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(54) PLATED STEEL SHEET FOR HOT PRESS FORMING HAVING EXCELLENT IMPACT RESISTANCE, HOT PRESS FORMED PART, AND MANUFACTURING METHODS THEREOF

(57) The present invention relates to a plated steel sheet for hot press forming, a hot press formed part, and manufacturing methods thereof and, more specifically, a plated steel sheet for hot press forming having excellent impact resistance, a hot press formed part, and manufacturing methods thereof.

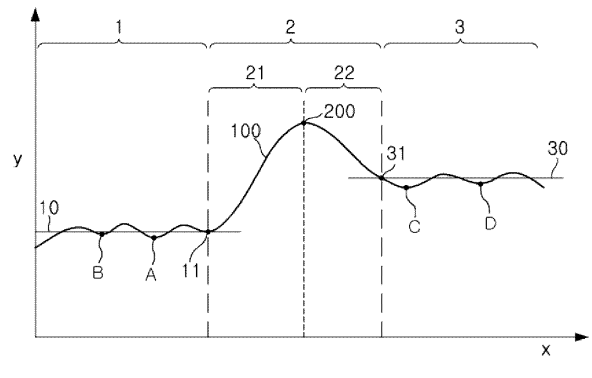

FIG. 1

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Description

Technical Field

[0001] The present disclosure relates to a plated steel sheet for hot press forming, a hot press formed part, and manufacturing methods thereof, and in particular, to a plated steel sheet for hot press forming having excellent impact resistance, a hot press formed part, and manufacturing methods thereof.

Background Art

[0002] Recently, a hot press formed part has mainly been applied to an automobile structural part to achieve improvement of fuel efficiency, protection of passengers, and the like through weight reduction of an automobile, and particularly, may be used for a bumper, a door, a pillar reinforcement, or the like that requires ultra-high strength or high energy absorption capacity.

[0003] Patent Document 1 was suggested as a representative technology regarding the hot press forming technology. In the patent, an Al-Si plated steel sheet is heated to 850°C or higher, and then hot press forming and quenching by a press are performed to form a structure of a part with martensite, such that ultra-high strength with high tensile strength may be secured. In a case in which such ultra-high strength steel for hot press forming is applied, a complex shape may be easily formed because the formation is performed at high temperature, and a weight reduction effect may be expected through an increase in strength by quenching in a mold.

[0004] However, along therewith, automobile manufacturers are increasingly required to improve impact resistance for passenger safety, but conventional steel for hot press forming has a martensite structure, which provides high strength but poor impact resistance in the case of collisions, and thus requires improvement.

[Prior Art Document]

[0005] (Patent Document 1) U.S. Patent No. 6,296,805 (published on October 2, 2001)

Summary of Invention

Technical Problem

[0006] An aspect of the present disclosure is to provide a plated steel sheet for hot press forming having excellent impact resistance, a hot press formed part, and manufacturing methods thereof.

[0007] An object of the present disclosure is not limited to the above description. Those skilled in the art will have no difficulties in understanding the additional objects of the present disclosure from the overall descriptions of the present specification.

Solution to Problem

[0008] According to an aspect of the present disclosure, a plated steel sheet includes a base steel sheet containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony (Sb) and a plating layer formed on a surface of the base steel sheet,

> wherein the base steel sheet includes an antimony (Sb)-enriched layer therein, and
> when contents of elements are analyzed in a thickness direction of the base steel sheet using a glow discharge spectrometer, a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) is 10 to 70% of a nominal carbon content (C_0) of the base steel sheet.

[0009] A decarburization rate (α) of carbon (C) in a region from an interface between the base steel sheet and the plating layer to a depth of 30 μm in the thickness direction may be 14 to 35%.

[0010] In the plated steel sheet, a point at which a content of carbon (C) is 50% of the nominal carbon content (C_0) may exist at a depth of more than 1.5 μm and less than 6 μm from an interface between the base steel sheet and the plating layer in the thickness direction.

[0011] In the plated steel sheet, a point at which a content of carbon (C) is 80% of the nominal carbon content (C_0) may exist at a depth of more than 6 μm and less than 15 μm from an interface between the base steel sheet and the plating layer in the thickness direction.

[0012] The plated steel sheet may have an R value defined in the following Relational Expression 1 of 1.2 or more, and a B value defined in the following Relational Expression 2 of 0.008 or more:

[Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(wherein Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel sheet and a point at which Sb_{max} is measured, and a unit thereof is μm).

[0013] A region from an interface between the base steel sheet and the plating layer to a depth of 10 μm in the thickness direction may have a microstructure containing ferrite as a main phase and 1 area% or more of pearlite.

[0014] The base steel sheet may contain 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

[0015] The plating layer may be formed of aluminum or an aluminum alloy.

[0016] According to another aspect of the present disclosure, a part includes a base steel containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony and a plating layer formed on a surface of the base steel,

wherein the base steel includes an antimony (Sb)-enriched layer therein, and
when contents of elements are analyzed in a thickness direction of the base steel using a glow discharge spectrometer, a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) is 80% or less of a nominal carbon content (C_0) of the base steel.

[0017] In the part, the content of carbon (C) at the depth at which the content of antimony (Sb) shows the maximum value (Sb_{max}) may be 15 to 80% of the nominal carbon content (C_0) of the base steel.

[0018] The part may have an R value defined in the following Relational Expression 1 of 1.5 or more, and

a B value defined in the following Relational Expression 2 of 0.01 or more:

[Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(wherein Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface where the plating layer and the base steel are in contact with each other and a point at which Sb_{max} is measured, and a unit thereof is μm).

[0019] A softening rate (β) in a region from an interface between the base steel and the plating layer to a depth of 45 to 100 μm in the thickness direction may be 2 to 7%.

[0020] A region from an interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction may have a microstructure containing less than 5 area% of ferrite.

[0021] A region from an interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction may have a microstructure containing martensite as a main phase, less than 5 area% of ferrite, and a balance of upper and lower bainite.

[0022] The base steel may contain 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

[0023] The plating layer may be formed of aluminum or an aluminum alloy.

[0024] The part may have a product of a tensile strength and a bending angle of 80,000 MPa·° or more.

[0025] The amount of diffusible hydrogen in the part may be 0.2 ppm or less.

[0026] According to still another aspect of the present disclosure, a manufacturing method of a plated steel sheet includes: preparing a cold-rolled steel sheet containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony;

annealing the cold-rolled steel sheet in a temperature range of Ac_1 to Ac_3; and
plating the annealed cold-rolled steel sheet,
wherein during the annealing, a product of an annealing time and an absolute humidity is 10,000 to 80,000 s·g/m^3, and during the annealing, based on a surface temperature of the steel sheet, an average temperature increase rate from room temperature to 500°C is 2.7 to 10.0°C/s, an average temperature increase rate in a section of 500 to 700°C is 0.5 to 2.5°C/s, and an average temperature increase rate from 700°C to an annealing temperature is 0.01 to 0.4°C/s.

[0027] During the annealing, the annealing time may be 100 to 200 seconds, and the absolute humidity may be 100 to 400 g/m^3.

[0028] The cold-rolled steel sheet may be manufactured by:

reheating a steel slab to a temperature range of 1,050 to 1,300°C;
finish rolling the reheated steel slab in a temperature range of 800 to 950°C;
coiling and cooling the rolled steel in a temperature range of 500 to 700°C; and
cold rolling the cooled steel at a reduction ratio of 30 to 80%.

[0029] The steel slab may contain 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

[0030] During the plating, the plating may be performed with aluminum or an aluminum alloy.

[0031] According to still another aspect of the present disclosure, a manufacturing method of a part includes: manufacturing a blank using any one of the plated steel sheets;

heating the blank to a temperature range of Ac_3 to 975°C and maintaining the blank for 10 to 1,000 seconds; and
forming and cooling the heated blank.

[0032] During the cooling, the cooling may be performed at a cooling rate of 20°C/s or more.

Advantageous Effects of Invention

[0033] According to an aspect of the present disclosure, it is possible to provide a plated steel sheet for hot press forming having excellent impact resistance, a hot press formed part, and manufacturing methods thereof.

[0034] According to an aspect of the present disclosure, it is possible to provide a plated steel sheet for hot press forming having excellent fatigue resistance and impact resistance, a hot press formed part, and manufacturing methods thereof.

Brief Description of Drawings

[0035]

FIG. 1 schematically illustrates an exemplary change in content of Sb of the present disclosure to show an Sb-enriched layer.
FIG. 2 schematically illustrates content profiles of Sb and C in a thickness direction from an interface in a plated steel sheet according to an exemplary embodiment in the present disclosure.
FIG. 3 schematically illustrates a decarburization rate (α) profile in the thickness direction from the interface in the

plated steel sheet according to an exemplary embodiment in the present disclosure.

FIG. 4 schematically illustrates a profile of an Sb-enriched layer of the plated steel sheet according to an exemplary embodiment in the present disclosure.

FIG. 5 schematically illustrates content profiles of Sb and C in a thickness direction from an interface in a part according to an exemplary embodiment in the present disclosure.

FIG. 6 schematically illustrates a hardness softening rate (β) profile in the thickness direction from the interface in the part according to an exemplary embodiment in the present disclosure.

FIG. 7 illustrates a content profile of C in the plated steel sheet according to an exemplary embodiment in the present disclosure.

FIG. 8 is a photograph of a microstructure of the plated steel sheet according to an exemplary embodiment in the present disclosure observed with scanning electron microscopy (SEM).

FIG. 9 is a photograph obtained by observing a microstructure of the part according to an exemplary embodiment in the present disclosure.

Best Mode for Invention

[0036] Hereinafter, preferred exemplary embodiments in the present disclosure will be described. The exemplary embodiments in the present disclosure may be modified in various forms, and the scope of the present disclosure should not be interpreted to be limited to the exemplary embodiments set forth below. The exemplary embodiments are provided in order to describe the present disclosure in more detail to those skilled in the art to which the present disclosure pertains.

[0037] In order to solve the problems of the related art, a measure to improve bendability by applying a decarburization technology may be considered, but fatigue characteristics may be deteriorated due to a local decrease in hardness of a surface layer part, which may limit the applications to automobile parts. Therefore, as a result of conducting intensive studies to solve these problems, the inventors of the present disclosure have found that when an antimony (Sb)-enriched layer is formed on a base steel sheet and a decarburization rate of the steel sheet is maintained at an appropriate level, the problem of deterioration of fatigue characteristics may be solved and the impact resistance may also be improved, thereby completing the present disclosure.

[0038] Hereinafter, the present disclosure will be described in more detail.

[0039] An aspect of the present disclosure relates to a plated steel sheet including a base steel sheet and a plating layer formed on a surface of the base steel sheet. The impact resistance and fatigue resistance may be greatly affected by a degree of decarburization of the steel sheet, and when a decarburization rate is appropriately controlled by using an enriched layer formed in the base steel sheet, the effects of the present disclosure may be advantageously obtained. That is, the plated steel sheet according to an aspect of the present disclosure may include a base steel sheet and a plating layer formed on a surface (may mean an interface between the base steel sheet and the plating layer) of the base steel sheet, and the base steel sheet may include an antimony (Sb)-enriched layer therein.

[0040] According to an exemplary embodiment in the present disclosure, when an antimony (Sb)-enriched layer is formed in the steel sheet, a decarburization rate according to a depth of the steel sheet in a thickness direction may be appropriately controlled by the formation of the Sb-enriched layer.

[0041] Hereinafter, an Sb-enriched layer and its role according to an exemplary embodiment in the present disclosure will be described in detail with reference to the graph of FIG. 1. FIG. 1 schematically illustrates an exemplary change in content of Sb of the present disclosure to show the Sb-enriched layer, and in FIG. 1, the X-axis represents a straight distance from the plating layer in a direction toward the base steel sheet, that is, in a thickness direction, at an arbitrary location in the plated steel sheet, and the Y-axis represents a content of Sb measured using a glow discharge spectrometer (GDS). FIG. 1 illustrates changes in contents of Sb in a plating layer 1, an Sb-enriched layer 2, and a base steel sheet 3 excluding the Sb-enriched layer 2. Here, the Sb-enriched layer 2 may have a content of Sb of 1.05 times or more the nominal Sb content (Sb_0) of the base steel sheet, and a point (200: Sb_{max}) at which the content of Sb is a maximum value may exist in the Sb-enriched layer 2. In addition, the Sb-enriched layer 2 may include an Sb content increasing section 21 in which the content of Sb increases to the point (200: Sb_{max}) at which the content of Sb is the maximum value in the X-axis direction, and an Sb content decreasing section 22 in which the content of Sb decreases from the point (200: Sb_{max}) at which the content of Sb is the maximum value in the X-axis direction. In FIG. 1, a final contact point 11 of an Sb average content line 10 of the plating layer 1 and the Sb content line 100 before reaching the point (200: Sb_{max}) at which the content of Sb is the maximum value in an X-axis (+) direction may be set as a starting point of the Sb content increasing section 21.

[0042] In an exemplary embodiment, the Sb average content line 10 of the plating layer 1 may mean an extended line obtained by horizontally extending the Sb average content in a section from a point A spaced apart from the point (200: Sb_{max}) at which the content of Sb in the Sb-enriched layer 2 is the maximum value to the plating layer 1 by 15 μm to a point B spaced apart from Sb_{max} by 20 μm.

[0043] In the same manner, in the Sb content decreasing section 22 from the point (200: Sb_{max}) at which the content of Sb is the maximum value in the X-axis (+) direction, an initial contact point 31 of an Sb average content line 30 of the base steel sheet and the Sb content line 100 in the X-axis (+) direction is regarded as an end point of the Sb-enriched layer 2.

[0044] In an exemplary embodiment, the Sb average content line 30 of the base steel sheet 3 excluding the Sb-enriched layer may mean an extended line obtained by horizontally extending the Sb average content in a section from a point C spaced apart from the point (200: Sb_{max}) at which the content of Sb in the Sb-enriched layer 2 is the maximum value to the base steel sheet 3 by 15 μm to a point D spaced apart from Sb_{max} by 20 μm.

[0045] In an exemplary embodiment in the present disclosure, the Sb-enriched layer may be formed directly under the interface between the base steel sheet and the plating layer. For example, when a content profile of Al is analyzed in the depth (thickness) direction from the surface of the plated steel sheet using a glow discharge spectrometer (GDS), the interface between the base steel sheet and the plating layer may be defined as a point at which a content of Al is 15%. In addition, for example, a thickness of the enriched layer may be 1 to 30 μm.

[0046] In addition, according to an exemplary embodiment in the present disclosure, when a content of antimony (Sb) is analyzed in the thickness direction of the base steel sheet using a glow discharge spectrometer (GDS), a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) may be 10 to 70% of a nominal carbon content (C_0) of the base steel sheet. In an exemplary embodiment in the present disclosure, the nominal carbon content (C_0) may mean a carbon average content in a region corresponding to 1/4 to 3/4 of the thickness based on a cross section of the base steel sheet, and specifically, may be an average carbon content obtained by analyzing a carbon profile at a distance of 50 μm or more from an arbitrary point in the region corresponding to 1/4 to 3/4 of the thickness of the base steel sheet using a glow discharge spectrometer (GDS).

[0047] FIG. 2 schematically illustrates content profiles of Sb and C in the thickness direction from the interface in the plated steel sheet according to an exemplary embodiment in the present disclosure. In FIG. 2, the X-axis may represent a depth (μm) from the interface between the base steel sheet and the plating layer, and the Y-axis may represent a content (wt%) of element. As illustrated in FIG. 2, 70% of the nominal carbon content (C_0) is 0.154%. Here, the nominal carbon content (C_0) is 0.22%, which may be obtained by analyzing a certain thickness (depth) using a glow discharge spectrometer (GDS) in the region corresponding to 1/4 to 3/4 of the thickness of the base steel sheet as described above. In this case, it can be confirmed that the content of carbon at the depth at which the content of Sb shows the maximum value (Sb_{max}) exhibits a content of carbon of 70% or less of the nominal carbon content (C_0).

[0048] As illustrated in FIG. 2, in an exemplary embodiment in the present disclosure, at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}), a ratio of the content of carbon to the nominal carbon content (C_0) is controlled to 10 to 70%, and in this case, the content of carbon affects a hardness softening rate of the surface layer and bendability of the part.

[0049] Meanwhile, when the content of carbon at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}) exceeds 70% of the nominal carbon content (C_0), the hardness of the surface layer part may increase, which may cause deterioration of the bendability. In addition, according to an exemplary embodiment in the present disclosure, when the content of carbon is less than 10% of the nominal carbon content (C_0), the hardness decreases excessively, and thus, the fatigue resistance may be deteriorated.

[0050] In an exemplary embodiment in the present disclosure, at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}), the ratio of the content of carbon to the nominal carbon content (C_0) may be 10.0 to 70.0%.

[0051] According to an exemplary embodiment in the present disclosure, a decarburization rate (α) of carbon (C) in a region from the interface between the base steel sheet and the plating layer to a depth of 30 μm in the thickness direction may be 14 to 35%.

[0052] FIG. 3 schematically illustrates a decarburization rate (α) profile in the thickness direction from the interface in the plated steel sheet according to an exemplary embodiment in the present disclosure. In FIG. 3, the decarburization rate (α) may be obtained from the results of measuring carbon in the plated steel sheet using a glow discharge spectrometer (GDS). In the drawing, the Y-axis represents a ratio of the content of carbon at the corresponding position to the nominal carbon content (C_0), and the X-axis represents a distance (μm) in the thickness (depth) direction from the interface between the base steel sheet and the plating layer. As illustrated in the drawing, it is possible to draw a square having a horizontal side corresponding to a depth of 0 to 30 μm in the thickness direction of the base steel sheet from the interface in the X-axis direction and a vertical side corresponding to a length of 0 to 100% in the Y-axis direction. Here, in the square, a carbon profile curve indicating a ratio of a content of carbon at the corresponding depth to the nominal carbon content (C_0) is drawn, and a ratio (%) of an area above the carbon profile curve in the square to the entire area of the square may be defined as the decarburization rate (α).

[0053] In other words, the decarburization rate (α) of the present disclosure means a ratio (%) of the area above the carbon profile curve to the entire area of the square in the square in which a horizontal axis represents the distance (μm) in the thickness (depth) direction from the interface between the base steel sheet and the plating layer, and a vertical axis represents the ratio (%) of the content of carbon at the corresponding position to the nominal carbon content (C_0).

[0054] When the decarburization rate (α) of carbon (C) in the region from the interface to the depth of 30 μm in the thickness direction is less than 14%, a carbon enrichment degree in the base steel sheet may excessively increase the hardness in the part after hot press forming, and thus, the effect of improving bendability may be significantly reduced. On the other hand, when the decarburization rate exceeds 35%, the martensite hardness in the part may decrease significantly due to a decrease in the amount of carbon in the surface layer of the base steel sheet, which may cause deterioration of the fatigue resistance of the part.

[0055] According to an exemplary embodiment in the present disclosure, a decarburization rate (α) of carbon (C) in a region from the interface between the base steel sheet and the plating layer to a depth of 30.0 μm in the thickness direction may be 14.0 to 35.0%.

[0056] In the plated steel sheet according to another exemplary embodiment in the present disclosure, a point at which a content of carbon (C) is 50% of the nominal carbon content (C_0) may exist at a depth of more than 1.5 μm and less than 6 μm from the interface between the base steel sheet and the plating layer in the thickness direction.

[0057] Controlling the ratio of the content of carbon (C) to the nominal carbon content (C_0) at the depth of more than 1.5 μm and less than 6 μm from the interface in the thickness direction is to secure both the fatigue resistance and the impact resistance. When a point at which the content of carbon (C) is 50% of the nominal carbon content (C_0) exists at the depth in the corresponding range, it is advantageous for securing both the impact resistance and the fatigue resistance, but when the point of 50% exists at a depth of 6 μm or more, the fatigue resistance may be deteriorated due to excessive decarburization. Meanwhile, when the point of 50% exists at a depth of 1.5 μm or less, it may be difficult to secure the desired bendability due to insufficient decarburization.

[0058] In the plated steel sheet according to another exemplary embodiment in the present disclosure, a point at which a content of carbon (C) is 50.0% of the nominal carbon content (C_0) may exist at a depth of more than 1.50 μm and less than 6.0 μm from the interface between the base steel sheet and the plating layer in the thickness direction.

[0059] In addition, in an exemplary embodiment in the present disclosure, a point at which a content of carbon (C) is 80% of the nominal carbon content (C_0) may exist at a depth of more than 6 μm and less than 15 μm from the interface between the base steel sheet and the plating layer in the thickness direction.

[0060] When a point at which the ratio of the content of carbon (C) to the nominal carbon content (C_0) is 80% exists at a depth of more than 6 μm and less than 15 μm from the interface in the thickness direction, it may be advantageous in securing appropriate bendability and suppressing excessive deterioration of the fatigue resistance. Meanwhile, when the point of 80% exists at a depth of 15 μm or more, the fatigue resistance may be deteriorated due to excessive decarburization, and when the point of 80% exists at a depth of 6 μm or less, it may be difficult to secure the desired bendability due to insufficient decarburization.

[0061] In an exemplary embodiment in the present disclosure, a point at which the content of carbon (C) is 80.0% of the nominal carbon content (C_0) may exist at a depth of more than 6.0 μm and less than 15.0 μm from the interface between the base steel sheet and the plating layer in the thickness direction.

[0062] In an exemplary embodiment in the present disclosure, an R value defined in the following Relational Expression 1 may be 1.2 or more, and a B value defined in the following Relational Expression 2 may be 0.008 or more.

[0063] In an exemplary embodiment in the present disclosure, the R value defined in the following Relational Expression 1 may be 1.20 or more, and the B value defined in the following Relational Expression 2 may be 0.0080 or more.

[0064] When the Sb-enriched layer is formed in the base steel sheet, it is difficult for oxygen dissociated in an annealing furnace to penetrate into the base steel sheet, and therefore, the Sb-enriched layer may serve as a barrier that makes decarburization difficult. In the present disclosure, it is confirmed that the decarburization rate may be appropriately controlled by controlling the content of Sb according to the depth in the thickness direction, and the present disclosure suggests the following Relational Expressions 1 and 2.

[Relational Expression 1]

$$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2]

$$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(In the expressions, Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel sheet and a point at which Sb_{max} is measured, and a unit thereof is μm.)

[0065] FIG. 4 schematically illustrates a profile of the Sb-enriched layer of the plated steel sheet according to an exemplary embodiment in the present disclosure. In FIG. 4, an area corresponding to the B value of Relational Expression 2 is indicated by the colored portion, and the area may indicate an Sb enriched degree according to Δt, which represents the distance between the point where Sb_{coat} is measured and the point where Sb_{max} is measured.

[0066] When the R value defined in Relational Expression 1 is less than 1.2 or the B value defined in Relational Expression 2 is less than 0.008, decarburization occurs excessively, resulting in an excessively high decarburization rate in the plated steel sheet, and the hardness of the surface layer of the part after hot press forming decreases significantly, which may cause deterioration of the fatigue resistance of the part.

[0067] In an exemplary embodiment in the present disclosure, the R value defined in Relational Expression 1 may be limited to 1.5 or more. In addition, in another exemplary embodiment in the present disclosure, the B value defined in Relational Expression 2 may be limited to 0.02 or more. However, when the R value is excessively high or the B value is excessively high, carbon on the surface is hardly removed, and the hardness of the surface layer of the part after hot press forming increases excessively, which may cause deterioration of the bendability of the surface layer part. Therefore, as an exemplary embodiment in the present disclosure, an upper limit of the R value may be limited to 6.5. In addition, as an exemplary embodiment in the present disclosure, an upper limit of the B value may be limited to 0.15.

[0068] In an exemplary embodiment in the present disclosure, the R value defined in Relational Expression 1 may be limited to 1.50 or more. In addition, in another exemplary embodiment in the present disclosure, the B value defined in Relational Expression 2 may be limited to 0.020 or more. However, when the R value is excessively high or the B value is excessively high, carbon on the surface is hardly removed, and the hardness of the surface layer of the part after hot press forming increases excessively, which may cause deterioration of the bendability of the surface layer part. Therefore, as an exemplary embodiment in the present disclosure, the upper limit of the R value may be limited to 6.50. In addition, as an exemplary embodiment in the present disclosure, the upper limit of the B value may be limited to 0.150.

[0069] As described above, the R value and the B value are controlled to the suggested ranges in the plated steel sheet, such that the R value and the B value of the part may be controlled to appropriate ranges, and accordingly, the intrusion of hydrogen may be effectively suppressed.

[0070] According to an exemplary embodiment in the present disclosure, in the plated steel sheet, a region from the interface between the base steel sheet and the plating layer to a depth of 10 μm in the thickness direction may have a microstructure containing ferrite as a main phase and 1 area% or more of pearlite. In the present disclosure, a phase having a fraction of 50 area% or more of the total microstructure fraction may be regarded as the main phase.

[0071] When the plated steel sheet of the present disclosure has an insufficient fraction of ferrite in a region from the interface between the base steel sheet and the plating layer to a depth of 10 μm in the thickness direction, the fatigue resistance of the part may be deteriorated.

[0072] In the region corresponding to a distance of 10 μm from the interface between the base steel sheet and the plating layer in the thickness (depth) direction, pearlite may play a role in preventing the hardness of the surface layer part from being deteriorated by providing carbon to the structure directly under the plating layer during a heat treatment for hot press forming. Therefore, in the present disclosure, 1 area% or more of pearlite may be contained.

[0073] Meanwhile, when pearlite is less than 1 area%, the hardness of the surface layer part may decrease excessively after hot press forming, which may increase the hardness softening rate and cause deterioration of the fatigue resistance of the part.

[0074] According to another exemplary embodiment in the present disclosure, a region from the interface between the base steel sheet and the plating layer to a depth of 10.0 μm in the thickness direction may contain ferrite as a main phase and 1.0 area% or more of pearlite.

[0075] Hereinafter, a composition of the base steel sheet of the present disclosure will be described in detail.

[0076] The base steel sheet according to an exemplary embodiment in the present disclosure may contain, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony.

[0077] The base steel sheet according to an exemplary embodiment in the present disclosure may contain, by wt%, 0.060 to 0.50% of carbon (C) and 0.010 to 0.10% of antimony.

[0078] In the present disclosure, unless otherwise specified, % indicating a content of each element is based on weight.

Carbon (C): 0.06 to 0.5%

[0079] Carbon (C) is an element that increases strength of a hot press formed part and improves hardenability, and should be appropriately added as an essential element for controlling the strength. When a content of carbon (C) is less than 0.06%, since the hardenability is low, when a cooling rate is reduced, sufficient martensite is not secured, and ferrite is formed, which may make it difficult to secure the desired strength. In an exemplary embodiment in the present disclosure, the content of carbon (C) may be 0.1% or more. On the other hand, when the content of carbon (C) exceeds 0.5%, the strength is excessively increased, brittleness may be caused, and weldability may be deteriorated. In an exemplary embodiment in the present disclosure, an upper limit of the content of carbon (C) may be 0.45%.

[0080] According to another exemplary embodiment in the present disclosure, carbon (C) may be contained in an amount of 0.060 to 0.50%.

[0081] According to still another exemplary embodiment in the present disclosure, carbon (C) may be 0.10% or more.

[0082] According to still another exemplary embodiment in the present disclosure, the upper limit of carbon (C) may be 0.450%.

Antimony (Sb): 0.01 to 0.1%

[0083] Antimony (Sb) is enriched inside the base steel sheet, and may thus play a role in preventing an excessive decrease in hardness in the part by controlling the amount of carbon that escapes when internal oxidation annealing is applied. When a content of antimony (Sb) is less than 0.01%, since a sufficient enriched layer is not formed at the interface between the plating layer and the base steel sheet, excessive decarburization occurs, which may cause an excessive decrease in hardness of the surface layer, resulting in deterioration of the fatigue resistance. According to an exemplary embodiment in the present disclosure, a lower limit of antimony (Sb) may be 0.02%. On the other hand, when the content of antimony (Sb) exceeds 0.1%, antimony (Sb) may be excessively precipitated at the grain boundaries, which may cause grain boundary destruction when stress occurs, resulting in deterioration of the material. According to an exemplary embodiment, an upper limit of the content of antimony (Sb) may be 0.08%.

[0084] According to another exemplary embodiment in the present disclosure, antimony (Sb) may be contained in an amount of 0.010 to 0.10%.

[0085] According to still another exemplary embodiment in the present disclosure, antimony (Sb) may be 0.020% or more.

[0086] According to still another exemplary embodiment in the present disclosure, the upper limit of antimony (Sb) may be 0.080%.

[0087] As for additive elements of the base steel sheet applied to the plated steel sheet for hot press forming of the present disclosure, the types and contents thereof are not limited as long as they are elements that may be generally added. However, according to an exemplary embodiment in the present disclosure, non-limiting examples of the elements that may be added to the base steel sheet include silicon (Si), manganese (Mn), molybdenum (Mo), phosphorus (P), sulfur (S), aluminum (Al), chromium (Cr), nitrogen (N), titanium (Ti), boron (B), copper (Cu), nickel (Ni), vanadium (V), calcium (Ca), niobium (Nb), tin (Sn), tungsten (W), magnesium (Mg), cobalt (Co), arsenic (As), zirconium (Zr), bismuth (Bi), and a rare earth element (REM), and the base steel sheet may further contain one or more of these elements.

[0088] According to an exemplary embodiment in the present disclosure, the base steel sheet may contain, by wt%, 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1.00% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

Silicon (Si): 0.001 to 2%

[0089] Silicon (Si) may be added as a deoxidizer in steelmaking. In addition, silicon (Si) is a solid solution strengthening element and a carbide formation suppressing element, and is added as an element that is effective in internal structure uniformity, contributes to increasing the strength of the hot press formed part, and is effective in material uniformity. However, when a content of silicon (Si) is less than 0.001%, the above effects are not expected, and when the content of silicon (Si) exceeds 2%, plating properties may be significantly deteriorated due to excessive Si oxides formed on the surface of the steel sheet during annealing. According to an exemplary embodiment in the present disclosure, a lower limit of the content of silicon (Si) may be 0.005%, and may be 0.01% in some cases. In addition, according to an exemplary embodiment in the present disclosure, an upper limit of the content of silicon (Si) may be 0.7%, and may be 0.65% in some cases.

[0090] According to another exemplary embodiment in the present disclosure, silicon (Si) may be contained in an amount of 0.001 to 2.0%.

[0091] According to still another exemplary embodiment in the present disclosure, silicon (Si) may be 0.0050% or more.

[0092] According to still another exemplary embodiment in the present disclosure, the upper limit of silicon (Si) may be 0.70%.

[0093] According to still another exemplary embodiment in the present disclosure, silicon (Si) may be 0.010% or more.

[0094] According to still another exemplary embodiment in the present disclosure, the upper limit of carbon (C) may be 0.650%.

Manganese (Mn): 0.1 to 4%

[0095] Manganese (Mn) needs to be added not only to secure the desired strength due to a solid solution strengthening effect thereof, but also to suppress the formation of ferrite during hot press forming through improvement of hardenability. When a content of manganese (Mn) is less than 0.1%, it is difficult to obtain a sufficient hardenability effect and other expensive alloying elements are excessively required to compensate for the insufficient hardenability, and thus, manufacturing costs may increase significantly. According to an exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.5% or more, and as another exemplary embodiment, manganese (Mn) may be contained in an amount of 0.8% or more. However, when the content of manganese (Mn) exceeds 4%, a band-like structure arranged in a microstructure rolling direction deepens, and non-uniformity of the internal structure may be caused, which may cause deterioration of the impact resistance. In an exemplary embodiment in the present disclosure, an upper limit of the content of manganese (Mn) may be 3.5%.

[0096] According to another exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.010 to 4.0%.

[0097] According to still another exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.050 to 4.0%.

[0098] According to still another exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.080 to 4.0%.

[0099] According to still another exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.050 to 3.50%.

[0100] According to still another exemplary embodiment in the present disclosure, manganese (Mn) may be contained in an amount of 0.080 to 3.50%.

Molybdenum (Mo): 1.0% or less

[0101] Molybdenum (Mo) may be contained as an element that may improve bendability by strengthening grains. However, when a content of molybdenum (Mo) exceeds 1.0%, the manufacturing costs may increase significantly. According to an exemplary embodiment in the present disclosure, an upper limit of the content of molybdenum (Mo) may be 0.5%, and may be 0.45% in some cases.

[0102] According to another exemplary embodiment in the present disclosure, molybdenum (Mo) may be contained in an amount of 1.0% or less. According to an exemplary embodiment in the present disclosure, an upper limit of the content of molybdenum (Mo) may be 0.50%, and may be 0.450% in some cases.

Phosphorus (P): 0.05% or less

[0103] Phosphorus (P) is present in the steel as an impurity, and when a content of phosphorus (P) exceeds 0.05%, the weldability of the hot press formed part and the physical properties of the material according to grain boundary segregation at a high temperature may be deteriorated. According to an exemplary embodiment, an upper limit of phosphorus (P) may be limited to 0.015%. Meanwhile, in an exemplary embodiment in the present disclosure, since a large amount of manufacturing costs are required to control the content of phosphorus (P) to an extremely small amount, a lower limit of phosphorus (P) may be limited to 0.001%.

[0104] According to another exemplary embodiment in the present disclosure, phosphorus (P) may be contained in an amount of 0.050% or less. According to an exemplary embodiment, the upper limit of phosphorus (P) may be limited to 0.0150%. Meanwhile, in some cases, the lower limit of phosphorus (P) may be limited to 0.0010%.

Sulfur (S): 0.02% or less

[0105] Sulfur (S) is an impurity in the steel, and an element that impairs ductility, impact properties, and weldability of the part, and thus, an upper limit of sulfur (S) may be limited to 0.02%. In an exemplary embodiment in the present disclosure, since a large amount of manufacturing costs may increase significantly to control the content of sulfur (S) to an extremely small amount, a lower limit of sulfur (S) may be limited to 0.0001%.

[0106] According to another exemplary embodiment in the present disclosure, sulfur (S) may be contained in an amount of 0.020% or less. According to an exemplary embodiment, a lower limit of sulfur (S) may be limited to 0.00010%.

Aluminum (Al): 0.001 to 1%

[0107] Aluminum (Al) is an element that serves as a deoxidizer in steelmaking to increase cleanness of the steel, together with Si. When a content of aluminum (Al) is less than 0.001%, it may be difficult to obtain the above effects. According to an exemplary embodiment in the present disclosure, a lower limit of aluminum (Al) may be 0.01%, and may be 0.2% in some cases. On the other hand, when the content of aluminum (Al) exceeds 1%, high-temperature ductility is deteriorated due to excessive AlN precipitates formed during a casting process, and slab cracks occur, which may cause problems in manufacturing. As an exemplary embodiment, an upper limit of aluminum (Al) may be limited to 0.1%, and may be limited to 0.09% in some cases.

[0108] According to another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.0010 to 1.0%.

[0109] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.010 to 1.0%.

[0110] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.020 to 1.0%.

[0111] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.010 to 0.10%.

[0112] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.010 to 0.090%.

[0113] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.020 to 0.10%.

[0114] According to still another exemplary embodiment in the present disclosure, aluminum (Al) may be contained in an amount of 0.020 to 0.090%.

Chromium (Cr): 1% or less

[0115] Similar to Mn, chromium (Cr) may be added as an element for securing the hardenability of the steel and suppressing the formation of ferrite after hot press forming. When a content of chromium (Cr) exceeds 1%, the effect of improving hardenability may be insufficient, as compared to the amount of Cr added, and coarse iron carbides are excessively formed and cracks may occur when stress is applied, which may cause deterioration of the material. According to an exemplary embodiment in the present disclosure, an upper limit of chromium (Cr) may be 0.8%. Meanwhile, as an exemplary embodiment in the present disclosure, in order to effectively secure the effects described above, a lower limit of chromium (Cr) may be limited to 0.01%, and may be limited to 0.05% in some cases.

[0116] According to another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 1.0% or less.

[0117] According to still another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 0.80% or less.

[0118] According to still another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 0.01 to 1.0%.

[0119] According to still another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 0.01 to 0.8%.

[0120] According to still another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 0.05 to 1.0%.

[0121] According to still another exemplary embodiment in the present disclosure, chromium (Cr) may be contained in an amount of 0.05 to 0.8%.

Nitrogen (N): 0.02% or less

[0122] Nitrogen (N) may be contained in the steel as an impurity. When a content of nitrogen (N) exceeds 0.02%, N forms AlN with added Al, which may cause slab cracks. Meanwhile, a large amount of manufacturing costs may be required to control the content of nitrogen (N) to an extremely small amount, and thus, according to an exemplary embodiment in the present disclosure, a lower limit of nitrogen (N) may be limited to 0.001%.

[0123] According to another exemplary embodiment in the present disclosure, nitrogen (N) may be contained in an amount of 0.020% or less.

[0124] According to still another exemplary embodiment in the present disclosure, nitrogen (N) may be contained in an amount of 0.0010 to 0.02%.

[0125] According to still another exemplary embodiment in the present disclosure, nitrogen (N) may be contained in an amount of 0.0010 to 0.020%.

Titanium (Ti): 0.1% or less

[0126] Titanium (Ti) may play a role in protecting B from being a compound for securing hardenability by forming TiN through a combination with N remaining in the steel as an impurity. In addition, the precipitation strengthening and grain refinement effects may be expected through the formation of Tic precipitates. However, when a content of titanium (Ti) exceeds 0.1%, a large amount of coarse TiN is formed, which may cause deterioration of the material of the steel. In an exemplary embodiment in the present disclosure, an upper limit of the content of titanium (Ti) may be limited to 0.09%.

[0127] According to another exemplary embodiment in the present disclosure, titanium (Ti) may be contained in an amount of 0.10% or less.

[0128] According to still another exemplary embodiment in the present disclosure, titanium (Ti) may be contained in an amount of 0.090% or less.

Boron (B): 0.01% or less

[0129] Boron (B) is an element that may effectively improve hardenability, and is an element that is segregated at a prior austenite grain boundary and may thus suppress brittleness of the hot press formed part due to grain boundary segregation of P or S, which is an impurity. Meanwhile, when a content of boron (B) exceeds 0.01%, brittleness may be caused in hot rolling due to the formation of a $Fe_{23}CB_6$ composite compound. In an exemplary embodiment in the present disclosure, an upper limit of the content of boron (B) may be limited to 0.008%.

[0130] According to another exemplary embodiment in the present disclosure, boron (B) may be contained in an amount of 0.010% or less.

[0131] According to still another exemplary embodiment in the present disclosure, boron (B) may be contained in an amount of 0.0080% or less.

[0132] In addition, as an exemplary embodiment in the present disclosure, the base steel sheet may further contain one or more of 1% or less of copper (Cu), 1% or less of nickel (Ni), 1.0% or less of vanadium (V), 0.01% or less of calcium (Ca), 0.1% or less of niobium (Nb), 1% or less of tin (Sn), 1% or less of tungsten (W), 0.1% or less of magnesium (Mg), 1% or less of cobalt (Co), 1% or less of arsenic (As), 1% or less of zirconium (Zr), 1% or less of bismuth (Bi), and 0.3% or less of a rare earth element (REM).

[0133] In addition, as an exemplary embodiment in the present disclosure, the base steel sheet may further contain one or more of 1.0% or less of copper (Cu), 1.0% or less of nickel (Ni), 1.0% or less of vanadium (V), 0.010% or less of calcium (Ca), 0.10% or less of niobium (Nb), 1.0% or less of tin (Sn), 1.0% or less of tungsten (W), 0.10% or less of magnesium (Mg), 1.0% or less of cobalt (Co), 1.0% or less of arsenic (As), 1.0% or less of zirconium (Zr), 1.0% or less of bismuth (Bi), and 0.30% or less of a rare earth element (REM).

[0134] The base steel sheet of the present disclosure may contain a balance of iron (Fe) and unavoidable impurities in addition to the composition described above. Since the unavoidable impurities may be unintentionally incorporated in a general manufacturing process, the unavoidable impurities may not be excluded. Since these impurities are known to those skilled in a general steel manufacturing field, all the contents thereof are not particularly described in the present specification.

[0135] According to an exemplary embodiment in the present disclosure, the plating layer of the plated steel sheet may be an aluminum or aluminum-based alloy plating layer. In addition, according to an exemplary embodiment, the plating layer may be an alloyed aluminum-based plating layer.

[0136] In addition, as an exemplary embodiment in the present disclosure, the plating layer may contain, in addition to Al, Si, Mg, and Fe, and may contain Mn, Cr, Cu, Mo, Ni, Sb, Sn, Ti, Ca, Sr, Zn, and the like in some cases. In the present disclosure, a thickness of the plating layer is not particularly limited, and the plating layer may have a thickness within a general range.

[0137] As an exemplary embodiment in the present disclosure, the plating layer may contain, by wt%, one or two or more selected from 5 to 11% of Si, 5% or less of Fe, and 5% or less of Mg, and may contain a balance of Al and other impurities. In addition to the composition described above, if necessary, the plating layer may further contain 30% or less of elements such as Mn, Cr, Cu, Mo, Ni, Sb, Sn, Ti, Ca, Sr, and Zn in total.

[0138] As an exemplary embodiment in the present disclosure, the plating layer may contain, by wt%, one or two or more selected from 5.0 to 11.0% of Si, 5.0% or less of Fe, and 5.0% or less of Mg, and may contain a balance of Al and other impurities. In addition to the composition described above, if necessary, the plating layer may further contain 30.0% or less of elements such as Mn, Cr, Cu, Mo, Ni, Sb, Sn, Ti, Ca, Sr, and Zn in total.

[0139] Hereinafter, a part of the present disclosure will be described in detail.

[0140] A part according to an exemplary embodiment in the present disclosure may include a base steel and a plating layer formed on a surface of the base steel.

[0141] The same alloy composition as that of the base steel sheet of the plated steel sheet suggested in the present disclosure may be applied to the base steel according to an aspect of the present disclosure.

[0142] In addition, according to an exemplary embodiment in the present disclosure, the plating layer may be formed on at least one surface of the base steel. The plating layer of the part may have an alloy composition in which components including Fe in the plating layer and the base steel sheet of the plated steel sheet described above are diffused.

[0143] The part according to an exemplary embodiment in the present disclosure may include an antimony (Sb)-enriched layer in the base steel.

[0144] The Sb-enriched layer of the present disclosure may be determined by analyzing a change in content of Sb from an arbitrary point of the plating layer in a thickness direction on a side of the base steel using a glow discharge spectrometer (GDS). In this regard, the method for determining the Sb-enriched layer in the plated steel sheet suggested in the present disclosure may be applied in the same manner. In an exemplary embodiment in the present disclosure, the antimony

(Sb)-enriched layer may be formed directly under an interface where the base steel and the plating layer are in contact with each other. According to an exemplary embodiment in the present disclosure, in the present disclosure, the interface between the base steel and the plating layer may mean a point at which a content of Al is 15%.

[0145] In the part according to an exemplary embodiment in the present disclosure, when contents of elements are analyzed in the thickness direction of the base steel using a glow discharge spectrometer (GDS), a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) may be 80% or less of a nominal carbon content (C_0) of the base steel.

[0146] In the part according to an exemplary embodiment in the present disclosure, when the contents of the elements are analyzed in the thickness direction of the base steel using a glow discharge spectrometer (GDS), the content of carbon (C) at the depth at which the content of antimony (Sb) in the antimony (Sb)-enriched layer shows the maximum value (Sb_{max}) may be 80.0% or less of the nominal carbon content (C_0) of the base steel.

[0147] The content of carbon at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}) affects the hardness of the surface layer structure and affects the bendability. Meanwhile, when the content of carbon at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}) exceeds 80% of the nominal carbon content (C_0), the hardness of the surface layer part may increase, which may cause deterioration of the bendability. However, when the content of carbon at the depth at which the content of Sb in the Sb-enriched layer shows the maximum value (Sb_{max}) is excessively low, the hardness of the surface layer part may be insufficient, which makes it difficult to secure fatigue resistance. Therefore, as an exemplary embodiment in the present disclosure, a lower limit thereof may be limited to 15%. As an exemplary embodiment in the present disclosure, the lower limit thereof may be limited to 15.0%.

[0148] FIG. 5 schematically illustrates content profiles of Sb and C in the thickness direction from the interface in the part according to an exemplary embodiment in the present disclosure. In FIG. 5, the X-axis may represent a depth (μm) from the interface between the base steel and the plating layer, and the Y-axis may represent a content (wt%) of element. As illustrated in FIG. 5, 80% of the nominal carbon content (C_0) is 0.176%. Here, the nominal carbon content (C_0) is 0.22%, which may be obtained by analyzing a certain thickness (depth) using a glow discharge spectrometer (GDS) in a region corresponding to 1/4 to 3/4 of the thickness of the base steel as described above. In this case, it can be confirmed that the content of carbon at the depth at which the content of Sb shows the maximum value exhibits a content of carbon of 80% or less of the nominal carbon content (C_0).

[0149] The part according to an exemplary embodiment in the present disclosure may have an R value defined in the following Relational Expression 1 of 1.5 or more and a B value defined in the following Relational Expression 2 of 0.01 or more.

[0150] The part according to an exemplary embodiment in the present disclosure may have an R value defined in the following Relational Expression 1 of 1.50 or more and a B value defined in the following Relational Expression 2 of 0.010 or more.

[0151]

[Relational Expression 1]
$$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2]
$$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(In the expressions, Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel and a point at which Sb_{max} is measured, and a unit thereof is μm.)

[0152] When the plating steel sheet is heated for hot press forming, an Sb enrichment degree in the Sb-enriched layer may be more increased. During the heat treatment for hot press forming, the Sb-enriched layer serves to effectively block penetration of diffusible hydrogen, and the bendability may be increased by reducing diffusible hydrogen since diffusible hydrogen accelerates the occurrence of grain boundary cracks when stress occurs. That is, when the relational expressions are not satisfied, and specifically, when the R value defined in Relational Expression 1 is less than 1.5 or the B value defined in Relational Expression 2 is less than 0.01, during hot press forming, the penetration of diffusible hydrogen is not sufficiently blocked, and thus, the impact resistance may be deteriorated. In an exemplary embodiment in the present disclosure, the R value defined in Relational Expression 1 may be 1.7 or more. In addition, in an exemplary embodiment in the present disclosure, the B value defined in Relational Expression 2 may be 0.014 or more. However, when the R value and the B value are excessively high, the hardness of the surface layer of the part may increase excessively, which may cause deterioration of the bendability, and therefore, in an exemplary embodiment in the present disclosure, an upper limit of the R value may be limited to 6.4. In addition, as an exemplary embodiment in the present disclosure, an upper limit of the B value may be limited to 0.5.

[0153] In an exemplary embodiment in the present disclosure, the R value defined in Relational Expression 1 may be 1.70 or more. In addition, in an exemplary embodiment in the present disclosure, the B value defined in Relational Expression 2 may be 0.0140 or more. In an exemplary embodiment in the present disclosure, the upper limit of the R value may be limited to 6.40. In addition, as an exemplary embodiment in the present disclosure, an upper limit of the B value may be limited to 0.50.

[0154] In the part according to an exemplary embodiment in the present disclosure, a softening rate (β) in a region from the interface between the base steel and the plating layer to a depth of 45 to 100 μm in the thickness direction may be 2 to 7%.

[0155] The region from the interface between the base steel and the plating layer to the depth of 45 to 100 μm in the thickness direction may affect the hardness of the surface layer part of the part, and may affect the bendability.

[0156] When the softening rate in a region to a depth of 45 to 100 μm in the thickness direction is less than 2%, the hardness of the surface layer part increases excessively, and thus, the effect of improving bendability may be reduced. On the other hand, when the softening rate exceeds 7%, the hardness of the surface layer part decreases excessively, and thus, the fatigue resistance may be deteriorated.

[0157] In the present disclosure, the hardness softening rate may be measured as illustrated in FIG. 6. FIG. 6 schematically illustrates a hardness softening rate (β) profile at a depth of 45 to 100 μm in the thickness direction from the interface in the part according to an exemplary embodiment in the present disclosure. Specifically, a Vickers hardness is measured and the hardness is measured by applying a weight of 1 kg. The hardness inside the base steel is set as a reference hardness (H_O), and the reference hardness (H_O) may be measured at a point of 1/5 of the thickness of the base steel. In FIG. 6, the Y-axis represents a ratio (%) of a hardness value (H) at the corresponding position to the reference hardness value (H_O), and the X-axis represents a distance (μm) from the interface in the thickness direction. As illustrated in FIG. 6, a square is drawn with 0 to 100% as the Y-axis range and a depth of 45 to 100 μm from the interface as the X-axis range. A hardness profile curve indicating a ratio of hardness values according to the depth from the interface in the square may be indicated, and a ratio of an area of an upper region in the square of the hardness profile to the entire area of the square may be defined as the hardness softening rate (β, %). Since an indentation or influence range of the Vickers hardness obtained by applying 1 kg within a range of 45 μm from the interface may be exposed to the plating layer and the outside, which makes it difficult to obtain an accurate hardness value, in the present disclosure, a hardness profile is created at a depth of 45 to 100 μm and used for the hardness softening rate (β).

[0158] In other words, the hardness softening rate (β) of the present disclosure means a ratio (%) of the area above the hardness profile curve to the entire area of the square in the square in which a horizontal axis represents the distance (μm) from the interface between the base steel sheet and the plating layer in the thickness (depth) direction, and a vertical axis represents the ratio (%) of the hardness value (H) at the corresponding position to the reference hardness (H_O).

[0159] In the part according to an exemplary embodiment in the present disclosure, a softening rate (β) in a region from an interface between the base steel and the plating layer to a depth of 45.0 to 100.0 μm in the thickness direction may be 2.0 to 7.0%.

[0160] According to an exemplary embodiment in the present disclosure, in the part, a region from the interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction may have a microstructure containing less than 5 area% of ferrite.

[0161] The ferrite in the region from the interface between the base steel and the plating layer to the depth of 50 μm in the thickness direction may cause propagation of cracks. That is, in a case where the ferrite is 5% or more in the corresponding region, when stress occurs in the surface layer part, the stress is locally concentrated on the relatively soft ferrite, and the propagation of cracks is accelerated, which may cause deterioration of the bendability and the fatigue resistance.

[0162] The part according to an exemplary embodiment in the present disclosure may have a microstructure containing martensite as a main phase in a region from the interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction, less than 5 area% of ferrite, and a balance of upper and lower bainite. In the present disclosure, a phase having an area fraction of 50% or more of the total microstructure fraction may be regarded as the main phase.

[0163] When the fraction of martensite is insufficient, the physical properties desired in the present disclosure may be insufficient.

[0164] According to an exemplary embodiment in the present disclosure, in the part, a region from the interface between the base steel and the plating layer to a depth of 50.0 μm in the thickness direction may have a microstructure containing less than 5.0 area% of ferrite.

[0165] The part according to an exemplary embodiment in the present disclosure may have a microstructure containing martensite as a main phase in a region from the interface between the base steel and the plating layer to a depth of 50.0 μm in the thickness direction, less than 5.0 area% of ferrite, and a balance of upper and lower bainite. In the present disclosure, a phase having an area fraction of 50.0% or more of the total microstructure fraction may be regarded as the main phase.

[0166] Hereinafter, a manufacturing method of a plated steel sheet of the present disclosure will be described in detail.

[0167] The plated steel sheet according to an aspect of the present disclosure may be manufactured by annealing and plating a cold-rolled steel sheet satisfying the alloy composition described above. Here, the cold-rolled steel sheet may be manufactured by reheating, hot rolling, coiling, cooling, and cold rolling a steel slab satisfying the alloy composition described above.

Reheating

[0168] A steel slab satisfying an alloy composition according to an exemplary embodiment in the present disclosure may be reheated to a temperature range of 1,050 to 1,300°C.

[0169] When the reheating temperature is lower than 1,050°C, a slab structure is not sufficiently homogenized, and thus, when precipitated elements are used, it is difficult to solid-dissolve these elements again. On the other hand, when the temperature exceeds 1,300°C, an oxide layer is excessively formed, which may cause an increase in manufacturing costs for removing the oxide layer and the occurrence of surface defects occurring after hot rolling.

Hot rolling

[0170] The reheated steel slab may be finish rolled in a temperature range of 800 to 950°C.

[0171] When the finish rolling temperature is lower than 800°C, two-phase region rolling is performed, and ferrite is introduced into the surface layer part of the steel sheet, which may make it difficult to control a sheet shape. On the other hand, when the temperature exceeds 950°C, coarsening of grains may occur.

Coiling and cooling

[0172] The rolled steel may be coiled and cooled in a temperature range of 500 to 700°C.

[0173] When the coiling temperature is lower than 500°C, during coiling, tension increases excessively, resulting in the occurrence of poor width shape of the hot-rolled coil and the occurrence of equipment problems. On the other hand, when the temperature exceeds 700°C, coarse carbides are excessively formed, and when stress is generated in the hot press formed part, the occurrence of cracks is accelerated, which may cause deterioration of the impact resistance.

Cold rolling

[0174] A cold-rolled steel sheet may be manufactured by cold rolling the cooled steel at a reduction ratio of 30 to 80%.

[0175] In the present disclosure, the reduction ratio is not particularly limited, and cold rolling may be performed at a reduction ratio of 30 to 80% to obtain a predetermined target thickness.

Annealing

[0176] The cold-rolled steel sheet may be annealed in a temperature range of Ac_1 to Ac_3.

[0177] When the annealing temperature is lower than Ac_1, the recrystallization of the cold-rolled structure may not be sufficiently completed, causing a poor sheet shape, and antimony may not be sufficiently enriched, which may make it difficult to sufficiently exert the effects of the present disclosure in the final part. On the other hand, when the temperature exceeds Ac_3, equipment problems may occur in an annealing furnace, and defects may occur on the surface due to the acceleration of surface oxide formation. According to an exemplary embodiment in the present disclosure, a lower limit of the annealing temperature may be 750°C. In addition, in another exemplary embodiment in the present disclosure, an upper limit of the annealing temperature may be limited to 860°C.

[0178] During the annealing, a product of an annealing time and an absolute humidity may be 10,000 to 80,000 $s \cdot g/m^3$.

[0179] During the annealing, the atmosphere and humidity may be controlled by using hydrogen gas, hydrogen-nitrogen mixed gas, and the like to form an oxidizing atmosphere, and it is important to control the annealing time and the absolute humidity in the temperature range of Ac_1 to Ac_3 to obtain an appropriate decarburization rate of the steel sheet.

[0180] Therefore, during the annealing, the product of the annealing time and the absolute humidity may be 10,000 to 80,000 $s \cdot g/m^3$.

[0181] When the product of the annealing time and the absolute humidity is less than 10,000 $s \cdot g/m^3$, the decarburization reaction due to internal oxidation does not occur sufficiently, which makes it difficult to obtain the desired decarburization rate, and the effect of improving impact resistance cannot be expected due to excessive carbon enrichment in the part. On the other hand, when the value exceeds 80,000 $s \cdot g/m^3$, surface oxides may be generated due to excessive oxidation of the steel sheet surface, which may cause surface defects during plating. According to an exemplary embodiment in the present disclosure, the annealing time may be 100 to 200 seconds. In addition, according to an exemplary embodiment in the present disclosure, the absolute humidity may be 100 to 400 g/m^3.

[0182] In addition, based on a surface temperature of the steel sheet, an average temperature increase rate from room temperature to 500°C may be controlled to 2.7 to 10.0°C/s, an average temperature increase rate in a section of 500 to 700°C may be controlled to 0.5 to 2.5°C/s, and an average temperature increase rate from 700°C to the annealing temperature may be controlled to 0.01 to 0.4°C/s.

[0183] Based on the surface temperature of the steel sheet, the average temperature increase rate from room temperature to 500°C is limited to 2.7 to 10.0°C/s to secure an Sb-enriched layer. When the average temperature increase rate from room temperature to 500°C is outside of the range of 2.7 to 10.0°C/s, specifically, when the average temperature increase rate is less than 2.7°C/s, an enriched layer is not sufficiently formed, and when the average temperature increase rate exceeds 10°C/s, temperature unevenness in a width direction of the steel sheet increases due to rapid heating, which may cause differences in structure and line trouble. In the section where the surface temperature of the steel sheet is 500 to 700°C, the Sb enrichment of the base steel may be affected. That is, when the average temperature increase rate in the corresponding section is outside of the range of 0.5 to 2.5°C/s, the Sb-enriched layer may not be sufficiently formed. The temperature of the surface of the steel sheet from 700°C to the desired annealing temperature is a temperature at which an Sb-enriched layer is sufficiently formed in the base steel, and it is preferable that the average temperature increase rate is 0.01 to 0.4°C/s in order to prevent defects of the Sb-enriched layer satisfying Relational Expressions 1 and 2 and the surface part of the steel sheet.

Plating

[0184] The annealed cold-rolled steel sheet may be plated.

[0185] A plating bath according to an aspect of the present disclosure may be formed of aluminum or an aluminum-based alloy.

[0186] According to one an exemplary embodiment in the present disclosure, the composition of the plating bath may contain, in addition to Al, Si, Mg, and Fe, and may contain Mn, Cr, Cu, Mo, Ni, Sb, Sn, Ti, Ca, Sr, Zn, and the like in some cases. In the plating, a coating amount is not particularly limited, and may be a coating amount in a general range.

[0187] As an exemplary embodiment in the present disclosure, the composition of the plating bath may contain, by wt%, one or two or more selected from 5 to 11% of Si, 5% or less of Fe, and 5% or less of Mg, and may contain a balance of Al and other impurities.

[0188] According to an exemplary embodiment in the present disclosure, an alloying process may be included after plating, and the alloying process is not particularly limited and may be performed under general conditions.

[0189] Hereinafter, a manufacturing method of a part of the present disclosure will be described in detail.

[0190] The part according to an aspect of the present disclosure may be manufactured by manufacturing a blank using a plated steel sheet to be manufactured by the method described, and heating, maintaining, forming, and cooling the blank.

Blank manufacturing

[0191] A blank for hot press forming may be manufactured using the plated steel sheet suggested in the present disclosure.

Heating and maintaining

[0192] The manufactured blank may be heated to a temperature range of Ac_3 to 975°C and maintained for 10 to 1,000 seconds.

[0193] When the blank heating temperature is lower than Ac_3, due to the presence of untransformed ferrite according to a two-phase region, it may be difficult to secure the strength and the impact resistance. On the other hand, when the heating temperature exceeds 975°C, excessive oxides are formed on the surface of the part, such that it is difficult to secure spot weldability, and manufacturing costs for maintaining a high temperature may increase. Thereafter, it is preferable that the heated blank has a heat treatment residence time of 10 to 1,000 seconds in the above temperature range. When the maintenance time is shorter than 10 seconds, it is difficult to uniformly distribute the temperature throughout the blank, which may cause a material variation for each position. On the other hand, when the maintenance time is longer than 1,000 seconds, as in the case when the heating temperature is exceeded, excessive oxide formation and excessive growth of an inter diffusion layer on the surface of the part may occur, which may make it difficult to secure spot weldability and cause an increase in manufacturing costs of the part.

Forming and cooling

[0194] The heated blank may be formed and cooled.

[0195] The heated blank may be transferred to a press, and hot press forming and die quenching may be performed at a cooling rate of 20°C/s or more, thereby manufacturing a final part. At a cooling rate that is less than 20°C/s, a ferrite phase may be introduced during cooling and formed at grain boundaries, which may cause deterioration of the strength and the impact resistance. According to an exemplary embodiment in the present disclosure, after forming the blank, the blank may be cooled at 25°C/s or more.

[0196] The plated steel sheet of the present disclosure manufactured as described above may maintain the hardness of the surface layer at a certain level or lower, and may maintain a blade lifespan at a certain level or lower when shearing is performed to manufacture a blank for hot press forming, thereby having the effect of reducing the costs consumed.

[0197] The part of the present disclosure manufactured as described above may have excellent fatigue resistance and bendability with a product of a tensile strength and a bending angle of 80,000 MPa·° or more and the amount of diffusible hydrogen of 0.2 ppm or less.

[0198] In the present disclosure, tensile strength (TS)*bending angle (BA) is used as an index to measure the impact resistance. The bending angle, which is an index of the impact resistance, is affected by the tensile strength and has an inversely proportional tendency. Therefore, as the value of the product of the tensile strength and the bending angle (TS*BA) increases, the impact resistance increases. The BA value may be measured through a bendability evaluation according to the VDA238-100 standard and is expressed as a bending outer angle converted from a maximum bending strength.

Mode for Invention

[0199] Hereinafter, the present disclosure will be described in more detail with reference to Examples. However, the following Examples are provided to illustrate and describe the present disclosure in detail, but are not intended to limit the scope of the present disclosure.

(Examples)

[0200] Slabs containing Sb in the contents disclosed in Table 1 and having a composition of 0.22C-0.25Si-1.25Mn-0.2Cr-0.03Al-0.03Ti-0.0025B and a thickness of 40 mm were manufactured by vacuum dissolving. The slabs were heated to 1,200°C and maintained for 1 hour, the heated slabs were hot-rolled at a hot rolling end temperature of 900°C, and then the hot-rolled slabs were coiled at a temperature of 600°C. Thereafter, a pickling process was performed, and cold rolling was performed at a reduction ratio of 30 to 80%, thereby manufacturing cold-rolled steel sheets. The cold-rolled steel sheets were annealed at a temperature of Ac_1 to Ac_3, an annealing time (s) and an absolute humidity (g/m^3) were controlled, and values of a product of the annealing time and the absolute humidity were shown in Table 1. After annealing, plating was performed by immersing the steel sheets in a plating bath formed of Al-9%Si-2%Fe and trace impurities.

[Table 1]

Specimen Nos.	Composition	Annealing			
	Sb (wt%)	Annealing time ·absolute humidity (s ·g/m^3)	Steel sheet surface average temperature increase rate (°C/s)		
			Room temperature to 500°C	500 to 700°C	700°C to annealing temperature
1	0.072	10,654	2.9	2.0	0.03
2	0.045	22,347	6.7	1.6	0.10
3	0.036	40,451	4.5	1.0	0.16
4	0.015	58,363	9. 4	1.1	0.08
5	0.072	50,667	7.9	0.6	0.32
6	0.015	11,210	2.8	2.4	0.18
7	0.061	9,518	3.0	1.9	0.21
8	0.030	9,357	4.5	2.0	0.10
9	0.003	35,940	10.6	3.0	0.43
10	0.002	5,560	2.4	1.8	0.008

(continued)

Specimen Nos.	Composition	Annealing			
	Sb (wt%)	Annealing time ·absolute humidity (s ·g/m^3)	Steel sheet surface average temperature increase rate (°C/s)		
			Room temperature to 500°C	500 to 700°C	700°C to annealing temperature
11	0.090	85,410	3.0	0.7	0.22
12	0.020	90,250	2.1	0.3	0.009

[0201] Table 2 shows the results of measuring an Sb-enriched layer, a microstructure, and a decarburization rate of each of the manufactured plated steel sheets. First, an area fraction of pearlite was measured by observing the structure directly under an interface using scanning electron microscopy (SEM). At this time, in all the specimens, the residual fraction excluding the area fraction of pearlite was observed as ferrite. In addition, in order to measure a carbon decarburization rate in a region from the interface to a depth of 30 μm in a thickness direction of a base steel sheet, GDS850A (model name, manufactured by LECO Corporation) and DC and RF devices were used, and the depth according to the decarburization rate (α) and the ratio of the content of carbon through the carbon profile obtained through the devices was shown in Table 2. Using a glow discharge spectrometer (GDS), the values of Relational Expressions 1 and 2 and the content of carbon at the depth at which the content of antimony showed the maximum value (Sb_{max}) were measured and shown. In addition, the presence or absence of non-plated areas was indicated by visually observing the plated steel sheet, and a case in which the number of non-plated areas with an average diameter satisfying 1 mm or more exceeded 2 area/m^2 was marked as O, and a case where the of non-plated areas with an average diameter satisfying 1 mm or more was less than 2 area/m^2 was marked as X.

[Table 2]

Specimen Nos.	Sb-enriched layer			Microstructure	Decarburization rate	Carbonnominal carbon		Presence or absence of non-plating (O,X)	Classification
	Relationa 1 Expression 1	Relationa 1 Expression 2	Content of carbon (C) at depth at which content of antimon y (Sb) shows maximum value (Sb_{max}) (wt%)	Pearlite fraction in 10 μm from interface (area%)	Decarburization rate in region from interface to 30 μm (α, %)	Point at which ratio of conten t of carbon (C) to nomina l carbon conten t (C_0) is 50% (μm)	Point at which ratio of conten t of carbon (C) to nomina l carbon conten t (C_0) is 80% (μm)		
1	4.10	0.102	68.8	4.3	14.66	1.8	6.4	X	Inventive Example 1
2	3.03	0.065	48.9	3.4	18.77	2.8	9.3	X	Inventive Example 2
3	2.60	0.053	31.4	2.9	24.95	3.9	11.1	X	Inventive Example 3
4	1.66	0.025	20.8	1.3	34.80	4.7	13.0	X	Inventive Example 4
5	3.97	0.097	47.2	2.8	17.08	2.8	8.4	X	Inventive Example 5
6	1.72	0.030	11.8	3.1	29.67	5.9	14.7	X	Inventive Example 6
7	3.59	0.088	76.3	5.1	11.34	1.1	4.3	X	Comparative Example 1
8	2.30	0.049	75.5	5.3	13.15	1.2	4.5	X	Comparative Example 2
9	1.10	0.007	9.7	0.4	54.15	7.1	24.1	X	Comparative Example 3
10	1.08	0.005	72.8	1.6	10.78	1.4	4.8	X	Comparative Example 4
11	5.01	0.127	9.8	1.2	25.71	6.1	15.9	O	Comparative Example 5
12	1.94	0.030	8.9	0.9	39.07	6.8	16.8	O	Comparative Example 6

[Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(In the expressions, Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel sheet and a point at which Sb_{max} is measured, and a unit thereof is μm.)

[0202] A part was manufactured by hot press forming using a plated steel sheet in which a non-plated area was not observed. A heat treatment temperature and time for hot press forming were 900°C and 360 seconds, and a transfer time from a heat treatment furnace to a forming press was set to 10 seconds.

[0203] Table 3 shows the structure and properties of the parts manufactured through the hot press forming were measured by the same method as described above. A Vickers hardness was measured by applying a load of 1.0 kg in a region from the interface between the plating layer and the base steel of the part to a depth of 45 to 100 μm, and a hardness softening rate (β) was shown using FIG. 6 and the method described above. In addition, the amount of diffusible hydrogen was measured using a thermal desorption analysis (TDA) equipment (Bruker G8, model name). Specifically, the temperature was increased to 400°C at 20°C/min and maintained for a certain time so that a diffusible hydrogen peak sufficiently appeared to measure a diffusible hydrogen curve, and the curve was integrated to obtain the amount of diffusible hydrogen in the steel.

[0204] In addition, a ferrite area fraction in a range from the interface between the base steel and the plating layer to a depth of 30 μm was measured using optical microscopy and was shown in Table 3. At this time, in all the specimens, the residual fraction excluding the ferrite area fraction was observed as martensite. In addition, the fatigue limit strength was measured by repeatedly performing a fatigue test 10,000,000 times or more by applying the JIS Z2275 standard, a case in which the value of the fatigue limit strength obtained by dividing the fatigue limit strength by the tensile strength was 0.25 or more was marked as O, and a case in which the value of the fatigue limit strength was less than 0.025 was marked as X. The impact resistance was expressed as the product of the tensile strength and the bending angle, and the tensile strength value was measured through a tensile test at room temperature using a JIS-5 specimen according to the ISO6892 standard. In addition, the bending angle was expressed as the bending outer angle converted from the maximum bending strength specified in the standard according to the bendability evaluation method of the VDA238-100 standard.

[Table 3]

Specimen Nos.	Sb-enriched layer			Microstructure	Softenin g rate	Physical properties			Classification
	Relational Expression 1	Relational Expression 2	Content of carbon (C) at depth at which content of antimon y (Sb) shows maximum value (Sb_{max}) (wt%)	Ferrite fraction in 50 µm from interface (area%)	Softenin g rate in region from interfac e to 45 to 100 µm (β, %)	Product of tensile strength and bending angle (MP · °)	Fatigue resistance (O,X)	Amount of diffusible hydrogen (ppm)	
1	5.89	0.3967	76.9	0.2	2.07	80,134	O	0.049	Inventive Example 1
2	4.09	0.1557	58.7	0.5	2.67	81,517	O	0.077	Inventive Example 2
3	3.30	0.0834	40.3	0.9	4.01	82,941	O	0.098	Inventive Example 3
4	1.86	0.0147	24.5	1.9	6.88	83,057	O	0.130	Inventive Example 4
5	5.70	0.3706	53.9	0.5	2.65	80,876	O	0.069	Inventive Example 5
6	1.95	0.0197	16.2	1.3	6.07	82,167	O	0.107	Inventive Example 6
7	4.67	0.2977	90.2	0.1	0.65	74,179	O	0.060	Comparative Example 1
8	2.70	0.1407	87.7	0.5	0.85	77,079	O	0.106	Comparative Example 2
9	1.15	0.0057	13.2	7.3	15.70	83,510	X	0.407	Comparative Example 3
10	1.10	0.0030	30.6	1.8	1.75	75,483	O	0.305	Comparative Example 4
11	Hot press forming is not performed due to non-plating								Comparative Example 5
12	Hot press forming is not performed due to non-plating								Comparative Example 6

[Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

(In the expressions, Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel and a point at which Sb_{max} is measured, and a unit thereof is μm.)

[0205] As shown in Tables 2 and 3, in the cases of Inventive Examples 1 to 6 satisfying the alloy composition and manufacturing conditions of the present disclosure, the features suggested in the present disclosure were satisfied, and the physical properties desired in the present disclosure were also secured.

[0206] In the cases of Comparative Examples 1 and 2 in which the product of the annealing time and the absolute humidity during annealing was less than the range suggested in the present disclosure, the decarburization rate of the plated steel sheet was outside the suggested range. Accordingly, the hardness softening rate of the part was lowered, and the impact resistance was deteriorated due to the excessive carbon enrichment in the surface layer part.

[0207] In Comparative Example 3, since the content of Sb was outside of the range of the present disclosure and the formation of the Sb-enriched layer was thus insufficient, excessive internal oxidation occurred during annealing, causing excessive softening of the hardness in the part after the heat treatment, and a large amount of ferrite was formed in the surface layer part, causing deterioration of the fatigue resistance.

[0208] FIG. 7 illustrates a carbon profile in the plated steel sheet according to an exemplary embodiment in the present disclosure. In Inventive Examples 1 and 3 in FIG. 7, it was confirmed that the decarburization control suggested in the present disclosure was sufficiently achieved, and as a result, the product of the tensile strength and the bending angle and the fatigue resistance at certain levels or higher were secured. On the other hand, it was confirmed that, in Comparative Example 1, the decarburization was not sufficiently achieved according to the depth, and in Comparative Example 3, excessive decarburization occurred due to insufficient formation of the Sb-enriched layer, and thus, the physical properties were deteriorated.

[0209] FIG. 8 illustrates photographs of the structures directly under the interfaces in the plated steel sheets of Inventive Example 3 and Comparative Example 3 according to an exemplary embodiment in the present disclosure observed with SEM. It was confirmed that, in Inventive Example 3, 2.9% of pearlite was observed, and in Comparative Example 3, less than 1% of pearlite was observed.

[0210] FIG. 9 illustrates optical photographs of the interfaces between the plating layers and the base steels in the parts of Inventive Example 3 and Comparative Example 3 of the present disclosure. In Inventive Example 3, less than 1% of ferrite was observed, but in Comparative Example 3, ferrite was 7.3%, and thus, the fatigue resistance desired in the present disclosure was not secured.

[0211] In Comparative Example 4, the content of Sb in the steel and the product of the annealing time and the absolute humidity were outside of the ranges suggested in the present disclosure, and the bendability was deteriorated because the amount of diffusible hydrogen in the part was excessive, and thus, the value of the product of the tensile strength and the bending angle, which is an index of impact resistance, did not reach the desired level.

[0212] In Comparative Examples 5 and 6, during annealing, the product of the annealing time and the absolute humidity exceeded the range of the present disclosure, and oxidation of the surface layer part became severe during annealing; thus, Fe oxides were formed on the surface layer. As a result, plating adhesion was deteriorated, and non-plating occurred.

[0213] Hereinabove, the present disclosure has been described in detail with reference to the exemplary embodiments, but other exemplary embodiments having different forms are possible. Therefore, the technical spirit and scope of the claims set forth below are not limited by the exemplary embodiments.

[Description of Reference Characters]

[0214]

1: Plating layer
2: Sb-enriched layer
21: In Sb-enriched layer, Sb content increasing section in X-axis (+) direction
22: In Sb-enriched layer, Sb content decreasing section in X-axis (+) direction
3: Base steel sheet excluding Sb-enriched layer

10: Sb average content line of plating layer
11: Final contact point of Sb average content line of plating layer and Sb content line by GDS in X-axis (+) direction
30: Sb average content line of base steel sheet
31: Initial contact point of Sb average content line of base steel sheet and Sb content line by GDS in X-axis (+) direction
100: Sb content line by GDS
200: Point at which Sb content is maximum value in Sb-enriched layer

Claims

1. A plated steel sheet comprising: a base steel sheet containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony; and a plating layer formed on a surface of the base steel sheet,

   wherein the base steel sheet includes an antimony (Sb)-enriched layer therein, and
   when contents of elements are analyzed in a thickness direction of the base steel sheet using a glow discharge spectrometer, a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) is 10 to 70% of a nominal carbon content (C_0) of the base steel sheet.

2. The plated steel sheet of claim 1, wherein a decarburization rate (α) of carbon (C) in a region from an interface between the base steel sheet and the plating layer to a depth of 30 μm in the thickness direction is 14 to 35%.

3. The plated steel sheet of claim 1 or 2, wherein in the plated steel sheet, a point at which a content of carbon (C) is 50% of the nominal carbon content (C_0) exists at a depth of more than 1.5 μm and less than 6 μm from an interface between the base steel sheet and the plating layer in the thickness direction.

4. The plated steel sheet of any one of claims 1 to 3, wherein in the plated steel sheet, a point at which a content of carbon (C) is 80% of the nominal carbon content (C_0) exists at a depth of more than 6 μm and less than 15 μm from an interface between the base steel sheet and the plating layer in the thickness direction.

5. The plated steel sheet of any one of claims 1 to 4, wherein the plated steel sheet has an R value defined in the following Relational Expression 1 of 1.2 or more, and

   a B value defined in the following Relational Expression 2 of 0.008 or more:

   [Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

   [Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

   wherein Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface between the plating layer and the base steel sheet and a point at which Sb_{max} is measured, and a unit thereof is μm.

6. The plated steel sheet of any one of claims 1 to 5, wherein a region from an interface between the base steel sheet and the plating layer to a depth of 10 μm in the thickness direction has a microstructure containing ferrite as a main phase and 1 area% or more of pearlite.

7. The plated steel sheet of any one of claims 1 to 6, wherein the base steel sheet contains 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

8. The plated steel sheet of any one of claims 1 to 7, wherein the plating layer is formed of aluminum or an aluminum alloy.

9. A part comprising: a base steel containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony; and a plating layer formed on a surface of the base steel,

wherein the base steel includes an antimony (Sb)-enriched layer therein, and
when contents of elements are analyzed in a thickness direction of the base steel using a glow discharge spectrometer, a content of carbon (C) at a depth at which a content of antimony (Sb) in the antimony (Sb)-enriched layer exhibits a maximum value (Sb_{max}) is 80% or less of a nominal carbon content (C_0) of the base steel.

10. The part of claim 9, wherein in the part, the content of carbon (C) at the depth at which the content of antimony (Sb) shows the maximum value (Sb_{max}) is 15 to 80% of the nominal carbon content (C_0) of the base steel.

11. The part of claim 9 or 10, wherein the part has an R value defined in the following Relational Expression 1 of 1.5 or more, and

a B value defined in the following Relational Expression 2 of 0.01 or more:

[Relational Expression 1] $$R = \frac{sb_{max}}{sb_{coat}}$$

[Relational Expression 2] $$B = \frac{(sb_{max} - sb_{coat})}{2} \times \Delta t$$

wherein Sb_{max} represents a maximum value of the content of Sb in the Sb-enriched layer, Sb_{coat} represents an average Sb content in the plating layer, and units thereof are wt%, and Δt represents a straight distance between an interface where the plating layer and the base steel are in contact with each other and a point at which Sb_{max} is measured, and a unit thereof is μm.

12. The part of any one of claims 9 to 11, wherein a softening rate (β) in a region from an interface between the base steel and the plating layer to a depth of 45 to 100 μm in the thickness direction is 2 to 7%.

13. The part of any one of claims 9 to 12, wherein a region from an interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction has a microstructure containing less than 5 area% of ferrite.

14. The part of any one of claims 9 to 13, wherein a region from an interface between the base steel and the plating layer to a depth of 50 μm in the thickness direction has a microstructure containing martensite as a main phase, less than 5 area% of ferrite, and a balance of upper and lower bainite.

15. The part of any one of claims 9 to 14, wherein the base steel contains 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

16. The part of any one of claims 9 to 15, wherein the plating layer is formed of aluminum or an aluminum alloy.

17. The part of any one of claims 9 to 16, wherein the part has a product of a tensile strength and a bending angle of 80,000 MPa·° or more.

18. The part of any one of claims 9 to 17, wherein the amount of diffusible hydrogen in the part is 0.2 ppm or less.

19. A manufacturing method of a plated steel sheet, comprising:

preparing a cold-rolled steel sheet containing, by wt%, 0.06 to 0.5% of carbon (C) and 0.01 to 0.1% of antimony;
annealing the cold-rolled steel sheet in a temperature range of Ac_1 to Ac_3; and

plating the annealed cold-rolled steel sheet,
wherein during the annealing, a product of an annealing time and an absolute humidity is 10,000 to 80,000 s·g/m^3, and
during the annealing, based on a surface temperature of the steel sheet, an average temperature increase rate from room temperature to 500°C is 2.7 to 10.0°C/s, an average temperature increase rate in a section of 500 to 700°C is 0.5 to 2.5°C/s, and an average temperature increase rate from 700°C to an annealing temperature is 0.01 to 0.4°C/s.

20. The manufacturing method of claim 19, wherein during the annealing, the annealing time is 100 to 200 seconds, and the absolute humidity is 100 to 400 g/m^3.

21. The manufacturing method of claim 19 or 20, wherein the cold-rolled steel sheet is manufactured by:

reheating a steel slab to a temperature range of 1,050 to 1,300°C;
finish rolling the reheated steel slab in a temperature range of 800 to 950°C;
coiling and cooling the rolled steel in a temperature range of 500 to 700°C; and
cold rolling the cooled steel at a reduction ratio of 30 to 80%.

22. The manufacturing method of any one of claims 19 to 21, wherein the steel slab contains 0.06 to 0.5% of carbon (C), 0.01 to 0.1% of antimony (Sb), 0.001 to 2% of silicon (Si), 0.1 to 4% of manganese (Mn), 1% or less of molybdenum (Mo), 0.05% or less of phosphorus (P), 0.02% or less of sulfur (S), 0.001 to 1% of aluminum (Al), 1% or less of chromium (Cr), 0.02% or less of nitrogen (N), 0.1% or less of titanium (Ti), 0.01% or less of boron (B), and a balance of iron (Fe) and impurities.

23. The manufacturing method of any one of claims 19 to 22, wherein during the plating, the plating is performed with aluminum or an aluminum alloy.

24. A manufacturing method of a part, comprising:

manufacturing a blank using any one of the plated steel sheets of claims 19 to 23;
heating the blank to a temperature range of Ac_3 to 975°C and maintaining the blank for 10 to 1,000 seconds; and
forming and cooling the heated blank.

25. The manufacturing method of claim 24, wherein during the cooling, the cooling is performed at a cooling rate of 20°C/s or more.

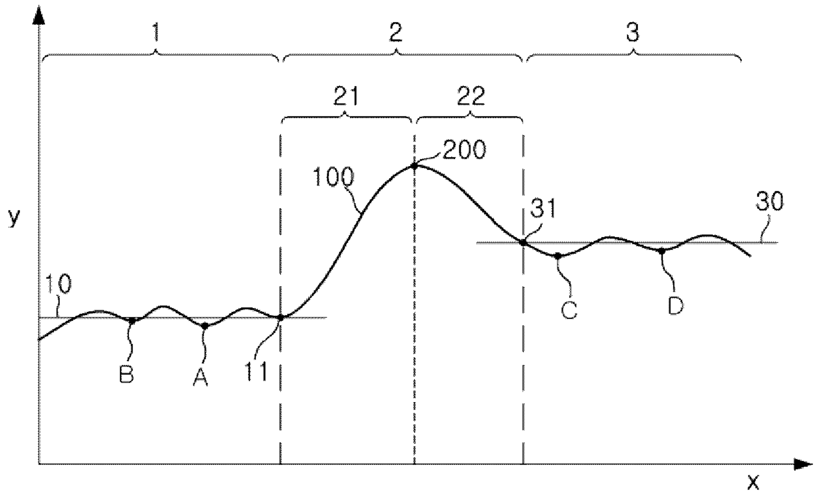


FIG. 1

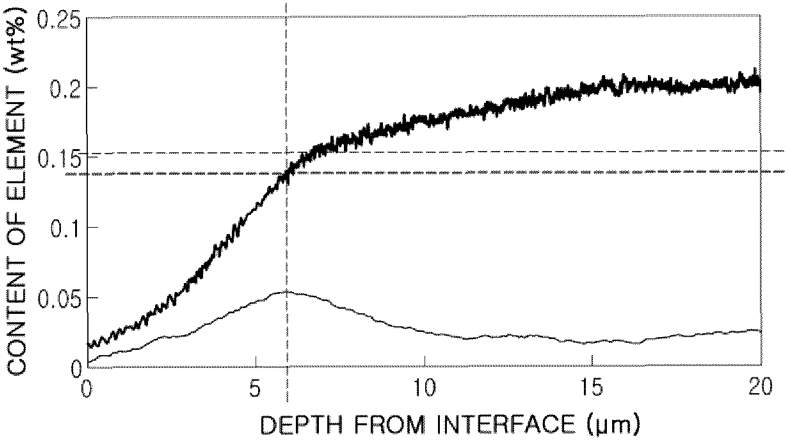

C
Sb
CONTENT OF ELEMENT (wt%)
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
DEPTH FROM INTERFACE (μm)

FIG. 2

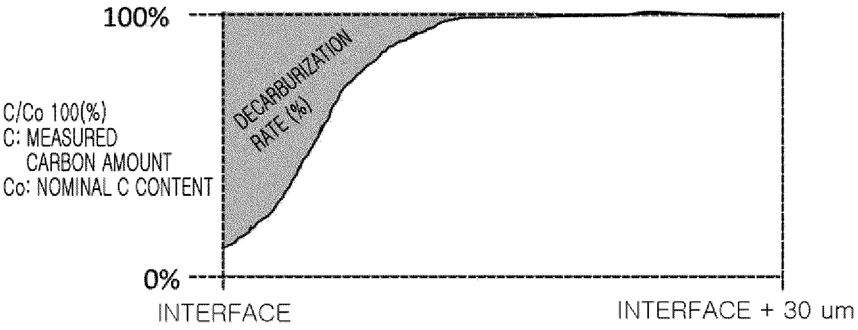

100%
C/Co 100(%)
C: MEASURED
CARBON AMOUNT
Co: NOMINAL C CONTENT
DECARBURIZATION
RATE (%)
0%
INTERFACE
INTERFACE + 30 um

FIG. 3

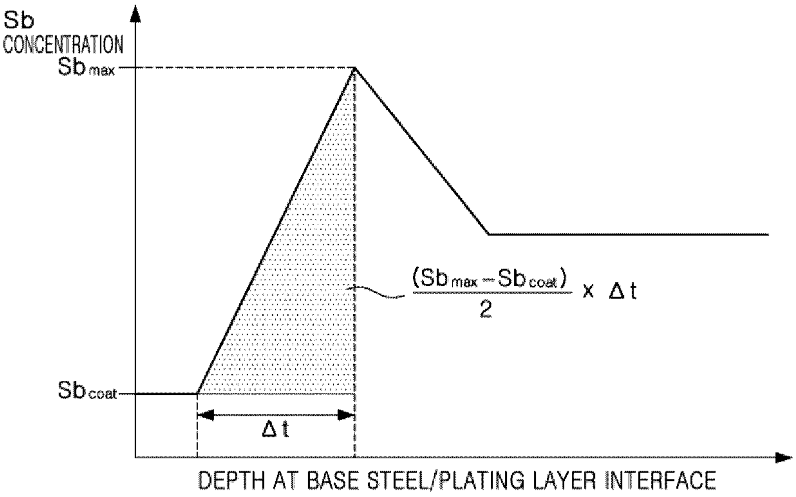

Sb
CONCENTRATION
Sb_{max}
Sb_{coat}
$\frac{(Sb_{max} - Sb_{coat})}{2} \times \Delta t$
Δt
DEPTH AT BASE STEEL/PLATING LAYER INTERFACE

FIG. 4

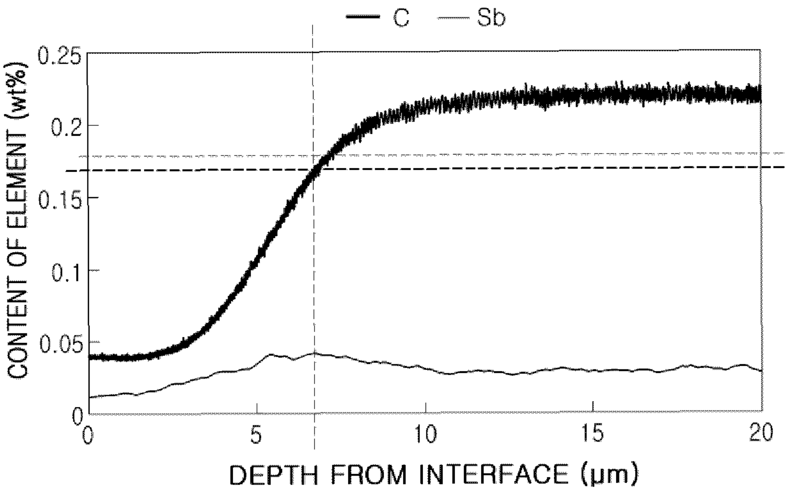

C
Sb
CONTENT OF ELEMENT (wt%)
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
DEPTH FROM INTERFACE (μm)

FIG. 5

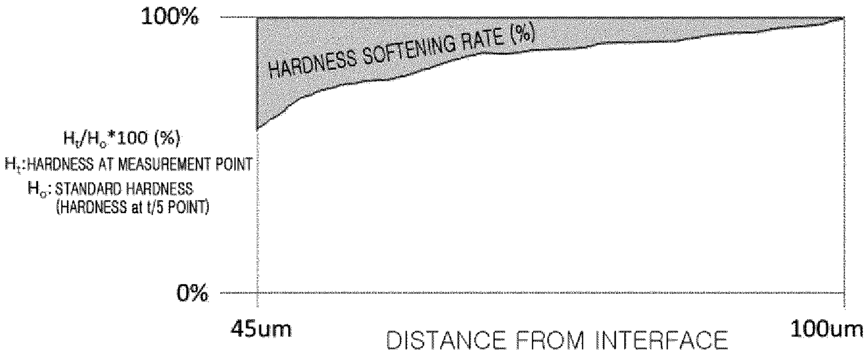

100%
HARDNESS SOFTENING RATE (%)
H_t/H_o*100 (%)
H_t:HARDNESS AT MEASUREMENT POINT
H_o: STANDARD HARDNESS
(HARDNESS at t/5 POINT)
0%
45um
DISTANCE FROM INTERFACE
100um

FIG. 6

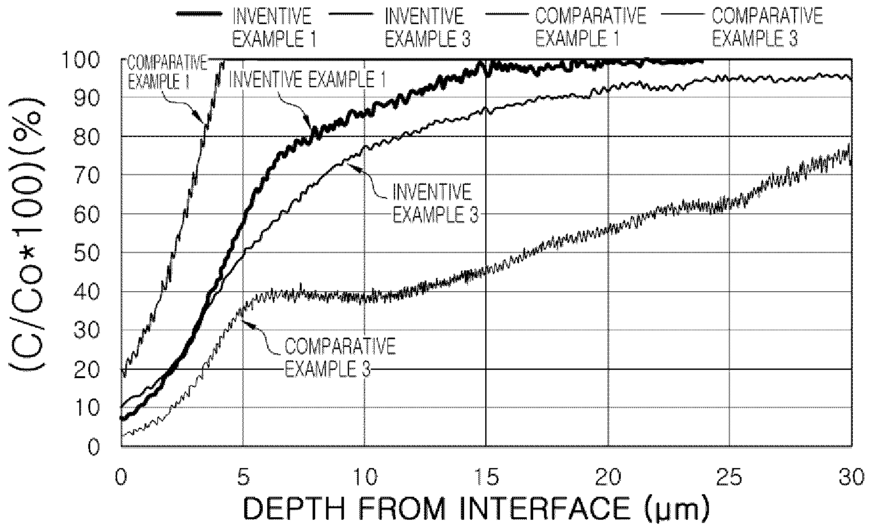
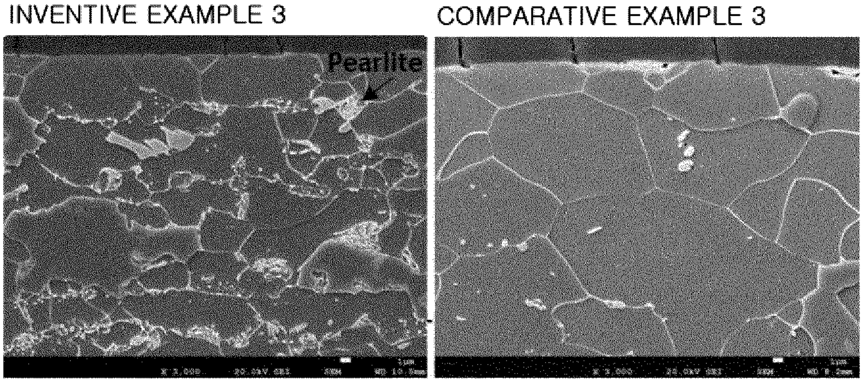

INVENTIVE EXAMPLE 1
INVENTIVE EXAMPLE 3
COMPARATIVE EXAMPLE 1
COMPARATIVE EXAMPLE 3
COMPARATIVE EXAMPLE 1
INVENTIVE EXAMPLE 1
INVENTIVE EXAMPLE 3
COMPARATIVE EXAMPLE 3
(C/Co*100)(%)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
DEPTH FROM INTERFACE (μm)

FIG. 7


INVENTIVE EXAMPLE 3

COMPARATIVE EXAMPLE 3

FIG. 8

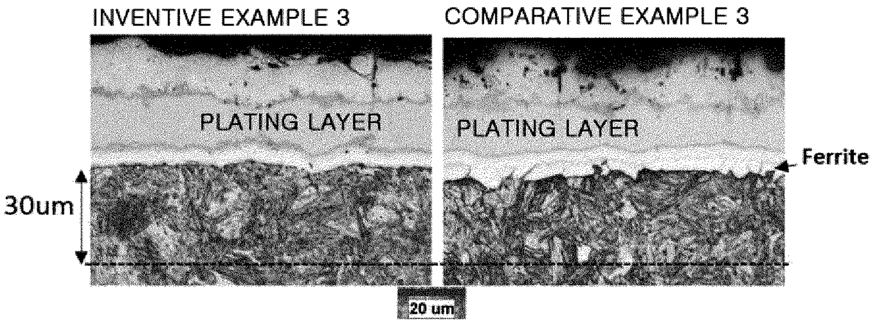

INVENTIVE EXAMPLE 3
COMPARATIVE EXAMPLE 3
PLATING LAYER
PLATING LAYER
Ferrite
30um
20 um

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2023/012157

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; **C22C 38/34**(2006.01)i; **C22C 38/22**(2006.01)i; **C22C 38/28**(2006.01)i; **C22C 38/00**(2006.01)i; **C21D 8/02**(2006.01)i; **B21C 47/02**(2006.01)i; **C21D 9/46**(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 38/38(2006.01); B21B 3/00(2006.01); B21C 47/02(2006.01); B21D 22/00(2006.01); C21D 8/02(2006.01); C21D 8/06(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C23C 2/02(2006.01); C23C 2/28(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: 내충돌성(impact resistance), 열간성형(hot press forming), 도금강판(plated steel sheet), 안티몬(Sb), 농화층(rich layer)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2022-0062962 A (POSCO CO., LTD.) 17 May 2022 (2022-05-17) See paragraphs [0081], [0156]-[0158] and [0162], claims 1, 10 and 17 and tables 1 and 2.	1-25
A	KR 10-1858868 B1 (POSCO) 16 May 2018 (2018-05-16) See paragraph [0132].	1-25
A	KR 10-2021-0098514 A (NIPPON STEEL CORPORATION) 10 August 2021 (2021-08-10) See paragraphs [0421] and [0434] and table 14.	1-25
A	JP 2004-250767 A (NIPPON STEEL CORP.) 09 September 2004 (2004-09-09) See paragraphs [0051] and [0053] and claim 1.	1-25
A	KR 10-2015-0074951 A (POSCO) 02 July 2015 (2015-07-02) See claims 5-6 and 10.	1-25

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

* Special categories of cited documents:
“A” document defining the general state of the art which is not considered to be of particular relevance
“D” document cited by the applicant in the international application
“E” earlier application or patent but published on or after the international filing date
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
“O” document referring to an oral disclosure, use, exhibition or other means
“P” document published prior to the international filing date but later than the priority date claimed
“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“&” document member of the same patent family

Date of the actual completion of the international search **13 November 2023**	Date of mailing of the international search report **14 November 2023**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2023/012157

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	KR 10-2023-0038389 A (POSCO CO., LTD.) 20 March 2023 (2023-03-20) See claims 1-25. This document is a published earlier application that serves as a basis for claiming priority of the present international application.	1-25

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2023/012157

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2022-0062962 A	17 May 2022	CN 116457490 A	18 July 2023
		EP 4242341 A1	13 September 2023
		JP 2023-536487 A	25 August 2023
		US 2023-0286030 A1	14 September 2023
		WO 2022-097965 A1	12 May 2022
KR 10-1858868 B1	16 May 2018	CN 110114500 A	09 August 2019
		CN 110114500 B	26 March 2021
		EP 3561142 A1	30 October 2019
		EP 3561142 B1	17 February 2021
		JP 2020-509203 A	26 March 2020
		JP 6931396 B2	01 September 2021
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		US 11274357 B2	15 March 2022
		US 11732323 B2	22 August 2023
		US 2020-0087747 A1	19 March 2020
		US 2021-0140006 A1	13 May 2021
		US 2022-0162720 A1	26 May 2022
		US 2023-0287535 A1	14 September 2023
		WO 2018-117543 A1	28 June 2018
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		CN 113195761 B	09 August 2022
		EP 3896184 A1	20 October 2021
		EP 3896184 A4	20 April 2022
		JP 6597939 B1	30 October 2019
		JP WO2020-121418 A1	15 February 2021
		MX 2021006649 A	15 July 2021
		US 2022-0127691 A1	28 April 2022
		WO 2020-121418 A1	18 June 2020
JP 2004-250767 A	09 September 2004	JP 4057930 B2	05 March 2008
KR 10-2015-0074951 A	02 July 2015	KR 10-1568522 B1	11 November 2015
KR 10-2023-0038389 A	20 March 2023	None	

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 6296805 B **[0005]**