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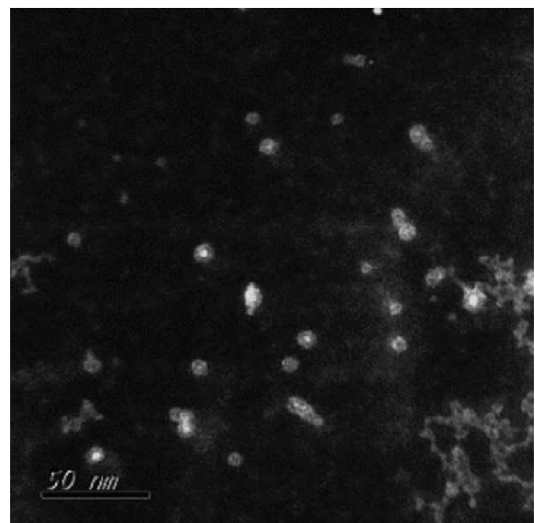
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(54) **HOT-ROLLED STEEL SHEET AND HOT-ROLLED PLATED STEEL SHEET, BOTH WITH HIGH STRENGTH, AND MANUFACTURING METHOD THEREOF**

(57) The present invention relates to a hot-rolled steel sheet and a hot-rolled plated steel sheet, both with high strength, and a manufacturing method thereof, wherein the steel sheet comprises, in weight%, C: 0.03-0.1%, Si: 0.1% or less, Mn: 0.7-1.4%, Ti: 0.03-0.09%, P: 0.02% or less, S: 0.02% or less, N: 0.01% or less, and the balance being Fe and other inevitable impurities, and satisfies relational expression 1 below: Relational expression 1) $3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2 \leq 1$ (in relational expression 1, [] indicates the weight% of each element, and the coiling temperature is given in degrees Celsius (°C)).

[FIG. 1]



EP 4 826 058 A1

Description

[Technical Field]

5 [0001] The present invention relates to a hot-rolled steel sheet and a hot-rolled plated steel sheet obtained by plating the hot-rolled steel sheet having excellent strength, and a manufacturing method thereof, and more specifically, to a hot-rolled steel sheet and a hot-rolled plated steel sheet that have high strength suitable for use as a high-strength supporting structure and simultaneously reduce a hot-roll finishing rolling load, and a manufacturing method thereof.

10 [Background Art]

[0002] A high-strength hot-rolled steel sheet and a high-strength hot-rolled plated steel sheet obtained by plating the high-strength hot-rolled steel sheet not only have the excellent deformation resistance of the high-strength hot-rolled steel sheet but also simultaneously secure corrosion resistance due to plating treatment.

15 [0003] Furthermore, the hot-rolled steel sheet and the hot-rolled plated steel sheet have superior economic efficiency compared to a cold-rolled steel sheet and a cold-rolled plated steel sheet.

[0004] Due to such excellent characteristics and economic efficiency, the high-strength hot-rolled steel sheet and hot-rolled plated steel sheet may be used as a structural member, particularly as a support structure.

20 [0005] As a specific example, the high-strength hot-rolled steel sheet and hot-rolled plated steel sheet are widely used as a material for a structural member, such as construction scaffolding, greenhouse structural member, and solar panel support structure.

[0006] In particular, in the case of solar structures, demand for variable-type support structures that move to follow the sun in upward, downward, leftward, and rightward directions, rather than fixed-type structures, is rapidly increasing in order to secure maximum power generation relative to installation cost.

25 [0007] Accordingly, market demand for high-strength steel materials is increasing.

[0008] In general, hot-rolled steel sheets and hot-rolled plated steel sheets do not require a cold rolling process as compared with cold-rolled steel sheets.

30 [0009] However, hot-rolled steel sheets and hot-rolled plated steel sheets are necessarily manufactured through a hot rolling process, and rolling load in the hot rolling process is a very important factor in terms of quality, productivity, and economic efficiency of the steel sheet.

[0010] When the rolling load in the hot rolling process, particularly the rolling load in finish rolling, is high, it becomes difficult to apply a sufficient reduction to the steel sheet, and as a result, there arises a problem in that control of a microstructure becomes difficult.

35 [0011] In addition, when the rolling load is high, finish rolling needs to be performed multiple times or a finish rolling temperature needs to be increased, which causes problems in control of the microstructure and productivity.

[0012] Furthermore, when the rolling load in finish rolling is high, a load applied to a finishing mill increases or a finishing mill having a larger capacity is required, thereby reducing economic efficiency.

40 [0013] Accordingly, there is an urgent need to develop hot-rolled steel sheets and hot-rolled plated steel sheets having high-strength characteristics suitable for a support structure while improving productivity.

[Disclosure]

[Technical Problem]

45 [0014] The present invention is directed to providing a hot-rolled steel sheet capable of reducing a hot-rolled finish rolling load while having high strength suitable for use as a structure, and a manufacturing method thereof.

[0015] The present invention is also directed to providing a hot-rolled plated steel sheet capable of reducing a hot-rolled finish rolling load while having high strength and corrosion resistance suitable for use as a structure, and a manufacturing method thereof.

50 [0016] Objects of the present invention are not limited to the above object, and other objects and advantages of the present invention which are not mentioned can be understood by the following description and more clearly understood by various embodiments of the present invention. In addition, it will be able to be easily seen that the objects and advantages of the present invention may be achieved by devices and combinations thereof that are described in the claims.

55 [0017] To achieve the above objects, a hot-rolled steel sheet according to the present invention contains, C: 0.03 to

0.1 wt%, Si: 0.1 wt% or less, Mn: 0.7 to 1.4 wt%, Ti: 0.03 to 0.09 wt%, P: 0.02 wt% or less, S: 0.02 wt% or less, N: 0.01 wt% or less, and the balance being Fe and other inevitable impurities, and satisfies relational expression 1 below:

$$3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2\leq 1 \quad \text{Relational expression 1)}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius (°C)).

[0018] In this case, the hot-rolled steel sheet may include at least 90% ferrite by area fraction, with the remainder includes one or more microstructures selected from pearlite, bainite, and martensite, wherein an average grain size of the ferrite may be 15 μm or less.

[0019] Meanwhile, the ferrite may be one or more of polygonal ferrite, bainitic ferrite, and acicular ferrite.

[0020] In this case, the hot-rolled steel sheet may contain carbides, wherein the carbides may have an average size of 8 nm or less and a distribution of 3.5 or more per 10,000 nm².

[0021] In this case, a yield strength of the hot-rolled steel sheet may be 440 MPa or more, a tensile strength thereof may be 490 MPa or more, and an elongation thereof may be 16% or more.

[0022] A hot-rolled plated steel sheet according to an embodiment of the present invention for achieving the above objects may be a hot-rolled plated steel sheet including at least one of the hot-rolled steel sheets as a base steel sheet.

[0023] In this case, the hot-rolled steel sheet may include plating layers disposed on opposite surfaces or at least one surface of the hot-rolled steel sheet.

[0024] In this case, the plating layer may include any one component selected from zinc, aluminum, a zinc alloy, and an aluminum alloy.

[0025] A manufacturing method of a hot-rolled steel sheet according to the present invention for achieving the above objects includes reheating a steel slab including C: 0.03 to 0.1 wt%, Si: 0.1 wt% or less, Mn: 0.7 to 1.4 wt%, Ti: 0.03 to 0.09 wt%, P: 0.02 wt% or less, S: 0.02 wt% or less, N: 0.01 wt% or less, and the balance being Fe and other inevitable impurities, hot-rolling the steel slab, and cooling the hot-rolled steel sheet to 570 to 680 °C and coiling the hot-rolled steel slab, and satisfies Relational expression 1 below:

$$3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2\leq 1 \quad \text{Relational expression 1)}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius (°C)).

[0026] In this case, the reheating may include reheating the steel slab at 1,150 to 1,300 °C.

[0027] A manufacturing method of a hot-rolled plated steel sheet according to one embodiment of the present invention for achieving the above objects may include at least one of the manufacturing methods of a hot-rolled steel sheet, and include forming a plating layer after the coiling.

[0028] In this case, the manufacturing method may further include heat-treating between the coiling and the forming of the plating layer, wherein the heat-treating may include heat-treating the coiled hot-rolled steel sheet at 450 to 750 °C.

[0029] In this case, the forming of the plating layer may include plating at least one surface of the hot-rolled steel sheet.

[0030] In this case, the forming of the plating layer may use any one selected from a molten plating process, an electroplating process, and a plasma process.

[0031] In this case, the plating layer may include any one component selected from zinc, aluminum, zinc alloy, and aluminum alloy.

[Advantageous Effects]

[0032] The hot-rolled steel sheet and hot-rolled plated steel sheet according to the present invention can have excellent mechanical properties, such as a yield strength (YS) of 400 MPa or more, a tensile strength (TS) of 490 MPa or more, and an elongation of 16% or more, through a controlled compositional range and microstructure.

[0033] As a result, the hot-rolled steel sheet and the hot-rolled plated steel sheet with excellent mechanical properties according to the present invention are suitable for use as support structures requiring high-strength properties.

[0034] The manufacturing method of the hot-rolled steel sheet and the hot-rolled plated steel sheet according to the present invention can reduce the hot-rolling finish rolling load, thereby providing a hot-rolled steel sheet and a hot-rolled plated steel sheet with high productivity and excellent mechanical properties and corrosion resistance.

[0035] Effects of the present invention are not limited to the above effects and may be construed to include effects that can be inferred by those skilled in the art based on the following description.

[Description of Drawings]

[0036] FIG. 1 is a photograph of a microstructure of a carbide observed by a transmission electron microscope (TEM) of Example 1 in an embodiment of the present invention.

[Mode for Invention]

[0037] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings so that those skilled in the art to which the present invention pertains can easily carry out the present invention. The present invention may be implemented in various different forms and is not limited to various embodiments described herein.

[0038] To clearly describe the present invention, parts not related to the description have been omitted, and the same or similar components are denoted by the same reference numerals throughout the specification. Hereinafter, some embodiments of the present invention will be described in detail with reference to exemplary drawings. In adding reference numerals to components in each drawing, the same components may have the same reference numerals as much as possible even when they are shown in different drawings. In addition, in the description of the present invention, when it is determined that a detailed description of a related known configuration or function may obscure the gist of the present invention, detailed description thereof may be omitted.

[0039] In the description of the components of the present invention, terms such as "first," "second," "A," "B," "(a)," "(b)," and the like may be used. These terms are only for the purpose of distinguishing one component from another component, and the nature, sequence, order, or the like of the corresponding component is not limited by these terms. When a certain component is described as being "connected," "coupled," or "joined" to the other component, the component may be directly connected or joined to the other component, but it should be understood that another component may be "interposed" between the components, or the components may be "connected," "coupled," or "joined" through another component.

[0040] A high-strength hot-rolled steel sheet and hot-rolled plated steel sheet, and a manufacturing method thereof according to exemplary embodiments of the present invention will be described in detail below with reference to the accompanying drawings as follows.

[0041] The high-strength hot-rolled steel sheet according to the embodiment of the present invention may be used as a structural member due to its high-strength characteristics.

[0042] As non-limiting and specific structural members, there are support structural members such as construction scaffolding, greenhouse structural member, and solar panel support structure.

[0043] To this end, the high-strength hot-rolled steel sheet according to one embodiment of the present invention may contain C: 0.03 to 0.1 wt%, Si: 0.1 wt% or less, Mn: 0.7 to 1.4 wt%, Ti: 0.03 to 0.09 wt%, P: 0.02 wt% or less, S: 0.02 wt% or less, N: 0.01 wt% or less, and the balance being Fe and other inevitable impurities.

[0044] In addition, the hot-rolled steel sheet with excellent strength according to one embodiment of the present invention may have a microstructure including one or more of pearlite, bainite, and martensite, and include at least 90% ferrite by area fraction, and an average grain size of the ferrite is 15 μm or less (average grain size refers to an equivalent circle diameter).

[0045] In this case, the hot-rolled steel sheet with excellent strength according to one embodiment of the present invention may include carbides having an average size of 8 nm or less and a distribution of 3.5 or more per 10,000 nm^2 .

[0046] By having the above-described components, composition range, and microstructure, the hot-rolled steel sheet with excellent strength according to one embodiment of the present invention can achieve mechanical properties such as a yield strength of 400 MPa or more, a tensile strength of 490 MPa or more, and an elongation of 16% or more.

[0047] Furthermore, the hot-rolled steel sheet with excellent strength according to one embodiment of the present invention is a hot-rolled steel sheet with excellent strength that satisfies Relational expression 1 below.

$$3*([\text{Mn}]-0.9)^2+1200*([\text{Ti}]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2 \leq 1 \quad \text{Relational expression 1:}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius ($^{\circ}\text{C}$)).

[0048] In addition, a hot-rolled plated steel sheet with excellent strength and corrosion resistance according to another embodiment of the present invention includes a hot-rolled steel sheet and a plating layer formed on at least one surface of the hot-rolled steel sheet.

[0049] In this case, the hot-rolled steel sheet in the hot-rolled plated steel sheet refers to any one of the above-described hot-rolled steel sheets.

[0050] In this case, the plating layer is formed of any one material selected from zinc, aluminum, a zinc alloy, and an aluminum alloy.

[0051] A manufacturing method of a hot-rolled steel sheet with excellent strength according to another embodiment of the present invention includes reheating a steel slab at 1,150 to 1,300 °C, hot-rolling the reheated steel slab by finish hot rolling at 800 to 1000 °C, and cooling the hot-rolled steel sheet to 570 to 680 °C and coiling the hot-rolled steel sheet.

[0052] A manufacturing method of a hot-rolled plated steel sheet with excellent strength and corrosion resistance according to still another embodiment of the present invention includes reheating a steel slab at 1,150 to 1,300 °C, hot rolling the reheated steel slab by finish hot rolling at 800 to 1000 °C, cooling the hot-rolled steel sheet to 570 to 680 °C and coiling the hot-rolled steel sheet, and heat-treating the coiled hot-rolled steel sheet at 450 to 750 °C, and plating at least one surface of the hot-rolled steel sheet to form a plating layer.

Hot-rolled steel sheet and plated steel sheet

[0053] Hereinafter, a steel composition and composition ratio thereof included in a hot-rolled steel sheet with excellent strength according to the embodiment of the present invention will be described in more detail.

[0054] Hereinafter, unless otherwise stated, percentages (%) indicating the content of each element are based on weight.

Carbon (C): 0.03 to 0.1 wt%

[0055] Carbon (C) is added not only for solid solution strengthening effects but also for the formation of carbides with Ti, and is an element for securing tensile strength.

[0056] To obtain the above effects, carbon (C) is preferably included in an amount of 0.03 wt% or more.

[0057] However, when an amount of carbon (C) exceeds 0.1 wt%, carbide coarsening occurs, making it impossible to sufficiently secure the precipitation strengthening effect, and the pearlite fraction in the microstructure increases, making it impossible to secure a ferrite structure having at least 90% ferrite by area fraction as intended in the present invention.

[0058] In addition, since surface cracks and the like caused by hypo-peritectic regions may occur during continuous casting, the carbon content needs to be limited to 0.1 wt% or less to ensure the integrity of the material.

[0059] On the other hand, when the carbon content is less than 0.03 wt%, there is a problem in which the strength of the steel sheet is insufficient because there is less carbon to form a Ti-based composition including a TiC composition.

[0060] Accordingly, carbon (C) is preferably included in an amount of 0.03 to 0.1 wt% based on the total weight of the hot-rolled steel sheet according to the present invention.

Silicon (Si): 0.1 wt% or less

[0061] Silicon (Si) is not only useful for deoxidizing steel but is also effective in securing strength through solid solution strengthening.

[0062] However, when the silicon (Si) content exceeds 0.1 wt%, there is a disadvantage in that silicon oxide is formed, making plating difficult.

[0063] Accordingly, the silicon (Si) content is preferably included in an amount of 0.1 wt% or less, and more specifically, may be included in an amount of 0.001 to 0.1 wt%.

Manganese (Mn): 0.7 to 1.4 wt%

[0064] Manganese (Mn) is included to secure solid solution strengthening effects and hardenability of a weld zone during cooling after welding.

[0065] In particular, manganese (Mn) is an element that lowers the Ar3 temperature, which is the phase transformation temperature in Relational expression 1 to be described below, thereby refining the size of carbides formed during phase transformation, and affects the material through solid solution strengthening, and thus, the content needs to be limited.

[0066] To obtain the above effects, manganese (Mn) is preferably included in an amount of 0.7 wt% or more.

[0067] However, when manganese (Mn) is included in an amount of more than 1.4 wt%, the hardenability caused by Mn increases, making it difficult to obtain the desired ferrite structure having at least 90% ferrite by area fraction due to the appearance of a low-temperature structure.

[0068] Accordingly, manganese (Mn) is preferably included in an amount of 0.7 to 1.4 wt% based on the total weight of the hot-rolled steel sheet according to the present invention.

Titanium (Ti): 0.03 to 0.09 wt%

[0069] Titanium (Ti) is included to provide a precipitation strengthening effect and suppress grain coarsening.

[0070] In particular, titanium (Ti) is one of the key elements that can increase strength through the precipitation of Ti-based compositions including TiC composition by controlling the content in Relational expression 1 to be described below.

[0071] When the amount of titanium (Ti) is less than 0.03 wt%, it is difficult to obtain the high strength targeted in the present invention.

[0072] However, when titanium (Ti) is included in an amount of more than 0.09 wt%, coarse carbides are formed, making it ineffective for precipitation strengthening.

[0073] Accordingly, titanium (Ti) is preferably included in an amount of 0.03 to 0.09 wt% based on the total weight of the hot-rolled steel sheet according to the present invention.

Phosphorus (P): 0.02 wt% or less

[0074] Phosphorus (P), as an impurity element, tends to segregate at grain boundaries and deteriorate toughness, and thus, is preferably not included as much as possible.

[0075] Accordingly, phosphorus (P) is preferably limited to 0.02 wt% or less based on the total weight of the hot-rolled steel sheet according to the present invention.

Sulfur (S): 0.02 wt% or less

[0076] Sulfur (S), as an impurity element, is a major element forming MnS, and the formation of coarse MnS can reduce toughness.

[0077] Accordingly, sulfur (S) is preferably limited to 0.02 wt% or less based on the total weight of the hot-rolled steel sheet according to the present invention.

Nitrogen (N): 0.01 wt% or less

[0078] Nitrogen (N), as an impurity element, reacts with Ti at high temperatures to form nitrides when the content exceeds 0.01 wt%, thereby reducing the amount of Ti effectively contributing to precipitation strengthening, and thus, lowering the strength of the steel sheet.

[0079] Accordingly, nitrogen (N) is preferably limited to 0.01 wt% or less based on the total weight of the hot-rolled steel sheet according to the present invention.

[0080] In addition, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention may include the balance being Fe and other inevitable impurities in addition to the above-described steel composition.

[0081] The inevitable impurities may be unintentionally incorporated during the conventional steel manufacturing process and cannot be completely excluded, and those skilled in the field of typical steel manufacturing can easily understand its meaning.

[0082] In addition, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention does not completely exclude the addition of compositions other than the above-described steel composition.

[0083] As described above, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention preferably has a microstructure containing at least 90% ferrite by area fraction.

[0084] In this way, in the present invention, it is important to secure a ferrite structure having at least 90% ferrite by area fraction to ensure excellent formability.

[0085] Theoretically, the microstructure of the present invention is preferably a single phase of ferrite, but due to the manufacturing process, one or more of pearlite, bainite, and martensite may inevitably be formed.

[0086] However, when there is an excessive amount of low-temperature transformation phases such as bainite or martensite, formability is reduced.

[0087] In addition, when pearlite is present in the hot-rolled steel sheet, cracks are prone to occur during processing due to cementite that is a hard phase.

[0088] Accordingly, in the high-strength hot-rolled steel sheet according to the embodiment of the present invention, the residual structure excluding ferrite is preferably as small as possible.

[0089] As a result, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention more preferably has at least 91% ferrite by area fraction, and even more preferably, at least 92% ferrite by area fraction.

[0090] Meanwhile, the ferrite may be one or more of polygonal ferrite, bainitic ferrite, and acetic ferrite.

[0091] In this case, the average grain size of the ferrite is preferably 15 μm or less, and more preferably, 13 μm or less.

[0092] When the average grain size of the ferrite exceeds 15 μm , sufficient strength cannot be obtained due to grain coarsening.

[0093] It is obvious to those skilled in the art that the average grain size can be obtained through statistical processing based on microstructural observation or the like.

[0094] In addition, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention preferably contains carbides containing Ti alone (meaning carbides in which the detected amount is only at the level of impurities, even when alloying components such as Nb and V are detected), and the average diameter of the carbides is preferably 8 nm or less.

[0095] In this way, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention forms and contains a large amount of fine carbides with an average diameter of 8 nm or less, and thus an excellent strength improvement effect can be obtained while preventing fracture of carbides.

[0096] As described above, the hot-rolled steel sheet with excellent strength according to the embodiment of the present invention has excellent mechanical properties including a yield strength (YS) of 400 MPa or more, a tensile strength (TS) of 490 MPa or more, and an elongation of 16% or more.

[0097] As a result, the hot-rolled steel sheet according to the embodiment of the present invention is used as a high-strength support structural member, such as construction scaffolding, greenhouse structural member, and solar panel support structure, which requires high strength and excellent formability.

[0098] Meanwhile, the present invention may provide a hot-rolled plated steel sheet manufactured using the above-described hot-rolled steel sheet.

[0099] In addition, a hot-rolled plated steel sheet with excellent strength and corrosion resistance according to another embodiment of the present invention includes a hot-rolled steel sheet and a plating layer formed on at least one surface of the hot-rolled steel sheet.

[0100] In this case, the hot-rolled steel sheet refers to any one of the above-described hot-rolled steel sheets.

[0101] In this case, the plating layer is formed of any one material selected from zinc, aluminum, a zinc alloy, and an aluminum alloy.

Manufacturing method of hot-rolled steel sheet and plated steel sheet

Reheating

[0102] In the reheating, a steel slab including C: 0.03 to 0.1 wt%, Si: 0.1 wt% or less, Mn: 0.7 to 1.4 wt%, Ti: 0.03 to 0.09 wt%, P: 0.02 wt% or less, S: 0.02 wt% or less, N: 0.01 wt% or less, and the balance being Fe and other inevitable impurities is reheated at 1,150 to 1,300 $^{\circ}\text{C}$.

[0103] In this operation, the reheating of the steel slab within a temperature range of 1,150 to 1,300 $^{\circ}\text{C}$ is intended to homogenize the alloy composition and microstructure.

[0104] In this case, when the reheating temperature is lower than 1,150 $^{\circ}\text{C}$, precipitates formed in the steel slab remain undissolved, making it impossible to obtain a sufficient precipitation strengthening effect in a subsequent process.

[0105] On the other hand, when the reheating temperature exceeds 1,300 $^{\circ}\text{C}$, excessive grain growth occurs, making it difficult to secure the target material properties and quality.

[0106] Accordingly, the reheating temperature of the steel slab may preferably range from 1,150 to 1,300 $^{\circ}\text{C}$, and more preferably 1,180 to 1,270 $^{\circ}\text{C}$.

Hot rolling

[0107] In the hot rolling, the reheated steel slab is hot-rolled by finish hot rolling at 800 to 1,000 $^{\circ}\text{C}$.

[0108] In this operation, when a finish delivery (finishing rolling) temperature is lower than 800 $^{\circ}\text{C}$, there is a risk that some of the austenite will transform into ferrite, resulting in non-uniform grain size in the final product.

[0109] On the other hand, when the finish delivery temperature exceeds 1000 $^{\circ}\text{C}$, the grain refinement effect can be reduced due to scale defects and a decrease in the effect of controlled rolling.

Cooling and coiling

[0110] In the cooling and coiling, the hot-rolled steel sheet is cooled to 570 to 680 $^{\circ}\text{C}$ and coiled.

[0111] The hot-rolled steel sheet may be coiled at a coiling temperature of 570 to 680 $^{\circ}\text{C}$ after undergoing water cooling.

[0112] Furthermore, the coiling temperature is a key factor inducing the growth of carbides generated during phase transformation and the additional precipitation of dissolved Ti in Relational expression 1 to be described below.

[0113] In this case, when the coiling temperature is lower than 570 °C, not only is it difficult to obtain a microstructure intended by the present invention, such as the formation of a low-temperature phase, but also sufficient precipitation strengthening cannot be achieved due to insufficient formation of carbides.

[0114] On the other hand, when the coiling temperature exceeds 680 °C, coarsening of carbides occurs, and the target strength cannot be obtained.

[0115] In this case, the hot-rolled steel sheet satisfies Relational expression 1 below:

$$3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2 \leq 1 \quad \text{Relational expression 1:}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius (°C)).

[0116] In Relational expression 1, Mn lowers the Ar3 transformation temperature, refines the size of carbides formed during phase transformation, and affects material properties through solid solution strengthening, and thus, the content needs to be limited.

[0117] In addition, Mn is one of the key elements capable of increasing strength through TiC precipitation by controlling the Ti content.

[0118] The coiling temperature is a key factor inducing the growth of carbides formed during phase transformation and the additional precipitation of dissolved Ti.

[0119] When the value of $3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2$ exceeds 1, the number of precipitates is insufficient or the precipitates grow too much, resulting in inadequate material quality.

[0120] Accordingly, the value of $3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2$ is preferably 1 or less as shown in Relational expression 1.

Heat treatment and plating treatment

[0121] In the heat treatment and plating, a plating layer is formed by heat-treating the coiled hot-rolled steel sheet and then plating at least one surface of the hot-rolled steel sheet.

[0122] In this operation, the heat treatment process is preferably performed within a temperature range of 450 to 720 °C to secure the temperature of the steel sheet and the stable formation of carbides during the subsequent plating process.

[0123] After the heat treatment process, the plating layer is formed on at least one surface of the heat-treated hot-rolled steel sheet.

[0124] The composition and forming method of the plating layer of the present invention are not particularly limited and may be construed as including the composition and forming method of the plating layer typically provided for the hot-rolled plated steel sheet.

[0125] As a non-limiting and specific example of the plating method, the plating layer may be formed by any one selected from a molten plating method, an electroplating method, and a plasma method.

[0126] In addition, as a non-limiting and specific example, the plating layer may be formed from any one material selected from zinc, aluminum, a zinc-based alloy, an aluminum-based alloy, etc.

[0127] The hot-rolled plated steel sheet manufactured by the manufacturing method according to the above-described embodiment of the present invention has excellent mechanical properties including a yield strength of 400 MPa or more, a tensile strength of 490 MPa or more, and an elongation of 16% or more.

[0128] As a result, the hot-rolled plated steel sheet produced by the manufacturing method according to the embodiment of the present invention is suitable for use as a high-strength support structural member, such as construction scaffolding, greenhouse structural member, and solar panel support structure, which require high strength and excellent formability.

Examples

[0129] Hereinafter, the configuration and operation of the present invention will be described in more detail through exemplary embodiments of the present invention.

[0130] However, this is suggested as exemplary examples of the present invention and may not be construed as limiting the present invention thereby in any sense.

[0131] Since contents not described herein may be technically inferred by those skilled in the art, a description thereof will be omitted.

1. Manufacturing of specimens

[0132] Steel slabs having alloy compositions listed in Table 1 below were prepared, and hot-rolled plated steel sheets were manufactured by applying process conditions listed in Table 2 below. In Table 1, the balance is iron (Fe) and other inevitable impurities, and hot-rolled plated steel sheets with a thickness of 1.6 mm were manufactured by applying the process conditions of Table 2.

[0133] In Table 2, both a relative comparison of an upper three-roll load in finishing rolling and a relative comparison of a lower three-roll load in finishing rolling refer to values calculated by relatively comparing load values measured in each experimental example after setting the upper three-roll load and the lower three-roll load in finishing rolling of Inventive Example 1 to 100 as a reference.

[Table 1]

Items	C	Si	Mn	P	S	Ti	Nb	N
Inventive Example 1	0.04	0.07	0.99	0.013	0.009	0.051	0	0.0034
Inventive Example 2	0.08	0.01	0.87	0.001	0.001	0.052	0	0.006
Inventive Example 3	0.08	0.1	0.95	0.004	0.010	0.042	tr	0.0054
Inventive Example 4	0.05	0.05	0.94	0.013	0.014	0.057	tr	0.0033
Inventive Example 5	0.05	0.1	0.84	0.009	0.009	0.053	tr	0.0054
Inventive Example 6	0.06	0.03	0.95	0.001	0.007	0.042	0	0.0051
Comparative Example 1	0.18	0.06	0.91	0.011	0.011	Tr(0.002)	0.012	0.0033
Comparative Example 2	0.12	0.06	0.87	0.012	0.008	0	0.023	0.0037
Comparative Example 3	0.05	0.01	1.01	0.014	0.012	Tr(0.001)	0.037	0.0047
Comparative Example 4	0.06	0.1	0.32	0.004	0.010	0.042	tr	0.0041
Comparative Example 5	0.1	0.06	2.03	0.007	0.005	0.05	tr	0.0036
Comparative Example 6	0.09	0.08	1.02	0.005	0.009	0.013	tr	0.0049
Comparative Example 7	0.06	0.07	0.9	0.009	0.012	0.093	0	0.0047
Comparative Example 8	0.06	0.01	1.02	0.010	0.005	0.06	0	0.003
Comparative Example 9	0.04	0.1	1.05	0.011	0.008	0.054	tr	0.0036

(Unit: wt%, where tr indicates that a measured composition range corresponds to a trace amount or an impurity level of several tens of ppm or less).

[Table 2]

Items	Reheating temperature (°C)	Finish hot rolling entry temperature (°C)	Finish delivery temperature (°C)	Coiling temperature (°C)	Relative comparison of upper three-roll load in finishing rolling (%)	Relative comparison of lower three-roll load in finishing rolling (%)
Inventive Example 1	1192	1007	874	650	100	100
Inventive Example 2	1278	1000	898	628	102	101
Inventive Example 3	1276	988	899	606	98	101
Inventive Example 4	1262	1021	911	649	102	100
Inventive Example 5	1195	993	882	609	100	99

(continued)

5	Items	Reheating temperature (°C)	Finish hot rolling entry temperature (°C)	Finish delivery temperature (°C)	Coiling temperature (°C)	Relative comparison of upper three-roll load in finishing rolling (%)	Relative comparison of lower three-roll load in finishing rolling (%)
10	Inventive Example 6	1220	980	877	600	106	103
	Comparative Example 1	1224	1068	946	628	103	110
15	Comparative Example 2	1226	1069	922	637	100	112
	Comparative Example 3	1207	1065	897	615	109	121
20	Comparative Example 4	1192	1017	905	589	96	97
	Comparative Example 5	1192	1007	912	643	101	103
25	Comparative Example 6	1274	1023	920	638	99	102
	Comparative Example 7	1251	995	872	626	103	103
30	Comparative Example 8	1226	992	881	517	99	96
	Comparative Example 9	1218	998	905	694	98	98

2. Physical properties evaluation

[0134] Table 3 shows the results of evaluating physical properties for the specimens according to Inventive Examples 1 to 6 and Comparative Examples 1 to 9.

1) Microstructure measurement

[0135] The types and fractions of the microstructure were measured using an optical microscope (OM). In addition, a ferrite grain size was measured using the circular Intercept method of ASTM E 112 after imaging with a scanning electron microscope (SEM).

2) Measurement of size of precipitates

[0136] The average size of precipitates was measured by collecting precipitates from the specimens using the carbon replica method and using a TEM.

3) Tensile test

[0137] Yield strength (YS), tensile strength (TS), and elongation (EL) were measured by performing a tensile test according to KS B 0802.

[0138] For hot-rolled steel sheets, tensile specimens were prepared using KS B 0801 No. 5 specimens, with the longitudinal direction aligned with the hot-rolling direction.

[Table 3]

Items		Microstructure						Mechanical characteristics			Expression 1
		Ferrite fraction	Pearlite fraction	Low-temperature microstructure (bainite or marten site)	Ferrite grain size	Average carbide size	per 100 nm ²	Yield strength	Tensile strength	Elongation	
	Inventive Example 1	99.0	1.0	0	8.7	4.2	5.36	479	580	23.5	0.2815
	Inventive Example 2	98.5	1.5	0	9.4	5.2	5.25	481	571	23.6	0.0811
	Inventive Example 3	99.0	1.0	0	8.9	4.4	5.01	498	572	26.4	0.6267
	Inventive Example 4	97.8	2.2	0	9.1	4.4	5.2	478	620	26.5	0.16
	Inventive Example 5	98.5	1.5	0	8.3	4.8	5.11	468	576	26.6	0.246
	Inventive Example 6	97.6	2.4	0	8.5	4.3	5.01	488	577	22.5	0.7563
	Comparative Example 1	95.6	4.4	0	6.6	4.6	1.0	435	580	27.4	4.0387
	Comparative Example 2	97.1	2.9	0	6.3	4.9	2.0	447	589	27.9	4.3423
	Comparative Example 3	98.8	1.2	0	6.7	4.9	3.3	436	601	28.1	4.3035
	Comparative Example 4	98.8	1.2	0	9	4.4	5.5	372	511	26.8	2.0704
	Comparative Example 5	84.6	1.2	14.2	9.1	4	5.4	509	600	14.3	4.0183
	Comparative Example 6	98.5	1.5	0	8.3	3.9	2.6	366	471	29.0	2.7196
	Comparative Example 7	97.8	2.2	0	7.9	6.1	3.3	555	618	15.4	1.3132
	Comparative Exam ple 8	84.4	2.0	13.6	7.9	4.4	3.1	394	621	15.1	5.1508
	Comparative Example 9	97.8	2.2	0	7.6	6.9	1.5	382	525	24.3	1.7491

[0139] As shown in Tables 1 to 3, in the case of Examples 1 to 6 satisfying the composition and compositional ranges, Relational expressions 1 and 2, and process conditions proposed by the present invention, it can be confirmed that, by securing the microstructure and precipitates intended by the present invention, high-strength mechanical properties are exhibited and a low finishing rolling load ratio is achieved.

[0140] On the other hand, Comparative Examples 1, 2, and 3 exhibited excellent mechanical properties due to grain refinement and strengthening by NbC precipitation by adding Nb instead of Ti.

[0141] However, in Comparative Examples 1, 2, and 3, an increase in a non-recrystallization region temperature due to Nb during finish hot rolling increased high-temperature deformation resistance of the material itself, resulting in an increase in finishing rolling load, particularly such that a load of lower three rolls after finishing rolling was relatively greater than that of upper three rolls.

[0142] Meanwhile, in the case of Comparative Example 4, due to a low Mn content, the solid solution strengthening effect was insufficient, and sufficient precipitation strengthening could not be obtained due to changes in phase transformation conditions during cooling, thereby failing to secure the high strength targeted by the present invention.

[0143] In addition, in Comparative Example 5, as the Mn content increased, hardenability increased, and as a result, although strength was significantly increased due to formation of a low-temperature microstructure, elongation was significantly reduced (16% or less).

[0144] Further, Comparative Examples 6 and 7 correspond to cases in which a Ti content is outside a range of the hot-rolled steel sheet of the present invention.

[0145] In the case of Comparative Example 6, when the Ti content is low, precipitation of TiC is insufficient, resulting in insufficient strength.

[0146] On the other hand, in the case of Comparative Example 7, when the Ti content is high, excessive precipitation strengthening by TiC results in an increase in strength, but elongation is significantly reduced (16% or less).

[0147] Meanwhile, Comparative Examples 8 and 9 correspond to cases in which, although the composition and compositional ranges of the hot-rolled steel sheet according to embodiments of the present invention are satisfied, a coiling temperature is outside a range of the manufacturing method according to embodiments of the present invention.

[0148] Specifically, in the case of Comparative Example 8, when the coiling temperature is lower than the range limited in the manufacturing method of the present invention, sufficient TiC precipitation does not occur and a low-temperature microstructure is formed, resulting in low yield strength and insufficient elongation.

[0149] On the other hand, in the case of Comparative Example 9, when the coiling temperature is higher than the limited range, TiC precipitates grow excessively, resulting in insufficient strength.

[0150] Furthermore, it can be confirmed from Table 3 that all of Comparative Examples 1 to 9 do not satisfy [Relational Expression 1] ≤ 1 due to at least one factor among Mn, Ti, and/or coiling temperature.

[0151] Although the present invention has been described above with reference to the exemplary drawings, the present invention is not limited by the embodiments and drawings disclosed in the specification, and it is apparent that various modifications can be made by those skilled in the art within the scope of the technical spirit of the present invention. In addition, even when the operational effects according to the configuration of the present invention have not been explicitly described in the description of the embodiments of the present invention, it goes without saying that the effects predictable by the corresponding configuration should also be recognized.

Claims

1. A hot-rolled steel sheet comprising: C: 0.03 to 0.1 wt%; Si: 0.1 wt% or less; Mn: 0.7 to 1.4 wt%; Ti: 0.03 to 0.09 wt%; P: 0.02 wt% or less; S: 0.02 wt% or less; N: 0.01 wt% or less; and the balance being Fe and other inevitable impurities, and satisfying Relational expression 1 below:

$$3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2 \leq 1 \quad \text{Relational expression 1)}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius (°C)).

2. The hot-rolled steel sheet of claim 1, comprising at least 90% ferrite by area fraction,

with the remainder includes one or more microstructures selected from pearlite, bainite, and martensite, wherein an average grain size of the ferrite is 15 μm or less,

3. The hot-rolled steel sheet of claim 1, comprising carbides,

wherein the carbides have an average size of 8 nm or less, and a distribution of 3.5 or more carbides per 10,000 nm².

4. The hot-rolled steel sheet of claim 1, wherein a yield strength of the hot-rolled steel sheet is 440 MPa or more,

a tensile strength thereof is 490 MPa or more, and an elongation thereof is 16% or more.

5. A hot-rolled plated steel sheet comprising the hot-rolled steel sheet of any one of claims 1 to 4 as a base steel sheet.

6. The hot-rolled plated steel sheet of claim 5, comprising plating layers disposed on opposite surfaces or at least one surface of the hot-rolled steel sheet.

7. The hot-rolled plated steel sheet of claim 6, wherein the plating layer includes any one selected from zinc, aluminum, a zinc alloy, and an aluminum alloy.

8. A manufacturing method of a hot-rolled steel sheet, comprising:

reheating a steel slab including C: 0.03 to 0.1 wt%, Si: 0.1 wt% or less, Mn: 0.7 to 1.4 wt%, Ti: 0.03 to 0.09 wt%, P: 0.02 wt% or less, S: 0.02 wt% or less, N: 0.01 wt% or less, and the balance being Fe and other inevitable impurities;

hot-rolling the steel slab; and

cooling the hot-rolled steel sheet to 570 to 680 °C and coiling the hot-rolled steel slab,

wherein the hot-rolled steel sheet satisfies Relational expression 1 below:

$$3*([Mn]-0.9)^2+1200*([Ti]-0.06)^2+0.0004*(\text{coiling temperature}-630)^2 \leq 1 \quad \text{Relational expression 1)}$$

(in Relational expression 1, [] indicates the wt% of each element, and the coiling temperature is given in degrees Celsius (°C)).

9. The manufacturing method of claim 8, wherein the reheating includes reheating the steel slab at 1,150 to 1,300 °C.

10. The manufacturing method of claim 8, wherein the hot rolling includes finishing hot rolling a steel slab at 800 to 1000 °C.

11. A manufacturing method of a hot-rolled plated steel sheet comprising the manufacturing method of a hot-rolled steel sheet of any one of claims 8 to 10, and comprising forming a plating layer after the coiling.

12. The manufacturing method of claim 11, further comprising heat-treating between the coiling and the forming of the plating layer,

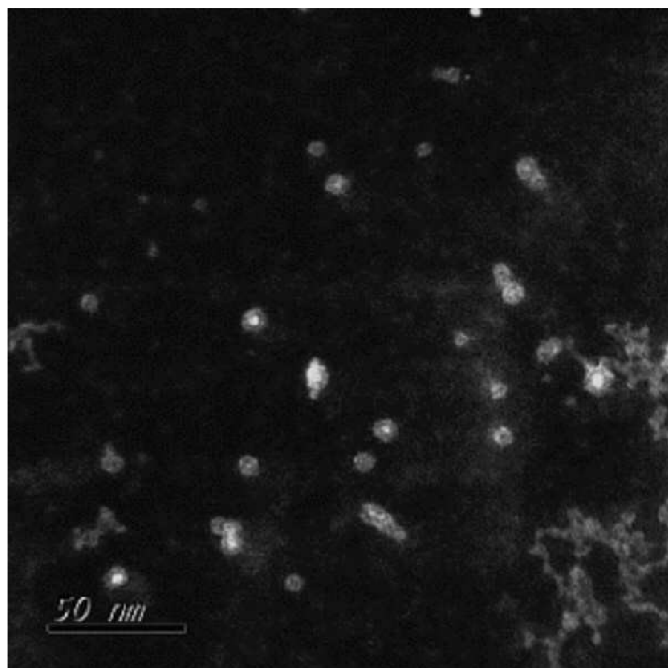
wherein the heat-treating includes heat-treating the coiled hot-rolled steel sheet at 450 to 750 °C.

13. The manufacturing method of claim 11, wherein the forming of the plating layer includes plating at least one surface of the hot-rolled steel sheet.

14. The manufacturing method of claim 11, wherein the forming of the plating layer uses any one selected from a molten plating process, an electroplating process, and a plasma process.

15. The manufacturing method of claim 11, wherein the plating layer includes any one component selected from zinc, aluminum, a zinc alloy, and an aluminum alloy.

[FIG. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019764

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; C22C 38/02(2006.01)i; C22C 38/14(2006.01)i; C22C 38/00(2006.01)i; C21D 8/02(2006.01)i;
C21D 9/46(2006.01)i; C25D 3/22(2006.01)i; C25D 3/44(2006.01)i; C23C 2/06(2006.01)i; C23C 2/12(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 38/04(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/14(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: 열연강판(hot rolled steel sheet), 망간(Mn), 티타늄(Ti), 페라이트(ferrite), 탄화물(carbide), 냉각(cooling), 도금(plating)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2015-0095923 A (JFE STEEL CORPORATION) 21 August 2015 (2015-08-21) See paragraphs [0085], [0100], [0119]-[0120] and [0143], claims 1 and 7-8 and tables 2-3.	1-15
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A	WO 2023-084926 A1 (NIPPON STEEL CORPORATION) 19 May 2023 (2023-05-19) See claims 1 and 6.	1-15
A	JP 5729523 B1 (JFE STEEL CORP.) 03 June 2015 (2015-06-03) See paragraphs [0077]-[0080] and claims 1 and 4.	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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

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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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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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Information on patent family members

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