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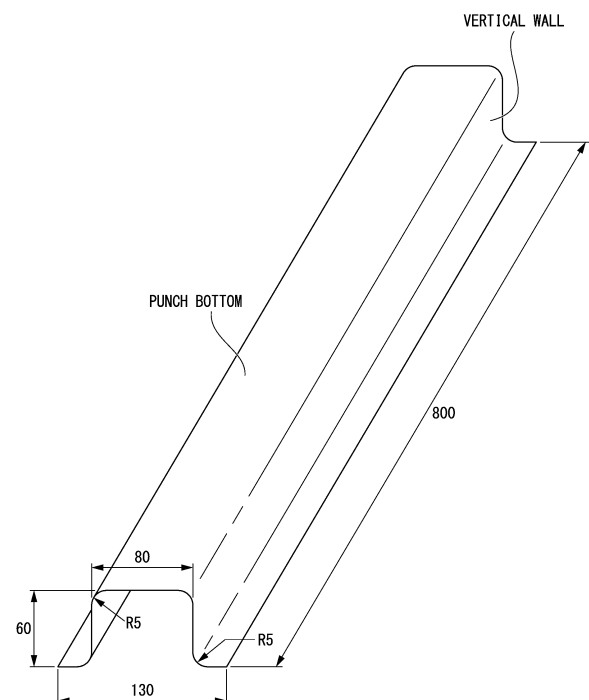
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(54) **HOT-STAMP FORMED ARTICLE**

(57) This hot-stamp formed body is a hot-stamp formed body comprising a steel sheet, in which the steel sheet has a predetermined chemical composition, an average B concentration in a region from a depth of 5.0 μm from a surface of the steel sheet to a depth of 25.0 μm from the surface is 0.700 times or less than a B concentration at a position of a depth of 100 μm from the surface, an average B concentration in a region from a depth of 0.5 μm from the surface to a depth of 4.0 μm from the surface is 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface, and an average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface is more than 0.0150 mass%.

FIG. 1



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Description

Technical Field of the Invention

5 **[0001]** The present invention relates to a hot-stamp formed body.

[0002] Priority is claimed on Japanese Patent Application No. 2022-067026, filed April 14, 2022, the content of which is incorporated herein by reference.

Background Art

10 **[0003]** In recent years, there has been a demand for a reduction in the weight of a vehicle body in terms of environmental protection and resource saving, and a high-strength steel sheet has been applied to vehicle members. When a high-strength steel sheet is applied, the desired strength can be imparted to vehicle bodies while reducing the thickness of the steel sheet and reducing the weight of the vehicle bodies. Vehicle members are manufactured by press forming steel sheets, but not only a forming load is increased but also the formability deteriorates as the strength of a steel sheet is increased. Furthermore, when press forming a high-strength steel sheet, since a shape of a member changes significantly due to spring-back when the member is taken out of a mold, it is difficult to ensure the dimensional accuracy of the member. And thus, it is not easy to manufacture vehicle members with the high-strength by press forming.

20 **[0004]** In order to solve this issue, until now, for example, as disclosed in Patent Document 1, a technique has been proposed in which press forming a heated steel sheet using a press mold with low temperature. This technique is called hot stamping or hot pressing, and since the steel sheet is press formed in a soft state by being heating to a high temperature, it is possible to manufacture members having complex shapes with high dimensional accuracy. In addition, since the steel sheet is rapidly cooled by contact with the mold, it is possible to significantly increase the strength by quenching at the same time as press forming. Patent Document 1 discloses that a member having a tensile strength of 1400 MPa or more can be obtained by hot stamping a steel sheet having a tensile strength of 500 MPa to 600 MPa.

25 **[0005]** The strength of a hot-stamp formed member can be further increased by increasing a C content of a steel sheet. However, when a C content of a steel sheet is increased, the deformability of a member decreases as the strength of the member increases, and when the member deforms during a collision, a cracking becomes easy to occur at an initial stage of deformation. And thus, it is not easy to manufacture a high-strength hot-stamp formed member with excellent collision resistance property, and especially when the tensile strength of the member exceeds 1900 MPa, it becomes difficult to achieve both strength and collision resistance property.

30 **[0006]** As a technology for manufacturing a hot stamping member with excellent collision resistance property, Patent Document 2 discloses a high-strength pressed component having a tensile strength of 1300 MPa or more and high impact absorbability, and a method for manufacturing the same. Furthermore, Patent Document 3 discloses a hot-stamping member for a vehicle, which has a tensile strength of 1100 MPa or more and has improved bendability from the viewpoint of absorbing impact energy, and a method for manufacturing the same. In the methods disclosed in Patent Document 2 and Patent Document 3, a steel sheet for hot stamping having a decarburized layer on a surface layer is subjected to hot stamping under predetermined conditions, a soft layer is formed on the surface layer of the hot stamping member, and thereby improving the collision resistance property of the component.

Prior Art Document

Patent Document

45 **[0007]**

Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2002-102980

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2015-30890

50 Patent Document 3: PCT International Publication No. WO2018/179839

Disclosure of the Invention

Problems to be Solved by the Invention

55 **[0008]** However, according to studies conducted by the present inventors, it has been found that when hot stamping is performed using steel sheets whose surface layer is decarburized, C flows from the inside of the steel sheets into the surface layer during a heating process of hot stamping, and the C concentration in the decarburized layer increases, the surface layer of the member does not soften and the collision resistance property may not be sufficiently improved.

[0009] The present invention has been made in view of the circumstances described above, and an object of the present invention is to provide a hot-stamp formed body having high strength with tensile strength of 1900 MPa or more and excellent collision resistance property.

5 Means for Solving the Problem

[0010] The gist of the present invention is as follows.

[0011]

10 (1) A hot-stamp formed body according to an aspect of the present invention is a hot-stamp formed body comprising a steel sheet, an entirety or a part of the steel sheet comprises, as a chemical composition, by mass%:

C: more than 0.32% and 0.70% or less;

Si: less than 2.00%;

15 Mn: 0.01% to 3.00%;

P: 0.200% or less;

S: 0.0200% or less;

sol. Al: 0.001% to 1.000%;

N: 0.0200% or less;

20 O: 0.0005% to 0.0200%;

B: 0.0005% to 0.0200%;

Cr: 0% to 2.00%;

Mo: 0% to 2.00%;

W: 0% to 2.00%;

25 Cu: 0% to 2.00%;

Ni: 0% to 2.00%;

Ti: 0% to 0.200%;

Nb: 0% to 0.200%;

V: 0% to 0.200%;

30 Zr: 0% to 0.200%;

Ca: 0% to 0.1000%;

Mg: 0% to 0.1000%;

REM: 0% to 0.1000%;

Sn: 0% to 0.200%;

35 As: 0% to 0.100%;

Bi: 0% to 0.0500%; and

a remainder comprising Fe and impurities,

wherein a tensile strength is 1900 MPa or more,

40 an average B concentration in a region from a depth of 5.0 μm from a surface of the steel sheet to a depth of 25.0 μm from the surface is 0.700 times or less than a B concentration at a position of a depth of 100 μm from the surface,

an average B concentration in a region from a depth of 0.5 μm from the surface to a depth of 4.0 μm from the surface is 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface, and

45 an average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface is more than 0.0150 mass%.

(2) In the hot-stamp formed body according to (1), the chemical composition may comprise, by mass%, one or two or more selected from the group consisting of:

50 Cr: 0.01% to 2.00%;

Mo: 0.01% to 2.00%;

W: 0.01% to 2.00%;

Cu: 0.01% to 2.00%;

Ni: 0.01% to 2.00%;

55 Ti: 0.001% to 0.200%;

Nb: 0.001% to 0.200%;

V: 0.001% to 0.200%;

Zr: 0.001% to 0.200%;

Ca: 0.0001% to 0.1000%;
Mg: 0.0001% to 0.1000%;
REM: 0.0001% to 0.1000%;
Sn: 0.001% to 0.200%;
As: 0.001% to 0.100%; and
Bi: 0.001% to 0.0500%.

Effects of the Invention

[0012] According to the above-described aspect of the present invention, it is possible to provide a hot-stamp formed body having high strength of tensile strength of 1900 MPa or more and excellent collision resistance property. The hot-stamp formed body according to the above-described aspect has excellent collision resistance property and does not crack at an initial stage of deformation, and thereby suitably applying to vehicle members of pillars, bumpers, and so on.

Brief Description of the Drawings

[0013]

[Fig. 1] A Figure of hat member manufactured in example.

[Fig. 2] A Figure of specimen for three-point bending test manufactured in example.

[Fig. 3] A Figure explaining three-point bending test performed in example. Embodiments of the Invention

[0014] The present inventors has studied a method for suppressing the occurrence of a cracking at an initial stage of deformation during a collision in a hot-stamp formed body having a tensile strength of 1900 MPa or more, and as a result, the following findings were obtained.

[0015]

(A) By softening a surface layer of a hot-stamp formed body, the collision resistance property of the hot-stamp formed body is improved.

(B) In order to soften a surface layer of a hot-stamp formed body, it is effective to perform hot stamping using a steel sheet for hot stamping having a decarburized layer in a surface layer. However, in the process of heating a steel sheet for hot stamping, C diffuses from the inside of the steel sheet to the surface layer, and a phenomenon (referred to as recarburization) in which the C concentration in the surface layer increases occurs. Therefore, a surface layer of a hot-stamp formed body does not sufficiently soften, and the collision resistance property of the hot-stamp formed body may not be sufficiently improved.

(C) In the hot-stamp formed body, (a) by decreasing an average B concentration in a region from a depth of 5.0 μm from a surface of a steel sheet constituting the hot-stamp formed body to a depth of 25.0 μm from the surface, (b) by increasing an average B concentration in a region from a depth of 0.5 μm from the surface to a depth of 4.0 μm from the surface, and (c) by increasing an average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface, it is possible to improve the collision resistance property of the hot-stamp formed body even if recarburization occurs during heating process of hot stamping.

(D) Although the reason is not clear, it is presumed that (a) in the region from the depth of 5.0 μm from the surface of the steel sheet constituting the hot-stamp formed body to the depth of 25.0 μm from the surface, the hardenability of the steel sheet decreases due to a decrease of the average B concentration, (b) in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface, B and O combine and the hardenability of the steel sheet decreases, and thereby softening the surface layer even if the C concentration in the surface layer of the hot-stamp formed body increases due to the recarburization.

[0016] Based on the findings of (A) to (D), the present inventors found that by adjusting the B concentration and O concentration in the surface layer (including a surface layer region and an outermost layer region described below) of the hot-stamp formed body to a specific range, a hot-stamp formed body having a tensile strength of 1900 MPa or more and excellent collision resistance property can be obtained.

[0017] Hereinafter, the hot-stamp formed body according to the present embodiment will be described in detail. First, the reason why the chemical composition of the steel sheet constituting the hot-stamp formed body according to the present embodiment is limited will be described.

[0018] An entirety or a part of the steel sheet constituting the hot-stamp formed body according to the present embodiment has the following chemical composition. When the hot-stamp formed body consists of only the steel sheet, an entirety or a part of the hot-stamp formed body has the chemical composition shown below.

[0019] Note that a limited numerical range described using "to" described below includes a lower limit and an upper limit. Numerical values represented using "less than" or "more than" are not included in a numerical range. All % related to the chemical composition mean mass%.

[0020] When the hot-stamp formed body has a part having a tensile strength of 1900 MPa or more and a part having a tensile strength of less than 1900 MPa, at least the part having a tensile strength of 1900 MPa or more may have the following chemical composition.

an entirety or a part of the steel sheet constituting the hot-stamp formed body according to the present embodiment comprises, as a chemical composition, by mass%, C: more than 0.32% and 0.70% or less, Si: less than 2.00%, Mn: 0.01% to 3.00%, P: 0.200% or less, S: 0.0200% or less, sol. Al: 0.001% to 1.000%, N: 0.0200% or less, O: 0.0005% to 0.0200%, B: 0.0005% to 0.0200%, and a remainder of Fe and impurities.

[0021] Each element will be described below.

C: more than 0.32% and 0.70% or less

[0022] C is an element that improves the strength of the steel sheet after hot stamping (the steel sheet constituting the hot-stamp formed body). When the C content is 0.32% or less, a tensile strength of the steel sheet after hot stamping becomes less than 1900 MPa, and the strength of the hot-stamp formed body becomes insufficient. In addition, collision resistance property of the hot-stamp formed body deteriorates. Therefore, the C content is set to more than 0.32%. The C content is preferably more than 0.34%, more than 0.38%, more than 0.42% or more than 0.45%.

[0023] On the other hand, when the C content is more than 0.70%, the strength of the hot-stamp formed body becomes too high, and excellent collision resistance property cannot be obtained. Therefore, the C content is set to 0.70% or less. The C content is preferably 0.65% or less, 0.60% or less, 0.55% or less or 0.50% or less.

Si: less than 2.00%

[0024] Si is an element that may be comprised as an impurity in steel, and makes steel brittle. When the Si content exceeds 2.00%, the adverse effects become particularly significant. Therefore, the Si content is set to less than 2.00%. The Si content is preferably less than 1.00%, less than 0.75%, less than 0.50% or less than 0.20%.

[0025] The lower limit of the Si content is not particularly limited, but may be 0%. Since excessively lowering the Si content causes an increase in steel manufacturing costs, the Si content is preferably set to 0.001% or more. In addition, since Si has the effect of improving the hardenability of steel, Si may be actively comprised. From the viewpoint of improving the hardenability, the Si content is preferably 0.05% or more, 0.10% or more or 0.15% or more.

Mn: 0.01% to 3.00%

[0026] Mn is an element that combines with S, which is an impurity, to form MnS and has the effect of suppressing the harmful effects of S. When the Mn content is less than 0.01%, the above effects cannot be obtained. Therefore, the Mn content is set to 0.01% or more. In addition, Mn is an element that improves the hardenability of steel and forms a microstructure mainly composed of martensite inside the steel sheet after hot stamping, and an effective element for ensuring the strength of the hot-stamp formed body. From the viewpoint of ensuring the strength, the Mn content is preferably 0.50% or more, 0.75% or more, 1.00% or more or 1.25% or more.

[0027] On the other hand, when the Mn content is more than 3.00%, excellent collision resistance property in the hot-stamp formed body cannot be obtained. Therefore, the Mn content is set to 3.00% or less. The Mn content is preferably 2.50% or less, 2.00% or less or 1.50% or less.

P: 0.200% or less

[0028] P is an element that may be comprised as an impurity in steel, and makes steel brittle. When the P content exceeds 0.200%, the adverse effects become particularly significant, and the weldability deteriorates significantly. Therefore, the P content is set to 0.200% or less. The P content is preferably less than 0.100%, less than 0.050% or less than 0.020%.

[0029] The P content may be 0%, but the dephosphorization cost increases significantly when the P content is reduced to less than 0.001%, which is not preferable economically. Therefore, the P content may be set to 0.001% or more or 0.005% or more.

S: 0.0200% or less

[0030] S is an element that may be comprised as an impurity in steel, and makes steel brittle. When the S content

exceeds 0.0200%, the adverse effects become particularly significant. Therefore, the S content is set to 0.0200% or less. The S content is preferably less than 0.0050%, less than 0.0020% or less than 0.0010%.

[0031] The S content may be 0%, but the desulfurization cost increases significantly when the S content is reduced to less than 0.0001%, which is not preferable economically. Therefore, the S content may be set to 0.0001% or more or 0.0002% or more.

sol. Al: 0.001% to 1.000%

[0032] Al is an element having an effect of deoxidizing molten steel. When the sol. Al content (acid-soluble Al content) is less than 0.001%, deoxidation is insufficient. Therefore, the sol. Al content is set to 0.001% or more. The sol. Al content is preferably 0.005% or more, 0.010% or more or 0.020% or more.

[0033] On the other hand, when the sol. Al content is too high, a transformation point increases, and it becomes difficult to heat the steel sheet to a temperature of higher than an Ac_3 point in heating step of hot stamping. In addition, the strength and the collision resistance property of the hot-stamp formed body deteriorate. Therefore, the sol. Al content is set to 1.000% or less. The sol. Al content is preferably less than 0.500%, less than 0.100%, less than 0.060% or less than 0.040%.

N: 0.0200% or less

[0034] N is an element that may be comprised as an impurity in steel, and forms nitrides during continuous casting of steel. Since the nitrides deteriorate ductility of the steel sheet after hot stamping, it is preferable that the N content is lower. When the N content exceeds 0.0200%, the adverse effects become particularly significant. Therefore, the N content is set to 0.0200% or less. The N content is preferably less than 0.0100%, less than 0.0080% or less than 0.0050%.

[0035] The N content may be 0%, but the denitrification cost increases significantly when the N content is reduced excessively, which is not preferable economically. Therefore, the N content may be set to 0.0005% or more, or 0.0010% or more or 0.0020% or more.

O: 0.0005% to 0.0200%

[0036] O is an element that forms B oxide by combining with B and reduces the hardenability of steel, and is an effective element for softening the surface layer of the steel sheet after hot stamping. When the O content is less than 0.0005%, the surface layer of the steel sheet after hot stamping does not soften, and the collision resistance property in the hot-stamp formed body deteriorates. Therefore, the O content is set to 0.0005% or more. The O content is preferably 0.0010% or more, 0.0015% or more or 0.0020% or more.

[0037] On the other hand, when the O content is more than 0.0200%, a large amount of coarse oxide inclusions is formed in steel. And thus, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the O content is set to 0.0200% or less. The O content is preferably 0.0150% or less, 0.0100% or less, 0.0060% or less or 0.0040% or less.

B: 0.0005% to 0.0200%

[0038] B is an element that improves the hardenability of steel and forms a microstructure mainly composed of martensite inside the steel sheet after hot stamping, and an effective element for ensuring the strength of the hot-stamp formed body. When the B content is less than 0.0005%, the desired strength in the hot-stamp formed body cannot be obtained. In addition, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the B content is set to 0.0005% or more. The B content is preferably 0.0010% or more, 0.0015% or more or 0.0020% or more.

[0039] On the other hand, when the B content is more than 0.0200%, carborides are formed in the hot-stamp formed body, and the effect of hardenability improvement of B is impaired. Therefore, the B content is set to 0.0200% or less. The B content is preferably less than 0.0050%, less than 0.0040% or less than 0.0030% or less,

[0040] The remainder of the chemical composition of the steel sheet constituting the hot-stamp formed body according to the present embodiment may be Fe and impurities. Elements, which are unavoidably mixed from a steel raw material or scrap and/or during the manufacture of steel and are allowed in a range where the properties of the hot-stamp formed body according to the present embodiment do not deteriorate, are exemplary examples of the impurities.

[0041] The steel sheet constituting the hot-stamp formed body according to the present embodiment may comprise the following elements as optional elements instead of a part of Fe. The content of the following optional elements obtained in a case where the following optional elements are not contained is 0%.

Cr: 0.01% to 2.00%

[0042] Cr is an element that increases the strength of the hot-stamp formed body by increasing the hardenability of steel. In order to reliably obtain the effect, the Cr content is preferably set to 0.01% or more. The Cr content is more preferably 0.05% or more or 0.10% or more.

[0043] On the other hand, when the Cr content is more than 2.00%, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Cr content is set to 2.00% or less. The Cr content is preferably less than 0.50%, less than 0.40% or less than 0.30%,

Mo: 0.01% to 2.00%

[0044] Mo is an element that increases the strength of the hot-stamp formed body by increasing the hardenability of steel. In order to reliably obtain the effect, the Mo content is preferably set to 0.01% or more. The Mo content is more preferably 0.05% or more, or 0.10% or more or 0.15% or more.

[0045] On the other hand, when the Mo content is more than 2.00%, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Mo content is set to 2.00% or less. The Mo content is preferably less than 0.50%, less than 0.40% or less than 0.30%,

W: 0.01% to 2.00%

[0046] W is an element that increases the strength of the hot-stamp formed body by increasing the hardenability of steel. In order to reliably obtain the effect, the W content is preferably set to 0.01% or more. The W content is more preferably 0.05% or more or 0.10% or more.

[0047] On the other hand, when the W content is more than 2.00%, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the W content is set to 2.00% or less. The W content is preferably less than 0.50%, less than 0.40% or less than 0.30%,

Cu: 0.01% to 2.00%

[0048] Cu is an element that increases the strength of the hot-stamp formed body by increasing the hardenability of steel. In order to reliably obtain the effect, the Cu content is preferably set to 0.01% or more. The Cu content is more preferably 0.10% or more.

[0049] On the other hand, when the Cu content is more than 2.00%, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Cu content is set to 2.00% or less. The Cu content is preferably less than 1.00% or less than 0.50%,

Ni: 0.01% to 2.00%

[0050] Ni is an element that increases the strength of the hot-stamp formed body by increasing the hardenability of steel. In order to reliably obtain the effect, the Ni content is preferably set to 0.01% or more. The Ni content is more preferably 0.10% or more.

[0051] On the other hand, when the Ni content is more than 2.00%, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Ni content is preferably set to 2.00% or less. The Ni content is preferably less than 1.00% or less than 0.50%.

Ti: 0.001% to 0.200%

[0052] Ti is an element that forms carbonitrides in steel and increases the strength of the hot-stamp formed body by precipitation strengthening. In addition, Ti is an element that improves the collision resistance property of the hot-stamp formed body through refinement of the microstructure. In order to reliably obtain these effects, the Ti content is preferably set to 0.001% or more. The Ti content is more preferably 0.005% or more or 0.010% or more.

[0053] On the other hand, when the Ti content is more than 0.200%, a large amount of coarse carbonitrides is formed in steel, and the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Ti content is set to 0.200% or less. The Ti content is preferably less than 0.050% or less than 0.030%.

Nb: 0.001% to 0.200%

[0054] Nb is an element that forms carbonitride in steel and increases the strength of the hot-stamp formed body by

precipitation strengthening. In addition, Nb is an element that improves the collision resistance property of the hot-stamp formed body through refinement of the microstructure. In order to reliably obtain these effects, the Nb content is preferably set to 0.001% or more. The Nb content is more preferably 0.005% or more or 0.010% or more.

[0055] On the other hand, when the Ti content is more than 0.200%, a large amount of coarse carbonitrides is formed in steel, and the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Nb content is set to 0.200% or less. The Nb content is preferably less than 0.050%, less than 0.030% or less than 0.020%.

V: 0.001% to 0.200%

[0056] V is an element that forms carbonitrides in steel and increases the strength of the hot-stamp formed body by precipitation strengthening. In addition, V is an element that improves the collision resistance property of the hot-stamp formed body through refinement of the microstructure. In order to reliably obtain these effects, the V content is preferably set to 0.001% or more. The V content is more preferably 0.005% or more or 0.010% or more.

[0057] On the other hand, when the V content is more than 0.200%, a large amount of coarse carbonitrides is formed in steel, and the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the V content is set to 0.200% or less. The V content is preferably less than 0.100% or less than 0.050%.

Zr: 0.001% to 0.200%

[0058] Zr is an element that forms carbonitrides in steel and increases the strength of the hot-stamp formed body by precipitation strengthening. In addition, Zr is an element that improves the collision resistance property of the hot-stamp formed body through refinement of the microstructure. In order to reliably obtain these effects, the Zr content is preferably set to 0.001% or more. The Zr content is more preferably 0.005% or more or 0.010% or more.

[0059] On the other hand, when the Zr content is more than 0.200%, a large amount of coarse carbonitrides is formed in steel, and the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the Zr content is set to 0.200% or less. The Zr content is preferably less than 0.100% or less than 0.050%.

Ca: 0.0001% to 0.1000%

[0060] Ca is an element that improves the ductility of the steel sheet after hot stamping by adjusting the shape of inclusions. In order to reliably obtain the effect, the Ca content is preferably set to 0.0001% or more.

[0061] On the other hand, even if Ca is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the Ca content is set to 0.1000% or less. The Ca content is preferably less than 0.0100%.

Mg: 0.0001% to 0.1000%

[0062] Mg is an element that improves the ductility of the steel sheet after hot stamping by adjusting the shape of inclusions. In order to reliably obtain the effect, the Mg content is preferably set to 0.0001% or more.

[0063] On the other hand, even if Mg is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the Mg content is set to 0.1000% or less. The Mg content is preferably less than 0.0100%.

REM: 0.0001% to 0.1000%

[0064] REM is an element that improves the ductility of the steel sheet after hot stamping by adjusting the shape of inclusions. In order to reliably obtain the effect, the REM content is preferably set to 0.0001% or more.

[0065] On the other hand, even if REM is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the REM content is set to 0.1000% or less. The REM content is preferably less than 0.0100%.

[0066] Note that in the present embodiment, REM refers to a total of 17 elements that are composed of Sc, Y and lanthanoid, and the REM content refers to the total content of these elements.

Sn: 0.001% to 0.200%

[0067] Sn is an element that has the effect of improving the corrosion resistance of hot-stamp formed body. In order to reliably obtain the effect, the Sn content is preferably set to 0.001% or more. The Sn content is more preferably 0.005% or more, 0.015% or more or 0.030% or more.

[0068] On the other hand, even if Sn is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the Sn content is set to 0.200% or less. The Sn content is preferably 0.150% or less or 0.100% or

less.

As: 0.001% to 0.100%

5 **[0069]** As is an element that has the effect of increasing the strength of hot-stamp formed body. In order to reliably obtain the effect, the As content is preferably set to 0.001% or more.

[0070] On the other hand, even if As is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the As content is set to 0.100% or less.

10 Bi: 0.001% to 0.0500%

[0071] Bi is an element that improves the collision resistance property of the hot-stamp formed body by making a solidification structure fine. In order to reliably obtain the effect, the Bi content is preferably set to 0.0001% or more.

15 **[0072]** On the other hand, even if Bi is comprised excessively, the above effect is saturated, and furthermore, excessive cost occurs. Therefore, the Bi content is set to 0.0500% or less. The Bi content is preferably 0.0100% or lower or 0.0050% or lower.

20 **[0073]** For the chemical composition of the steel sheet constituting the hot-stamp formed body described above, a test piece is taken from the steel sheet constituting the hot-stamp formed body, a coating is removed when the steel sheet is coated, and then the average elemental content throughout the sheet thickness may be measured using a standard analysis method. Note that C and S may be measured using a combustion-infrared absorption method, O and N may be measured using an inert gas fusion-thermal conductivity method. When a plating layer is provided on the surface of the steel sheet constituting the hot-stamp formed body, the measurement of the chemical composition may be performed after removing the plating layer.

25 **[0074]** As described above, when the hot-stamp formed body has a part having a tensile strength of 1900 MPa or more and a part having a tensile strength of less than 1900 MPa, at least the part having a tensile strength of 1900 MPa or more may have the chemical composition described above. In order to perform the measurement of the chemical composition of the part having a tensile strength of 1900 MPa or more, a test piece may be taken from a tensile test piece that has a tensile strength of 1900 MPa or more when the tensile test described below is performed, or from a part adjacent to the part from which the tensile test piece is taken.

30 **[0075]** Next, the B concentration distribution and the O concentration distribution in the sheet thickness direction of the steel sheet constituting the hot-stamp formed body according to the present embodiment will be described.

[0076] In the present embodiment, in the process of heating the steel sheet for hot stamping, by heating the steel sheet for hot stamping under the specific condition, it is possible to diffuse B existing in the surface layer region to the outermost layer region and combine B with O in the outermost layer region, and thereby improving the collision resistance property of the hot-stamp formed body.

35 **[0077]** In the hot-stamp formed body according to the present embodiment, an average B concentration in a region from a depth of 5.0 μm from a surface of the steel sheet constituting the hot-stamp formed body to a depth of 25.0 μm from the surface is 0.700 times or less than a B concentration at a position of a depth of 100 μm from the surface, an average B concentration in a region from a depth of 0.5 μm from the surface to a depth of 4.0 μm from the surface is 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface, and an average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface is more than 0.0150 mass%.

40 **[0078]** Note that the region from the depth of 5.0 μm from the surface of the steel sheet to the depth of 25.0 μm from the surface can be referred to as a region whose starting point is the depth of 5.0 μm from the surface of the steel sheet and ending point is the depth of 25.0 μm from the surface. In addition, the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface can be referred to as a region whose starting point is the depth of 0.5 μm from the surface and ending point is the depth of 4.0 μm from the surface.

[0079] When the hot-stamp formed body has the part having a tensile strength of 1900 MPa or more and the part having a tensile strength of less than 1900 MPa, at least the part having a tensile strength of 1900 MPa or more may have the following B concentration distribution and O concentration distribution.

50 **[0080]** Each requirement will be explained below.

[0081] Average B concentration in region from depth of 5.0 μm from surface to depth of 25.0 μm from surface: 0.700 times or less than B concentration at position of depth of 100 μm from surface

55 **[0082]** When the average B concentration in the region from the depth of 5.0 μm from the surface to the depth of 25.0 μm from the surface (hereinafter, it may be referred to as a surface layer region) is more than 0.700 times than the B concentration at the position of the depth of 100 μm from the surface, the surface layer region does not soften and the desired collision resistance property in the hot-stamp formed body cannot be obtained. Therefore, the average B concentration in the surface layer region is set to 0.700 times or lower than the B concentration at the position of the depth of 100 μm from the surface. The average B concentration in the surface layer region is preferably 0.700 times or

lower than the B concentration at the position of the depth of 100 μm from the surface and 0.0015 mass% or less. The average B concentration in the surface layer region is more preferably 0.500 times or lower or 0.300 times or lower than the B concentration at the position of the depth of 100 μm from the surface. In addition, the average B concentration in the surface layer region is even more preferably 0.0010 mass% or less or 0.0006 mass% or less.

[0083] The lower limit is not particularly limited, but may be set to 0.0002 mass% or more since the effect is saturated and the strength of the hot-stamp formed body deteriorates even if it is decreased excessively.

[0084] Note that the surface refers to the surface of the steel sheet constituting the hot-stamp formed body. When the hot-stamp formed body has a plating layer on the surface, the surface refers to the interface between the plating layer and the steel sheet.

[0085] Average B concentration in region from depth of 0.5 μm from surface to depth of 4.0 μm from surface: 1.600 times or more than B concentration at position of depth of 100 μm from surface

[0086] When the average B concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface (hereinafter, it may be referred to as an outermost layer region) is less than 1.600 times than the B concentration at the position of the depth of 100 μm from the surface, as described below, B and O do not combine sufficiently in the outermost layer region and the outermost layer region does not soften. And thus, the desired collision resistance property in the hot-stamp formed body cannot be obtained. Therefore, the average B concentration in the outermost layer region is set to 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface. The average B concentration in the outermost layer region is preferably 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface and 0.0040 mass% or more. The average B concentration in the outermost layer region is more preferably 2.000 times or more, 3.000 times or more or 4.000 times or more than the B concentration at the position of the depth of 100 μm from the surface. In addition, the average B concentration in the outermost layer region is even more preferably 0.0050 mass% or more, 0.0060 mass% or more or 0.0070 mass% or more.

[0087] The upper limit is not particularly limited, but may be set to 0.2000 mass% or less since the effect is saturated and the productivity of the hot-stamp formed body is greatly impaired even if the average B concentration in the outermost layer region is increased excessively.

Average O concentration in region from depth of 0.5 μm from surface to depth of 4.0 μm from surface: more than 0.0150 mass%

[0088] When the average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface (outermost layer region) is 0.0150 mass% or less, the amount of O that combines with B is insufficient, the amount of B in solid solution increases, and the outermost layer region does not soften. And thus, the desired collision resistance property in the hot-stamp formed body cannot be obtained. Therefore, the average O concentration in the outermost layer region is set to more than 0.0150 mass%. The average O concentration in the outermost layer region is preferably more than 0.0200 mass%, more than 0.0300 mass% or more than 0.0400 mass%.

[0089] The upper limit is not particularly limited, but may be set to 1.0000 mass% or less since the effect is saturated and the productivity of the hot-stamp formed body is greatly impaired even if the average O concentration in the outermost layer region is increased excessively.

[0090] The average B concentration in the surface layer region, the average B concentration and the average O concentration in the outermost layer region, and the B concentration at the position of the depth of 100 μm from the surface are measured by the following method.

[0091] A test piece is taken from the hot-stamp formed body, a coating is removed when the steel sheet is coated, and then the concentration (mass%) of each element is measured from the measurement starting surface to a depth position of 100 μm or more in the depth direction (sheet thickness direction) by Glow Discharge Optical Emission Spectrometry (GDS analysis). Note that the "measurement starting surface" is different from the "surface of the steel sheet".

[0092] In the GDS analysis, the measurement pitch is adjusted so that there are 1200 to 1800 measurement points from the surface of the steel sheet to a depth position of 100 μm . In order to eliminate the influence of foreign substances such as oil adhering to the measurement starting surface, from the start of measurement, the depth at which the Fe concentration initially becomes 95% or more of the "Fe concentration at the position of the depth of 100 μm from the measurement starting surface" is defined as the surface of the steel sheet. Similarly, when the hot-stamp formed body has a plating layer on the surface, the depth at which the Fe concentration initially becomes 95% or more of the "Fe concentration at the position of the depth of 100 μm from the measurement starting surface" is defined as the interface between the plating layer and the steel sheet, that is, the surface of the steel sheet.

[0093] From the obtained measuring results, by calculating the average B concentration in the region from the depth of 5.0 μm from the surface of the steel sheet to the depth of 25.0 μm from the surface of the steel sheet, the average B concentration in the surface layer region is obtained. In addition, by calculating the average B concentration and the average O concentration in the region from the depth of 0.5 μm from the surface of the steel sheet to the depth of 4.0 μm

from the surface of the steel sheet respectively, the average B concentration and the average O concentration in the outermost layer region are obtained. In addition, by calculating the B concentration at the position of the depth of 100 μm from the surface, the B concentration at the depth of 100 μm from the surface is obtained. Note that when there is no measurement value of GDS analysis at the depth position of 100 μm from the surface of the steel sheet, the first measurement value exceeding the depth position of 100 μm from the surface may be regarded as the B concentration at the depth position of 100 μm from the surface.

[0094] It is preferable that the GDS analysis is performed on test pieces taken from three or more positions of the hot-stamp formed body, and the average value of the obtained results is taken as the B concentration and the O concentration. Note that for a test piece, after performing the tensile test described below, the test piece may be taken from a part adjacent to the part from which the tensile test piece that obtained a tensile strength of 1900 MPa or more was taken.

[0095] The microstructure of the steel sheet constituting the hot-stamp formed body is not particularly limited as long as the desired strength and collision resistance property can be obtained, but it is preferable to have the microstructure shown below.

[0096] An entirety or a part of the steel sheet constituting the hot-stamp formed body according to the present embodiment preferably has the microstructure having the following amount of martensite. In the following explanation regarding the microstructure, "%" means "volume%". When the hot-stamp formed body has a part having a tensile strength of 1900 MPa or more and a part having a tensile strength of less than 1900 MPa, at least the part having a tensile strength of 1900 MPa or more may have the following microstructure.

Microstructure in inner layer region

[0097] It is preferable that the microstructure in an inner layer region (a region from the depth of 100 μm from the surface of the steel sheet constituting the hot-stamp formed body to a center of the sheet thickness (a position of 1/2 of the sheet thickness)) contains martensite of more than 90.0%.

[0098] Since martensite is an effective structure for increasing a tensile strength of the steel sheet after hot stamping, it is preferable that the volume ratio of martensite in the region from the depth of 100 μm from the surface of the steel sheet constituting the hot-stamp formed body to the center of the sheet thickness (hereinafter, it may be referred to as the inner layer region) is more than 90.0%. When the volume ratio of martensite in the inner layer region is 90.0% or less, a tensile strength of the hot-stamp formed body may become less than 1900 MPa, and the strength of the hot-stamp formed body may become insufficient. Therefore, the volume ratio of martensite in the inner layer region is preferably set to more than 90.0%. The volume ratio of martensite in the inner layer region is more preferably more than 91.0%, more than 93.0% or more than 95.0%.

[0099] The upper limit of the volume ratio of martensite in the inner layer region is not particularly limited. In order to greatly increase the volume ratio of martensite, it is necessary to excessively increase a heating temperature of a steel sheet for hot stamping or excessively increase a cooling rate in a hot stamping process, and thereby greatly impairing the productivity of a hot-stamp formed body. Therefore, the volume ratio of martensite in the inner layer region is preferably set to 99.0% or less or 98.0% or less.

[0100] In the present embodiment, in addition to fresh martensite that is not tempered, martensite includes tempered martensite that is tempered and has iron carbides inside.

[0101] The remainder of the microstructure in the inner layer region may contain ferrite, pearlite, bainite or retained austenite, and may also contain precipitates such as cementites or oxides existing alone. Since it is not necessary to contain ferrite, pearlite, bainite, retained austenite, and precipitates, all the lower limit of the volume ratio of ferrite, pearlite, bainite, retained austenite, and precipitates is all 0%.

[0102] Retained austenite has an effect that improves ductility of the steel sheet after hot stamping. In order to obtain the effect, the volume ratio of retained austenite in the inner layer region is preferably set to 0.5% or more, 1.0% or more or 2.0% or more.

[0103] On the other hand, in order to excessively increase the volume ratio of retained austenite, performing austempering treatment at a high temperature after hot stamping is needed, and thereby greatly decreasing the productivity of a hot-stamp formed body. In addition, when retained austenite contained excessively, the collision resistance property of the hot-stamp formed body may deteriorate. Therefore, the volume ratio of retained austenite in the inner layer region is preferably set to less than 9.0%, less than 7.0%, less than 5.0% or less than 4.0%.

Microstructure in outermost layer region

[0104] It is preferable that the microstructure in the outermost layer region contains ferrite of more than 5.0%.

[0105] Ferrite is soft and has an effect that improves the collision resistance property of the hot-stamp formed body. In order to obtain the effect, the volume ratio of ferrite in the outermost layer region is preferably set to more than 5.0%. The volume ratio of ferrite in the outermost layer region is more preferably set to more than 10.0%, more than 20.0%, more than

40.0% or more than 60.0%.

[0106] In the present embodiment, in addition to polygonal ferrite, ferrite includes acicular ferrite and bainitic ferrite which have a high dislocation density. In order to efficiently improve the collision resistance property of the hot-stamp formed body, it is more preferable that polygonal ferrite which is the softest is included with the volume ratio described above in the outermost layer region.

[0107] The remainder of the microstructure in the outermost layer region may contain pearlite, bainite, retained austenite or martensite, and may also contain precipitates such as cementites or oxides existing alone. Since it is not necessary to contain pearlite, bainite, retained austenite, martensite, and precipitates, all the lower limit of the volume ratio of pearlite, bainite, retained austenite, martensite, and precipitates is 0%. When martensite is contained excessively, the outermost layer region becomes hard and the collision resistance property of the hot-stamp formed body may deteriorate. Therefore, the volume ratio of martensite in the outermost layer region is preferably set to less than 90.0%, less than 40.0%, less than 10.0% or less than 5.0%.

[0108] Bainite is softer than martensite and has an effect that improves the collision resistance property of the hot-stamp formed body. In order to obtain the effect, the volume ratio of bainite in the outermost layer region is preferably set to more than 10.0%. The volume ratio of bainite in the outermost layer region is more preferably set to more than 20.0% or more than 40.0%. On the other hand, when bainite is contained excessively, the outermost layer region becomes hard and the collision resistance property of the hot-stamp formed body may deteriorate. Therefore, the volume ratio of bainite in the outermost layer region is preferably set to less than 80.0% or less than 60.0%.

[0109] In the present embodiment, the volume ratio of each structure is measured by the following method.

[0110] First, a test piece is taken out from the hot-stamp formed body, buffing a longitudinal section (a sheet thickness section) of a steel sheet is performed, and then the structure is observed in the inner layer region and the outermost layer region. For the inner layer region, the structure is observed in the region from the depth of 100 μm from the surface of the steel sheet constituting the hot-stamp formed body to the center of the sheet thickness (the position of 1/2 of the sheet thickness). For the outermost layer region, the structure is observed in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface.

[0111] Specifically, after performing nital etching or electrolytic polishing on a polished surface, by taking a microstructure photograph using an optical microscope and a Scanning Electron Microscope (SEM), and by performing image analysis based on the differences of brightness or the differences in the shape of iron carbides existing in the phase, the area ratio of ferrite, pearlite, bainite, tempered martensite, and precipitates are obtained. After that, Le Pera etching is performed on the same observation position, and then a structure photograph is taken using an optical microscope and a Scanning Electron Microscope (SEM), and by performing image analysis on the obtained structure photograph, the total area ratio of "retained austenite and fresh martensite" is calculated.

[0112] In addition, electrolytically polishing is performed on the longitudinal section at the same observation position, and then the area ratio of retained austenite is measured using a SEM equipped with an Electron Beam Backscatter Pattern analyzer (EBSP device). Note that the area ratio of retained austenite is obtained by calculating the area ratio of a region having fcc crystal structure from the crystal orientation information obtained by the EBSP analysis.

[0113] The area ratio of fresh martensite is obtained by subtracting the area ratio of retained austenite from the total area ratio of the "retained austenite and fresh martensite" described above.

[0114] Based on these results, the area ratios of each of ferrite, pearlite, bainite, martensite (tempered martensite and fresh martensite), retained austenite, and precipitates are obtained. Then, the area ratio is regarded to be equal to the volume ratio, the obtained area ratio is regarded as the volume ratio of each structure.

[0115] In observation of structure, tempered martensite can be distinguished from fresh martensite in that iron carbides present inside. In addition, tempered martensite can be distinguished from bainite in that the iron carbides present inside and extend not in a single direction but in multiple directions. Note that extending in a single direction means that the difference in extension direction is within 5°.

Sheet thickness

[0116] The sheet thickness (sheet thickness of the steel sheet when the hot-stamp formed body consists of only the steel sheet) of the hot-stamp formed body according to the present embodiment is not particularly limited, but from the viewpoint of reducing the weight of the vehicle body, it is preferably 2.5 mm or less, 2.0 mm or less, 1.8 mm or less or 1.6 mm or less.

[0117] On the other hand, from the viewpoint of ensuring an amount of impact absorption, the sheet thickness is preferably 0.4 mm or more, 0.6 mm or more, 0.8 mm or more or 1.0 mm or more.

Tensile strength

[0118] An entirety or a part of the hot-stamp formed body according to the present embodiment has a tensile strength of 1900 MPa or more. For this purpose, it is necessary that the tensile strength of an entirety or a part of the steel sheet

constituting the hot-stamp formed body according to the present embodiment is 1900 MPa or more. When the tensile strength of at least a part of the hot-stamp formed body is not 1900 MPa or more, the deformation load of the hot-stamp formed body cannot be ensured. As a result, the collision resistance property of the hot-stamp formed body deteriorates. Therefore, the tensile strength of an entirety or a part of the hot-stamp formed body is set to 1900 MPa or more. The tensile strength of an entirety or a part of the hot-stamp formed body is preferably 2000 MPa or more, 2100 MPa or more, 2300 MPa or more or 2500 MPa or more.

[0119] On the other hand, since excessively increasing the strength of the hot-stamp formed body causes a decrease of the collision resistance property, the tensile strength of the hot-stamp formed body is preferably set to less than 3000 MPa or less than 2800 MPa.

[0120] In the hot-stamp formed body according to the present embodiment, the tensile strength of the entire (the entire hot-stamp formed body) may be 1900 MPa or more, but a part having a tensile strength of 1900 MPa or more and a part having a tensile strength of less than 1900 MPa may coexist in the hot-stamp formed body. By providing parts with different strengths, it becomes possible to control a deformation state of the hot-stamp formed body at the time of collision. A hot-stamp formed body having parts with different strengths can be produced by performing hot stamping after joining two or more types of steel sheet with different chemical compositions, by partially changing the heating temperature of the steel sheet or the cooling rate after hot stamping in the hot stamping process, or by a method of partially reheating the hot-stamp formed body.

[0121] The tensile strength of a hot-stamp formed body is obtained by taking a small piece in strip-shaped from the hot-stamp formed body, processing it into a tensile test piece without grinding of the surface of the steel sheet, and performing a tensile test. Specifically, it is preferable to take a sheet-shaped test piece of No. 13B from the hot-stamp formed body in accordance with JIS Z 2241:2011 and perform a tensile test at a tensile speed of 10 mm/min. When the sheet-shaped test piece of No. 13B cannot be taken because the size of the hot-stamp formed body is small or the shape is complicated, a small piece in strip-shaped having a parallel part with an arbitrary width is taken, a tensile test may be performed at a tensile speed of 10 mm/min, and the tensile strength may be determined from the maximum test force and the original cross-sectional area of the parallel part.

[0122] Note that when high-strength parts and low-strength parts coexist in the hot-stamp formed body, a tensile test piece is taken from the high-strength parts.

[0123] The hot-stamp formed body according to the present embodiment may have a plating layer on the surface. By having the plating layer on the surface, the corrosion resistance can be improved after hot stamping. Examples of the plating layer include a zinc-based plating layer or an aluminum-based plating layer. A hot-stamp formed body having these plating layers can be obtained by performing hot stamping using a zinc-based plated steel sheet or an aluminum-based plated steel sheet. The plating layer may be formed on both sides of the hot-stamp formed body, or may be formed on one side. The plating layer of the hot-stamp formed body can be formed by performing hot stamping using a plated steel sheet having the plating layer. However, since the plating layer provided on the plated steel sheet prevents the formation of the preferable B concentration distribution and O concentration distribution in the surface layer region and the outermost layer region of the hot-stamp formed body during the process of manufacturing the hot-stamp formed body, it is necessary to more strictly control the manufacturing method, and the productivity of hot-stamp formed body may be significantly decreased. Therefore, from the viewpoint of the productivity, it is preferable that the hot-stamp formed body does not have the plating layer on the surface.

[0124] Next, the steel sheet for hot stamping suitable for obtaining the hot-stamp formed body according to the present embodiment will be described.

[0125] Since the change in chemical composition due to hot stamping is negligibly small, the chemical composition of the steel sheet for hot stamping may be the same as the chemical composition of the hot-stamp formed body described above. The chemical composition of the steel sheet for hot stamping may be determined by taking a test piece from the steel sheet for hot stamping and measuring it in the same method as in the case of the hot-stamp formed body.

[0126] In the steel sheet for hot stamping, an average B concentration in a region (a surface layer region) from a depth of 5.0 μm from a surface of the steel sheet to a depth of 25.0 μm from the surface is preferably 0.850 times or less than a B concentration at a position of a depth of 100 μm from the surface of the steel sheet. When the average B concentration in the surface layer region is more than 0.850 times than the B concentration at the position of the depth of 100 μm from the surface of the steel sheet, it is not possible to preferably control the B concentration distribution and the O concentration distribution in the surface layer region and the outermost layer region of the hot-stamp formed body even if the hot stamping condition described below is applied. As a result, the desired collision resistance property in the hot-stamp formed body cannot be obtained. Note that when the steel sheet for hot stamping has a plating layer, the surface refers to the interface between the plating layer and the steel sheet.

[0127] The B concentration distribution in the sheet thickness direction of the steel sheet for hot stamping can be determined by taking a test piece from the steel sheet for hot stamping and performing a GDS analysis in the same method as in the case of the hot-stamp formed body.

[0128] Hereinafter, a method for manufacturing the steel sheet for hot stamping for obtaining the hot-stamp formed body

according to the present embodiment will be described.

[0129] The steel sheet for hot stamping is manufactured by the manufacturing method including a hot rolling process of performing hot rolling on a slab having the chemical composition described above to obtain a hot-rolled steel sheet, a cold rolling process of performing cold rolling on the hot-rolled steel sheet to obtain a cold-rolled steel sheet, and an annealing process of performing annealing on the cold-rolled steel sheet to obtain an annealed steel sheet.

[0130] A manufacturing method of the slab provided for the manufacturing method of the steel sheet for hot stamping to the present embodiment is not particularly limited. A steel having the chemical composition described above is melted by a known method, thereafter made into a steel ingot by a continuous casting method, or made into a steel ingot by any casting method, and then made into a steel piece by a blooming method or the like. In the continuous casting process, in order to suppress the occurrence of surface defects due to inclusions, it is preferable to cause an external additional flow such as an electromagnetic stirring in molten steel in a mold. The steel ingot or the steel piece may be reheated after being cooled once and subjected to hot rolling, or the steel ingot in a high temperature state after the continuous casting or the steel piece in a high temperature state after the blooming may be subjected to hot rolling as it is, or after being kept hot, or after being subjected to auxiliary heating, may be subjected to hot rolling. Such the steel ingot and the steel piece are collectively referred to as a "slab" as the material for hot rolling.

[0131] For the heating temperature of the slab subjected to hot rolling, in order to prevent coarsening of austenite, it is preferably set to lower than 1250°C, and more preferably set to lower than 1200°C. Since rolling becomes difficult when the slab heating temperature is low, the slab heating temperature may be set to 1050°C or higher.

[0132] The heated slab is subjected to hot rolling to obtain a hot-rolled steel sheet. Hot rolling is preferably completed in a temperature range of Ar₃ point or higher in order to refine the microstructure of the hot-rolled steel sheet by transforming austenite after completion of rolling.

[0133] When coiling the hot-rolled steel sheet after hot rolling, a coiling temperature is preferably set to less than 550°C. When the coiling temperature is 550°C or higher, iron carbides which are thermally stable are generated, and the collision resistance property of the hot-stamp formed body may deteriorate.

[0134] On the other hand, when the coiling temperature is too low, since the hot-rolled steel sheet excessively harden and it is difficult to perform cold rolling, the coiling temperature is preferably set to higher than 500°C.

[0135] The hot-rolled steel sheet subjected to hot rolling and coiled is pickled in accordance with a typical method, and then subjected to cold rolling in accordance with a typical method to obtain a cold-rolled steel sheet. In the cold rolling process, the cumulative rolling reduction at cold rolling is preferably set to 40% or more. When the cumulative rolling reduction is less than 40%, the microstructure of the steel sheet for hot stamping may coarsen. When the microstructure of the steel sheet for hot stamping is coarse, the microstructure of the hot-stamp formed body coarsens after hot stamping, and this causes a decrease in the collision resistance property of the formed body.

[0136] On the other hand, excessively increasing the cumulative rolling reduction increases the load on rolling mills and causes a decrease in the productivity, therefore the cumulative rolling reduction is preferably set to less than 70%. After cold rolling, treatments such as degreasing may be performed in accordance with a typical method.

[0137] The cold-rolled steel sheet is annealed to obtain an annealed steel sheet. In the annealing process, in order to refine the microstructure of the annealed steel sheet (steel sheet for hot stamping) by recrystallization, the soaking temperature is preferably set to higher than 700°C. When the soaking temperature is 700°C or lower, the B concentration distribution in the surface layer region of the steel sheet for hot stamping may not be preferably controlled. As a result, the desired collision resistance property in the hot-stamp formed body may not be obtained.

[0138] On the other hand, when the heating rate is too slow, the soaking temperature is too high, or the soaking time is too long, the microstructure of the annealed steel sheet coarsens due to grain growth, and the collision resistance property of the hot-stamp formed body may deteriorate. Therefore, the average heating rate to the soaking temperature is preferably set to 1 °C/sec or more, the soaking temperature is preferably set to 800 °C or lower, and the soaking time (retention time at the soaking temperature) is preferably set to shorter than 600 seconds. In addition, the dew point of the atmosphere in the annealing furnace is preferably set to -20 °C or higher and lower than 0°C, and the residence time in a temperature range of 700 °C or higher and lower than "Ac₃ point -30 °C" is preferably set to longer than 360 seconds and shorter than 600 seconds. In addition, the atmosphere in the annealing furnace is preferably set to a nitrogen-hydrogen atmosphere containing hydrogen of 1 volume% or more and less than 4 volume%.

[0139] When the dew point is lower than -20 °C or 0 °C or higher, or the residence time in the temperature range of 700 °C or higher and less than "Ac₃ point -30 °C" is 360 seconds or shorter, the B concentration distribution in the surface layer region of the steel sheet for hot stamping may not be preferably controlled. As a result, the desired collision resistance property in the hot-stamp formed body may not be obtained.

[0140] On the other hand, when the residence time in the above temperature range is 600 seconds or longer, excessive decarburization occurs in the steel sheet for hot stamping, and the strength of the hot-stamp formed body may be insufficient after hot stamping. The annealed steel sheet manufactured by the method described above may be plated in accordance with a typical method to obtain a plated steel sheet. The annealed steel sheet or plated steel sheet obtained in this way may be subjected to temper rolling in accordance with a typical method.

[0141] Note that the Ac_3 point is the temperature at which ferrite disappears in the microstructure when a steel sheet material is heated, and can be obtained from a change in thermal expansion when the cold-rolled steel sheet is heated at a heating rate of 8 °C /sec.

[0142] The hot-stamp formed body according to the present embodiment can be manufactured by the manufacturing method including a heating process of heating the steel sheet for hot stamping (the annealed steel sheet or the plated steel sheet) manufactured by the method described above, and a hot stamping process of performing hot stamping the heated steel sheet for hot stamping. In order to stably obtain the hot-stamp formed body according to the present embodiment, hot stamping is preferably performed by the following method.

[0143] In the heating process, prior to the hot stamping process, a steel sheet for hot stamping having the above-described chemical composition and the B concentration distribution in the sheet thickness direction is heated. In the heating process, it is preferable to use a gas combustion furnace using a flammable gas containing propane gas to heat the steel sheet for hot stamping at an air ratio of 0.84 or less. The heating temperature is preferably set to higher than 950 °C and higher than Ac_3 point, and the retention time at the heating temperature is preferably set to longer than 360 seconds. Note that the air ratio is the ratio (A/A_0) of the amount of air (A) actually introduced to the theoretical amount of air (A_0). In addition, the Ac_3 point in the heating process means the Ac_3 point of the inner layer region of the steel sheet for hot stamping, and may be set to the same value as the Ac_3 point of the cold-rolled steel sheet determined by the above method.

[0144] When the air ratio is higher than 0.84, the heating temperature is 950 °C or lower, or the retention time is 360 seconds or shorter, the B concentration distribution and the O concentration distribution in the surface layer region and the outermost layer region of the hot-stamp formed body may not be preferably controlled. In addition, when the heating temperature is Ac_3 point or lower, the volume ratio of martensite may be insufficient in the microstructure of the inner layer region of the hot-stamp formed body, and the strength of the hot-stamped body may decrease.

[0145] On the other hand, when the heating temperature is too high or the retention time at the heating temperature is too long, the microstructure of the hot-stamp formed body coarsens, and thereby decreasing the collision resistance property of the hot-stamp formed body and decreasing its strength. Therefore, the heating temperature is preferably set to lower than 1050 °C, and the retention time is preferably set to shorter than 600 seconds.

[0146] In the hot stamping process, it is preferable that the heated steel sheet for hot stamping is taken out of the heating furnace and left to cool in the atmosphere, and then hot stamping is started in a temperature range of higher than 750 °C. When the starting temperature of hot stamping is 750 °C or lower, ferrite may be excessively generated in the microstructure of the inner layer region of the hot-stamp formed body, and the strength of the hot-stamp formed body may decrease. After forming by hot stamping, the hot-stamp formed body is cooled while being held in the mold, and/or the hot-stamp formed body is taken out of the mold and cooled by an arbitrary method.

[0147] When the cooling rate is slow, the volume ratio of martensite in the microstructure of the inner layer region of the hot-stamp formed body may be insufficient, and the strength of the hot-stamp formed body may decrease. Therefore, the average cooling rate from the start temperature of hot stamping to 400 °C is preferably set to 30 °C/sec or faster, 60 °C/sec or faster or 90 °C/sec or faster. In addition, when the cooling stop temperature is high, the volume ratio of martensite may be insufficient in the microstructure of the inner layer region of the hot-stamp formed body, and the strength of the hot-stamp formed body may decrease. Therefore, the cooling stop temperature of the cooling described above is preferably set to lower than 90 °C.

[0148] By the above method, the hot-stamp formed body according to the present embodiment is obtained. Note that after the hot stamp forming, a reheating treatment may be performed as long as the strength of the hot-stamp formed body is ensured. When performing the reheating treatment, the heating temperature is preferably set to lower than " Ac_3 point - 100 °C". When the heating temperature of the reheating treatment is " Ac_3 point - 100 °C" or higher, the surface layer region and the outermost layer region of the hot-stamp formed body do not sufficiently soften, and the collision resistance property of the hot-stamp formed body may deteriorate. A part of the hot-stamp formed body may be reheated by laser irradiation or the like to provide a partially softened region. In addition, a blasting treatment may be performed on the hot-stamp formed body, or painting and baking treatment may be performed.

Example

[0149] Next, examples of the present invention will be described. Conditions in the examples are one example of conditions employed to confirm the feasibility and effects of the present invention, but the present invention is not limited to these examples. The present invention may employ various conditions to achieve the object of the present invention without departing from the scope of the present invention.

[0150] By casting molten steel using a vacuum melting furnace, steels having the chemical composition shown in Table 1 were obtained. The obtained steels were heated to 1200 °C and retained for 60 minutes, and then subjected to hot rolling with 10 pass at the temperature range of 900 °C or higher to obtain hot-rolled steel sheets with a thickness of 3.5 mm. After hot rolling, the hot-rolled steel sheets were cooled to 540 °C with water spray. A cooling finishing temperature was regarded as a coiling temperature, the hot-rolled steel sheets were loaded into an electric heating furnace held at the coiling

temperature and retained for 60 minutes. After that, the hot-rolled steel sheets were subjected to furnace cooling to room temperature at an average cooling rate of 20 °C/h, and slow cooling after coiling was simulated. The hot-rolled steel sheets subjected to furnace cooling were pickled, and then subjected to cold rolling to obtain cold-rolled steel sheets with a thickness of 1.4 mm. The cumulative reduction rate during cold rolling was set to 60%.

[0151] Note that "-" in Table 1 indicates that the content of the element was less than the detection limit.

[0152] Ac_3 points in Table 1 were obtained from a change in thermal expansion when the cold-rolled steel sheets of Steels A to N were heated at 8 °C/sec.

[0153] The obtained cold-rolled steel sheets were annealed using a continuous annealing simulator under the annealing conditions shown in Table 2A and Table 2B. Note that heating was performed at an average heating rate of 8 °C/sec to the soaking temperature shown in Table 2A and Table 2B. The atmosphere in the annealing furnace was set to a nitrogen-hydrogen atmosphere containing hydrogen of 3 volume%, and the dew point was set as shown in Table 2A and Table 2B. After soaking, annealed steel sheets (steel sheets for hot stamping) were obtained by cooling to room temperature.

[0154] Test piece for GDS analysis were taken from three positions of the obtained steel sheet for hot stamping, the surface of the test piece was set as the measurement starting surface, and GDS analysis was performed from the measurement starting surface to a depth position of 120 μm in the steel thickness direction in accordance with the method described above. And thus, an average B concentration in the region (the surface layer region) from the depth of 5.0 μm from the surface of the steel sheet for hot stamping to the depth of 25.0 μm from the surface, and the B concentration at the position of the depth of 100 μm from the surface. The number of measurement points from the surface of the steel sheet to the position of the depth of 100 μm was set to 1500 points. The obtained results are shown in Table 2.

[0155] Next, element sheets for hot stamping having a width of 240 mm and a length of 800 mm were taken from the obtained steel sheets for hot stamping, and hat members (hot stamping formed bodies) having the shape shown in FIG. 1 were obtained by performing hot stamping. In the hot stamping process, the element sheets were heated under the conditions shown in Table 3 using a gas heating furnace. Specifically, propane gas was used as the combustion gas, and the heating temperature, the retention time, and the air ratio were set as shown in Table 3. After that, the element sheets for hot stamping were taken out of the heating furnace and subjected to air cooling, and then sandwiched between the molds having cooling apparatus and subjected to hat forming at the forming start temperature of 770 °C or higher. And then, the average cooling rate from the forming start temperature to 400 °C was set to 50 °C/sec or faster, and cooling was performed to the cooling stop temperature of 80 °C or lower in the molds. In addition, oxide scales (iron oxides) generated on the surface of the hat member were removed by shot blasting.

[0156] Test pieces were taken from vertical wall parts of the obtained hat members, and the chemical composition was measured by the method described above.

[0157] In addition, from the vertical wall parts of the hat members, sheet-shaped test pieces of No. 13B were taken along the longitudinal direction of the hat member in accordance with JIS Z 2241:2011 and tensile tests were performed at a tensile speed of 10 mm/min to obtain tensile strengths.

[0158] When the obtained tensile strength was 1900 MPa or more, it was determined as having high strength and successful. On the other hand, when the obtained tensile strength was less than 1900 MPa, it was determined as not having high strength and not successful.

[0159] Test pieces for GDS analysis were taken from three positions of the vertical wall parts of the hat members, the surface of the test piece was set as the measurement starting surface, and GDS analysis was performed from the measurement starting surface to a depth position of 120 μm in the steel thickness direction in accordance with the method described above. And thus, an average B concentration in the region (the surface layer region) from the depth of 5.0 μm from the surface to the depth of 25.0 μm from the surface, an average B concentration and an average O concentration in the region (the outermost layer region) from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface, and a B concentration at the position of the depth of 100 μm from the surface were obtained. The number of measurement points from the surface of the steel sheet to the position of the depth of 100 μm was set to 1500 points.

[0160] In addition, test pieces for structure observation were taken from the vertical wall parts of the hat members, the longitudinal sections of the test pieces were polished, and then the microstructure in the region (outermost layer region) from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface and a region (inner layer region) from the depth of 100 μm from the surface to a center position of 1/2 of the sheet thickness were observed by the method described above.

[0161] In addition, as shown in FIG.2, specimens for three-point bending test were obtained by welding closing plates with a thickness of 1.4 mm, a width of 130 mm, and a length of 800 mm to the hat members. Steel sheets having a tensile strength of 1553 MPa were used for the closing plates.

[0162] As shown in Fig. 3, the obtained specimen with a length of 800 mm was placed on two supporting rolls arranged with a roll interval of 700 mm so that the closing plate faces downward, and a three-point bending test was performed at a test speed of 2 m/sec. As a result, the maximum load and the displacement (displacement until crack) from when the specimen and the impactor contacts until the specimen started to crack were determined.

[0163] In a case where the tensile strength of the steel sheet constituting the hot-stamp formed body was less than 2300

MPa, when the maximum load was 18.0 kN or more, and the displacement until crack was 50 mm or more, it was determined as having excellent collision resistance property and successful. In addition, in a case where the tensile strength was 2300 MPa or more, when the maximum load was 23.0 kN or more, and the displacement until crack was 35 mm or more, it was determined as having excellent collision resistance property and successful. When these conditions

5 [0164] Table 4A and Table 4B show the results of measurement of the chemical composition of the hot-stamp formed body, the results of measurement of the mechanical properties of the hot-stamp formed body, the results of measurement of the B and O concentration distribution in the hot-stamp formed body, and the results of evaluation of the collision resistance property of the hot-stamp formed body.

10 [0165] Note that the contents of the elements other than C in the hot-stamp formed body were omitted because they were the same as the contents of the elements shown in Table 1.

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[Table 1]

Steel	Chemical composition (mass%) remainder: Fe and impurities														Ac ₃ point (°C)	Notes
	C*	Si	Mn	P	S	sol. Al	N	O	B	Cr	Mo	Ti	Nb	Others		
A	0.31	0.05	1.24	0.010	0.0006	0.055	0.0041	0.0010	0.0020	0.31	-	0.023	0.047		794	Comparative steel
B	0.35	0.17	1.28	0.009	0.0005	0.042	0.0038	0.0010	0.0019	0.20	-	0.025	0.042		786	Steel of pre-sent invention
C	0.37	0.15	0.91	0.010	0.0007	0.044	0.0037	0.0012	0.0020	0.41	0.10	0.025	0.045		795	Steel of pre-sent invention
D	0.50	0.19	0.54	0.009	0.0008	0.042	0.0044	0.0015	0.0021	0.43	0.19	0.022	0.048		790	Steel of pre-sent invention
E	0.49	0.24	1.26	0.010	0.0004	0.045	0.0033	0.0011	0.0020	0.19	0.05	0.022	0.010		767	Steel of pre-sent invention
F	0.72	0.01	0.45	0.008	0.0007	0.043	0.0018	0.0016	0.0020	-	0.05	-	-		741	Comparative steel
G	0.45	0.13	0.52	0.010	0.0006	0.047	0.0046	0.0015	0.0002	-	-	-	0.048		783	Comparative steel
H	0.36	0.20	0.42	0.009	0.0006	1.080	0.0033	0.0009	0.0020	0.20	0.18	0.022	0.051		1188	Comparative steel
I	0.36	0.41	1.25	0.010	0.0004	0.052	0.0038	0.0014	0.0020	0.19	-	0.023	-	V:0.042 Zr:0.020	802	Steel of pre-sent invention
J	0.36	0.19	1.20	0.010	0.0004	0.050	0.0039	0.0013	0.0022	-	-	0.023	0.040	Cu:0.30 Ni:0.15	786	Steel of pre-sent invention
K	0.37	0.18	1.25	0.009	0.0005	0.050	0.0039	0.0014	0.0020	0.21	-	0.025	0.044	Ca:0.0003 Mg:0.0004 REM:0.0005	785	Steel of pre-sent invention
L	0.37	0.01	1.26	0.008	0.0007	0.051	0.0042	0.0016	0.0020	0.21	-	0.024	0.044	Bi:0.0024	778	Steel of pre-sent invention
M	0.36	0.36	1.21	0.009	0.0007	0.048	0.0039	0.0012	0.0019	0.10	-	0.025	0.041	W:0.11	800	Steel of pre-sent invention

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Steel	Chemical composition (mass%) remainder: Fe and impurities													Ac ₃ point (°C)	Notes	
	C*	Si	Mn	P	S	sol. Al	N	O	B	Cr	Mo	Ti	Nb	Others		
N	0.37	0.06	1.26	0.009	0.0005	0.049	0.0040	0.0015	0.0019	0.19	-	0.023	0.043	Sn:0.166 As:0.002	783	Steel of pre-sent invention
The underline indicates that it is outside the scope of the present invention.																
*C content is the C content of the steel. The contents of the other elements are the contents of the elements of the steel and the hot-stamp formed body.																

[Table 2A]

Test No.	Steel	Annealing conditions			Steel sheet for hot stamping			Notes
		Soaking temperature (°C)	Residence time in temperature range of 700 °C or higher and lower than Ac ₃ point -30 °C (s)	Dew point (°C)	A: Average B concentration in surface layer region (mass%)	B: B concentration at position of depth of 100 μm from surface (mass%)	A/B	
1	<u>A</u>	740	403	-5	0.0016	0.0020	0.800	Comparative example
2	B	740	403	-5	0.0015	0.0019	0.789	Present invention example
3	B	740	403	-10	0.0016	0.0019	0.842	Present invention example
4	B	705	<u>352</u>	-20	0.0017	0.0019	<u>0.895</u>	Comparative example
5	B	740	<u>733</u>	-5	0.0014	0.0019	0.737	Comparative example
6	C	750	376	-5	0.0016	0.0020	0.800	Present invention example
7	C	750	376	-10	0.0017	0.0020	0.850	Present invention example
8	C	750	376	<u>15</u>	0.0018	0.0020	<u>0.900</u>	Comparative example
9	D	730	370	-10	0.0017	0.0021	0.810	Present invention example
10	D	730	370	-15	0.0017	0.0021	0.810	Present invention example
11	D	<u>680</u>	<u>0</u>	-10	0.0020	0.0021	<u>0.952</u>	Comparative example
12	E	730	370	-5	0.0016	0.0020	0.800	Present invention example
13	E	730	370	-10	0.0017	0.0020	0.850	Present invention example
The underline indicates that the manufacturing condition is not preferable.								

[Table 2B]

Test No.	Steel	Annealing conditions			Steel sheet for hot stamping			Notes
		Soaking temperature (°C)	Residence time in temperature range of 700 °C or higher and lower than Ac ₃ point -30 °C (s)	Dew point (°C)	A: Average B concentration in surface layer region (mass%)	B: B concentration at position of depth of 100 μm from surface (mass%)	A/B	
14	E	730	370	<u>-40</u>	0.0019	0.0020	<u>0.950</u>	Comparative example
15	F	710	363	-15	0.0017	0.0020	0.850	Comparative example
16	G	740	373	-15	0.0002	0.0002	<u>1.000</u>	Comparative example
17	H	740	373	-10	0.0017	0.0020	0.850	Comparative example
18	I	740	373	-5	0.0016	0.0020	0.800	Present invention example
19	J	740	403	-5	0.0017	0.0022	0.773	Present invention example
20	K	740	403	-5	0.0016	0.0020	0.800	Present invention example
21	L	740	403	-5	0.0016	0.0020	0.800	Present invention example
22	M	740	403	-5	0.0015	0.0019	0.789	Present invention example
23	N	740	403	-5	0.0016	0.0019	0.842	Present invention example
24	J	710	363	<u>-25</u>	0.0020	0.0022	<u>0.909</u>	Comparative example
25	J	710	363	-5	0.0018	0.0022	0.818	Present invention example
26	M	740	403	-5	0.0015	0.0019	0.789	Present invention example
27	M	710	363	5	0.0017	0.0019	<u>0.895</u>	Comparative example
The underline indicates that the manufacturing condition is not preferable.								

[Table 3]

Test No.	Steel	Hot stamping conditions				Notes
		Ac3 (°C)	Heating temperature (°C)	Retention time (s)	Air ratio	
<u>1</u>	<u>A</u>	794	980	390	0.83	Comparative example
2	B	786	980	390	0.83	Present invention example
3	B	786	980	<u>60</u>	0.83	Comparative example
4	B	786	980	390	0.83	Comparative example
<u>5</u>	B	786	980	390	0.83	Comparative example
6	C	795	970	390	0.83	Present invention example
7	C	795	970	390	<u>1.10</u>	Comparative example
<u>8</u>	C	795	970	390	0.83	Comparative example
9	D	790	960	390	0.83	Present invention example
10	D	790	<u>870</u>	390	0.83	Comparative example
<u>11</u>	D	790	960	390	0.83	Comparative example
12	E	767	970	390	0.83	Present invention example
13	E	767	970	390	<u>1.10</u>	Comparative example
<u>14</u>	E	767	970	390	0.83	Comparative example
<u>15</u>	<u>F</u>	741	960	390	0.83	Comparative example
<u>16</u>	<u>G</u>	783	960	390	0.83	Comparative example
<u>17</u>	<u>H</u>	1188	<u>960</u>	390	0.83	Comparative example
18	I	802	980	390	0.83	Present invention example
19	J	786	980	390	0.83	Present invention example
20	K	785	980	390	0.83	Present invention example
21	L	778	980	390	0.83	Present invention example
22	M	800	980	390	0.83	Present invention example
23	N	783	960	390	0.83	Present invention example
<u>24</u>	J	786	980	390	0.83	Comparative example
25	J	786	960	<u>330</u>	0.83	Comparative example
26	M	800	980	390	0.81	Present invention example
<u>27</u>	M	800	980	390	0.83	Comparative example
The underline indicates that the manufacturing condition is not preferable.						

[Table 4A]

Test No.	Steel	Hot-stamp formed body										Notes
		Chemical composition	C: Average B concentration in surface layer region (mass%)	D: Average B concentration in outermost layer region (mass%)	Average O concentration in surface layer region (mass%)	E: B concentration at position of depth of 100 μm from surface (mass%)	C/E	D/E	Tensile strength (MPa)	Collision resistance property		
										Maximum load (kN)	Displacement until crack (mm)	
<u>1</u>	<u>A</u>	<u>0.30</u>	0.0004	0.0094	0.0520	0.0019	0.211	4.947	<u>1844</u>	<u>17.5</u>	70	Comparative example
2	B	0.33	0.0003	0.0103	0.0870	0.0018	0.167	5.722	1998	19.4	63	Present invention example
<u>3</u>	B	0.33	0.0015	0.0042	0.0250	0.0019	<u>0.789</u>	2.211	2019	19.6	<u>42</u>	Comparative example
<u>4</u>	B	0.34	0.0014	0.0030	<u>0.0140</u>	0.0019	<u>0.737</u>	<u>1.579</u>	2047	20.6	38	Comparative example
<u>5</u>	B	<u>0.31</u>	0.0002	0.0137	0.1040	0.0017	0.118	8.059	<u>1883</u>	<u>17.8</u>	68	Comparative example
6	C	0.35	0.0004	0.0098	0.0570	0.0019	0.211	5.158	2086	20.4	61	Present invention example
<u>7</u>	C	0.35	0.0015	0.0031	0.0260	0.0020	<u>0.750</u>	<u>1.550</u>	2113	20.8	<u>39</u>	Comparative example
<u>8</u>	C	0.36	0.0016	0.0028	<u>0.0120</u>	0.0020	<u>0.800</u>	<u>1.400</u>	2159	21.2	<u>38</u>	Comparative example
9	D	0.46	0.0006	0.0083	0.0340	0.0020	0.300	4.150	2501	24.3	49	Present invention example
<u>10</u>	D	0.47	0.0015	0.0045	0.0240	0.0021	<u>0.714</u>	2.143	2522	<u>226</u>	<u>17</u>	Comparative example
<u>11</u>	D	0.49	0.0017	0.0027	<u>0.0130</u>	0.0021	<u>0.810</u>	<u>1.286</u>	2543	<u>22.9</u>	<u>18</u>	Comparative example

(continued)

Test No.	Steel	Hot-stamp formed body										Notes	
		Chemical composition		C: Average B concentration in surface layer region (mass%)	D: Average B concentration in outermost layer region (mass%)	Average O concentration in surface layer region (mass%)	E: B concentration at position of depth of 100 μm from surface (mass%)	C/E	D/E	Tensile strength (MPa)	Collision resistance property		
											Maximum load (kN)		Displacement until crack (mm)
12	E	0.46	0.0004	0.0088	0.0550	0.0019	0.211	4.632	2536	24.7	46	Present invention example	
<u>13</u>	E	0.47	0.0015	0.0029	0.0230	0.0020	<u>0.750</u>	<u>1.450</u>	2550	<u>22.5</u>	<u>17</u>	Comparative example	
The underline indicates that it is outside the scope of the present invention, or the characteristic value is not preferable.													

[Table 4B]

Test No.	Steel	Hot-stamp formed body										Notes
		Chemical composition	C: Average B concentration in surface layer region (mass%)	D: Average B concentration in outermost layer region (mass%)	Average O concentration in surface layer region (mass%)	E: B concentration at position of depth position of 100 μm from surface (mass%)	C/E	D/E	Tensile strength (MPa)	Collision resistance property		
										Maximum load (kN)	Displacement until crack (mm)	
<u>14</u>	<u>E</u>	0.49	0.0016	0.0028	<u>0.0140</u>	0.0020	<u>0.800</u>	<u>1.400</u>	2574	<u>22.3</u>	<u>16</u>	Comparative example
<u>15</u>	<u>F</u>	<u>0.71</u>	0.0011	0.0052	0.0280	0.0019	0.579	2.737	-	22.9	<u>12</u>	Comparative example
<u>16</u>	<u>G</u>	0.44	0.0001	0.0003	<u>0.0080</u>	0.0002	0.500	<u>1.500</u>	<u>1836</u>	<u>17.3</u>	<u>42</u>	Comparative example
<u>17</u>	<u>H</u>	0.35	0.0006	0.0068	0.0300	0.0019	0.316	3.579	<u>1870</u>	<u>17.7</u>	51	Comparative example
18	I	0.34	0.0003	0.0116	0.0810	0.0019	0.158	6.105	2045	20.0	63	Present invention example
19	J	0.34	0.0004	0.0108	0.0630	0.0021	0.190	5.143	2063	20.3	60	Present invention example
20	K	0.35	0.0004	0.0094	0.0560	0.0019	0.211	4.947	2117	20.7	61	Present invention example
21	L	0.35	0.0006	0.0073	0.0400	0.0019	0.316	3.842	2124	20.4	57	Present invention example
22	M	0.34	0.0004	0.0089	0.0490	0.0018	0.222	4.944	2058	20.1	61	Present invention example
23	N	0.35	0.0011	0.0034	0.0290	0.0018	0.611	1.889	2136	20.6	53	Present invention example

(continued)

Test No.	Steel	Hot-stamp formed body										Notes
		Chemical composition	C: Average B concentration in surface layer region (mass%)	D: Average B concentration in outermost layer region (mass%)	Average O concentration in surface layer region (mass%)	E: B concentration at position of depth position of 100 μm from surface (mass%)	C/E	D/E	Tensile strength (MPa)	Collision resistance property		
										Maximum load (kN)	Displacement until crack (mm)	
<u>24</u>	J	0.35	0.0018	0.0028	<u>0.0140</u>	0.0022	<u>0.818</u>	<u>1.273</u>	2084	20.5	<u>38</u>	Comparative example
25	J	0.34	0.0015	0.0051	<u>0.0140</u>	0.0021	<u>0.714</u>	2.429	2081	20.4	<u>39</u>	Comparative example
26	M	0.34	0.0003	0.0096	0.0580	0.0018	0.167	5.333	2052	20.0	64	Present invention example
<u>27</u>	M	0.35	0.0015	0.0028	<u>0.0130</u>	0.0019	<u>0.789</u>	<u>1.474</u>	2080	20.4	<u>39</u>	Comparative example
The underline indicates that it is outside the scope of the present invention, or the characteristic value is not preferable.												

[0166] The hot-stamp formed bodies according to the present invention examples had a tensile strength of 1900 MPa or more and high strength. In addition, the average B concentration in the surface layer region was low, the average B concentration and the average O concentration in the outermost layer region were high, and the collision resistance property was excellent.

[0167] In the microstructure of the hot-stamp formed bodies according to the present invention examples, the volume ratio of martensite in the inner layer region was 91.0 % or more, and the total volume ratio of structures other than martensite was 9.0 % or less.

[0168] In addition, in the outermost layer region, the volume ratio of ferrite was 6.0 % or more, and the total volume ratio of structures other than ferrite was 94.0% or less.

[0169] On the other hand, in the comparative examples (Test Nos. 1, 5 and 17) in which the chemical composition of the hot-stamp formed body was outside the scope of the invention, since the C content was too low or the sol. Al content was too high, the tensile strength of the hot-stamp formed body was less than 1900 MPa resulting in poor in the strength, the maximum load was low and collision resistance property was inferior.

[0170] In Test No. 15, since the C content was too high, the displacement until crack of the hot-stamp formed body was low, and the collision resistance property was inferior. Note that in the tensile test, an early fracture occurred and the tensile strength could not be determined, and the fracture strength was less than 1900 MPa.

[0171] In Test No. 16, since the B content was too low, the tensile strength of the hot-stamp formed body was less than 1900 MPa resulting in poor in the strength. In addition, the average B concentration and the average O concentration in the outermost layer region were low, the maximum load and the displacement until crack were low, and the collision resistance property was inferior.

[0172] In Test Nos. 3, 4, 7, 8, 10, 11, 13, 14, 24, 25, and 27 of comparative examples whose chemical compositions of the hot-stamp formed bodies were within the preferable range and manufacturing conditions were outside the preferable range, one or more of the average B concentration in the surface layer region, the average B concentration in the outermost layer region, and the average O concentration in the outermost layer region became outside the invention range. Therefore, the displacement until crack of the hot-stamp formed body was low, or the maximum load and the displacement until crack were low, and collision resistance property was inferior.

Industrial Applicability

[0173] According to the above-described aspect of the present invention, it is possible to provide a hot-stamp formed body having high strength and excellent collision resistance property.

Claims

1. A hot-stamp formed body comprising a steel sheet, an entirety or a part of the steel sheet comprising, as a chemical composition, by mass%:

C: more than 0.32% and 0.70% or less;

Si: less than 2.00%;

Mn: 0.01% to 3.00%;

P: 0.200% or less;

S: 0.0200% or less;

sol. Al: 0.001% to 1.000%;

N: 0.0200% or less;

O: 0.0005% to 0.0200%;

B: 0.0005% to 0.0200%;

Cr: 0% to 2.00%;

Mo: 0% to 2.00%;

W: 0% to 2.00%;

Cu: 0% to 2.00%;

Ni: 0% to 2.00%;

Ti: 0% to 0.200%;

Nb: 0% to 0.200%;

V: 0% to 0.200%;

Zr: 0% to 0.200%;

Ca: 0% to 0.1000%;

Mg: 0% to 0.1000%;

REM: 0% to 0.1000%;

Sn: 0% to 0.200%;

As: 0% to 0.100%;

Bi: 0% to 0.0500%; and

a remainder comprising Fe and impurities,

wherein a tensile strength is 1900 MPa or more,

an average B concentration in a region from a depth of 5.0 μm from a surface of the steel sheet to a depth of 25.0 μm from the surface is 0.700 times or less than a B concentration at a position of a depth of 100 μm from the surface,

an average B concentration in a region from a depth of 0.5 μm from the surface to a depth of 4.0 μm from the surface is 1.600 times or more than the B concentration at the position of the depth of 100 μm from the surface, and an average O concentration in the region from the depth of 0.5 μm from the surface to the depth of 4.0 μm from the surface is more than 0.0150 mass%.

2. The hot-stamp formed body according to claim 1 comprising, as the chemical composition, by mass%, one or two or more selected from the group consisting of:

Cr: 0.01% to 2.00%;

Mo: 0.01% to 2.00%;

W: 0.01% to 2.00%;

Cu: 0.01% to 2.00%;

Ni: 0.01% to 2.00%;

Ti: 0.001% to 0.200%;

Nb: 0.001% to 0.200%;

V: 0.001% to 0.200%;

Zr: 0.001% to 0.200%;

Ca: 0.0001% to 0.1000%;

Mg: 0.0001% to 0.1000%;

REM: 0.0001% to 0.1000%;

Sn: 0.001% to 0.200%;

As: 0.001% to 0.100%; and

Bi: 0.001% to 0.0500%.

FIG. 1

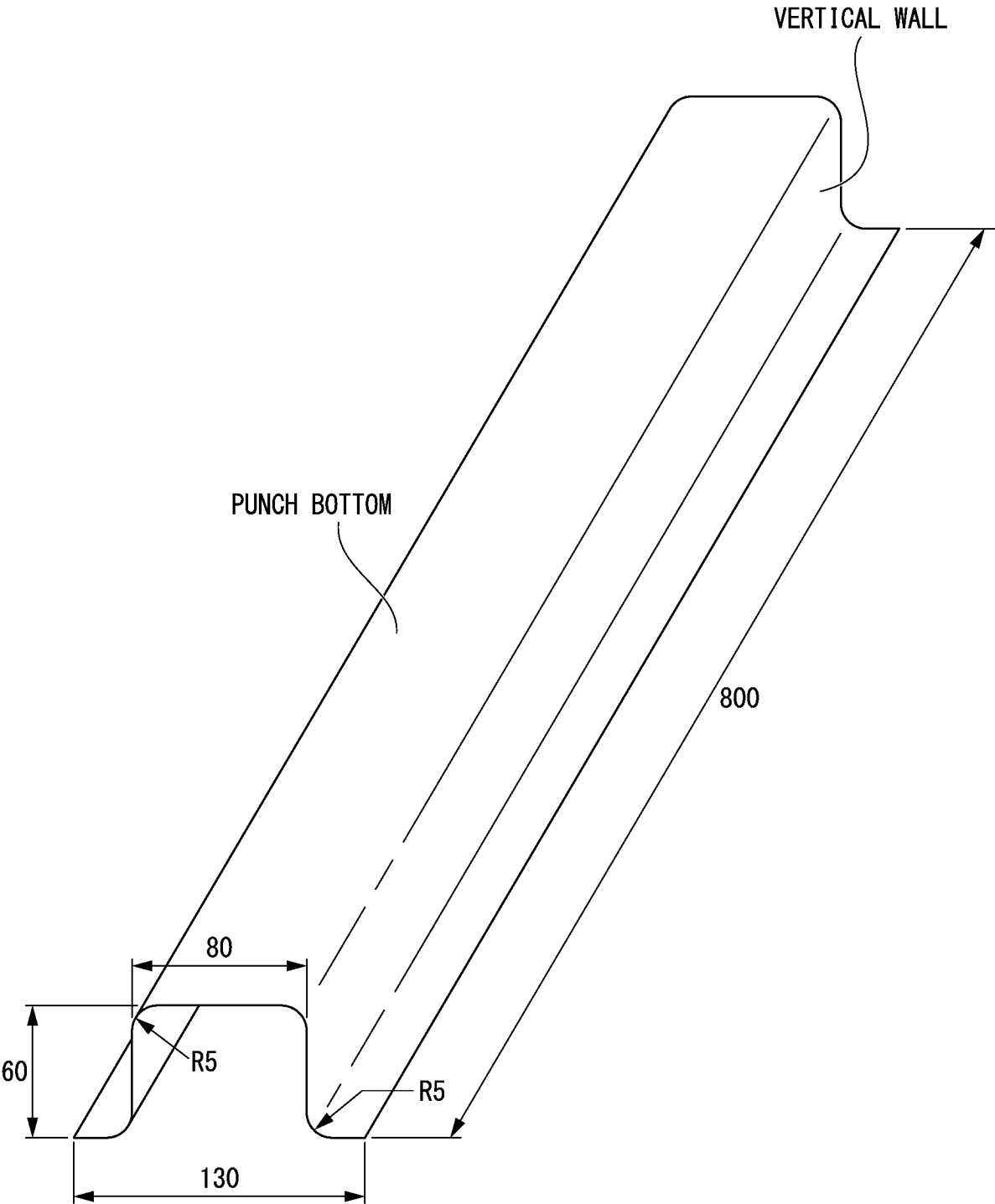


FIG. 2

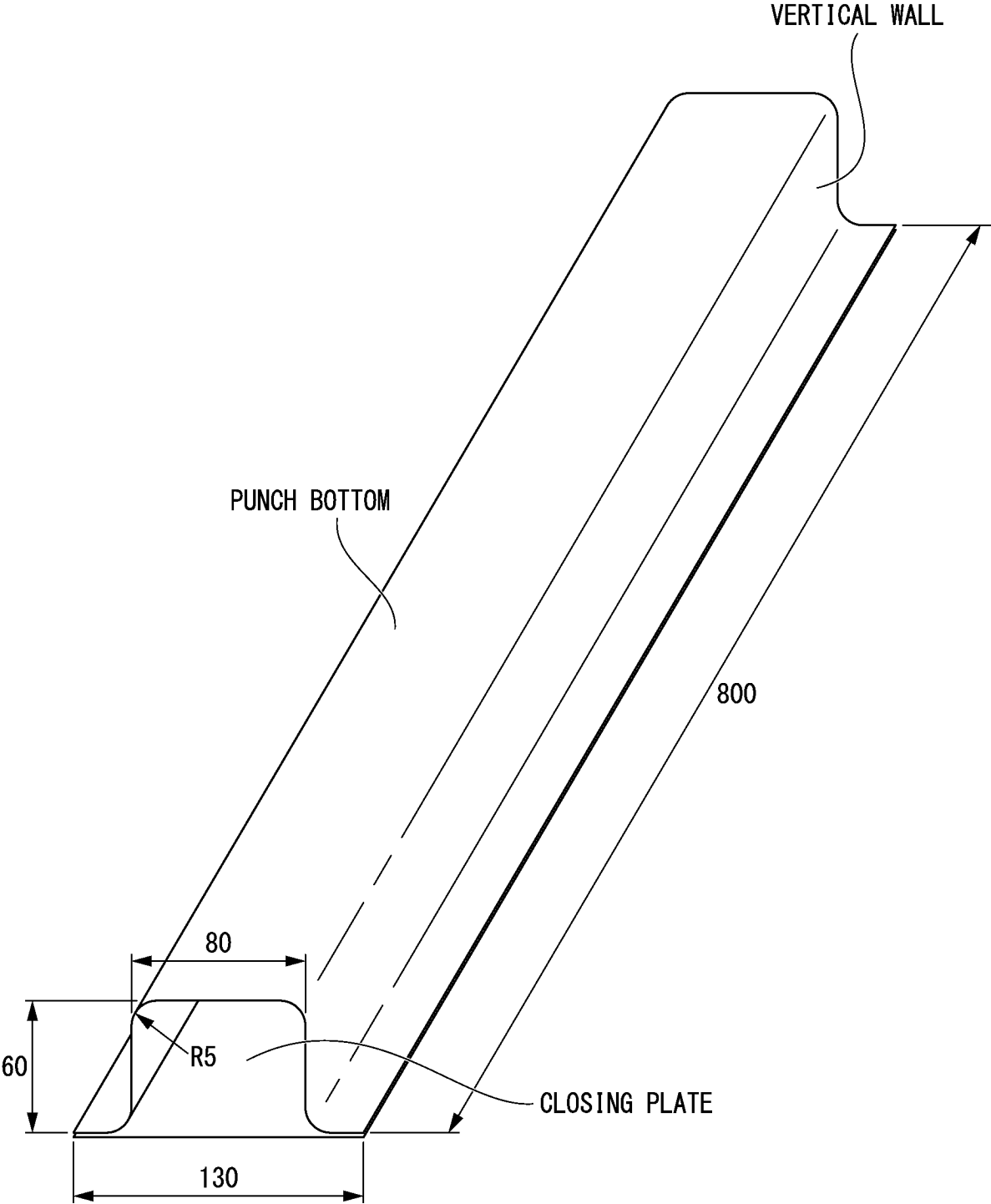
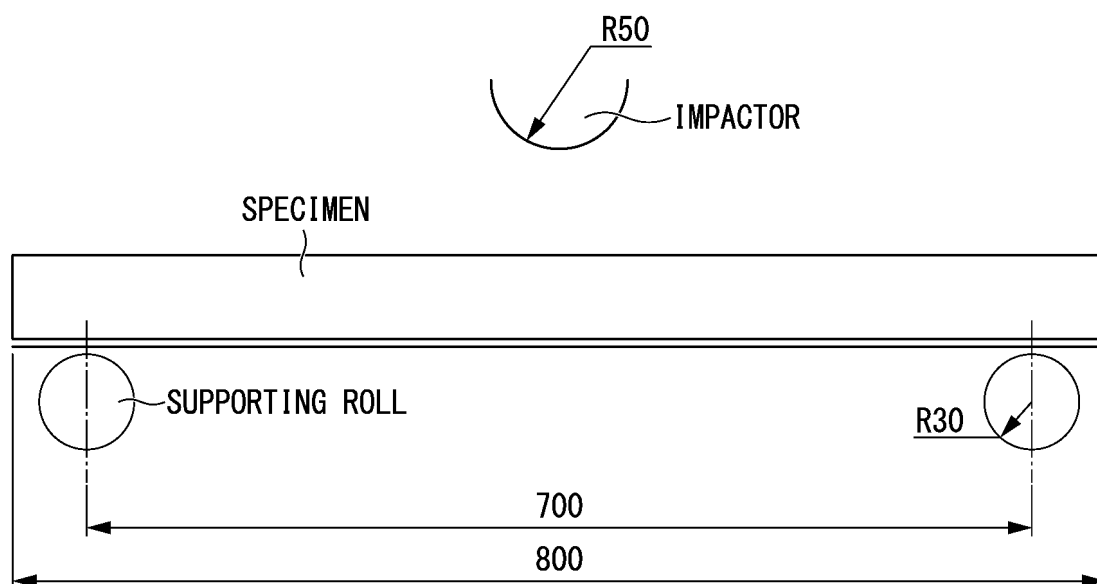


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/013803

A. CLASSIFICATION OF SUBJECT MATTER <i>C22C 38/00</i> (2006.01)i; <i>B21D 22/20</i> (2006.01)i; <i>C21D 1/18</i> (2006.01)i; <i>C21D 9/00</i> (2006.01)i; <i>C21D 9/46</i> (2006.01)i; <i>C22C 38/58</i> (2006.01)i FI: C22C38/00 301Z; C22C38/00 301S; C22C38/58; C21D1/18 C; C21D9/00 A; C21D9/46 G; B21D22/20 E; B21D22/20 H 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) C22C38/00-38/60; B21D22/20; C21D1/18; C21D9/00; C21D9/46 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2023 Registered utility model specifications of Japan 1996-2023 Published registered utility model applications of Japan 1994-2023 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)															
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th><th>Citation of document, with indication, where appropriate, of the relevant passages</th><th>Relevant to claim No.</th></tr> </thead> <tbody> <tr> <td>A</td><td>WO 2016/163469 A1 (NIPPON STEEL & SUMITOMO METAL CORP) 13 October 2016 (2016-10-13) claims, paragraphs [0007]-[0011]</td><td>1-2</td></tr> <tr> <td>A</td><td>JP 2021-155793 A (NIPPON STEEL CORP) 07 October 2021 (2021-10-07) claims, paragraphs [0015]-[0017]</td><td>1-2</td></tr> <tr> <td>A</td><td>JP 2006-152427 A (SUMITOMO METAL IND LTD) 15 June 2006 (2006-06-15) claims, paragraphs [0006]-[0008], [0035]</td><td>1-2</td></tr> <tr> <td>A</td><td>WO 2019/003449 A1 (JFE STEEL CORP) 03 January 2019 (2019-01-03) claims</td><td>1-2</td></tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	WO 2016/163469 A1 (NIPPON STEEL & SUMITOMO METAL CORP) 13 October 2016 (2016-10-13) claims, paragraphs [0007]-[0011]	1-2	A	JP 2021-155793 A (NIPPON STEEL CORP) 07 October 2021 (2021-10-07) claims, paragraphs [0015]-[0017]	1-2	A	JP 2006-152427 A (SUMITOMO METAL IND LTD) 15 June 2006 (2006-06-15) claims, paragraphs [0006]-[0008], [0035]	1-2	A	WO 2019/003449 A1 (JFE STEEL CORP) 03 January 2019 (2019-01-03) claims	1-2	☐ 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 “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
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.														
A	WO 2016/163469 A1 (NIPPON STEEL & SUMITOMO METAL CORP) 13 October 2016 (2016-10-13) claims, paragraphs [0007]-[0011]	1-2														
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A	JP 2006-152427 A (SUMITOMO METAL IND LTD) 15 June 2006 (2006-06-15) claims, paragraphs [0006]-[0008], [0035]	1-2														
A	WO 2019/003449 A1 (JFE STEEL CORP) 03 January 2019 (2019-01-03) claims	1-2														
Date of the actual completion of the international search 15 June 2023	Date of mailing of the international search report 27 June 2023															
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.															

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2023/013803

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