr] + 664[Mo] \geq 1380$$

[Relational Expression 2]

$$2853[C] + 95[Si] + 309[Mn] - 153[Al] + 4661[Nb] - 780[Ti] + 210[Cr] + 457[Mo] \geq 1300$$

[Relational Expression 3]

$$-29[C] + 0.6[Si] - 7.3[Mn] + 7.8[Al] - 145.2[Nb] + 62.6[Ti] - 3.3[Cr] - 2.2[Mo] \geq -24$$

[0057] (In Relational Expressions 1 to 3, each element represents a weight content.)

[0058] Relational Expressions 1 and 2 are component relational expressions derived by quantifying a degree of contribution to reinforcing the yield strength and the tensile strength of the steel sheet through control of the fraction of the microstructural phase constituting the steel sheet and improvement of the solid solution strengthening effect.

[0059] In Relational Expressions 1 and 2, C has a relatively larger coefficient than Si and Mn, and this is because C is solid-dissolved in the grains of the steel sheet and significantly contributes to the improvement of the strength. On the other hand, Si has a relatively smaller coefficient than C, which is due to a smaller effect contributing to solid solution strengthening than C. In addition, Al has a negative coefficient value, which contributes to solid solution strengthening, but causes retaining of ferrite in a dual phase region during annealing or promotion of ferrite transformation during subsequent cooling, resulting in a further decrease in strength. Meanwhile, Cr and Mo are representative hardenable elements, and suppress ferrite transformation during cooling after annealing, such that they have an effect of improving strength and are represented by positive values.

[0060] Meanwhile, since Ti and Nb are elements that form fine carbides and contribute to improvement of the strength, Ti and Nb may have a positive coefficient value in the strength relational expression according to the component elements. However, fine carbides are formed and the amount of solid-dissolved carbon is reduced at the same time, and thus, the solid solution strengthening effect of carbon is decreased. Accordingly, Ti and Nb have a positive coefficient value when the precipitation strengthening effect is dominant due to addition thereof, whereas Ti and Nb may have a negative coefficient value when the solid solution strengthening effect of carbon due to precipitation of carbides is dominant.

[0061] Relational Expression 3 is a component relational expression derived by quantifying a degree of contribution to improving the elongation of the steel sheet as well as the improvement of the solid solution strengthening effect by specific elements.

[0062] In general, considering that the elongation tends to be decreased as the strength of the steel sheet is increased, the coefficient of each element in Relational Expression 3 tends to be opposite to those of Relational Expressions 1 and 2.

[0063] Specifically, C and Mn are advantageous for the improvement of strength by the solid solution strengthening effect, but since the elongation tends to be decreased due to the improvement of strength, C and Mn have a negative coefficient value. On the other hand, Al has a positive coefficient value because it is effective in increasing the elongation. Meanwhile, Si also has a positive coefficient value in Relational Expression 3 because it contributes to the improvement of strength by the solid solution strengthening and securing retained-austenite.

[0064] When any one of Relational Expressions 1 to 3 suggested in the present disclosure is not satisfied, one or more of the physical properties of the steel sheet, in particular, the tensile strength, the yield strength, and the elongation, are deteriorated. It should be noted that this is proven from Examples described below.

[0065] The steel sheet having the alloy composition system of the present disclosure contains a soft phase and a hard phase that are properly dispersed as a microstructure, and in particular, contains, in terms of an area fraction, 3 to 20% of ferrite, 1 to 10% of retained-austenite, 1 to 30% of bainite, 30 to 70% of tempered martensite, and a balance of fresh martensite.

[0066] The ferrite is an allotrope of iron (Fe) having a body centered cubic (BCC) structure, and is a soft structure unlike martensite and bainite. Therefore, an elongation thereof is higher than those of the bainite and martensite phases, and has excellent impact absorption energy.

[0067] When a fraction of ferrite exceeds 20%, a soft structure is excessively formed in the steel sheet, and thus, plastic deformation may be promoted, causing a decrease in yield strength of the steel sheet. On the other hand, when the fraction of the ferrite is less than 3%, the elongation of the steel sheet is decreased and the formability is deteriorated.

[0068] Therefore, the ferrite may be contained in an area fraction of 3 to 20% and more preferably 5 to 15%.

[0069] The retained-austenite refers to an austenite structure remaining in the steel without being transformed into martensite or bainite in a series of heat treatment processes during the manufacturing process of the steel sheet (in the present disclosure, corresponding to [annealing - cooling - reheating and maintaining] processes), and serves to adjust a balance between the strength and the elongation of the steel sheet.

[0070] In general, when the strength of the steel sheet is increased, the elongation is decreased, causing deterioration of the formability, and when the elongation of the steel sheet is increased, the strength is decreased, causing difficulty in securing physical properties required for a structural member. However, the retained-austenite phase is useful for improving the balance between strength and elongation because it increases the tensile strength (TS) $\times$ elongation (EI) value of the steel sheet.

[0071] In order to sufficiently obtain the above effect, the retained-austenite phase may be contained in an area fraction of 1% or more, but when the fraction thereof exceeds 10%, sensitivity of liquid metal embrittlement is increased, causing deterioration of spot weldability.

[0072] Therefore, the retained-austenite may be contained in an area fraction of 1 to 10% and more preferably 3 to 9%.

[0073] The bainite may contribute to improving workability by reducing a difference in strength between the structures in the steel. That is, the bainite serves to prevent cracks, defects, and fractures in the steel sheet due to a difference in hardness between ferrite and retained-austenite phases having relatively low hardness and tempered martensite and fresh martensite having relatively high hardness.

[0074] In order to sufficiently obtain the above effect, the bainite may be contained in an area fraction of 1% or more and more preferably 5% or more. However, when the fraction exceeds 30%, the fraction of fresh martensite is decreased, and thus, it is difficult to secure a desired level of strength.

[0075] Therefore, the bainite may be contained in an area fraction of 1 to 30%.

[0076] The tempered martensite refers to a structure obtained by tempering a martensite phase obtained by quenching austenite at a temperature of about 500°C to soften the martensite phase. Such a tempered martensite phase has higher strength than the structures described above, and thus significantly contributes to improving the yield strength and the tensile strength of the steel sheet. In addition, carbon in the martensite obtained by quenching is distributed to the surrounding austenite during the tempering process to increase thermal stability of the austenite, which may allow the austenite to remain at room temperature. Therefore, the tempered martensite has an effect of improving the elongation of the steel sheet.

[0077] In order to sufficiently obtain the above effect, the tempered martensite phase is preferably contained in an area fraction of 30% or more. However, when the fraction exceeds 70%, a fraction of the retained-austenite phase may be relatively decreased.

[0078] Therefore, the tempered martensite may be contained in an area fraction of 30 to 70%.

[0079] As a residual structure other than the ferrite, retained-austenite, bainite, and tempered martensite phases, a fresh martensite phase may be contained.

[0080] Since the fresh martensite phase is a structure obtained in a process of final cooling to room temperature and has the highest strength, the fresh martensite phase significantly contributes to improving the yield strength and the tensile strength of the steel sheet. A fraction of the fresh martensite phase is not particularly limited, but as an example, it should be noted that the fresh martensite phase may be contained in an area fraction of 3% or more.

[0081] As described above, the steel sheet of the present disclosure has an excellent tensile strength, yield strength, and elongation due to appropriate formation of a soft phase and a hard phase, and specifically, may have a yield strength of 700 MPa or more, a tensile strength of 980 MPa or more, and an elongation of 13% or more.

[0082] Meanwhile, the steel sheet of the present disclosure may be a cold-rolled steel sheet, and may be a hot-dip galvanized steel sheet including a zinc-based plating layer formed on at least one surface of the cold-rolled steel sheet or an alloyed hot-dip galvanized steel sheet obtained by subjecting the hot-dip galvanized steel sheet to an alloying treatment.

[0083] Although not particularly limited, the zinc-based plating layer may be a zinc plating layer mainly containing zinc or a zinc alloy plating layer containing aluminum and/or magnesium in addition to zinc.

[0084] Hereinafter, a method for manufacturing an ultra-high strength steel sheet having excellent ductility provided by the present disclosure, which is another aspect of the present disclosure, will be described in detail.

[0085] Briefly, according to the present disclosure, a desired steel sheet may be manufactured through processes of [steel slab reheating - hot rolling - coiling - cold rolling - continuous annealing - cooling - reheating and maintaining], and then, processes of [hot-dip galvanizing - alloying heat treatment] may be further performed.

[0086] The conditions for each step will be described in detail below.

[Steel slab heating]

[0087] First, a steel slab satisfying all the alloy composition systems described above may be prepared and then heated. This process is performed to smoothly perform a subsequent hot rolling process and to obtain sufficient physical properties of a desired steel sheet.

[0088] The heating process may be performed to a temperature within a range of 1,050 to 1,300°C. When the heating temperature is lower than 1,050°C, friction between the steel sheet and the rolling mill is increased, and a load applied to the roller during the hot rolling is rapidly increased. On the other hand, the temperature exceeds 1,300°C, the energy cost required for temperature rise is increased, and the amount of surface scale is also increased, which may lead to a loss of the material.

[0089] Therefore, the heating process may be performed to a temperature within a range of 1,050 to 1,300°C, and more preferably may be performed to a temperature within a range of 1,090 to 1,250°C.

[Hot rolling]

[0090] The steel slab heated according to the above may be hot-rolled to manufacture a hot-rolled steel sheet, and in this case, finish hot rolling may be performed at a temperature within a range of 800 to 1,000°C.

[0091] When the finish hot rolling is performed in the above temperature range, an effect of improving both rigidity and formability of the steel sheet may be obtained. However, when the temperature is lower than 800°C, as rolling is performed in a ferrite region, the friction between the steel sheet and the rolling mill is increased, causing a significant increase in load due to rolling. In this case, excessive dislocations are formed, causing formation of coarse grains on the surface of the steel sheet in a subsequent coiling or cold rolling process, resulting in a cause of a decrease in strength. On the other hand, when the temperature exceeds 1,000°C, as a size of the ferrite grain is increased, the strength is also decreased. In addition, a scale occurs on the surface of the hot-rolled steel sheet, which may cause surface defects

and a reduction in life of the rolling roll.

[0092] Therefore, the finish hot rolling process in the hot rolling may be performed at a temperature within a range of 800 to 1,000°C, and more preferably may be performed at a temperature within a range of 850 to 950°C.

5 [Coiling]

[0093] The hot-rolled steel sheet manufactured according to the above may be coiled, and in this case, the coiling may be performed at a temperature within a range of 400 to 700°C.

10 **[0094]** When the coiling temperature is lower than 400°C, the strength of the hot-rolled steel sheet is excessively increased, which may cause a rolling load during subsequent cold rolling. In addition, an excessive cost and time are required to cool the hot-rolled steel sheet to the coiling temperature, causing an increase in process cost. On the other hand, when the temperature exceeds 700°C, a scale is excessively generated on the surface of the hot-rolled steel sheet, which is highly likely to cause surface defects and deteriorates plating properties.

15 **[0095]** Therefore, the coiling process may be performed at a temperature within a range of 400 to 700°C, and more preferably may be performed at a temperature within a range of 500 to 700°C.

[Cooling]

20 **[0096]** The coiled hot-rolled steel sheet may be cooled to room temperature. In this case, a cooling rate is not particularly limited, but the cooling may be performed by air cooling.

[Cold rolling]

25 **[0097]** Thereafter, the hot-rolled steel sheet may be cold-rolled to manufacture a cold-rolled steel sheet, and in this case, the cold rolling may be performed at a cold reduction ratio of 20 to 70%.

30 **[0098]** When the cold reduction ratio during the cold rolling is less than 20%, it is difficult to obtain a steel sheet having a desired thickness, and it is difficult to correct a shape of the steel sheet. On the other hand, when the cold reduction ratio exceeds 70%, cracks are likely to occur at an edge portion of the steel sheet, and a cold rolling load is caused. In addition, due to an excessive load on the surface of the steel sheet, coarse ferrite may be formed during subsequent continuous annealing.

[0099] Therefore, the cold rolling may be performed at a cold reduction ratio of 20 to 70%, and more preferably may be performed at a cold reduction ratio of 30 to 60%.

35 **[0100]** Meanwhile, prior to performing the cold rolling, the hot-rolled steel sheet may be subjected to a pickling treatment. The pickling treatment is a process of removing the scale formed on the surface of the hot-rolled steel sheet using hydrochloric acid (HCl) or the like, and may be performed under common conditions, and therefore, the conditions thereof are not particularly limited.

[Annealing]

40 **[0101]** The cold-rolled steel sheet manufactured according to the above may be subjected to an annealing treatment, as an example, a continuous annealing process may be performed, but is not limited thereto. Any of known annealing methods may be used.

45 **[0102]** In the present disclosure, ferrite formed in the cold-rolled steel sheet may be recrystallized through the annealing process, and the fractions of ferrite and austenite in the steel may be adjusted. In this case, the strength of the steel sheet manufactured after the final heat treatment (referred to a reheating process described below) is determined by the fraction of each phase formed. In general, as the fraction of the austenite is increased, the fraction of martensite or bainite transformed from austenite is increased, and thus the strength of the steel sheet tends to be improved. However, in the present disclosure, the strength may be additionally controlled by a series of heat treatment conditions described below.

50 **[0103]** In addition, carbon (C) in the steel may be distributed through the annealing process, and as a result, the amount of carbon (C) contained in austenite is increased, such that the steel sheet may have up to 10 area% of an austenite phase even at room temperature.

[0104] The annealing process may be performed at a temperature within a range of 800 to 900°C.

55 **[0105]** When the temperature during the annealing is lower than 800°C, the fraction of austenite formed through the annealing process is decreased, such that fractions of tempered martensite, bainite, and fresh martensite formed during a heat treatment described below may not be sufficient. This may cause decreases in yield strength and tensile strength of a final steel sheet. On the other hand, when the temperature exceeds 900°C, the fraction of austenite in the steel sheet is excessively high, such that some austenite is transformed into ferrite during a heat treatment process described

below. In addition, a carbon concentration in retained-austenite is decreased and mechanical stability is reduced, causing a decrease in elongation of the steel sheet. In addition, in the annealing process, moisture generated as Fe in the steel is oxidized reacts with Si, Mn, and Al in the steel to increase the possibility of forming an oxide coating film on the steel sheet. The oxide coating film inhibits wettability of Zn during hot-dip galvanizing, which may cause deterioration of the surface quality of the steel sheet.

[0106] Therefore, the annealing process may be performed at a temperature within a range of 800 to 900°C, and more preferably may be performed at a temperature within a range of 820 to 870°C.

[Cooling]

[0107] The cold-rolled steel sheet after completing the annealing process according to the above may be cooled.

[0108] In the present disclosure, quenched martensite may be formed by performing cooling on the annealed cold-rolled steel sheet, and to this end, the cooling is preferably performed at a temperature equal to or lower than a martensite transformation initiation temperature (Ms). More preferably, the cooling may be performed to a temperature range of 250 to 400°C.

[0109] A fraction of quenched martensite is increased as the temperature during the cooling is lower, which may induce improvement of the strength of the steel sheet. In addition, supersaturated carbon in martensite is distributed to surrounding austenite in a subsequent heat treatment process to increase the stability of retained-austenite, and as a result, an increase in elongation may be achieved.

[0110] However, when the cooling temperature is lower than 250°C, the fraction of quenched martensite is excessively increased, such that a fraction of retained-austenite is decreased and the shape of the steel sheet may be deteriorated. On the other hand, when the temperature exceeds 400°C, quenched martensite is not sufficiently formed, and thus, the above effect is not obtained.

[0111] When the cooling is performed to the above temperature range, the cooling may be performed at an average cooling rate of 2 to 50°C/s. When the cooling rate is less than 2°C/s, ferrite is further transformed during the cooling, resulting in a decrease in strength. On the other hand, rapid cooling is performed at a cooling rate of more than 50°C/s, a cooling deviation between positions of the steel sheet occurs, causing deterioration of the shape of the steel sheet. In the cooling performed at the above cooling rate, a cooling method is not particularly limited. As an example, the cooling may be performed by a single cooling method in which cooling is performed to a cooling end temperature at an initial set cooling rate as it is, and as another example, the cooling may be performed by a step-by-step cooling method in which slow cooling is performed up to a certain section and then strong cooling is performed to a cooling end temperature, but the cooling method is not limited thereto.

[0112] Meanwhile, a process of maintaining the steel sheet at the cooled temperature for a certain period of time may be performed, and in this process, an isothermal transformation phase may be additionally introduced to obtain an effect of accelerating the transformation of bainite in a subsequent process. To this end, the maintaining process may be performed for 0.1 to 60 minutes.

[Reheating and maintaining]

[0113] The cooled cold-rolled steel sheet, and furthermore, the cooled and maintained cold-rolled steel sheet may be tempered by reheating the cooled cold-rolled steel sheet to a temperature range higher than the cooling temperature by about 50 to 200°C, and then maintaining the cooled cold-rolled steel sheet for a predetermined time.

[0114] By reheating the cooled cold-rolled steel sheet, the quenched martensite phase formed in the cooling process is tempered and transformed into tempered martensite, and the tempered martensite has an advantage of a high yield strength because carbon is fixed to dislocations. In addition, in the tempering process, supersaturated carbon (C) in quenched martensite is redistributed into the surrounding austenite, or bainite transformation is induced to improve the stability of retained-austenite, such that an effect of improving an elongation may be obtained.

[0115] Since the fixation of the dislocations and the distribution of carbon into austenite occur smoothly as the tempering temperature is increased, it is required to reheat the cooled cold-rolled steel sheet at a temperature higher than the cooling temperature by 50°C or higher (cooled temperature + 50°C or higher). However, when the temperature is excessively high, cementite is generated in quenched martensite and cementite is coarsened, such that the strength of the steel sheet is decreased and the redistribution effect of carbon into austenite is decreased. Therefore, it is difficult to expect an improvement of the elongation. In consideration of this, the reheating may be limited to be performed at the cooled temperature + 200°C or lower.

[0116] It is preferable to sufficiently implement the above effect by reheating the cooled cold-rolled steel sheet to the above temperature range and then maintaining the reheated cold-rolled steel sheet at the temperature for 0.1 to 60 minutes.

[0117] When the maintenance time is excessive and exceeds 60 minutes, ferrite and cementite that are equilibrium

phases are formed at the maintaining temperature, causing a decrease in strength of the steel sheet, and when the maintenance time is shorter than 0.1 minutes, the intended effect may not be obtained.

[0118] After completing the process of reheating and maintaining the cooled cold-rolled steel sheet as described above, the steel sheet may be cooled to room temperature under common conditions, and finally, a steel sheet having a structure in which certain fractions of a soft phase and a hard phase are properly distributed may be obtained.

[0119] Specifically, a steel sheet having a microstructure composed of, in terms of an area fraction, 3 to 20% of ferrite, 1 to 10% of retained-austenite, 1 to 30% of bainite, 30 to 70% of tempered martensite, and a balance of fresh martensite may be obtained, and such a steel sheet of the present disclosure may have an excellent yield strength and tensile strength and improved ductility.

[0120] The process of cooling to room temperature is not particularly limited, but may be performed by air cooling as an example. However, it is obvious that the process may be replaced with known cooling methods such as water cooling, oil cooling, and furnace cooling.

[0121] Meanwhile, a plated steel sheet including a plating layer formed on at least one surface thereof may be manufactured by plating the cold-rolled steel sheet after completing the series of heat treatment processes according to the above as described below.

[Hot-dip galvanizing]

[0122] A hot-dip galvanized steel sheet may be manufactured by immersing the steel sheet manufactured through the series of processes described above in a hot-dip zinc-based plating bath.

[0123] In this case, the hot-dip galvanizing may be performed under common conditions, and as an example, the hot-dip galvanizing may be performed to a temperature within a range of 430 to 490°C. In addition, the composition of the hot-dip zinc-based plating bath in the hot-dip galvanizing is not particularly limited, and the hot-dip zinc-based plating bath may be a pure zinc plating bath or a zinc-based alloy plating bath containing Si, Al, Mg, and the like.

[Alloying heat treatment]

[0124] An hot-dip galva-annealed steel sheet may be obtained by subjecting the hot-dip galvanized steel sheet to an alloying heat treatment, if necessary.

[0125] In the present disclosure, the process conditions of the alloying heat treatment process are not particularly limited as long as they are common conditions. As an example, the alloying heat treatment process may be performed to a temperature within a range of 480 to 600°C.

[0126] Hereinafter, the present disclosure will be described in more detail with reference to Examples. However, the following Examples are provided to illustrate and describe the present disclosure in detail, but are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by contents disclosed in the claims and contents reasonably inferred therefrom.

[Mode for Invention]

(Examples)

[0127] 30 kg of a slab having the alloy composition shown in Table 1 was heated at a temperature of 1,200°C for 1 hour, and then the heated slab was subjected to finish hot rolling at 900°C, thereby manufacturing a hot-rolled steel sheet. Thereafter, hot rolling and coiling in which each hot-rolled steel sheet was charged into a furnace preheated at 600°C and maintained for 1 hour and then the furnace was cooled were simulated. Thereafter, cooling (air cooling) was performed to room temperature, and then cold rolling was performed at a cold reduction ratio of 45%, thereby manufacturing a cold-rolled steel sheet.

[0128] Each cold-rolled steel sheet manufactured according to the above was subjected to a continuous annealing treatment at the temperature T1 (°C) shown in Table 2 for 1 minute, the continuous annealed steel sheet was cooled to the temperature T2 (°C) and then maintained for 10 seconds, the steel sheet was reheated to the temperature T3 (°C) and then maintained for 1 minute, and then the reheated steel sheet was cooled (air-cooled) to room temperature, thereby manufacturing a final steel sheet. The cooling to the temperature T2 after the annealing treatment was uniformly performed at a cooling rate of 15°C/s.

[0129] The physical properties and internal structure were measured for each steel sheet manufactured through all of the processes described above. The results thereof are shown in Table 3.

[0130] As the mechanical properties, the yield strength (YS), the tensile strength (TS), and the elongation (EI) were measured, and the mechanical properties were measured by a universal tensile tester using ASTM tensile test pieces.

[0131] As for the internal structure, the specimen was polished and then nital etched, and then the area of each phase was calculated using a scanning electron microscope (SEM).

[Table 1]

Steel type	Alloy composition (wt%)												Relation al Expressi on 1	Relation al Expressi on 2	Relation al Expressi on 3
	C	Si	Mn	Sol.A l	Nb	Ti	Cr	Mo	Sb	P	S	N			
Steel 1	0.14	0.6	2.5	0.035	0.02	0.04	0.2	0.2	0.03	0.010	0.005	0.002	1485	1419	-23.2
Steel 2	0.14	0.6	2.4	0.035	0.02	0.04	0.4	0.2	0.03	0.008	0.005	0.003	1479	1430	-23.1
Steel 3	0.14	0.6	2.4	0.039	0.02	0.04	0.2	0.2	0.03	0.009	0.006	0.004	1423	1387	-22.4
Steel 4	0.14	0.6	2.5	0.038	0.02	0.04	0	0.2 ₁	0.03	0.011	0.009	0.002	1437	1381	-22.5
Steel 5	0.14	0.5	2.4	0.30	0	0	0.6	0.2	0.03	0.011	0.004	0.003	1516	1360	-21.4
Steel 6	0.14	0.5	2.4	0.40	0	0	0.7	0.2	0.03	0.012	0.009	0.003	1433	1366	-20.9
Steel 7	0.14	0.6	2.4	0.40	0	0	0.7	0.2	0.03	0.009	0.007	0.002	1437	1375	-20.9
Steel 8	0.16	0.6	2.3	0.40	0	0	0.7	0.2	0.03	0.012	0.004	0.004	1402	1401	-20.7
Steel 9	0.10	0.5	2.4	0.50	0	0	1.0	0.1	0.03	0.009	0.006	0.004	<u>1290</u>	<u>1254</u>	-19.7
Steel 10	0.14	0.5	2.4	0.30	0.02	0.04	0.6	0.2	0.03	0.009	0.006	0.004	<u>1237</u>	1422	-21.8
Steel 11	0.18	0.8	2.3	0.025	0.02	0.01 ₅	0.5	0.2	0.03	0.008	0.006	0.005	1640	1574	<u>-25.4</u>

[Table 2]

Steel type	Annealing temperature T1 (°C)	Cooling temperature T2 (°C)	Reheating temperature T2 (°C)	Classification
Steel 1	850	300	450	Inventive Example 1
Steel 2	830	320	460	Inventive Example 2
Steel 3	870	300	430	Inventive Example 3
Steel 4	830	280	460	Inventive Example 4
Steel 4	850	320	470	Inventive Example 5
Steel 5	850	300	440	Inventive Example 6
Steel 6	840	310	460	Inventive Example 7
Steel 6	860	300	460	Inventive Example 8
Steel 7	860	300	460	Inventive Example 9
Steel 8	850	300	460	Inventive Example 10
Steel 8	880	320	460	Inventive Example 11
Steel 9	850	300	460	Comparative Example 1
Steel 10	850	300	460	Comparative Example 2
Steel 5	<u>780</u>	300	460	Comparative Example 3
Steel 6	850	<u>500</u>	<u>550</u>	Comparative Example 4
Steel 6	850	300	<u>300</u>	Comparative Example 5
Steel 7	<u>780</u>	300	460	Comparative Example 6
Steel 11	850	300	460	Comparative Example 7

[0132] (In Table 2, Steels 9, 10, and 11 are classified as Comparative Examples due to the alloy composition system deviating from the present disclosure.)

[Table 3]

Classification	Mechanical properties			Microstructure (area%)				
	YS (MPa)	TS (MPa)	El (%)	F	R-A	T-M	B	F-M
Inventive Example 1	817	1064	13.4	19	5	54	17	5
Inventive Example 2	788	1052	13.9	15	6	61	8	10
Inventive Example 3	713	1045	13.2	11	4	49	16	20
Inventive Example 4	709	1016	13.5	15	7	65	10	3
Inventive Example 5	740	1032	13.2	10	7	55	17	11
Inventive Example 6	862	1051	13.2	9	8	61	12	10
Inventive Example 7	780	1026	15.0	11	6	57	20	6
Inventive Example 8	776	1024	13.2	12	5	61	15	7
Inventive Example 9	800	1044	14.5	8	6	49	17	20
Inventive Example 10	736	1060	14.8	11	8	56	11	14
Inventive Example 11	789	1071	14.8	9	9	41	16	25
Comparative Example 1	520	886	15.7	31	1	22	11	35
Comparative Example 2	606	1106	12.6	25	3	23	15	34
Comparative Example 3	650	865	17.2	23	2	10	10	55
Comparative Example 4	900	1100	8.5	10	0	0	20	70
Comparative Example 5	801	1040	11.2	10	0	20	0	70
Comparative Example 6	670	875	16.5	22	1	11	14	52
Comparative Example 7	910	1207	9.5	7	0	75	8	10

[0133] As shown in Tables 1 to 3, in Inventive Examples 1 to 11 in which all of the alloy component system and manufacturing conditions suggested in the present disclosure were satisfied, the intended structure configuration was formed, and thus, the desired physical properties were secured.

[0134] On the other hand, it could be appreciated that, in Comparative Examples 1 and 2 in which at least one of Relational Expressions 1 and 2 of the component relational expressions suggested in the present disclosure was not satisfied, one or more physical properties of the yield strength and the tensile strength were not secured at a desired level. In addition, it could be confirmed that in Comparative Example 7 in which Relational Expression 3 among the component relational expressions was not satisfied, the elongation was significantly deteriorated.

[0135] From this, it is proved that Relational Expression 1, characterized in the present disclosure, contributes to enhancing the yield strength by the microstructure fraction and solid solution strengthening effect of the steel sheet, Relational Expression 2 contributes to improving the tensile strength of the steel sheet, and Relational Expression 3 contributes to improving the ductility of the steel sheet.

[0136] In other words, when Relational Expressions 1 and 2 of the present disclosure are not satisfied, the strength of the steel sheet is deteriorated, and when Relational Expression 3 is not satisfied, the ductility of the steel sheet is deteriorated.

[0137] Meanwhile, in Comparative Examples 3 to 6 in which the alloy composition system suggested in the present disclosure was satisfied but the heat treatment conditions deviated from the present disclosure, the soft phase and the hard phase were not properly formed as intended, and as a result, it was not possible to secure excellent compatibility of the strength and the ductility in all cases.

[0138] FIG. 1 is a photograph of the structure of Inventive Example 1, and it may be confirmed that ferrite, retained-austenite, tempered martensite, and bainite are formed within the desired fraction ranges, and the fresh martensite phase is formed as a residual structure.

[0139] FIG. 2 is a photograph of the structure of Comparative Example 6, and it may be confirmed that the tempered martensite phase is not formed in a desired fraction, the retained-austenite phase is not sufficiently secured, and the fresh martensite phase is formed in a relatively high fraction.

Claims

1. An ultra-high strength steel sheet having excellent ductility comprising, by wt%, 0.1 to 0.2% of carbon (C), 0.1 to 1.0% of silicon (Si), 2.0 to 3.0% of manganese (Mn), 1.0% or less (excluding 0%) of aluminum (Al), 1.0% or less of chromium (Cr), 0.5% or less of molybdenum (Mo), 0.1% or less of titanium (Ti), 0.1% or less of niobium (Nb), 0.1% or less (excluding 0%) of antimony (Sb), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.02% or less of nitrogen (N), and a balance of Fe and unavoidable impurities, wherein the ultra-high strength steel sheet satisfies the following Relational Expressions 1 to 3:

[Relational Expression 1]

$$1110[C] + 41.5[Si] + 575[Mn] - 1092[Al] - 3590[Nb] - 5181[Ti] + 258[Cr] + 664[Mo] \geq 1380$$

[Relational Expression 2]

$$2853[C] + 95[Si] + 309[Mn] - 153[Al] + 4661[Nb] - 780[Ti] + 210[Cr] + 457[Mo] \geq 1300$$

[Relational Expression 3]

$$-29[C] + 0.6[Si] - 7.3[Mn] + 7.8[Al] - 145.2[Nb] + 62.6[Ti] - 3.3[Cr] - 2.2[Mo] \geq -24$$

(in Relational Expressions 1 to 3, each element represents a weight content).

2. The ultra-high strength steel sheet having excellent ductility of claim 1, wherein the steel sheet contains, in terms of an area fraction, 3 to 20% of ferrite, 1 to 10% of retained-austenite, 1 to 30% of bainite, 30 to 70% of tempered martensite, and a balance of fresh martensite, as a microstructure.
3. The ultra-high strength steel sheet having excellent ductility of claim 2, wherein the steel sheet contains a fresh martensite phase in an area fraction of 3% or more.
4. The ultra-high strength steel sheet having excellent ductility of claim 1, wherein the steel sheet has a yield strength of 700 MPa or more, a tensile strength of 980 MPa or more, and an elongation of 13% or more.
5. The ultra-high strength steel sheet having excellent ductility of claim 1, wherein the steel sheet is any one of a cold-rolled steel sheet, a hot-dip galvanized steel sheet, and an hot-dip galva-annealed steel sheet.
6. A method for manufacturing an ultra-high strength steel sheet having excellent ductility, the method comprising:
 preparing a steel slab containing, by wt%, 0.1 to 0.2% of carbon (C), 0.1 to 1.0% of silicon (Si), 2.0 to 3.0% of manganese (Mn), 1.0% or less (excluding 0%) of aluminum (Al), 1.0% or less of chromium (Cr), 0.5% or less of molybdenum (Mo), 0.1% or less of titanium (Ti), 0.1% or less of niobium (Nb), 0.1% or less (excluding 0%) of antimony (Sb), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.02% or less of nitrogen (N), and a balance of Fe and unavoidable impurities, and satisfying the following Relational Expressions 1 to 3;
 heating the steel slab to a temperature within a range of 1,050 to 1,300°C;
 hot rolling the heated steel slab at a temperature within a range of 800 to 1,000°C to manufacture a hot-rolled steel sheet;
 coiling the hot-rolled steel sheet at a temperature within a range of 400 to 700°C;
 cold rolling the coiled hot-rolled steel sheet at a total reduction ratio of 20 to 70% to manufacture a cold-rolled steel sheet;

annealing the cold-rolled steel sheet at a temperature within a range of 800 to 900°C;
 cooling the continuously annealed cold-rolled steel sheet to a temperature range of 250 to 400°C; and
 reheating and maintaining the cooled cold-rolled steel sheet,
 wherein the reheating and maintaining are performed at a temperature within a range of the cooled temperature
 + 50°C or higher to the cooled temperature + 200°C or lower for 0.1 to 60 minutes:

[Relational Expression 1]

$$1110[C] + 41.5[Si] + 575[Mn] - 1092[Al] - 3590[Nb] - 5181[Ti] + 258[Cr] + 664[Mo] \geq 1380$$

[Relational Expression 2]

$$2853[C] + 95[Si] + 309[Mn] - 153[Al] + 4661[Nb] - 780[Ti] + 210[Cr] + 457[Mo] \geq 1300$$

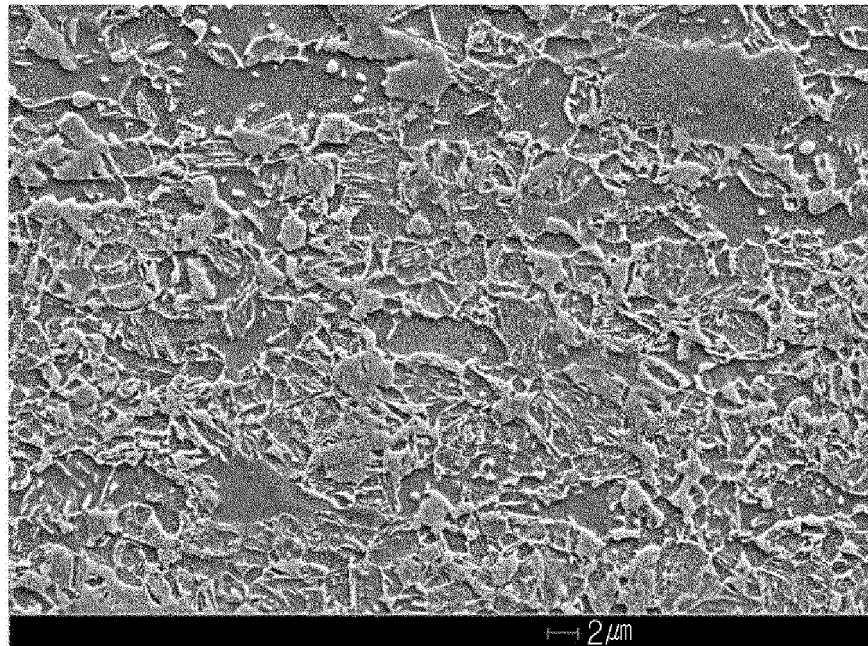
[Relational Expression 3]

$$-29[C] + 0.6[Si] - 7.3[Mn] + 7.8[Al] - 145.2[Nb] + 62.6[Ti] - 3.3[Cr] - 2.2[Mo] \geq -24$$

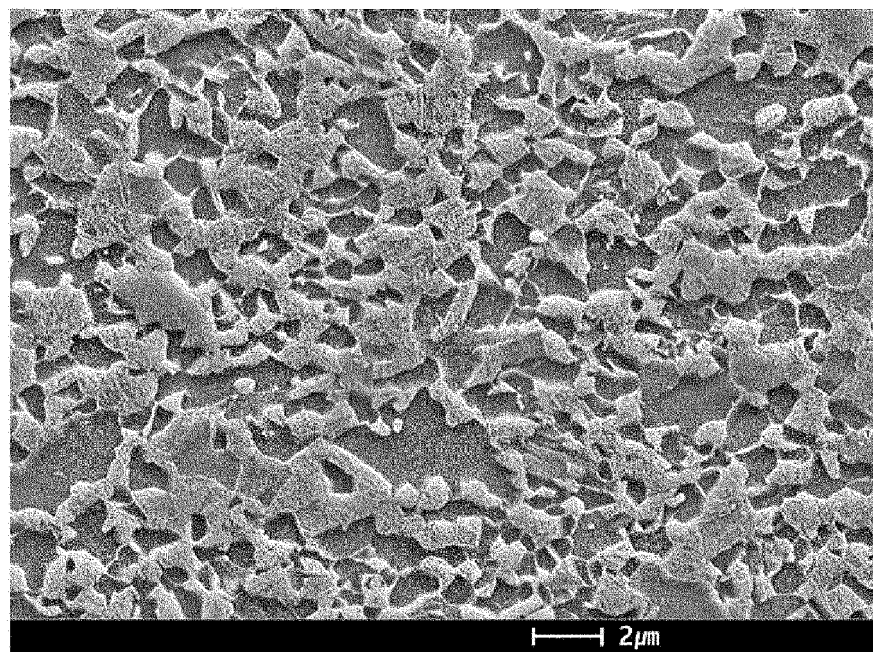
(in Relational Expressions 1 to 3, each element represents a weight content).

7. The method for manufacturing an ultra-high strength steel sheet having excellent ductility of claim 6, wherein the cooling of the cold-rolled steel sheet is performed at a cooling rate of 2 to 50°C/s.
8. The method for manufacturing an ultra-high strength steel sheet having excellent ductility of claim 6, further comprising, before the reheating of the cooled cold-rolled steel sheet, maintaining the cooled cold-rolled steel sheet in the cooled temperature range for 0.1 to 60 minutes.
9. The method for manufacturing an ultra-high strength steel sheet having excellent ductility of claim 6, further comprising, after the reheating and maintaining, performing hot-dip galvanizing.
10. The method for manufacturing an ultra-high strength steel sheet having excellent ductility of claim 6, further comprising, after the hot-dip galvanizing, performing an alloying heat treatment.

【FIG.1】



【FIG.2】



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2021/014215

A. CLASSIFICATION OF SUBJECT MATTER

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 강(steel), 연성(ductility), 크롬(Cr), 몰리브덴(Mo), 안티몬(Sb), 페라이트(ferrite),
베이나이트(bainite), 마르텐사이트(martensite)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2020-162556 A1 (NIPPON STEEL CORPORATION et al.) 13 August 2020 (2020-08-13) See paragraphs [0051]-[0054], [0058]-[0065] and [0087], claim 1 and table 3-1.	1-10
X	KR 10-2015-0130612 A (POSCO) 24 November 2015 (2015-11-24) See claims 1, 3-5, 9 and 13-14.	1,6-10
A	KR 10-2153197 B1 (POSCO) 08 September 2020 (2020-09-08) See claims 1-2, 4, 7 and 9-12.	1-10
A	KR 10-2020411 B1 (POSCO) 10 September 2019 (2019-09-10) See claims 1 and 4-11.	1-10
A	KR 10-2020-0036759 A (POSCO) 07 April 2020 (2020-04-07) See claims 1-12.	1-10

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

* Special categories of cited documents:

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

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2021/014215

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2020-162556 A1	13 August 2020	CN 112840047 A	25 May 2021
		EP 3922739 A1	15 December 2021
		JP 6777274 B1	28 October 2020
		JP WO2020-162556 A1	18 February 2021
		KR 10-2021-0086686 A	08 July 2021
		WO 2020-162556 A1	13 August 2020
KR 10-2015-0130612 A	24 November 2015	CN 107075649 A	18 August 2017
		CN 107075649 B	30 November 2018
		EP 3144406 A1	22 March 2017
		EP 3144406 B1	31 July 2019
		JP 2017-519900 A	20 July 2017
		JP 6383808 B2	29 August 2018
		KR 10-1594670 B1	17 February 2016
		US 10519526 B2	31 December 2019
		US 2017-0051378 A1	23 February 2017
		WO 2015-174605 A1	19 November 2015
KR 10-2153197 B1	08 September 2020	CN 113242912 A	10 August 2021
		EP 3901299 A1	27 October 2021
		KR 10-2020-0075991 A	29 June 2020
		US 10941467 B2	09 March 2021
		US 2020-0190640 A1	18 June 2020
		WO 2020-130560 A1	25 June 2020
KR 10-2020411 B1	10 September 2019	CN 111448332 A	24 July 2020
		EP 3730636 A1	28 October 2020
		JP 2021-507992 A	25 February 2021
		KR 10-2019-0076307 A	02 July 2019
		US 2020-0347476 A1	05 November 2020
		WO 2019-124693 A1	27 June 2019
KR 10-2020-0036759 A	07 April 2020	CN 112752862 A	04 May 2021
		EP 3859041 A1	04 August 2021
		KR 10-2276741 B1	13 July 2021
		WO 2020-067752 A1	02 April 2020

Form PCT/ISA/210 (patent family annex) (July 2019)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 20150130612 [0007]
- KR 20130106142 [0007]