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(54) **STEEL PLATE AND MANUFACTURING METHOD THEREOF**

(57) According to exemplary embodiments of the present invention, provided is an ultra-high strength steel plate having improved formability. According to

other exemplary embodiments of the present invention, provided is a method for manufacturing the ultra-high strength steel plate having improved formability.

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Description**Technical Field**

5 **[0001]** The present disclosure relates to a steel sheet and a manufacturing method thereof.

[0002] More specifically, the present disclosure relates to a steel sheet used in automobile collisions and structural members, and a manufacturing method thereof.

Background Art

10 **[0003]** Recently, a steel sheet for automobiles is required to have higher strength to improve fuel efficiency and durability due to various environmental regulations and energy use regulations. In particular, as impact safety regulations for automobiles have recently expanded, high-strength steel having excellent yield strength is being adopted for use in structural members such as a member, a seat rail, a pillar, and the like, to improve impact resistance of a vehicle body. The structural member has a characteristic, which is advantageous for impact energy absorption capability, as yield strength increases relative to tensile strength, that is, a yield ratio (tensile strength/yield strength) increases. However, as the strength of the steel sheet generally increases, elongation may decrease, which may cause an issue of reduced formability. Therefore, there is a need to develop a material that can compensate for this.

15 **[0004]** Typically, methods for strengthening steel include solid solution strengthening, precipitation strengthening, strengthening by grain refinement, and transformation strengthening. However, among such methods, solid solution strengthening and strengthening by grain refinement have the disadvantage that it is very difficult to manufacture high-strength steel having a tensile strength of 490 MPa or more.

20 **[0005]** There is provided a technology in which precipitation strengthening-type high-strength steel secures strength by strengthening a steel sheet by precipitating carbides and nitrides by adding carbide and nitride forming elements such as Cu, Nb, Ti, and V, or by refining grains through suppressing grain growth by fine precipitates. The technology has the advantage that can easily obtain high strength at low manufacturing costs, but has the disadvantage that high-temperature annealing should be performed to secure ductility by causing recrystallization because a recrystallization temperature rises rapidly due to fine precipitates. In addition, precipitation strengthening steel, which is strengthened by precipitating carbides and nitrides in a ferrite matrix, has the problem that it is difficult to obtain high-strength steel of 25 600 MPa or more.

30 **[0006]** Various types of transformation strengthening-type high-strength steels have been developed, including ferrite-martensite dual phase steel in which hard martensite is included in a ferrite matrix, transformation induced plasticity (TRIP) steel using transformation-induced plasticity of retained austenite, and complexed phase (CP) steel composed of a structure of ferrite and hard bainite or martensite. However, when the tensile strength that can be implemented in such an advanced high strength steel is 1500 MPa, elongation thereof is limited to about 8%. In addition, hot press forming steel, which secures a final strength by rapid cooling through direct contact with a die which is formed at high temperature and then cooled by water, is gaining attention for application to structural members to secure collision safety. However, the application thereto is not greatly expanded due to the excessive investment costs in facilities and high heat treatment and process costs.

35 **[0007]** Recently, in order to further improve passenger safety during collisions, the implementation of high strength and weight reduction of seat parts of a vehicle are being undertaken at the same time. These parts are manufactured using two methods: roll forming and press forming. Seat parts are parts connecting passengers to a vehicle body, and should support passengers with high stress to prevent the passengers from being thrown out of the vehicle during a collision. To this end, high yield strength and yield ratio are required. In addition, most of the processed parts are parts requiring strength flangeability, so the application of a steel material having excellent a hole expansion ratio is required.

40 **[0008]** Meanwhile, Patent Document 1 discloses a technology for a high-strength cold-rolled steel sheet, controlled to have a single-phase structure of martensite, and having a tensile strength of 880 to 1170 MPa, by optimizing the composition and heat-treatment conditions of the steel sheet. Patent Document 2 discloses a technology for manufacturing a high-strength steel sheet in which a volume ratio of a low-temperature transformation phase comprised of martensite and retained austenite accounts for 90% or more of the total metal structure is heated and maintained in a dual-phase region, to control the steel sheet to have a structure of fine ferrite and austenite including a lath of the low-temperature transformation phase, and through subsequent cooling, to ultimately have a metal structure in which ferrite and the low-temperature transformation phase are finely dispersed in the lath phase.

45 **[0009]** Patent documents 1 and 2 claim that high yield strength may be obtained without a water cooling treatment. However, when a proper water cooling treatment is not performed, there are disadvantages such as greatly reduced ductility or reduced strength flangeability due to the occurrence of a large amount of austenite in steel.

[0010] Therefore, it is necessary to develop ultra-high strength steel sheets with excellent formability.

(Patent Document 1) Japanese Registered Patent Publication No. 3729108
 (Patent Document 2) Japanese Published Patent Publication No. 2005-272954

Summary of Invention

Technical Problem

[0011] An aspect of the present disclosure is to provide a steel sheet and a manufacturing method thereof.

[0012] More specifically, an aspect of the present disclosure is to provide an ultra-high strength steel sheet having excellent formability and a manufacturing method thereof.

[0013] An object of the present disclosure is not limited to the above description. The object of the present disclosure will be understood from the entire content of the present specification, and a person skilled in the art to which the present disclosure pertains will understand an additional object of the present disclosure without difficulty.

Solution to Problem

[0014] According to aspects of the present disclosure, provided is a steel sheet, the steel sheet including by weight%: 0.10 to 0.30% of carbon (C), 2.5% or less (excluding 0%) of silicon (Si), 1.0 to 3.0% of manganese (Mn), 1.20% or less (excluding 0%) of chromium (Cr), 0.0010 to 0.10% of phosphorus (P), 0.010% or less (excluding 0%) of sulfur (S), 0.010 to 0.10% of soluble aluminum (Sol.Al), 0.001 to 0.2% of molybdenum (Mo), 0.0010 to 0.0050% of boron (B), 0.010 to 0.080% of titanium (Ti), and a balance of Fe and other unavoidable impurities, wherein the following Relational Expression 1 is satisfied, wherein a microstructure of the steel sheet includes by area%, 60 to 90% of a total content of tempered martensite and bainite, 3 to 15% of retained austenite, and a balance of at least one of ferrite and fresh martensite.

$$2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0 \quad [\text{Relational Expression 1}]$$

[0015] In Relational Expression 1, [C], [Si], [Mn], [Cr], [Mo], [B], and [Ti] represent a content (weight%) of C, Si, Mn, Cr, Mo, B, and Ti, respectively.

[0016] An average grain size of the tempered martensite may be 3 μm or less (excluding 0 μm).

[0017] An average grain size of the bainite may be 3 μm or less (excluding 0 μm).

[0018] The steel sheet may have a tensile strength of 1180 MPa or more, a hole expansion ratio of 30% or more, and an elongation of 14% or more.

[0019] The steel sheet may have a yield strength of 800 MPa or more.

[0020] According to other aspects of the present disclosure, provided is a manufacturing method of a steel sheet, the method comprising operations of: heating a steel slab including by weight%, 0.10 to 0.30% of carbon (C), 2.5% or less (excluding 0%) of silicon (Si), 1.0 to 3.0% of manganese (Mn), 1.20% or less (excluding 0%) of chromium (Cr), 0.0010 to 0.10% of phosphorus (P), 0.010% or less (excluding 0%) of sulfur (S), 0.010 to 0.10% of soluble aluminum (Sol.Al), 0.001 to 0.20% of molybdenum (Mo), 0.0010 to 0.0050% of boron (B), 0.010 to 0.080% of titanium (Ti), and a balance of Fe and other unavoidable impurities, wherein the following Relational Expression 1 is satisfied; finish hot rolling the heated steel slab at a temperature within a range of Ar3 to 1000°C to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet; pickling and cold rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet; annealing the cold-rolled steel sheet at a temperature within a range of 780 to 870°C; primarily cooling the annealed cold-rolled steel sheet to a temperature within a range of 550 to 700°C; secondarily cooling the primarily-cooled cold-rolled steel sheet to a temperature within a range of 250 to 350°C; and over-aging the secondarily-cooled cold-rolled steel sheet at a temperature within a range of 200 to 450°C.

$$2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0 \quad [\text{Relational Expression 1}]$$

$$80.0 \leq 0.3*[SS-Ac1] + 0.85*[Ms-Tq] - 1.22(Tp-Tq) + 65*[Relational Expression 1] \leq 110.0 \quad [\text{Relational Expression 1}]$$

[0021] In Relational Expression 2, SS represents a continuous annealing temperature, Ac1 represents a eutectoid transformation temperature, Ms represents a martensite transformation start temperature, Tq represents a secondary cooling end temperature, and Tp represents an overaging treatment temperature, and [Relational Expression 1] represents a value calculated by Relational Expression 1.

[0022] In the operation of heating the steel slab, a heating temperature may be from 1000 to 1350°C.

[0023] In the operation of coiling the hot-rolled steel sheet, a coiling temperature may be from 500 to 750°C.

[0024] In the operation of primarily cooling the steel sheet, a cooling rate may be 1 to 10°C/s.

[0025] In the operation of secondarily cooling the steel sheet, a cooling rate may be 5 to 40°C/s.

[0026] The manufacturing method of the steel sheet may further include an operation of skin pass rolling the over-aged steel sheet at a reduction ratio in a range of 0.1 to 1.0%.

Advantageous Effects of Invention

[0027] As set forth above, according to aspects of the present disclosure, the formability of a steel sheet may be improved by controlling an alloy composition and microstructure of the steel sheet.

[0028] According to other aspects of the present disclosure, a manufacturing method of a steel sheet that can provide an ultra-high strength steel sheet with excellent formability by optimizing manufacturing conditions of the steel sheet may be provided.

[0029] The various and beneficial advantages and effects of the present disclosure are not limited to the above-described contents, and may be more easily understood through descriptions of specific embodiments of the present disclosure.

Best Mode for Invention

[0030] As described above, controlling a microstructure of a steel sheet is very important for manufacturing a steel sheet with excellent formability. Generally, a structure having the highest strength among low-temperature structures is martensite. As known in the art, the easiest method for manufacturing martensite is to maintain martensite for a sufficient amount of time for austenite to form during annealing, and then to water-cool and temper martensite. However, the water cooling method known in the art may cause material variations, shape defects, and the like, leading to a deterioration in the productivity of steel sheets.

[0031] The inventors of the present disclosure have intended to secure uniform martensite by controlling a composition of alloying elements. That is, the inventors of the present disclosure intended to secure martensite even at low cooling rates by adding a certain amount or more of hardenable elements such as Mn and Cr. However, this method can cause problems such as weldability deterioration due to the addition of high alloying elements. Therefore, in the present disclosure, a carbon content, having the greatest influence on weldability, was minimized.

[0032] In addition, to secure a high yield ratio under cooling conditions such as those of the steel sheets according to exemplary embodiments of the present disclosure, alloying elements should be added in as large a quantity as possible. However, such attempts cause additional problems such as a deterioration in weldability and increased hot-rolled strength, so a solution thereof is required.

[0033] Accordingly, the inventors of the present disclosure have discovered that the formability of the steel sheet may be improved, and the yield ratio may be increased, when the size of martensite and nano precipitates are controlled without adding excessive amounts of alloying elements through various studies, thereby completing the present disclosure.

[0034] Hereinafter, preferred embodiments of the present disclosure will be described in detail with reference to the attached drawings. Prior to the detailed description of the present disclosure, the terms or words used in this specification and claims described below should not be construed as being limited to a common or dictionary meanings, and the inventors should conceptualize their own invention in the best manner possible. It should be interpreted as having a meaning and concept corresponding to the technical idea of the present disclosure, based on the principle that it may be properly defined as a concept of a term for explanation.

[0035] Hereinafter, a steel sheet and a manufacturing method of the steel sheet according to exemplary embodiment of the present disclosure will be described in detail with reference to the attached drawings. Prior to the detailed description thereof, the terms or words used in this specification and claims described below should not be construed as being limited to a common or dictionary meaning, and the inventors should use their own invention in the best way. It should be interpreted as a meaning and concept corresponding to the technical idea of the present disclosure based on the principle that it may be properly defined as a concept of a term for explanation.

[0036] Hereinafter, when describing with reference to the drawings, identical or corresponding components will be assigned the same reference numerals and duplicate descriptions thereof will be omitted.

[0037] In the following examples, terms such as first, second, and the like are used not in a limited sense but for the purpose of distinguishing one component from another component.

[0038] In the following examples, singular terms include plural terms unless the context clearly dictates otherwise.

[0039] In the following examples, singular terms include plural terms unless the context clearly dictates otherwise. In the following embodiments, terms such as include or have mean that the features or components described in the specification exist, and do not exclude in advance the possibility of adding one or more other features or components.

[0040] In the drawings, for convenience of explanation, the sizes of components may be exaggerated or reduced. For example, the size and thickness of each component shown in the drawings are shown arbitrarily for convenience of explanation, so the present invention is not necessarily limited to that which is shown.

[0041] In a case in which an embodiment can be implemented differently, a specific process sequence may be performed differently from the described sequence. For example, two processes described in succession may be performed at substantially the same time, or may be performed in an order opposite to the order described.

[0042] In addition, in describing the present invention, when it is determined that a detailed description of related known components or functions may obscure the essence of the invention, such detailed description thereof is omitted.

[0043] In addition, unless otherwise defined, the content of the alloy composition described below refers to a weight %.

[0044] According to exemplary embodiments, carbon (C) may be included in an amount of 0.10 to 0.30%. More specifically, C may be included in an amount of 0.15 to 0.30%. C may be included in an amount of 0.2 to 0.3%. More specifically, C may be included in an amount of 0.25 to 0.30%.

[0045] In steel, carbon (C) is a very important element added to strengthen a transformation structure. Carbon promotes high strength and promotes the formation of martensite in a transformation structure steel. As a content of C increases, an amount of martensite in the steel increases. However, when the content of C exceeds 0.30%, the strength of martensite may increase, but a difference in strength with ferrite with a low carbon concentration may increase. Due to such a difference in strength between such microstructures, fracturing may easily occur at an interphase interface when stress is applied, and thus, stretch flangeability may be reduced. In addition, weldability may be deteriorated, so weld defects may occur when processing steel sheets. When the content of carbon is less than 0.10%, it may be very difficult to secure the strength of martensite presented in the present disclosure.

[0046] According to exemplary embodiments, silicon (Si) may be included in an amount of 2.50% or less (excluding 0%). More specifically, Si may be included in an amount of 2.30% or less. Si may be included in an amount of 2.0% or less. Si may be included in an amount greater than 1.0%. Si may be included in an amount greater than 1.0% and less than or equal to 2.3%.

[0047] In steel, silicon (Si) promotes ferrite transformation and increases the content of carbon in untransformed austenite, forming a composite structure of ferrite and martensite, thereby hindering an increase in strength of martensite. In addition, since it is preferable to limit the possible addition of Si because it not only causes surface scale defects in terms of surface characteristics of the steel sheet but also reduces phosphatability.

[0048] According to exemplary embodiments, manganese (Mn) may be included in an amount of 1.0 to 3.0%. More specifically, Mn may be included in an amount of 1.5 to 3.0%. Mn may be included in an amount of 2.0 to 3.0%. Mn may be included in an amount of 2.3 to 2.9%.

[0049] In steel, manganese (Mn) may refine grains without damaging ductility and completely precipitate sulfur in steel as MnS, thereby preventing hot brittleness caused by the formation of FeS and strengthening steel. Mn simultaneously may serve to lower a critical cooling rate at which a martensite phase is obtained, making it easier to form martensite. When a content of Mn is less than 1.0%, it is difficult to secure the strength targeted by the present disclosure. When the content of Mn exceeds 3.0%, problems such as weldability and hot rolling properties of the steel sheet may occur.

[0050] According to exemplary embodiments, chromium (Cr) may be included in an amount of 1.2% (excluding 0%). More specifically, Cr may be included in an amount of 1.0% or less. Cr may be included in an amount of 0.01 to 1.0%.

[0051] In steel, chromium (Cr) is a component, added to improve the hardenability of steel and secure high strength. In particular, Cr is an element which plays a very important role in forming martensite, a low-temperature transformation phase. Therefore, the higher a content of Cr, the more the above-described effect may be enhanced. However, when the content of Cr exceeds 1.2%, not only will the effect described above be saturated, but an excessive increase in hot-rolled strength will also cause a problem of deterioration in cold rollability.

[0052] According to exemplary embodiments, molybdenum (Mo) may be included in an amount of 0.001 to 0.20%. More specifically, Mo may be included in an amount of 0.04 to 0.2%. Mo may be included in an amount of 0.04 to 0.1%.

[0053] Molybdenum (Mo) is an element added to secure strength and hardenability, and when added together with Ti, Mo forms carbides together with Ti. In order to obtain a structure strengthening effect due to the formation of such carbides, the content of Mo should be at least 0.001%. However, Mo is an expensive element and Mo can impair economic feasibility of the steel sheet and delay the phase transformation too much, which may induce the formation of fresh martensite, so the content of Mo may not exceed 0.2%.

[0054] According to exemplary embodiments, boron (B) may be included in an amount of 0.0010 to 0.0050%. More specifically, B may be included in an amount of 0.0010 to 0.0025%. B may be included in an amount of 0.0010 to 0.0021%. B may be included in an amount of 0.0014 to 0.0018%.

[0055] In steel, boron (B) is a component which delays the transformation of austenite into pearlite during the cooling

process during annealing, and is added as an element which suppresses the formation of ferrite, and promotes the formation of martensite. However, when the content of B is less than 0.0010%, it is difficult to obtain the above-described effect, and when the content of B exceeds 0.0050%, deterioration in costs may occur due to excessive alloy iron.

[0056] According to exemplary embodiments, titanium (Ti) may be included in an amount of 0.010 to 0.080%. More specifically, Ti may be included in an amount of 0.010 to 0.050%. Ti may be included in an amount of 0.010 to 0.030%. Ti may be included in an amount of 0.020 to 0.080%. Ti may be included in an amount of 0.030 to 0.060%.

[0057] In steel, titanium (Ti) may contribute grain refinement by increasing the strength of the steel sheet and by precipitating nano-precipitates through bonding with carbon. The nano-precipitates may strengthen a matrix structure and reduce a difference in interphase hardness thereof. To this end, Ti may be included in an amount of 0.01% or more. However, when the content of Ti exceeds 0.08%, the elongation may be reduced due to coarsening precipitation.

[0058] According to exemplary embodiments, soluble aluminum (sol.Al) may be included in an amount of 0.010 to 0.10%.

[0059] Sol.Al may combine with oxygen in steel to perform deoxidation and distribute carbon within ferrite to austenite, like Si, thereby improving hardenability of martensite. To this end, Sol.Al may be included in an amount of 0.01% or more. However, when the content of Sol.Al exceeds 0.10%, not only will the effect described above be saturated, but manufacturing costs may also increase.

[0060] According to exemplary embodiments, sulfur (S) may be included in an amount of 0.010% or less (excluding 0%).

[0061] In steel, sulfur (S) is an impurity element which can impair ductility and weldability of a steel sheet. More specifically, when a content of S exceeds 0.01%, there is a high possibility that the ductility and weldability of the steel sheet may be impaired. Therefore, it is preferable for the content of S to be as low as possible. However, since S may be inevitably included during the manufacturing process, 0% may be excluded from the content of S.

[0062] According to exemplary embodiments, phosphorus (P) may be included in an amount of 0.0010 to 0.10%. More specifically, P may be included in an amount of 0.0010 to 0.050%. P may be included in an amount of 0.0010 to 0.030%. P may be included in an amount of 0.0010 to 0.011%.

[0063] In steel, phosphorous (P) is a substitutional alloying element with the greatest solid solution strengthening effect, which can improve in-plane anisotropy and improves strength and contribute to the improvement of the strength of a steel sheet. When a content of P is less than 0.001%, not only may the above-described effect not be secured, but it also may cause a problem of manufacturing costs. When the content of P is excessively added, press formability of the steel sheet may deteriorate and brittleness of the steel sheet may occur.

[0064] The remaining component of the present disclosure is iron (Fe). However, since in the common manufacturing process, unintended impurities may be inevitably incorporated from raw materials or the surrounding environment, the component may not be excluded. Since these impurities are known to any person skilled in the common manufacturing process, the entire contents thereof are not particularly mentioned in the present specification.

[0065] According to exemplary embodiments, the steel sheet satisfies the alloy composition described above and simultaneously satisfies the following Relational Expression 1.

$$2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0 \quad [\text{Relational Expression 1}]$$

[0066] In Relational Expression 1, [C], [Si], [Mn], [Cr], [Mo], [B], and [Ti] represent a content (weight%) of C, Si, Mn, Cr, Mo, B, and Ti, respectively.

[0067] In order to improve formability of a steel sheet while maintaining the strength of the steel sheet, numerous experiments were conducted on steel sheets satisfying the alloy composition of the steel sheet described above. Through the experiment, it was confirmed that in order to secure a hole expansion ratio (HER) of at least 25% and an elongation of at least 10% under conditions of securing ductility of the steel sheet, it is important to satisfy Relational Expression 1. Therefore, even if the alloy composition satisfies the range described above, when Relational Expression 1 is not satisfied, it may be difficult to achieve a steel sheet according to the exemplary embodiments of the present disclosure and the effects thereof.

[0068] According to exemplary embodiments, a microstructure of the steel sheet may include, by area %, 60 to 90% of a total content of tempered martensite and bainite, 3 to 15% of retained austenite, and a balance of at least one of ferrite and fresh martensite.

[0069] In order to achieve an ultra-high strength steel sheet having a tensile strength (TS) of 1180 MPa or higher, the microstructure of the steel sheet may include by area%, 60% or more of tempered martensite and bainite as a total fraction thereof. However, considering the improvement of the elongation of the steel sheet, the sum of tempered martensite and bainite may be 90% or less. As a non-limiting example, tempered martensite may be included in an

amount of 50 to 80%. Bainite may be included in an amount of 10 to 30%.

[0070] The steel sheet of the present disclosure is intended to secure excellent formability at a tensile strength (TS) of 1180 MPa or higher, and in particular, to obtain high local formability, a difference in hardness between the interphases of the microstructure, forming the steel sheet should be reduced. Retained austenite is a structure increasing an elongation of the steel sheet through the TRIP effect, and the higher the fraction, the higher the elongation can be obtained. To obtain the required level of elongation, the fraction of retained austenite may be 3% or more. However, in order to obtain retained austenite exceeding 15%, a phase transformation should be obtained at a high temperature, and it may be difficult to achieve a high strength of 1180 MPa or more.

[0071] A fresh martensite phase is formed during final cooling and contributes significantly to strength, but since the fresh martensite phase is not tempered, it greatly impairs formability; therefore, in order to obtain a high elongation thereof in the present disclosure, the fraction may be kept low. As such, controlling the fraction of fresh martensite to a low level can be advantageous for ensuring the formability of the steel sheet, so a final steel sheet may not substantially include fresh martensite. As a non-limiting example, fresh martensite may be included in an amount of 10% or less (including 0%).

[0072] Meanwhile, when the fraction of ferrite exceeds 5%, the yield strength may decrease and formability, such as a hole expansion ratio, may deteriorate. As such, ferrite may contribute to improving the formability of the steel sheet as a soft structure, and a lower limit of the fraction of ferrite may be 0.5% or more.

[0073] An average grain size of tempered martensite may be 3 μm or less (excluding 0 μm). More specifically, the average grain size of the tempered martensite may be 2 μm or less. The average grain size of the tempered martensite may be 1.2 to 2.0 μm .

[0074] An average grain size of bainite may be 3 μm or less (excluding 0 μm). The average grain size of the bainite may be 2.5 μm or less. The average grain size of the bainite may be 2.0 to 3.0 μm .

[0075] A grain size of a hard structure is related to formability of a steel sheet. In other words, the formability of the steel sheet may be improved by finely controlling the grain size of the hard structure.

[0076] The steel sheet according to the exemplary embodiments including the alloy composition and microstructure described above may have a tensile strength of 1180 MPa or more and a yield strength of 800 MPa or more. At the same time, the steel sheet may have a hole expansion ratio (HER) of 30% or more and an elongation of 14% or more. As described above, according to exemplary embodiments, an ultra-high strength steel sheet with excellent formability and a tensile strength of 1180 MPa or higher may be provided.

[0077] Hereinafter, a manufacturing method of a steel sheet according to exemplary embodiments will be described in detail. According to exemplary embodiments, a steel sheet may be manufactured through processes of [steel slab heating - hot rolling - cold rolling - continuous annealing - cooling - overaging treatment]. However, the present disclosure is not limited thereto, and a person skilled in the art may make appropriate modifications within the scope of the technical concept of the present disclosure.

[0078] Steel slab heating may be performed by heating a steel slab satisfying the alloy composition and Relational Expression 1 described above. According to exemplary embodiments, steel slab heating may be performed by heating the steel slab at a temperature within a range of 1000 to 1350°C. More specifically, steel slab heating may be performed at a temperature within a range of 1100 to 1350°C. Steel slab heating may be performed at a temperature within a range of 1130 to 1350°C. Steel slab heating may be performed at a temperature within a range of 1100 to 1300°C. Steel slab heating may be performed at a temperature within a range of 1100 to 1250°C.

[0079] When a heating temperature of the steel slab is lower than 1000°C, a steel slab may be hot-rolled in a region below a finishing hot-rolling temperature range. However, when the heating temperature of the steel slab exceeds 1350°C, there is a possibility that it will reach a melting point of a steel and melt.

[0080] Hot rolling may be performed on the heated steel slab. As a result, a hot-rolled steel sheet may be obtained.

[0081] According to exemplary embodiments, hot rolling may be performed such that an exit temperature of a finishing rolling mill is Ar3 to 1000°C. More specifically, hot rolling may be performed such that the exit temperature of the finishing rolling mill is 800°C or higher during finishing hot rolling. Hot rolling may be performed such that the exit temperature of the finishing rolling mill is 850°C or higher during finishing hot rolling. Hot rolling may be performed such that the exit temperature of the finishing rolling mill is 980°C or lower during finishing hot rolling. Hot rolling may be performed such that the exit temperature of the finishing rolling mill is 960°C or lower during finishing hot rolling.

[0082] That is, when the exit temperature of the finishing rolling mill is lower than Ar3, there is a high possibility that hot deformation resistance may be rapidly increased, and also, after coiling, top, tail, and edge portions of a hot-rolled coil become a single-phase region, to increase in-plane anisotropy and deteriorate formability. However, when the exit temperature of the finishing rolling mill exceeds 1000°C, not only will an excessively thick oxide scale occur, but there is a high possibility that the microstructure of the steel sheet will become coarse.

[0083] Ar3 can be obtained through the following [Formula 1].

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

[0084] In Formula 1, [C], [Mn], [Si], [Cr], [Mo], and [Ni] represent a content of alloy components, respectively.

[0085] According to exemplary embodiments, a hot-rolled steel sheet may be coiled at a temperature within a range of 500 to 750°C. Thus, a hot-rolled coil may be obtained. More specifically, a hot-rolled steel sheet may be coiled at a temperature within a range of 530 to 750°C. A hot-rolled steel sheet may be coiled at a temperature within a range of 600 to 750°C. A hot-rolled steel sheet may be coiled at a temperature within a range of 500 to 700°C.

[0086] When a coiling temperature thereof is lower than 500°C, excessive martensite or bainite may be generated, which can lead to an excessive increase in the strength of the hot-rolled steel sheet. This can cause problems such as shape defects due to the load during subsequent cold rolling. On the other hand, when the coiling temperature exceeds 750°C, pickling performance may be reduced due to an increase in surface scales.

[0087] Cold rolling can be performed on hot rolling. More specifically, cold rolling may be performed using a hot-rolled coil. As a result, a cold-rolled steel sheet may be obtained.

[0088] As a non-limiting example, pickling can be performed on the hot-rolled steel sheet before cold rolling.

[0089] In the present disclosure, the pickling and cold rolling conditions are not specifically limited, and all conditions used in the relevant technical field may be used. However, as an example, the cold rolling may be performed with a cold reduction ratio of 20 to 90%. When the cold reduction ratio is less than 20%, it is difficult to secure the target thickness precision, and it may also be difficult to correct the shape of the steel sheet. When the cold reduction ratio exceeds 90%, cracks may occur at an edge of the steel sheet, and a cold rolling load may become excessive in terms of productivity.

[0090] Continuous annealing may be performed on a cold-rolled steel sheet.

[0091] According to exemplary embodiments, an annealing temperature may be from 780 to 870°C.

[0092] When the annealing temperature is low, a large amount of ferrite is generated, making it impossible to secure yield strength and tensile strength. However, when the annealing temperature is high, a martensite packet size produced during cooling may increase due to an increase in an austenite grain size due to high-temperature annealing. As a result, it may become difficult to control an average grain size of the transformation structures.

[0093] Cooling can be performed on a continuously annealed cold-rolled steel sheet. According to exemplary embodiments, cooling may include primary cooling and secondary cooling.

[0094] According to exemplary embodiments, primary cooling may be performed by cooling a continuously annealed cold-rolled steel sheet to 550 to 700°C. More specifically, a cooling rate during the primary cooling may be 1 to 10°C/s. The primary cooling operation is to suppress transformation of austenite into ferrite and to transform most of the austenite into martensite. To this end, it is important to control a cooling rate and a cooling end temperature within the above-described ranges. When a primary cooling end temperature is lower than 550°C or exceeds 700°C, productivity may decrease. When the first cooling rate is less than 1°C/s, a ferrite phase may form during cooling, making it difficult to secure high strength. When the first cooling rate exceeds 10°C/s, there may be a disadvantage in that the amount of cooling in the secondary cooling increases, leading to an increase in the final temperature deviation and material deviation.

[0095] Secondary cooling may be performed after the primary cooling. According to exemplary embodiments, the secondary cooling may be performed by cooling the primarily-cooled steel sheet to 250 to 350°C. More specifically, a cooling rate during secondary cooling may be 5 to 40°C/s.

[0096] Such a secondary cooling end temperature is intended to ensure the shape of a coil in the width and length directions, as well as to secure a high yield ratio and hole expansion ratio thereof. When the secondary cooling end temperature is low, a yield strength and tensile strength may increase at the same time and ductility may deteriorate significantly due to a significant increase in an amount of martensite during an overaging treatment. In particular, shape degradation due to rapid cooling is expected to result in deterioration of workability during the processing of automotive parts. When the secondary cooling end temperature is high, austenite generated during annealing fails to transform into martensite, and high-temperature transformation phases such as bainite and granular bainite are excessively formed, causing a problem in which the yield strength deteriorates rapidly. Excessive occurrence of such a structure may cause a decrease in a yield ratio and a deterioration in a hole expansion ratio.

[0097] Overaging treatment may be performed by reheating and overaging heat treating the cold-rolled steel sheet obtained after cooling. According to exemplary embodiments, the overaging treatment may be performed at 200 to 450°C.

[0098] The overaging treatment is intended for interphase carbon distribution and additional bainite phase transformation necessary for stabilizing the residual austenite. When the overaging treatment temperature is lower than 200°C, there may be a disadvantage in that the strength becomes excessively high and the formability deteriorates. When the overaging treatment temperature exceeds 450°C, it may be difficult to achieve the strength intended to be obtained in the present disclosure.

[0099] According to exemplary embodiments, the manufacturing method of a steel sheet may further include an operation of skin pass rolling the over-aged steel sheet.

[0100] Skin pass rolling may be performed by skin-pass rolling the over-aged steel sheet at a reduction ratio in a range of 0.1 to 1.0%.

[0101] Typically, when a transformed structure steel is skin pass rolled, an increase in yield strength of at least 50 MPa occurs with almost no increase in tensile strength. When the reduction ratio is less than 0.10%, it can be very difficult to control the shape of ultra-high strength steel such as the steel in the present disclosure. When the reduction ratio exceeds 1.0%, the operability may become significantly unstable due to high elongation operations.

[0102] According to exemplary embodiments, a manufacturing method of a steel sheet may satisfy the following Relational Expression 2.

$$80.0 \leq 0.3 * [SS-A1] + 0.85 * [Ms-Tq] - 1.22(Tp-Tq) + 65 * [\text{Relational Expression 1}] \leq [\text{Relational Expression 1}]$$

[0103] In Relational Expression 2, SS represents a continuous annealing temperature, Ac1 represents an eutectoid transformation temperature, Ms represents a martensite transformation start temperature, Tq represents a secondary cooling end temperature, and Tp represents an overaging treatment temperature.

[0104] In Relational Expression 2, [Relational Expression 1] refers to a value calculated by Relational Expression 1.

[0105] In Relational Expression 2, $Ac1 = 723 - 10.7 [Mn] - 16.9 [Ni] + 29.1 [Si] + 16.9 [Cr]$ and $Ms = 539 - 423 [C] - 30.4 [Mn] - 12.1 [Cr] - 7.5 [Mo]$. [Mn], [Ni], [Si], [Cr], [C], and [Mo] represent a content (weight%) of Mn, Ni, Si, Cr, C, and Mo, respectively.

[0106] Relational Expression 2 is intended to simultaneously secure strength, elongation, and hole expansion ratio. When a value of Relational Expression 2 is less than 80.0, the target tensile strength may not be obtained. When the value of Relational Expression 2 exceeds 110.0, a target elongation cannot be obtained. Therefore, it is desirable for the value of Relational Expression 2 to have a range of 80.0 to 110.0.

Mode for Invention

[0107] Hereinafter, embodiments of the present disclosure will be described in detail so that those skilled in the art can easily implement the present disclosure. However, the present disclosure may be implemented in various different forms and is not limited to the embodiments described herein.

(Example)

[0108] A steel slab having the composition described in Table 1 below was heated at a temperature of 1200°C for 1 hour. Thereafter, the heated steel slab was hot rolled and then coiled. During the hot rolling, hot rolling was terminated under temperature conditions in a temperature range of 880 to 920°C, which is Ar3 or higher, as shown in Table 2, and a coiling temperature was controlled to a temperature within a range of 500 to 680°C. Pickling was performed using a hot-rolled steel sheet and cold rolling was performed. The cold-rolled steel sheets were subjected to continuous annealing, cooling, and over-aging treatments using the conditions shown in Table 2, and skin-pass rolled with a reduction ratio of 0.2%.

[Table 1]

Steel type	C	Si	Mn	Cr	Ti	Mo	B	Sol.Al	P	S	Relational Expression 1
1	0.181	1.45	2.25	0.32	0.021	0.048	0.0014	0.021	0.009	0.003	2.21
2	0.151	1.71	2.43	0.4	0.032	0.1	0.0021	0.021	0.011	0.004	2.21
3	0.22	1.3	2.12	0.05	0.04	0.05	0.0018	0.018	0.011	0.004	2.46
4	0.31	0.76	2.69	0.53	0.09	0.12	0.0022	0.025	0.011	0.003	3.32
5	0.18	0.62	2.34	0.21	0.04	0.07	0.0017	0.025	0.012	0.003	2.09
[Relational Expression 1] $2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0$											

[Table 2]

Division	Steeltype No.	Ar3 (°C)	Ac1 (°C)	Ms (°C)	Exit Temperature of finishing rolling mill (°C)	Coiling temperature (°C)	Continuous annealing temperature (SS) (°C)	Primary cooling end temperature (°C)	Secondary cooling end temperature (Tq) (°C)	Overaging treatment temperature (Tp) (°C)	Relational Expression 2
Invention Example 1	1	819	747.65	390	905	522	855	612	304	418	110.0
Invention Example 2	1	819	747.65	390	905	522	849	623	318	434	94.0
Comparative Example 1	1	819	747.65	390	905	522	852	613	311	<u>495</u>	<u>18.0</u>
Comparative Example 2	1	819	747.65	390	905	522	853	651	<u>200</u>	420	<u>68.0</u>
Comparative Example 3	1	819	747.65	390	905	522	821	614	298	435	<u>77.0</u>
Invention Example 3	2	833	754.74	396	897	543	851	611	311	423	108.0
Invention Example 4	2	833	754.74	396	897	543	853	611	298	426	100.0
Comparative Example 4	2	833	754.74	396	897	543	852	623	<u>198</u>	423	<u>66.0</u>
Invention Example 5	3	810	740.05	381	910	532	855	614	300	425	110.0
Invention Example 6	3	810	740.05	381	910	532	851	614	300	428	105.0
Invention Example 7	3	810	740.05	381	910	532	847	614	299	435	95.0
Comparative Example 5	3	810	740.05	381	910	532	855	623	298	375	<u>170.0</u>
Comparative Example 6	4	748	726.64	319	898	524	850	614	300	420	<u>122.0</u>
Comparative Example 7	4	748	726.64	319	898	524	857	624	300	420	<u>124.0</u>

(continued)

Division	Steeltype No.	Ar3 (°C)	Ac1 (°C)	Ms (°C)	Exit Temperature of finishing rolling mill (°C)	Coiling temperature (°C)	Continuous annealing temperature (SS) (°C)	Primary cooling end temperature (°C)	Secondary cooling end temperature (Tq) (°C)	Overaging treatment temperature (Tp) (°C)	Relational Expression 2
Comparative Example 8	4	748	726.64	319	898	524	855	614	300	420	<u>124.0</u>
Comparative Example 9	4	748	726.64	319	898	524	852	603	305	420	<u>125.0</u>
Comparative Example 10	5	781	720.72	389	903	512	853	617	302	307	<u>243.0</u>
[Relational Expression 2] 80.0 ≤0.3*[SS-Ac1]+0.85*[Ms-Tq]-1.22*(Tp-Tq)+65*[Relational Expression 1]≤110.0											

[0109] A microstructure and mechanical properties of the steel sheets manufactured in this manner were measured, and the results were shown in Table 3 below.

[0110] The type, fraction, and average grain size of the microstructure were measured using EBSD and XRD analysis techniques.

[0111] A hole expansion ratio (HER) was measured by forming a 10 mm Ψ punching hole (die inner diameter 10.3 mm, clearance 12.5%) by pressing and expanding a conical punch with an apex angle of 60° to the punching hole at a speed of 20 mm/min in a direction in which a burr of the punching hole becomes outward.

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

where D is a hole diameter (mm) when a crack penetrates the steel sheet, and D₀ is an initial hole diameter (mm) when a crack penetrates the steel sheet.

[0112] A yield strength (YS), tensile strength (TS), and elongation (EI) of the steel sheet were measured by performing a tensile test after preparing a JIS No. 5 tensile test specimen.

[Table 3]

Division	Microstructure					Properties of steel sheet			
	TM+B (area %)	Balance of γ (area %)	FM + F (area %)	TM grain size (μm)	B grain size(μm)	Yield strength (MPa)	Tensile strength (MPa)	elongation (%)	Hole expansion ratio (%)
Invention Ex- ample 1	87	7.4	5.6	1.7	2.4	995	1210	14.9	41
Invention Ex- ample 2	87	8.3	4.7	1.4	2.2	956	1198	14.6	35
Comparative Example 1	84	<u>2.3</u>	13.7	1.5	3.4	1050	1125	<u>12.6</u>	38
Comparative Example 2	<u>95</u>	<u>1.9</u>	3.1	1.2	2.1	923	1325	<u>10.5</u>	34
Comparative Example 3	<u>55</u>	7.3	37.7	1.3	2.4	1211	1342	<u>10.6</u>	<u>29</u>
Invention Ex- ample 3	88	8.4	3.6	1.6	2.3	945	1234	15.9	46
Invention Ex- ample 4	85	7	8	1.3	2.5	995	1210	14.9	35
Comparative Example 4	<u>96</u>	<u>2.2</u>	1.8	1.2	2.1	1265	1385	<u>8.1</u>	<u>21</u>
Invention Ex- ample 5	87	8.8	4.2	1.3	2.3	1011	1220	16.1	36
Invention Ex- ample 6	81	10.1	8.9	1.5	2.5	1026	1198	15.2	32
Invention Ex- ample 7	82	11.8	6.2	1.4	2.3	1033	1234	15.4	<u>29</u>
Comparative Example 5	83	11.8	5.2	1.5	2.1	1105	1302	<u>10.3</u>	38
Comparative Example 6	84	3.4	12.6	1.5	2.5	1125	1302	<u>9.8</u>	<u>23</u>
Comparative Example 7	86	3.1	10.9	1.4	2.3	1135	1287	<u>9.5</u>	32

(continued)

Division	Microstructure					Properties of steel sheet			
	TM+B (area %)	Balance of γ (area %)	FM + F (area %)	TM grain size (μm)	B grain size(μm)	Yield strength (MPa)	Tensile strength (MPa)	elongation (%)	Hole expansion ratio (%)
Comparative Example 8	84	3.2	12.8	1.6	2.4	1165	1295	<u>8.5</u>	<u>28</u>
Comparative Example 9	84	4.2	11.8	1.5	2.3	1221	1312	<u>10.2</u>	<u>21</u>
Comparative Example 10	89	8	3	1.6	1.6	1052	1324	<u>11.2</u>	36
TM: Tempered Martensite, B: Bainite, γ : Austenite, FM: Fresh Martensite, F: Ferrite									

[0113] Referring to Table 3, it was confirmed that Invention Examples 1 to 7, which satisfy both the alloy composition and manufacturing conditions according to the exemplary embodiments, have a tensile strength of 1180 MPa or higher, a HER of 30% or higher, and an elongation of 14% or higher. That is, according to the exemplary embodiments of the present disclosure, an ultra-high strength steel sheet with excellent formability and a tensile strength of 1180 MPa or higher may be provided.

[0114] Comparative Example 1 satisfied the alloy composition presented in the present disclosure, but the elongation was inferior because the residual austenite was not properly formed. This is determined to be because the overaging treatment temperature was excessively high and a range of Relational Expression 2 of the manufacturing process conditions was not satisfied.

[0115] Comparative Examples 2 and 4 satisfied the alloy composition presented in the present disclosure, but the sum of tempered martensite and bainite was excessively high, and residual austenite was not properly formed. As a result, an elongation of the steel sheet was inferior. This is determined to be because the formability of the steel sheet was inferior as the transformation structure was rapidly formed due to the excessively low secondary cooling end temperature.

[0116] Comparative Example 3 satisfied the alloy composition and individual process conditions presented in the present disclosure, but had an inferior elongation and hole expansion ratio. This is determined to be because the manufacturing process conditions did not satisfy a range of Relational Expression 2, resulting in the excessive formation of fresh martensite.

[0117] Comparative Examples 5 to 10 satisfied the individual process conditions presented in the present disclosure, but the formability of the steel sheet was inferior. This is determined to be because the alloy component composition range was not satisfied and the manufacturing process conditions did not satisfy a range of Relational Expression 2.

[0118] While the present invention has been described in detail through exemplary embodiment, other types of exemplary embodiments are also possible. Therefore, the technical spirit and scope of the claims set forth below are not limited to exemplary embodiments.

Claims

1. A steel sheet, comprising by weight%:

0.10 to 0.30% of carbon (C), 2.5% or less (excluding 0%) of silicon (Si), 1.0 to 3.0% of manganese (Mn), 1.20% or less (excluding 0%) of chromium (Cr), 0.0010 to 0.10% of phosphorus (P), 0.010% or less (excluding 0%) of sulfur (S), 0.010 to 0.10% of soluble aluminum (Sol.Al), 0.001 to 0.20% of molybdenum (Mo), 0.0010 to 0.0050% of boron (B), 0.010 to 0.080% of titanium (Ti), and a balance of Fe and other unavoidable impurities, wherein the following Relational Expression 1 is satisfied, wherein a microstructure of the steel sheet includes by area%, 60 to 90% of a total content of tempered martensite and bainite, 3 to 15% of retained austenite, and a balance of at least one of ferrite and fresh martensite,

$$2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0$$

[Relational Expression 1]

in Relational Expression 1, [C], [Si], [Mn], [Cr], [Mo], [B], and [Ti] represent a content (weight%) of C, Si, Mn, Cr, Mo, B, and Ti, respectively.

2. The steel sheet of claim 1, wherein an average grain size of the tempered martensite is 3 μm or less (excluding 0 μm).
3. The steel sheet of claim 1, wherein an average grain size of the bainite is 3 μm or less (excluding 0 μm).
4. The steel sheet of claim 1, wherein the steel sheet has a tensile strength of 1180 MPa or more, a hole expansion ratio of 30% or more, and an elongation of 14% or more.
5. The steel sheet of claim 1, wherein the steel sheet has a yield strength of 800 MPa or more.
6. A manufacturing method of a steel sheet, comprising operations of:

heating a steel slab including by weight%, 0.10 to 0.30% of carbon (C), 2.5% or less (excluding 0%) of silicon (Si), 1.0 to 3.0% of manganese (Mn), 1.20% or less (excluding 0%) of chromium (Cr), 0.0010 to 0.10% of phosphorus (P), 0.010% or less (excluding 0%) of sulfur (S), 0.010 to 0.10% of soluble aluminum (Sol.Al), 0.001 to 0.20% of molybdenum (Mo), 0.0010 to 0.0050% of boron (B), 0.010 to 0.080% of titanium (Ti), and a balance of Fe and other unavoidable impurities, wherein the following Relational Expression 1 is satisfied; finish hot rolling the heated steel slab at a temperature within a range of Ar3 to 1000°C to obtain a hot-rolled steel sheet;

coiling the hot-rolled steel sheet;

pickling and cold rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet;

continuously annealing the cold-rolled steel sheet at a temperature within a range of 780 to 870°C;

primarily cooling the annealed cold-rolled steel sheet to a temperature within a range of 550 to 700°C;

secondarily cooling the primarily-cooled cold-rolled steel sheet to a temperature within a range of 250 to 350°C; and

over-aging the secondarily-cooled cold-rolled steel sheet at a temperature within a range of 200 to 450°C,

$$2.1 \leq 7*[C] + (1.3*[Si] + [Mn])/6 + ([Cr] + 1.2*[Mo])/5 + 100*[B] + 2*[Ti] \leq 3.0 \quad [\text{Relational Expression 1}]$$

$$80.0 \leq 0.3*[SS - Ac1] + 0.85*[Ms - Tq] - 1.22(Tp - Tq) + 65*[\text{Relational Expression 1}] \leq 110.0 \quad [\text{Relational Expression 2}]$$

in Relational Expression 2, SS represents a continuous annealing temperature, Ac1 represents an eutectoid transformation temperature, Ms represents a martensite transformation start temperature, Tq represents a secondary cooling end temperature, and Tp represents an overaging treatment temperature, and [Relational Expression 1] represents a value calculated by Relational Expression 1.

7. The manufacturing method of a steel sheet of claim 6, wherein in the operation of heating the steel slab, a heating temperature is from 1000 to 1350°C.
8. The manufacturing method of a steel sheet of claim 6, wherein in the operation of coiling the hot-rolled steel sheet, a coiling temperature is from 500 to 750°C.
9. The manufacturing method of a steel sheet of claim 6, wherein in the operation of primarily cooling the steel sheet, a cooling rate is 1 to 10°C/s.
10. The manufacturing method of a steel sheet of claim 6, wherein in the operation of secondarily cooling the steel sheet, a cooling rate may be 5 to 40°C/s.
11. The manufacturing method of a steel sheet of claim 6, wherein the manufacturing method of the steel sheet further comprises an operation of skin pass rolling the over-aged steel sheet at a reduction ratio in a range of 0.1 to 1.0%.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019417

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; C21D 8/02(2006.01)i;
C23G 1/08(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 8/02(2006.01); C22C 38/00(2006.01); C22C 38/06(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), 템퍼드 마르텐사이트(tempered martensite), 베이나이트(bainite), 오스테나이트(austenite), 페라이트(ferrite), 소둔(annealing), 냉각(cooling), 강도(strength), 크롬(chromium), 보론(boron)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2023-218731 A1 (JFE STEEL CORPORATION) 16 November 2023 (2023-11-16) See paragraphs [0013]-[0015], [0059], [0097], [0099], [0102], [0111], [0115], [0122], [0125] and [0127]-[0128] and claims 1-2 and 7.	1-11
A	JP 2015-193897 A (KOBELITE LTD.) 05 November 2015 (2015-11-05) See paragraphs [0061]-[0065] and claims 1-7.	1-11
A	KR 10-2014-0083286 A (HYUNDAI STEEL COMPANY) 04 July 2014 (2014-07-04) See paragraph [0094] and claims 1-2 and 4-5.	1-11
A	KR 10-2012-0074798 A (POSCO) 06 July 2012 (2012-07-06) See paragraph [0049] and claim 1.	1-11
A	JP 2014-034716 A (NIPPON STEEL & SUMITOMO METAL) 24 February 2014 (2014-02-24) See claims 1-3 and 8.	1-11

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

* Special categories of cited documents:

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 February 2025	26 February 2025
Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208	
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/019417

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