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

(57) The present invention provides: a steel sheet suitable for vehicle exterior panel materials and specifically having excellent low-temperature bake hardening

properties and room-temperature aging resistance; and a manufacturing method thereof.

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Description

Technical Field

- 5 **[0001]** The present disclosure relates to a steel sheet suitable as a material for automobiles, and more particularly, to a steel sheet suitable as a material for exterior panel materials and a manufacturing method thereof.

Background Art

- 10 **[0002]** Recently, in countries around the world, the demand for vehicle body weight reduction has been increasing to cope with strengthened fuel efficiency regulations in automobile production. To achieve this, higher strength and reduced thickness of steel sheets are required, and among them, a certain level or more of bake hardenability (BH) is required for automotive exterior panel materials.
- 15 **[0003]** The bake hardening phenomenon of a steel sheet refers to a phenomenon in which yield strength increases as solute carbon and solute nitrogen are fixed by the formation of a Cottrell atmosphere during paint baking on dislocations formed during the processing of the steel sheet. A steel sheet with excellent bake hardenability has the advantage of facilitating the forming process performed before paint baking, and the final product has the characteristic of improved dent resistance. For this reason, a steel sheet with excellent bake hardenability is evaluated as a very ideal material for automotive exterior panels.
- 20 **[0004]** The commonly performed bake hardening process involves applying a few percent of pre-strain to the steel sheet, followed by painting and then heat treatment at 170°C for several tens of minutes. Under these conditions, the amount of bake hardening is generally secured to be approximately 30 MPa based on the yield strength.
- 25 **[0005]** Such automotive exterior panel materials are also required to have a certain level of aging resistance to ensure guaranteed to aging over a certain period.
- 30 **[0006]** In general, when the bake hardenability of a steel sheet increases, its aging resistance tends to decrease. Therefore, even if the bake hardenability of the steel sheet is secured, there is a problem that surface defects may occur during parts processing due to aging over a certain period. For this reason, materials for automotive exterior panels need to have an appropriate level of bake hardenability along with aging resistance.
- 35 **[0007]** Meanwhile, some automobile manufacturers are considering lowering the temperature during bake hardening after painting the steel sheet to achieve cost reduction and CO₂ reduction during automobile manufacturing.
- 40 **[0008]** When the bake hardening temperature of a steel sheet is lowered, it is common for the amount of fixation of solute carbon and solute nitrogen and the time required for fixation to be delayed, resulting in a decrease in bake hardenability.
- 45 **[0009]** Nevertheless, to cope with the increasingly stringent regulations, it is necessary to secure an appropriate level of bake hardenability or higher at a lowered bake hardening temperature. For this, bake hardenability at high temperatures must be fundamentally high, but in this case, the aging resistance of the steel sheet is conversely degraded, increasing the possibility of surface defects during parts processing.
- 50 **[0010]** Patent Document 1 proposes a technology for improving the bake hardenability of a steel sheet by adding tin (Sn) as an alloying composition of the steel. However, it does not provide a fundamental solution to the problem of deterioration in aging resistance due to the improvement in bake hardenability.
- 55 **[0011]** Therefore, there is a need to develop a steel sheet suitable as a material for automotive exterior panels by securing bake hardenability, especially at low temperatures, and at the same time, satisfying the required level of aging resistance.
- 60 **[0012]** (Patent Document 1) Japanese Application Publication No. 1994-306531

Disclosure of Invention

Technical Problem

- 50 **[0013]** According to an aspect of the present disclosure, it is intended to provide a steel sheet suitable as a material for automotive exterior panels, which specifically has excellent bake hardenability at low temperatures and, at the same time, excellent room-temperature aging resistance, and a manufacturing method thereof.
- 55 **[0014]** Furthermore, the technical problems to be achieved by the present disclosure are not limited to the technical problems mentioned above, and other unmentioned technical problems will be clearly understood by those of ordinary skill in the art to which the present disclosure pertains from the following description.

Solution to Problem

[0015] According to an aspect of the present disclosure, a steel sheet is provided, comprising, by weight %: carbon (C): 0.0010 to 0.0300%, manganese (Mn): 1.500 to 2.500%, chromium (Cr): more than 0% to 1.000% or less, phosphorus (P): more than 0% to 0.100% or less, sulfur (S): more than 0% to 0.0100% or less, nitrogen (N): more than 0% to 0.010% or less, aluminum (Al): 0.010 to 0.060%, the remainder being Fe and unavoidable impurities.

[0016] In an embodiment of the present disclosure, the steel sheet may have a microstructure including a ferrite phase of 95% or more by area fraction and a remainder of a second phase, and may satisfy the following Relational Expression 1.

[Relational Expression 1]

$$0.01 \leq D_{\text{second}}/D_{\text{grain}} \leq 0.15$$

(In Relational Expression 1, D_{grain} denotes the average grain size (μm) of ferrite, and D_{second} denotes the radius (μm) of the second phase based on the equivalent circle diameter.)

[0017] The steel sheet having such alloy composition and microstructure may have advantageous effects of excellent bake hardenability at low temperature and excellent room-temperature aging resistance.

[0018] A steel sheet according to an embodiment of the present disclosure may have a bake hardening amount of 30 MPa or more when bake-hardened at 150°C for 20 minutes.

[0019] A steel sheet according to an embodiment of the present disclosure may further include silicon (Si): 0.100% or less as an alloy composition, and in addition thereto, may further include one or more of boron (B): 0.004% or less and molybdenum (Mo): 0.4% or less.

[0020] A steel sheet according to an embodiment of the present disclosure may include a plating layer or an alloyed plating layer on at least one surface. Hereby, the steel sheet according to an embodiment of the present disclosure may be a cold-rolled steel sheet, and may be a plated steel sheet obtained by plating the cold-rolled steel sheet.

[0021] According to another aspect of the present disclosure, a method for manufacturing a steel sheet is provided, the method comprising: a step of heating a steel slab in a temperature range of 1100 to 1300°C; a step of obtaining a hot-rolled steel sheet by finish hot-rolling the slab after the heating at a temperature of 880°C or higher; a step of obtaining a hot-rolled coil by coiling the hot-rolled steel sheet; a step of air-cooling the hot-rolled coil; a step of obtaining a cold-rolled steel sheet by cold-rolling the hot-rolled coil after the air-cooling at a cold reduction ratio of 50 to 90%; and a step of cooling the cold-rolled steel sheet after annealing it in a temperature range of 750 to 850°C.

[0022] In an embodiment of the present disclosure, the steel slab may have the aforementioned alloy composition.

[0023] In an embodiment of the present disclosure, the coiling process may be performed under a condition that satisfies the following Relational Expression 2.

[Relational Expression 2]

$$18 \leq (T_{\text{coil}}/100) \times ((100 \times [\text{C}]) + [\text{Mn}] + [\text{Cr}]) \leq 35$$

(In Relational Expression 2, [C], [Mn], and [Cr] denote the content by weight of the corresponding elements, and T_{coil} denotes the coiling temperature (°C).)

[0024] As such, by controlling the coiling process, the microstructure of the manufactured steel sheet may have the characteristic of satisfying the aforementioned Relational Expression 1.

[0025] In an embodiment of the present disclosure, the method may further include a step of obtaining a hot-dip plated steel sheet by hot-dip plating the cooled cold-rolled steel sheet, and may further include a step of alloying heat treatment of the hot-dip plated steel sheet as needed. Advantageous Effects of Invention

[0026] According to the present disclosure, it is possible to provide a steel sheet having excellent low-temperature bake hardenability and room-temperature aging resistance, and such a steel sheet may be advantageously applied as a material for automotive exterior panels.

[0027] Furthermore, according to the present disclosure, the bake hardening temperature may be lowered, which has the effect of reducing manufacturing costs and CO₂ emissions during steel sheet production. Moreover, since the steel sheet according to the present disclosure can be applied as a multi-material, it will be possible to further promote the weight reduction of the vehicle body.

Best Mode for the Invention

[0028] The inventors of the present disclosure have conducted in-depth research on a method for achieving both bake hardenability and aging resistance, while also realizing continuously strengthening fuel efficiency regulations, in providing a steel sheet suitable as a material for automotive exterior panels.

[0029] As a result, it was confirmed that it is possible to provide a steel sheet that may secure bake hardenability equal to or higher than that under conventional bake hardening conditions even at a lower temperature, while also securing aging resistance at a target level, leading to the completion of the present disclosure.

[0030] Hereinafter, the present disclosure will be described in detail.

[0031] A steel sheet according to an aspect of the present disclosure may include, by weight %: carbon (C): 0.0010 to 0.0300%, manganese (Mn): 1.500 to 2.500%, chromium (Cr): more than 0% to 1.000% or less, phosphorus (P): more than 0% to 0.100% or less, sulfur (S): more than 0% to 0.0100% or less, nitrogen (N): more than 0% to 0.010% or less, and aluminum (Al): 0.010 to 0.060%.

[0032] Hereinafter, the reasons for limiting the alloy composition of the steel sheet according to an embodiment of the present disclosure will be described in detail. Meanwhile, unless otherwise specified, the content of each element is based on weight, and the ratio of the structure is based on area. In addition, unless otherwise stated, it is noted that the steel sheet refers to a cold-rolled steel sheet.

Carbon (C): 0.0010 to 0.0300%

[0033] Carbon (C) is an interstitial solid solution element and generally contributes effectively to securing the strength of steel. In addition, C is an element that increases the hardenability of steel, contributes to the formation of a martensite phase in the microstructure constituting the steel, and the addition of a certain level or more of C is required to implement a composite structure.

[0034] In an embodiment of the present disclosure, if the C content is less than 0.0010%, there is a limit to implementing a composite structure, and it is also difficult to secure low-temperature bake hardenability. Therefore, the C may be included in an amount of 0.0010% or more. However, if the C content exceeds 0.0300%, the strength of the steel may become excessively high, leading to a decrease in the ductility of the steel, and plastic anisotropy may be degraded, increasing the possibility of defects such as undulations on the product surface during processing into parts.

[0035] Therefore, in an embodiment of the present disclosure, C may be included in an amount of 0.0010 to 0.0300%. According to another embodiment of the present disclosure, the C may be 0.0030% or more, or 0.0040% or more. According to yet another embodiment, the C may be 0.0270% or less, or 0.0250% or less.

Manganese (Mn): 1.500 to 2.500%

[0036] Manganese (Mn) is a solid-solution strengthening element that not only contributes to increasing the strength of steel, but also serves to prevent defects such as red shortness caused by S by precipitating S present in the steel as MnS. In addition, similar to C, it increases the hardenability of steel and contributes to the formation of martensite.

[0037] In an embodiment of the present disclosure, Mn may be included in an amount of 1.500% or more in terms of implementing a composite structure and securing low-temperature bake hardenability and aging resistance. However, if the content exceeds 2.500%, a large amount of annealing oxides may be generated on the surface during the annealing heat treatment process, which may cause surface defects in the steel. In addition, the workability may be degraded as the strength becomes excessively high and the ductility decreases.

[0038] Therefore, in an embodiment of the present disclosure, Mn may be included in an amount of 1.500 to 2.500%. According to another embodiment of the present disclosure, the Mn may be 1.600% or more, or 1.700% or more. According to yet another embodiment, the Mn may be 2.400% or less, or 2.300% or less.

Chromium (Cr): more than 0% to 1.000% or less

[0039] Chromium (Cr) is a solid-solution strengthening element and has properties similar to those of Mn. In particular, Cr may effectively contribute to the formation of a martensite phase by increasing the hardenability of steel. In addition, by generating coarse Cr-based carbides such as Cr_{23}C_6 during hot rolling, the amount of solute C present in the steel can be managed to an appropriate level or less, thereby suppressing the occurrence of yield point elongation (YP-EI), which is effective in manufacturing steel with a low yield ratio. Furthermore, Cr is also an element that effectively contributes to securing high ductility by minimizing the decrease in elongation relative to the increase in strength.

[0040] In an embodiment of the present disclosure, it is advantageous to add Cr as an essential element to obtain

the aforementioned effects, and thus the content thereof may exceed 0%. However, if the content exceeds 1.000% and is added in an excessive amount, the ductility of the steel may be lowered due to the excessive formation of a martensite phase, and the corrosion resistance of the steel may also be lowered.

[0041] Therefore, in an embodiment of the present disclosure, Cr may be included in an amount of more than 0% to 1.000% or less. According to another embodiment of the present disclosure, the Cr may be 0.001% or more, or 0.005% or more, and according to yet another embodiment, the Cr may be 0.900% or less, or 0.800% or less.

Phosphorus (P): more than 0% to 0.100% or less

[0042] Phosphorus (P) is the element with the greatest solid-solution strengthening effect and is useful for effectively securing the strength of steel without significantly impairing its drawability. If the content of P is excessive, the possibility of brittle fracture increases, which may cause slab fracture during the hot rolling process. In addition, it may significantly impair the surface properties of plated steel sheets.

[0043] In consideration of this, according to an embodiment of the present disclosure, the P content may be limited to 0.100% or less. However, considering the level of unavoidable introduction during the steel manufacturing process, 0% may be excluded from the content.

Sulfur (S): more than 0% to 0.0100% or less

[0044] Sulfur (S) is an impurity that is unavoidably added to steel, and it impairs the ductility and weldability of the steel, so it is advantageous to manage its content as low as possible. In particular, S in steel has a high probability of causing red shortness.

[0045] In consideration of this, according to an embodiment of the present disclosure, the S content may be limited to 0.0100% or less. However, considering the level of unavoidable introduction during the steel manufacturing process, 0% may be excluded from the content.

Nitrogen (N): more than 0% to 0.010% or less

[0046] Nitrogen (N) is also an impurity that is unavoidably added to steel, so it is advantageous to manage its content as low as possible. However, a certain amount may be allowed in consideration of the load during steelmaking for removing these impurity elements, operating conditions, and the like.

[0047] According to an embodiment of the present disclosure, even if N is contained up to a maximum of 0.010%, there is no problem in securing the intended physical properties, so the content may be limited to 0.010% or less. In addition, considering the level of unavoidable introduction during the steel manufacturing process, 0% may be excluded from the content.

Aluminum (Al): 0.010 to 0.060%

[0048] Aluminum (Al) is an element added to obtain the effect of refining the grain size of steel and a deoxidation effect.

[0049] In an embodiment of the present disclosure, Al may be included in an amount of 0.010% or more to produce a stable Al-killed steel. However, if the content is excessive, it is advantageous for improving strength by grain refinement, but the surface quality of the manufactured steel sheet may be degraded due to excessive formation of inclusions during the steelmaking and continuous casting operations. This may also lead to an increase in manufacturing costs. In consideration of this, Al may be included in an amount of 0.060% or less.

[0050] Therefore, in an embodiment of the present disclosure, Al may be included in an amount of 0.010 to 0.060%. According to another embodiment of the present disclosure, the Al may be 0.020% or more, and according to yet another embodiment, it may be 0.050% or less.

[0051] Meanwhile, in an embodiment of the present disclosure, other elements may be further included to further improve the physical properties of the steel sheet. As one example, silicon (Si) may be further included, and as another example, one or more of boron (B) and molybdenum (Mo) may be further included. At this time, the Si, B, and Mo may be included together, and the respective contents thereof will be described in detail below.

Silicon (Si): 0.100% or less

[0052] Silicon (Si) is an element that contributes to the increase in the strength of steel through solid-solution strengthening. In the present disclosure, even if Si is not added, there is no problem in securing the desired physical properties, so it is not intentionally added.

[0053] Meanwhile, in obtaining the effect of adding Si, if the content is excessive, a large amount of Si oxides are formed, which deteriorates the surface properties of the plated steel sheet. In consideration of this, according to an embodiment of the present disclosure, the content of Si may be limited to 0.100% or less when added. According to another embodiment, the Si may be 0.080% or less.

Boron (B): 0.004% or less

[0054] Boron (B) is an element that readily segregates to grain boundaries, and B may be added to prevent secondary processing embrittlement that may occur when P is added for a solid-solution strengthening effect. In addition, in composite structure steel, hardenability can be greatly increased by adding a small amount of B, so it can effectively contribute to the transformation of martensite during cooling after annealing.

[0055] In an embodiment of the present disclosure, a certain amount of B may be added to obtain the aforementioned effects. However, if the content exceeds 0.004%, the ductility of the steel may rather be lowered. Accordingly, according to an embodiment of the present disclosure, the content of B may be limited to 0.004% or less when added.

Molybdenum (Mo): 0.4% or less

[0056] Molybdenum (Mo) is an element that improves hardenability in steel sheets having a composite structure, and is a particularly important element in forming the martensite phase of the composite structure. Such Mo, when added alone or in combination with the aforementioned B, induces the formation of uniform grains during annealing, and is thus effective in terms of securing the formability of the steel.

[0057] In an embodiment of the present disclosure, a certain amount of Mo may be added to obtain the aforementioned effects. However, if the content exceeds 0.4%, the martensite phase may be formed more than necessary, which may rather lower the ductility, and as an expensive element, the manufacturing cost may increase significantly, leading to lower economic feasibility. Accordingly, according to an embodiment of the present disclosure, the content of Mo may be limited to 0.4% or less when added.

[0058] The remaining component of the present disclosure is iron (Fe). However, in a normal manufacturing process, unintended impurities from raw materials or the surrounding environment may be unavoidably incorporated, so these cannot be excluded. Since these impurities are known to any person skilled in the art of the normal manufacturing process, all of their contents are not specifically mentioned in this specification.

[0059] Hereinafter, the microstructure characteristics of the steel sheet according to an embodiment of the present disclosure will be described in detail. At this time, the phase fraction of the microstructure constituting the steel sheet may be a result measured over the entire thickness (t, mm) of the steel sheet, and as one example, the result measured at the t/4 point in the thickness direction may be representatively shown.

[0060] A steel sheet according to an embodiment of the present disclosure, that is, a cold-rolled steel sheet, may have the aforementioned alloy composition, and may contain carbon (C) in an amount of 0.0300% or less in the alloy composition. A steel having such a C content corresponds to an ultra-low carbon steel or a low carbon steel, and its microstructure may be mainly composed of a ferrite phase. According to an embodiment of the present disclosure, the ferrite phase may be included in an area fraction of 95% or more.

[0061] Meanwhile, a steel sheet according to an embodiment of the present disclosure may have a composite structure, and in this case, it may be composed of ferrite and a remainder structure, a second phase. As one example, the second phase may be included in an area fraction of 5% or less (excluding 0%), and as the phase type, one or more of a martensite phase and a bainite phase, which correspond to a hard phase, may be included.

[0062] In an embodiment of the present disclosure, the lower the fraction of the ferrite phase in the composite structure, the relatively higher the fraction of the second phase, that is, the hard phase, which may be advantageous for implementing the composite structure. However, the higher the fraction of the hard phase, the inevitably the increase in yield strength and yield ratio is accompanied, and the possibility of defects such as undulations on the surface when processing such a steel sheet into parts increases. Accordingly, in implementing a composite structure, it is advantageous to appropriately limit the fractions of the ferrite phase and the second phase, and in an embodiment of the present disclosure, the ferrite phase may be configured to be 95% or more by area fraction, and the second phase may be configured to be 5% or less (excluding 0%).

[0063] Meanwhile, a steel sheet according to an embodiment of the present disclosure, in which the microstructure is composed of a composite structure, may satisfy the following Relational Expression 1.

[Relational Expression 1]

$$0.01 \leq D_{\text{second}}/D_{\text{grain}} \leq 0.15$$

(In Relational Expression 1, D_{grain} denotes the average grain size (μm) of ferrite, and D_{second} denotes the radius (μm) of the second phase based on the equivalent circle diameter.)

[0064] Through in-depth research, the present inventors have confirmed that, in securing the bake hardenability and aging resistance of a steel sheet to a required level or higher, it is not only advantageous to have a composite structure, but also that the grain size of such a composite structure affects the securing of low-temperature bake hardenability.

[0065] From this, Relational Expression 1 according to an embodiment of the present disclosure is a parameterization of the ratio of the grain sizes of each phase constituting the composite structure. That is, a steel sheet according to an embodiment of the present disclosure, in having a composite structure as its microstructure, may have the characteristic that the size of the second phase is refined compared to the size of ferrite. In the above Relational Expression 1, the size of ferrite and the size of the second phase denote values measured for a steel sheet that has not been subjected to bake hardening.

[0066] The value of Relational Expression 1 according to an embodiment of the present disclosure being less than 0.01 may mean that the ferrite grains are coarse compared to the grain size of the second phase, or that the second phase is almost non-existent. In this case, it becomes difficult to secure bake hardenability at low temperatures. On the other hand, the value of Relational Expression 1 according to an embodiment of the present disclosure exceeding 0.15 may mean that the grains of the second phase are coarse compared to the ferrite grain size, which not only makes it difficult to secure bake hardenability at low temperatures, but also may result in poor workability due to the occurrence of yield point elongation (YP-El).

[0067] A steel sheet according to an embodiment of the present disclosure may have excellent bake hardenability and room-temperature aging resistance by controlling its alloy composition and microstructural characteristics, and in particular, bake hardenability at low temperatures may be secured.

[0068] As one example, the steel sheet may have a bake hardening amount of 30 MPa or more when bake-hardened at 150°C for 20 minutes. At this time, the bake hardening amount denotes the change in the lower yield strength before and after bake hardening, based on the flow stress after applying 2% pre-strain.

[0069] The bake hardening amount of a steel sheet was generally measured at about 170°C, and it was determined that the required physical properties were met if the change in yield strength at this temperature was 30 MPa or more. However, since the bake hardening amount of the steel sheet according to an embodiment of the present disclosure measured at 150°C corresponds to the conventional level, it can be said to have a remarkable effect in terms of bake hardenability. As such, by securing bake hardenability at a relatively low temperature, the present disclosure not only has the economic effect of reducing the manufacturing cost of materials for automotive exterior panels, but also may reduce CO₂ generated during the process of manufacturing the target steel sheet, so that an eco-friendly effect can also be expected.

[0070] Furthermore, since the steel sheet according to an embodiment of the present disclosure can also be applied as a multi-material, additional weight reduction of the vehicle body can be achieved.

[0071] Meanwhile, a steel sheet according to an embodiment of the present disclosure may be a cold-rolled steel sheet, and may also be a plated steel sheet including a plating layer on at least one surface of the cold-rolled steel sheet. At this time, the cold-rolled steel sheet may have the aforementioned alloy composition and microstructural characteristics, and these characteristics may also be possessed by the plated steel sheet.

[0072] In an embodiment of the present disclosure, since the plating layer may be a zinc-based plating layer, the plated steel sheet may be a galvanized steel sheet or a galvanized steel sheet obtained by alloying treatment the galvanized steel sheet. The galvanized steel sheet at this time may be manufactured by any plating method such as hot-dip galvanizing or electro-galvanizing.

[0073] Although not particularly limited, the plating layer may be a zinc-based plating layer as one example, and as a non-limiting example, it may be a galvanized layer mainly containing zinc, or a zinc alloy plated layer containing aluminum and/or magnesium in addition to zinc. Meanwhile, a plated steel sheet having a zinc alloy plated layer containing aluminum and magnesium in addition to zinc may be a Zn-Mg-Al-based ternary plated steel sheet.

[0074] Hereinafter, a method for manufacturing a steel sheet according to another aspect of the present disclosure will be described in detail. It is noted that the following manufacturing method corresponds to one example for manufacturing a steel sheet according to an embodiment of the present disclosure.

[0075] According to an embodiment of the present disclosure, a steel sheet may be manufactured by subjecting a prepared steel slab to a [heating - hot rolling - cooling - coiling - cold rolling - annealing - cooling] process, and each process step will be described in detail below.

[Steel Slab Heating]

[0076] After preparing a steel slab according to an embodiment of the present disclosure, the steel slab may be heated. The heating process of the steel slab is a process for smoothly performing the hot rolling process described

below and sufficiently obtaining the desired physical properties of the steel sheet. As one example, the steel slab may have the same alloy composition as the steel sheet according to an embodiment of the present disclosure, and the description of each alloy element is replaced by the aforementioned matters.

[0077] In an embodiment of the present disclosure, the process of heating the steel slab may be performed under normal conditions, and as one example, it may be performed in a temperature range of 1100 to 1300°C. If the heating temperature is less than 1100°C, there is a problem that the friction between the steel sheet and the rolling mill increases, causing a sharp increase in the load applied to the rollers during hot rolling. On the other hand, if the temperature exceeds 1300°C, not only does the energy cost required for the temperature increase, but also the amount of surface scale increases, which can lead to material loss.

[Hot Rolling]

[0078] The heated steel slab may be hot-rolled to obtain a hot-rolled steel sheet.

[0079] In an embodiment of the present disclosure, a hot-rolled steel sheet may be manufactured by performing finish hot rolling at or above the Ar3 transformation point during the hot rolling. In an embodiment of the present disclosure, if the finish hot rolling process is performed at a temperature below the Ar3 transformation point, two-phase region of ferrite and austenite rolling is performed, which may cause material non-uniformity.

[0080] As one example, the finish hot rolling may be performed in a temperature range of 880 to 1000°C, and if the temperature exceeds 1000°C, there is a concern that material non-uniformity may be caused by the formation of abnormally coarse grains due to high-temperature rolling, which may cause a problem of coil warpage during subsequent cooling.

[Coiling]

[0081] The manufactured hot-rolled steel sheet may be coiled, and a hot-rolled coil may be obtained therefrom.

[0082] This coiling process may be performed in a certain temperature range, and according to an embodiment of the present disclosure, coiling may be performed at a temperature that satisfies the following Relational Expression 2. That is, in setting the coiling temperature, it is controlled in relation to the contents of C, Mn, and Cr, which are elements that improve the hardenability of the steel and induce the formation of a second phase such as a martensite phase.

[Relational Expression 2]

$$18 \leq (T_{\text{coil}}/100) \times ((100 \times [\text{C}]) + [\text{Mn}] + [\text{Cr}]) \leq 35$$

(In Relational Expression 2, [C], [Mn], and [Cr] denote the content by weight of the corresponding elements, and T_{coil} denotes the coiling temperature (°C).)

[0083] The coiling temperature during the coiling process affects the grain size of the hot-rolled material. The higher the coiling temperature, the coarser the grain size of the hot-rolled material, and the precipitation of solute C occurs, so that the ferrite is in a relatively clean state, which improves workability. That is, yield point elongation does not occur. Meanwhile, to secure the second phase according to an embodiment of the present disclosure, it is necessary to contain a certain amount or more of elements that affect the second phase transformation, that is, C, Mn, and Cr. Based on this, the inventors of the present disclosure found that when the coiling temperature is raised to secure the workability of the steel, the possibility of the formation of a structure such as pearlite increases, but by appropriately controlling the content of the hardenability elements contained in the steel, the fraction of pearlite may be suppressed even at a high coiling temperature, and thus derived the aforementioned Relational Expression 2.

[0084] If the value of Relational Expression 2 according to an embodiment of the present disclosure is less than 18, it means that the coiling process is performed at a relatively low temperature, and in this case, it is difficult to secure workability, making it impossible to secure low-temperature bake hardenability. On the other hand, if the value of Relational Expression 2 exceeds 35, there is a problem that yield point elongation occurs.

[0085] The inventors of the present disclosure, in order to provide a steel sheet having room-temperature aging resistance while securing bake hardenability, especially at low temperatures, have configured a composite structure of ferrite and a second phase as the microstructure, and have confirmed that the grain size between the composite structures affects the securing of the intended physical properties.

[Cooling]

[0086] The hot-rolled coil on which the coiling process has been performed under the specific conditions may be

cooled, and in an embodiment of the present disclosure, it may be air-cooled to room temperature.

[0087] In an embodiment of the present disclosure, if a certain cooling rate is applied during the cooling of the hot-rolled coil, there is a concern that non-uniformity of the grain distribution may occur during the cooling process. Accordingly, the cooling of the hot-rolled coil may be performed by air cooling.

[Cold Rolling]

[0088] A cold-rolled steel sheet may be manufactured by uncoiling and cold-rolling the coiled and cooled hot-rolled coil. Meanwhile, a pickling process for removing surface scale of the hot-rolled coil may be performed prior to the cold rolling process, and the pickling process may be performed under normal conditions, and the conditions thereof are not particularly limited.

[0089] In an embodiment of the present disclosure, cold rolling may be performed at a cold reduction ratio (total reduction ratio) of 50 to 90%. If the cold reduction ratio during cold rolling is less than 50%, it becomes difficult to secure the target thickness, and it also becomes difficult to correct the shape of the steel sheet. On the other hand, if the cold reduction ratio exceeds 90%, the load on the rolling rolls becomes excessive, which may worsen the shape of the steel sheet.

[Annealing]

[0090] The manufactured cold-rolled steel sheet may be annealed. As a non-limiting example, the continuous annealing treatment may be performed in a continuous galvannealing line.

[0091] In an embodiment of the present disclosure, the annealing heat treatment may be performed in a temperature range of 750 to 850°C. That is, by performing the annealing treatment of the cold-rolled steel sheet in a two-phase region where ferrite and austenite of Ac1 point or higher coexist, it is possible to form not only austenite but also ferrite simultaneously with the recrystallization of the structure, while distributing carbon.

[0092] During the annealing heat treatment according to an embodiment of the present disclosure, if the temperature is less than 750°C, not only is recrystallization not sufficiently achieved, but also the austenite phase is not sufficiently formed, making it impossible to secure the target microstructure phase composition after the continuous annealing treatment, for example, a composite structure of ferrite and a second phase. On the other hand, if the temperature exceeds 850°C, the austenite phase is excessively formed in the intercritical region, and it is difficult to secure the target level of the second phase as the unstable austenite transforms back to ferrite during the subsequent cooling process. In this case, the yield strength increases and the ductility decreases, making it impossible to secure the intended bake hardenability and aging resistance. In addition, the surface enrichment of elements that inhibit the wettability of hot-dip galvanizing, such as Si and Mn, in the alloy composition becomes severe, which may degrade the quality of the plated surface.

[0093] Therefore, in an embodiment of the present disclosure, the annealing heat treatment may be performed in a temperature range of 750 to 850°C. According to another embodiment of the present disclosure, the continuous annealing treatment may be performed at 770°C or higher.

[Cooling]

[0094] The cold-rolled steel sheet annealed in the two-phase region temperature range may be cooled.

[0095] In an embodiment of the present disclosure, the cooling may be performed in stages, and as one example, it may be a process of first cooling the continuously annealed cold-rolled steel sheet to a temperature range of 600 to 700°C at a cooling rate of 3 to 10°C/s, and then second cooling the first-cooled cold-rolled steel sheet to a temperature range of 400 to 600°C at a cooling rate of 5°C/s or more. At this time, the cooling rate of the second cooling may be performed faster than the cooling rate of the first cooling.

[0096] As such, it is possible to control the cold-rolled steel sheet to have a composite structure by performing staged cooling to a specific temperature range according to the cooling rate during cooling of the cold-rolled steel sheet in which a certain fraction of ferrite phase is formed along with austenite in the annealing heat treatment process according to an embodiment of the present disclosure.

[0097] In an embodiment of the present disclosure, a ferrite phase may be additionally introduced into the annealed cold-rolled steel sheet by performing a first cooling of the annealed cold-rolled steel sheet to a temperature range of 600 to 700°C at a cooling rate of 3 to 10°C/s.

[0098] If the cooling rate during the first cooling exceeds 10°C/s, the additionally introduced ferrite phase becomes insufficient, which may lead to a decrease in the ductility of the steel sheet. On the other hand, if the cooling rate during the first cooling is less than 3°C/s, the fraction of the ferrite phase becomes excessive, making it impossible to secure the second phase at the target level in the final microstructure. In addition, if the cooling end temperature during the

first cooling is less than 600°C, the ferrite phase is not sufficiently formed, while if the temperature exceeds 700°C, there is a problem that the cooling rate must be excessively increased in the subsequent second cooling process, and the second phase may not be formed at the target level in the final microstructure.

[0099] In an embodiment of the present disclosure, after the first cooling of the continuously annealed cold-rolled steel sheet, a second cooling may be performed to a temperature range of 400 to 600°C at a cooling rate of 5°C/s or more, and in this process, a second phase may be introduced.

[0100] If the cooling rate during the second cooling is less than 5°C/s, pearlite may be generated during the cooling process, and the intended second phase may not be completely formed. Meanwhile, the upper limit of the cooling rate during the second cooling is not particularly limited, and a person of ordinary skill in the art can appropriately select it in consideration of the specifications of the cooling equipment. As one example, it may be performed at 100°C/s or less. In addition, if the cooling end temperature during the second cooling is less than 400°C, the martensite phase among the second phases is excessively formed, which may lower the aging resistance of the steel sheet. On the other hand, if the temperature exceeds 600°C, there is a concern that the bainite phase among the second phases may be excessively formed, and the grains of the second phase may become coarse.

[0101] According to an embodiment of the present disclosure, a steel sheet (cold-rolled steel sheet) having a composite structure may be obtained by controlling the alloy components and manufacturing conditions. Specifically, a steel sheet according to an embodiment of the present disclosure may have a composite structure composed of ferrite and a second phase, and in particular, the grain relationship between these phases may satisfy Relational Expression 1. As a result, the steel sheet according to an embodiment of the present disclosure may not only secure bake hardenability at low temperatures, but also secure room-temperature aging resistance at a target level.

[0102] Meanwhile, according to an aspect of the present disclosure, a plated steel sheet may be provided. Specifically, a plated steel sheet may be obtained by plating a cold-rolled steel sheet manufactured through a series of processes according to an embodiment of the present disclosure. As one example, hot-dip plating can be performed on a cold-rolled steel sheet that has undergone an annealing heat treatment and a staged cooling process, and as a non-limiting example, hot-dip galvanizing may be performed.

[Hot-dip galvanizing]

[0103] A hot-dip zinc-based plated steel sheet may be manufactured by immersing a cold-rolled steel sheet according to an embodiment of the present disclosure, which has undergone annealing heat treatment and a cooling process, into a molten zinc-based plating bath of a continuous coating line.

[0104] In an embodiment of the present disclosure, the hot-dip galvanizing process may be performed under normal conditions, but as one example, it may be performed in a temperature range of 430 to 480°C. In addition, the composition of the molten zinc-based plating bath during the hot-dip galvanizing is not particularly limited, and it may be a pure zinc plating bath or a zinc-based alloy plating bath containing Si, Al, Mg, and the like.

[Alloying Heat Treatment]

[0105] In addition, if necessary, a galvanized molten zinc-based plated steel sheet may be obtained by subjecting the molten zinc-based plated steel sheet manufactured by hot-dip galvanizing according to an embodiment of the present disclosure to an alloying heat treatment.

[0106] In an embodiment of the present disclosure, the conditions for the alloying heat treatment process are not particularly limited, and normal conditions are acceptable. As one example, the alloying heat treatment process may be performed in a temperature range of 460 to 610°C. If the temperature during the alloying heat treatment is less than 460°C, the alloying reaction (e.g., Fe-Zn alloying) does not proceed sufficiently, while if the temperature exceeds 610°C, the alloying proceeds excessively, which may cause the plating layer to become brittle. In this case, problems such as peeling of the plating layer may occur during processing such as pressing.

Mode for the Invention

[0107] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are for illustrating the present disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

(Example)

[0108] After preparing steel slabs having the alloy compositions shown in Table 1 below, they were heated at a

temperature of 1200°C, and then each heated slab was finish hot-rolled at 900 to 950°C to manufacture hot-rolled steel sheets. Thereafter, a coiling process was performed according to the conditions shown in Table 2 to obtain hot-rolled coils, which were then air-cooled to room temperature. Then, each hot-rolled coil was pickled under normal conditions and then cold-rolled at a reduction ratio of 76% to obtain cold-rolled steel sheets. Thereafter, final cold-rolled steel sheets were manufactured through an annealing heat treatment and a cooling process under the conditions shown in Table 2. Thereafter, the cold-rolled steel sheets were immersed in a hot-dip galvanizing bath at 460°C to manufacture hot-dip galvanized steel sheets, and then subjected to an alloying heat treatment at 460 to 610°C to obtain galvanized steel sheets. At this time, the processes from the annealing heat treatment to the alloying heat treatment were carried out using continuous equipment (for example, a continuous galvannealing line).

[0109] The microstructure of each of the galvanized steel sheets manufactured as described above was measured, and the mechanical properties were evaluated, and the results are shown in Table 3.

[0110] First, for the microstructure, a specimen was collected from the 1/4t point in the thickness direction (where t denotes the thickness (mm) of the cold-rolled steel sheet), and after Lepera etching, the phase type was classified using an optical microscope, and the fraction and grain size were measured. At this time, the grain size was measured as an average value based on the equivalent circle diameter.

[0111] The bake hardening amount (BH) was measured by applying 2% pre-strain to the same specimen as above, and then, based on the flow stress, measuring the increase in the lower yield strength after bake treatment at 150°C for 20 minutes.

[0112] In addition, the yield point elongation (YP-El) was evaluated through a tensile test after heat treatment of the specimen at 100°C for 1 hour, and it was evaluated that aging resistance was guaranteed based on the result that the length of the yield point elongation during the tensile test was 0.2% or less. The tensile test at this time was conducted in the C direction on a specimen collected in accordance with the JIS-5 standard.

[Table 1]

Steel Type	Alloy composition (wt%)							
	C	Mn	Si	Cr	Al	P	S	N
A	0.0074	1.98	0.009	0.389	0.027	0.012	0.0013	0.004
B	0.0150	2.09	0.005	0.412	0.023	0.012	0.0010	0.004
C	0.0240	2.03	0.022	0.411	0.025	0.011	0.0011	0.003
D	0.0340	1.82	0.047	0.508	0.036	0.011	0.0011	0.004
E	0.0015	0.588	0.005	0	0.030	0.010	0.0010	0.006
F	0.0016	0.585	0.004	0.486	0.018	0.010	0.0010	0.006

[Table 2]

Steel Type	Coiling Temp. (°C)	Annealing Temp. (°C)	1st Finish Temp. (°C)	1st Cooling Rate (°C/s)	2nd Finish Temp. (°C)	2nd Cooling Rate (°C/s)	Alloying Heat Treatment Temp. (°C)	Relational Expression 2	Category
A	700	800	650	4.2	560	8.5	530	22	Invention Example 1
A	650	800	650	4.2	560	8.5	530	20	Invention Example 2
A	600	800	650	4.2	560	8.5	530	19	Invention Example 3
B	700	800	620	5.1	500	11.3	530	28	Invention Example 4
C	700	800	620	5.1	480	13.2	530	34	Invention Example 5
D	700	800	650	4.2	560	8.5	530	40	Comparative Example 1

(continued)

Steel Type	Coiling Temp. (°C)	Annealing Temp. (°C)	1st Finish Temp. (°C)	1st Cooling Rate (°C/s)	2nd Finish Temp. (°C)	2nd Cooling Rate (°C/s)	Alloying Heat Treatment Temp. (°C)	Relational Expression 2	Category
E	700	800	650	4.2	560	8.5	530	5	Comparative Example 2
F	700	800	650	4.2	560	8.5	530	9	Comparative Example 3
A	500	800	650	4.2	560	8.5	530	16	Comparative Example 4
A	700	740	650	2.8	560	8.5	530	22	Comparative Example 5
A	700	860	650	5.6	560	8.5	530	22	Comparative Example 6

[Table 3]

Category	Second Phase Fraction (Area %)	Relational Expression 1	BH (150°C)	Aging Resistance (YP-EI)
Invention Example 1	0.28	0.06	36	0
Invention Example 2	0.30	0.06	35	0
Invention Example 3	0.25	0.08	33	0
Invention Example 4	1.37	0.07	31	0
Invention Example 5	1.82	0.12	31	0
Comparative Example 1	3.44	0.35	23	0.5
Comparative Example 2	0	0	12	0
Comparative Example 3	0	0	29	0
Comparative Example 4	0.35	0.2	27	0
Comparative Example 5	0	0	28	0.2
Comparative Example 6	<0.01 (approx. 0.005)	0	25	0
In all examples, the remaining structure excluding the second phase fraction was a ferrite phase. In all examples, the second phase was one or more of a martensite phase and a bainite phase.				
Relational Expression 1 denotes the calculated value of $[D_{\text{second}}/D_{\text{grain}}]$, which is the relationship between the radius of the second phase based on the equivalent circle diameter and the average grain size of ferrite.				

[0113] As shown in Tables 1 to 3, in Invention Examples 1 to 5, which satisfy both the alloy composition and manufacturing conditions according to an embodiment of the present disclosure, a microstructure was formed as intended. As a result, the bake hardenability (BH) at 150°C was 30 MPa or more, and the aging resistance was also excellent.

[0114] On the other hand, in Comparative Examples 1 to 6, which do not satisfy at least one of the alloy composition and manufacturing conditions according to an embodiment of the present disclosure, the microstructure was not formed as intended. As a result, the desired physical properties, especially low-temperature bake hardenability, could not be secured.

[0115] Specifically, in Comparative Example 1, the C content in the alloy composition was excessive, and thus the condition of Relational Expression 2 was not satisfied during the coiling process, resulting in the formation of coarse second phase grains compared to the ferrite grain size. As a result, not only the bake hardenability but also the aging resistance was poor. In Comparative Example 1, the yield point elongation was 0.5, and when processing such a steel sheet, there is a high possibility of defects due to stretcher-strain, making it difficult to use as a material for automotive exterior panels.

[0116] In Comparative Examples 2 and 3, the Mn content was insufficient, so the condition of Relational Expression 2 was not satisfied during the coiling process, and the bake hardenability was poor because no second phase was formed at all. Among them, the bake hardenability of Comparative Example 2, which had a lower content of hardenability elements, was even poorer.

[0117] In Comparative Example 4, the alloy composition according to an embodiment of the present disclosure was satisfied, but the coiling temperature was too low and deviated from the condition of Relational Expression 2, so that the grain size of the generated second phase was coarse compared to the ferrite grain size. As a result, the bake hardenability was poor.

[0118] In Comparative Examples 5 and 6, the alloy composition according to an embodiment of the present disclosure was satisfied, but the annealing temperature was lower or higher than the range according to an embodiment of the present disclosure, respectively, so that almost no second phase was generated, and the grain size characteristic corresponding to Relational Expression 1 could not be secured. As a result, the bake hardenability was poor.

Claims

1. A steel sheet, comprising, by weight %:

carbon (C): 0.0010 to 0.0300%, manganese (Mn): 1.500 to 2.500%, chromium (Cr): more than 0% to 1.000% or less, phosphorus (P): more than 0% to 0.100% or less, sulfur (S): more than 0% to 0.0100% or less, nitrogen (N): more than 0% to 0.010% or less, aluminum (Al): 0.010 to 0.060%, and a remainder of Fe and unavoidable impurities; and

a microstructure comprising a ferrite phase of 95% or more by area fraction and a remainder of a second phase,

wherein the following Relational Expression 1 is satisfied:

$$[\text{Relational Expression 1}]$$

$$0.01 \leq D_{\text{second}}/D_{\text{grain}} \leq 0.15$$

(wherein, in Relational Expression 1, D_{grain} denotes an average grain size (μm) of ferrite, and D_{second} denotes a radius (μm) of the second phase based on an equivalent circle diameter).

2. The steel sheet of claim 1, wherein the steel sheet further comprises, by weight %, silicon (Si): 0.100% or less.

3. The steel sheet of claim 1, wherein the steel sheet further comprises, by weight %, one or more of boron (B): 0.004% or less and molybdenum (Mo): 0.4% or less.

4. The steel sheet of claim 1, wherein the steel sheet has a bake hardening amount of 30 MPa or more when bake-hardened at 150°C for 20 minutes (wherein the bake hardening amount denotes a change in lower yield strength before and after bake hardening.).

5. The steel sheet of any one of claims 1 to 4, wherein the steel sheet comprises a plating layer or an alloyed plating layer on at least one surface thereof.

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

preparing a steel slab comprising, by weight %: carbon (C): 0.0010 to 0.0300%, manganese (Mn): 1.500 to 2.500%, chromium (Cr): more than 0% to 1.000% or less, phosphorus (P): more than 0% to 0.100% or less, sulfur (S): more than 0% to 0.0100% or less, nitrogen (N): more than 0% to 0.010% or less, aluminum (Al): 0.010 to 0.060%, and a remainder of Fe and unavoidable impurities;

heating the steel slab in a temperature range of 1100 to 1300°C;

obtaining a hot-rolled steel sheet by finish hot-rolling the slab after the heating at a temperature of 880°C or higher; obtaining a hot-rolled coil by coiling the hot-rolled steel sheet;

air-cooling the hot-rolled coil;

obtaining a cold-rolled steel sheet by cold-rolling the hot-rolled coil after the air-cooling at a cold reduction ratio of 50 to 90%; and

cooling the cold-rolled steel sheet after annealing it in a temperature range of 750 to 850°C,

wherein the coiling is performed at a temperature that satisfies the following Relational Expression 2:

[Relational Expression 2]

$$18 \leq (T_{\text{coil}}/100) \times ((100 \times [\text{C}]) + [\text{Mn}] + [\text{Cr}]) \leq 35$$

(wherein, in Relational Expression 2, [C], [Mn], and [Cr] denote a content by weight of a corresponding element, and T_{coil} denotes a coiling temperature (°C)).

7. The method of claim 6, wherein the steel slab further comprises, by weight %, silicon (Si): 0.1% or less.
8. The method of claim 6, wherein the steel slab further comprises, by weight %, one or more of boron (B): 0.004% or less and molybdenum (Mo): 0.4% or less.
9. The method of claim 6, wherein the step of cooling after the annealing heat treatment comprises:
 - a step of first-cooling the cold-rolled steel sheet to a temperature range of 600 to 700°C at a cooling rate of 3 to 10°C/s; and
 - a step of second-cooling the cold-rolled steel sheet after the first cooling to a temperature range of 400 to 600°C at a cooling rate of 5°C/s or more.
10. The method of claim 6, further comprising a step of obtaining a hot-dip plated steel sheet by hot-dip plating the cold-rolled steel sheet after the cooling.
11. The method of claim 10, further comprising a step of selectively subjecting the hot-dip plated steel sheet to an alloying heat treatment.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020436

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/32**(2006.01)i; **C22C 38/22**(2006.01)i;
C21D 8/02(2006.01)i; **C23C 2/04**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/38(2006.01); B21B 1/24(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/54(2006.01);
C22C 38/58(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), 페라이트(ferrite), 냉각(cooling), 크롬(chromium), 열연(hot rolling), 냉연(cold rolling), 소둔(annealing), 소부 경화성(bake hardenability)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2021-0094031 A (NIPPON STEEL CORPORATION) 28 July 2021 (2021-07-28) See paragraphs [0146] and [0180]-[0181], claims 1, 6 and 8 and tables 2B, 3A-3C and 4A-4C.	1-11
A	KR 10-2023-0094273 A (POSCO) 28 June 2023 (2023-06-28) See paragraph [0098] and claims 1-10.	1-11
A	KR 10-2021-0079720 A (HYUNDAI STEEL COMPANY) 30 June 2021 (2021-06-30) See paragraph [0070] and claims 1-2.	1-11
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A	WO 2022-206915 A1 (BAOSHAN IRON & STEEL CO., LTD.) 06 October 2022 (2022-10-06) See claims 1-3.	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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020436

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