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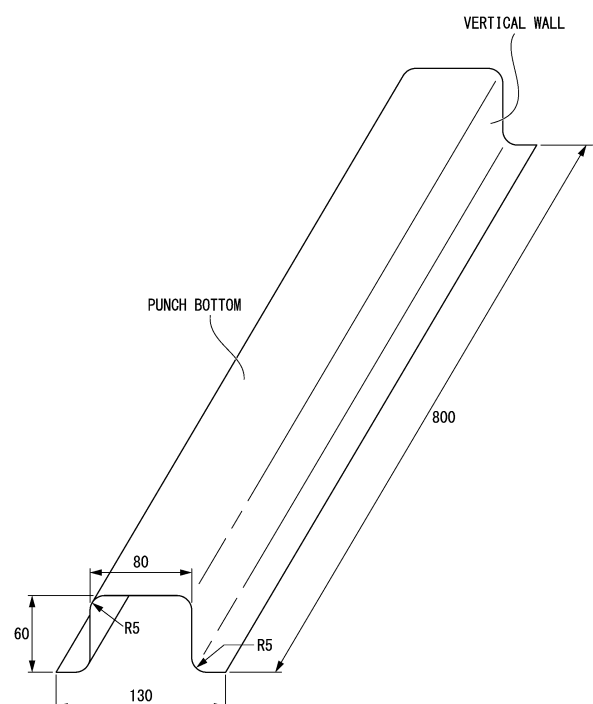
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(54) **HOT STAMP MOLDED BODY**

(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  $\mu\text{m}$  from a surface of the steel sheet to a depth of 25  $\mu\text{m}$  from the surface is 0.700 times or less than a B concentration at a depth of 100  $\mu\text{m}$  from the surface, and an average O concentration in a region from the surface to a depth of 0.5  $\mu\text{m}$  from the surface is 4.000 mass% or less.

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. 2022-067028, 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 body can be further increased by increasing a C content of a steel sheet. However, when a C content of a steel sheet is increased, susceptibility to hydrogen embrittlement is increased and a hydrogen embrittlement cracking becomes easy to occur. In addition the deformability of a steel sheet constituting a hot-stamp formed body decreases, and a cracking becomes easy to occur at a collision. And thus, it is not easy to manufacture a high-strength hot-stamp formed body with excellent hydrogen embrittlement resistance and deformability, and especially when the tensile strength of the hot-stamp formed body exceeds 1900 MPa, it becomes more difficult to achieve both hydrogen embrittlement resistance and deformability.

30 **[0006]** Patent Document 2 discloses a technique according to a hot-stamp formed body having improved hydrogen embrittlement resistance by making precipitates containing one or more of Nb, Ti, V, Cr, Mo, and Mg function as hydrogen trap sites.

35 **[0007]** Patent Document 3 discloses a technique for manufacturing a hot-stamp formed body with increased toughness and hydrogen embrittlement resistance by refining prior austenite grains.

40 **[0008]** Patent Document 4 discloses a hot pressed member having high strength and excellent hydrogen embrittlement resistance, and a method for manufacturing the same. In the method disclosed in Patent Document 4, the hydrogen embrittlement resistance of the member is improved by refining prior austenite grains, using Nb-based precipitates as hydrogen trap sites, and suppressing variations in hardness on a surface of steel sheet.

## Prior Art Document

45 Patent Document

**[0009]**

50 Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2002-102980  
 Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2005-97725  
 Patent Document 3: Japanese Unexamined Patent Application, First Publication No. 2010-150612  
 Patent Document 4: PCT International Publication No. WO2019/003445

## Disclosure of the Invention

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## Problems to be Solved by the Invention

**[0010]** The techniques disclosed in Patent Document 2 and Patent Document 3 are excellent in that a hot-stamp formed

body having excellent hydrogen embrittlement resistance and a tensile strength of 950 MPa or more can be obtained. However, Patent Documents 2 and 3 do not disclose a hot-stamp formed body having a tensile strength of 1900 MPa or more. According to the studies of the present inventors, in Patent Documents 2 and 3, there is room for improvement in order to achieve both high strength and hydrogen embrittlement resistance at a higher level.

**[0011]** Patent Document 4 discloses that a hot pressed member with excellent hydrogen embrittlement resistance and a tensile strength of 1780 MPa or more can be obtained, but it does not consider about a decrease in deformability and is thought that collision property is insufficient.

**[0012]** 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 hydrogen embrittlement resistance and deformability.

Means for Solving the Problem

**[0013]** The gist of the present invention is as follows.

(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%;
- Mn: 0.01% or more and less than 1.00%;
- P: 0.200% or less;
- S: 0.0200% or less;
- sol. Al: 0.001% to 1.000%;
- N: 0.0200% or less;
- O: 0.0200% or less;
- 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 μm from a surface of the steel sheet to a depth of 25 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,  
 and  
 an average O concentration in a region from the surface to a depth of 0.5 μm from the surface is 4.000 mass% or less.

(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:

- 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%;  
 5 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  
 10 Bi: 0.001% to 0.0500%.

Effects of the Invention

15 **[0014]** 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 hydrogen embrittlement resistance and deformability.

**[0015]** The hot-stamp formed body according to the above-described aspect hardly occurs a hydrogen embrittlement cracking, is excellent in deformability, and a cracking hardly occurs at a collision, and thereby suitably applying to vehicle members of pillars, bumpers, and so on.

20 Brief Description of the Drawings

**[0016]** [Fig. 1] A Figure of hat member manufactured in example.

25 Embodiments of the Invention

**[0017]** The present inventors has studied a method for improving the hydrogen embrittlement resistance and the deformability in a hot-stamp formed body having a tensile strength of 1900 MPa or more, and as a result, the following findings were obtained.

30 (A) In a hot-stamp formed body, by decreasing an average B concentration in a region from a depth of 5  $\mu\text{m}$  from a surface of a steel sheet constituting the hot-stamp formed body to a depth of 25  $\mu\text{m}$  from the surface, the hydrogen embrittlement resistance and the deformability of the hot-stamp formed body can be improved.

35 (B) Although the reason is not clear, it is presumed that (a) a cracking due to hydrogen embrittlement and a cracking due to a decrease in deformability easily occur from a surface layer of the steel sheet constituting the hot-stamp formed body as a starting point, (b) in the region from the depth of 5  $\mu\text{m}$  from the surface of the steel sheet constituting the hot-stamp formed body to the depth of 25  $\mu\text{m}$  from the surface (a surface layer region), the hardenability of the steel sheet decreases due to a decrease of an average B concentration, and (c) the surface layer softens due to the decrease of the hardenability and a cracking in the surface layer is suppressed.

40 (C) In the hot-stamp formed body, by decreasing an average O concentration in a region from the surface of the steel sheet constituting the hot-stamp formed body to a depth of 0.5  $\mu\text{m}$  from the surface (a region vicinity the surface), the hydrogen embrittlement resistance of the hot-stamp formed body can be improved.

45 (D) Although the reason is not clear, it is presumed that (d) when scales generated during the manufacturing process of the hot-stamp formed body are not sufficiently removed and remain, the average O concentration in the region vicinity the surface increases, and (e) when scales remain, hydrogen that penetrated into the hot-stamp formed body becomes difficult to be released, and a hydrogen embrittlement cracking becomes easy to occur.

(E) By decreasing the Mn content in the chemical composition of the steel sheet constituting the hot-stamp formed body, the hydrogen embrittlement resistance of the hot-stamp formed body can be improved.

50 (F) Although the reason is not clear, it is presumed that (f) the Mn concentration at grain boundaries decreases, a cracking starting from grain boundaries is suppressed, and (g) the average B concentration in the surface layer region of the steel sheet constituting the hot-stamp formed body becomes easy to decrease due to a decrease of the Mn content.

55 **[0018]** Based on the findings of (A) to (F), the present inventors found that by controlling the B concentration and O concentration in a surface layer (including a surface layer region and a region vicinity the surface described below) of the hot-stamp formed body to a specific range, and by decreasing the Mn content in the chemical composition of the hot-stamp formed body, the hot-stamp formed body having a tensile strength of 1900 MPa or more, and excellent hydrogen embrittlement resistance and the deformability can be obtained.

**[0019]** 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.

**[0020]** 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.

**[0021]** 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%.

**[0022]** 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.

**[0023]** 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% or more and less than 1.00%, P: 0.200% or less, S: 0.0200% or less, sol. Al: 0.001% to 1.000%, N: 0.0200% or less, O: 0.0200% or less, B: 0.0005% to 0.0200%, and a remainder of Fe and impurities.

**[0024]** Each element will be described below.

C: more than 0.32% and 0.70% or less

**[0025]** 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. 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%.

**[0026]** 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 hydrogen embrittlement resistance and deformability 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%

**[0027]** 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%.

**[0028]** 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% or more and less than 1.00%

**[0029]** Mn is an element that combines with S 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. The Mn content is preferably 0.10% or more or 0.20% 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 0.20% or more or 0.30% or more.

**[0030]** On the other hand, when the Mn content is 1.00% or more, excellent hydrogen embrittlement resistance in the hot-stamp formed body cannot be obtained. Therefore, the Mn content is set to less than 1.00%. The Mn content is preferably less than 0.80%, less than 0.60% or less than 0.50%.

P: 0.200% or less

**[0031]** 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%.

**[0032]** 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

5 **[0033]** 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%.

10 **[0034]** 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%

15 **[0035]** 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.

20 **[0036]** 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 of the hot-stamp formed body become insufficient. 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

25 **[0037]** 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 the deformability of the hot-stamp formed body, 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%.

30 **[0038]** 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: 0.0200% or less

35 **[0039]** O is an element that may be comprised as an impurity in steel, and forms oxide inclusions. When the O content is more than 0.0200%, a large amount of coarse oxide inclusions is formed in steel. And thus, the deformability 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.

40 **[0040]** O may be 0%, but O is an element that forms B oxide by combining with B and reduces the hardenability of steel, and an effective element for softening the surface layer of the steel sheet after hot stamping. In order to reliably obtain the effect, the O content is preferably set to 0.0005% or more. The O content is more preferably 0.0010% or more, 0.0015% or more or 0.0020% or more.

B: 0.0005% to 0.0200%

45 **[0041]** 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. 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.

**[0042]** On the other hand, when the B content is more than 0.0200%, carbides 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,

55 **[0043]** 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.

**[0044]** 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%

5 **[0045]** 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.

10 **[0046]** On the other hand, when the Cr content is more than 2.00%, the deformability 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%

15 **[0047]** 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.

20 **[0048]** On the other hand, when the Mo content is more than 2.00%, the deformability 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%

25 **[0049]** 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.

30 **[0050]** On the other hand, when the W content is more than 2.00%, the deformability 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%

35 **[0051]** 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.

**[0052]** On the other hand, when the Cu content is more than 2.00%, the deformability 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%,

40 Ni: 0.01% to 2.00%

**[0053]** 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.

45 **[0054]** On the other hand, when the Ni content is more than 2.00%, the deformability 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%

50 **[0055]** 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 hydrogen embrittlement resistance and the deformability 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.

55 **[0056]** 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 deformability 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%

**[0057]** 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 hydrogen embrittlement resistance and the deformability 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.

**[0058]** 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 deformability 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%

**[0059]** 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 hydrogen embrittlement resistance and the deformability 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.

**[0060]** 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 deformability 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%

**[0061]** 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 hydrogen embrittlement resistance and the deformability 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.

**[0062]** 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 deformability 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%

**[0063]** Ca is an element that improves the deformability of the hot-stamp formed body by adjusting the shape of inclusions. In order to reliably obtain the effect, the Ca content is preferably set to 0.0001% or more.

**[0064]** 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%

**[0065]** Mg is an element that improves the deformability of the hot-stamp formed body by adjusting the shape of inclusions. In order to reliably obtain the effect, the Mg content is preferably set to 0.0001% or more.

**[0066]** 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%

**[0067]** REM is an element that improves the deformability of the hot-stamp formed body by adjusting the shape of inclusions. In order to reliably obtain the effect, the REM content is preferably set to 0.0001% or more.

**[0068]** 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%.

**[0069]** 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%

**[0070]** 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.

**[0071]** 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%

**[0072]** 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.

**[0073]** 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.

Bi: 0.001% to 0.0500%

**[0074]** Bi is an element that improves the hydrogen embrittlement resistance and the deformability 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.

**[0075]** 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.

**[0076]** 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.

**[0077]** 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.

**[0078]** 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.

**[0079]** 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 decrease the amount of B existing in the surface layer region, and thereby improving the hydrogen embrittlement resistance and the deformability of the hot-stamp formed body. In addition, by performing a blasting treatment under the specific condition after hot stamping, it is possible to decrease the amount of O existing in the region vicinity the surface, and thereby improving the hydrogen embrittlement resistance of the hot-stamp formed body.

**[0080]** In the hot-stamp formed body according to the present embodiment, an average B concentration in a region from a depth of 5  $\mu\text{m}$  from a surface of the steel sheet constituting the hot-stamp formed body to a depth of 25  $\mu\text{m}$  from the surface is 0.700 times or less than a B concentration at a position of a depth of 100  $\mu\text{m}$  from the surface, and an average O concentration in a region from the surface to a depth of 0.5  $\mu\text{m}$  from the surface is 4.000 mass% or less.

**[0081]** Note that the region from the depth of 5  $\mu\text{m}$  from the surface of the steel sheet to the depth of 25  $\mu\text{m}$  from the surface can be referred to as a region whose starting point is the depth of 5  $\mu\text{m}$  from the surface of the steel sheet and ending point is the depth of 25  $\mu\text{m}$  from the surface. In addition, the region from the surface to the depth of 0.5  $\mu\text{m}$  from the surface can be referred to as a region whose starting point is the surface of the steel sheet and ending point is the depth of 0.5  $\mu\text{m}$  from the surface.

**[0082]** 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.

**[0083]** Each requirement will be explained below.

**[0084]** Average B concentration in region from depth of 5  $\mu\text{m}$  from surface to depth of 25  $\mu\text{m}$  from surface: 0.700 times or less than B concentration at position of depth of 100  $\mu\text{m}$  from surface

**[0085]** When the average B concentration in the region from the depth of 5  $\mu\text{m}$  from the surface to the depth of 25  $\mu\text{m}$  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  $\mu\text{m}$  from the surface, the surface layer region does not soften and the desired hydrogen embrittlement resistance and deformability 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  $\mu\text{m}$  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  $\mu\text{m}$  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  $\mu\text{m}$  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.

**[0086]** 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.

**[0087]** 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.

**[0088]** Average O concentration in region from surface to depth of 0.5  $\mu\text{m}$  from surface: 4.000 mass% or less

**[0089]** When the average O concentration in the region from the surface to the depth of 0.5  $\mu\text{m}$  from the surface (hereinafter, it may be referred to as a region vicinity the surface) is more than 4.000 mass%, the desired hydrogen embrittlement resistance in the hot-stamp formed body cannot be obtained. Therefore, the average O concentration in the region vicinity the surface is set to 4.000 mass% or less. The average O concentration in the region vicinity the surface is preferably 3.500 mass% or less, 3.000 mass% or less or 2.500 mass% or less.

**[0090]** The lower limit is not particularly limited, but may be set to more than 0.0050 mass%, more than 0.0100 mass% or more than 0.0200 mass% 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 region vicinity the surface is decreased excessively.

**[0091]** The average B concentration in the surface layer region, the average O concentration in the region vicinity the surface, and the B concentration at the position of the depth of 100  $\mu\text{m}$  from the surface are measured by the following method.

**[0092]** 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  $\mu\text{m}$  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".

**[0093]** 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  $\mu\text{m}$ . 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  $\mu\text{m}$  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  $\mu\text{m}$  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.

**[0094]** From the obtained measuring results, by calculating the average B concentration in the region from the depth of 5  $\mu\text{m}$  from the surface of the steel sheet to the depth of 25  $\mu\text{m}$  from the surface of the steel sheet, the average B concentration in the surface layer region is obtained. In addition, by calculating the average O concentration in the region from the surface of the steel sheet to the depth of 0.5  $\mu\text{m}$  from the surface of the steel sheet, the average O concentration in the region vicinity the surface is obtained. In addition, by calculating the B concentration at the position of the depth of 100  $\mu\text{m}$  from the surface, the B concentration at the position of the depth of 100  $\mu\text{m}$  from the surface is obtained. Note that when there is no measurement value of GDS analysis at the position of the depth of 100  $\mu\text{m}$  from the surface of the steel sheet, the first measurement value exceeding the position of the depth of 100  $\mu\text{m}$  from the surface may be regarded as the B concentration at the position of the depth of 100  $\mu\text{m}$  from the surface.

**[0095]** 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.

**[0096]** The microstructure of the steel sheet constituting the hot-stamp formed body is not particularly limited as long as the desired strength, hydrogen embrittlement resistance and deformability can be obtained, but it is preferable to have the microstructure shown below.

**[0097]** 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.

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Microstructure in inner layer region

**[0098]** It is preferable that the microstructure in an inner layer region (a region from the depth of 100  $\mu\text{m}$  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%.

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**[0099]** 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  $\mu\text{m}$  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%.

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**[0100]** 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.

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**[0101]** 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.

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**[0102]** 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%.

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**[0103]** 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.

**[0104]** 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%.

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**[0105]** In the present embodiment, the volume ratio of each structure is measured by the following method.

**[0106]** 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 region from the depth of 100  $\mu\text{m}$  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).

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**[0107]** 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.

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**[0108]** 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.

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**[0109]** 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.

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**[0110]** 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.

**[0111]** 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°.

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Sheet thickness

**[0112]** 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

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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. **[0113]** 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

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**[0114]** 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 during deformation

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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.

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**[0115]** On the other hand, since excessively increasing the strength of the hot-stamp formed body causes a decrease of the hydrogen embrittlement resistance and the deformability, the tensile strength of the hot-stamp formed body is preferably set to less than 3000 MPa or less than 2800 MPa. **[0116]** 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

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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. **[0117]** 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.

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**[0118]** 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.

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**[0119]** 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 region vicinity the surface 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.

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**[0120]** Next, the steel sheet for hot stamping suitable for obtaining the hot-stamp formed body according to the present embodiment will be described.

**[0121]** 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.

**[0122]** In the steel sheet for hot stamping, an average B concentration in a region (a surface layer region) from a depth of 5  $\mu\text{m}$  from a surface of the steel sheet to a depth of 25  $\mu\text{m}$  from the surface is preferably 0.850 times or less than a B concentration at a position of a depth of 100  $\mu\text{m}$  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  $\mu\text{m}$  from the surface of the steel sheet, it is not possible to preferably control the B concentration distribution in the surface layer region of the hot-stamp formed body even if the hot stamping condition described below is applied. As a result, the desired hydrogen embrittlement resistance and deformability 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.

**[0123]** 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.

**[0124]** 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.

**[0125]** 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.

**[0126]** 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.

**[0127]** 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.

**[0128]** 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  $A_{r3}$  point or higher in order to refine the microstructure of the hot-rolled steel sheet by transforming austenite after completion of rolling.

**[0129]** 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.

**[0130]** 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.

**[0131]** 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.

**[0132]** 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.

**[0133]** 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 hydrogen embrittlement resistance and deformability in the hot-stamp formed body may not be obtained.

**[0134]** 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 hydrogen embrittlement resistance and the deformability 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.

5 **[0135]** 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 "Ac<sub>3</sub> 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%.

10 **[0136]** 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 "Ac<sub>3</sub> 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 hydrogen embrittlement resistance and deformability in the hot-stamp formed body may not be obtained.

15 **[0137]** 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.

20 **[0138]** Note that the Ac<sub>3</sub> 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.

25 **[0139]** 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, a hot stamping process of performing hot stamping the heated steel sheet for hot stamping, and a blasting process of performing blasting treatment on the hot-stamp formed body subjected to 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.

30 **[0140]** 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<sub>3</sub> point, and the retention time at the heating temperature is preferably set to longer than 360 seconds.

35 **[0141]** Note that the air ratio is the ratio (A/A<sub>0</sub>) of the amount of air (A) actually introduced to the theoretical amount of air (A<sub>0</sub>). In addition, the Ac<sub>3</sub> point in the heating process means the Ac<sub>3</sub> point of the inner layer region of the steel sheet for hot stamping, and may be set to the same value as the Ac<sub>3</sub> point of the cold-rolled steel sheet determined by the above method.

40 **[0142]** 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 in the surface layer region of the hot-stamp formed body may not be preferably controlled. In addition, when the heating temperature is Ac<sub>3</sub> 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.

45 **[0143]** 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 hydrogen embrittlement resistance and the deformability 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.

50 **[0144]** 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.

55 **[0145]** 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.

**[0146]** In the blasting process, it is preferable that a blasting treatment with a blasting intensity of more than 0.20 mmN in

Almen arc height value is performed on the hot-stamp formed body subjected to hot stamping. The hot-stamp formed body according to the present embodiment has high scale adhesion due to low Mn content, and when the blasting intensity is 0.20 mmN or less, the O concentration distribution in the region vicinity the surface of the hot-stamp formed body may not be preferably controlled. It is preferable that the Almen arc height value is adjusted by using cast steel shot, cut wire shot, or conditioned cut wire shot specified in JIS B 2711:2013 as the blasting material, using a pneumatic blasting device, and by changing the blasting speed, the blasting time, and the blasting distance. The Almen arc height value is measured using an Almen strip N piece and an Almen gauge in accordance with JIS B 2711:2013.

**[0147]** 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<sub>3</sub> point - 100 °C". When the heating temperature of the reheating treatment is "Ac<sub>3</sub> point - 100 °C" or higher, the surface layer region of the hot-stamp formed body do not sufficiently soften, and the hydrogen embrittlement resistance and the deformability 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, painting and baking treatment may be performed on the hot-stamp formed body.

#### Example

**[0148]** 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.

**[0149]** 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%.

**[0150]** Note that "-" in Table 1 indicates that the content of the element was less than the detection limit.

**[0151]** Ac<sub>3</sub> points in Table 1 were obtained from a change in thermal expansion when the cold-rolled steel sheets in Table were heated at 8 °C/sec.

**[0152]** 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.

**[0153]** 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 μm from the surface of the steel sheet for hot stamping to the depth of 25 μm from the surface, and a 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.

**[0154]** 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-stamp 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.

**[0155]** Subsequently, cast steel shot having an average particle diameter of about 300 μm was projected onto the obtained hat member using a direct pressure - pneumatic blasting device, and blasting treatment was performed under the conditions shown in Table 3.

[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, tensile 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  $\mu\text{m}$  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  $\mu\text{m}$  from the surface to the depth of 25  $\mu\text{m}$  from the surface, an average O concentration in the region (the region vicinity the surface) from the surface to the depth of 0.5  $\mu\text{m}$  from the surface, and a B concentration at the position of the depth of 100  $\mu\text{m}$  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  $\mu\text{m}$  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 a region (inner layer region) from the depth of 100  $\mu\text{m}$  from the surface to a center position of 1/2 of the sheet thickness was observed by the method described above.

[0161] In addition, test pieces with a 60 mm square for a bending test were taken from hat bottom of the hat members, and a bending test was performed in accordance with VDA 238-100 of the Verband der Automobilindustrie standard. The test piece was bent so that the bending ridge direction was perpendicular to the rolling direction of the steel sheet for hot stamping, and the bending angle (VDA bending angle) at the time when the bending load decreased by 60 N from the highest point was determined. When a cracking occurred before the bending load reached its highest point, the bending angle at the time the cracking occurred was determined and defined as the VDA bending angle.

[0162] In a case where the tensile strength of the steel sheet constituting the hot-stamp formed body was less than 2300 MPa, when the VDA bending angle was 60° or more, it was determined as having excellent deformability and successful. In addition, in a case where the tensile strength was 2300 MPa or more, when the VDA bending angle was 40° or more, it was determined as having excellent deformability and successful. When these conditions were not satisfied, it was determined as not having excellent deformability and not successful.

[0163] In addition, test pieces with a width of 6 mm and a length of 68 mm for a hydrogen embrittlement test were taken from the hat bottom of the hat members, and a four-point bending hydrochloric acid immersion test was performed. The test piece was immersed in hydrochloric acid at pH 4 while various stresses were applied to the test piece, and it was examined whether cracking would occur within 72 hours.

[0164] In a case where the tensile strength of the steel sheet constituting the hot-stamp formed body was less than 2300 MPa, when no cracking occurred with the applied stress of 1400 MPa, it was determined as having excellent hydrogen embrittlement resistance and successful. In addition, in a case where the tensile strength was 2300 MPa or more, when no cracking occurred with the applied stress of 900 MPa, it was determined as having excellent hydrogen embrittlement resistance and successful. When these conditions were not satisfied, it was determined as not having excellent hydrogen embrittlement resistance and not successful. Examples that were determined as successful were written as "OK" in Tables, and examples that were determined as not successful were written as "NG" in Tables.

[0165] 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, the results of evaluation of the deformability of the hot-stamp formed body, and the results of evaluation of the hydrogen embrittlement resistance of the hot-stamp formed body.

[0166] 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.

[Table 1]

Steel	Chemical composition (mass%) remainder: Fe and impurities													Ac <sub>3</sub> point (°C)	Notes	
	C*	Si	Mn	P	S	sol. Al	N	O	B	Cr	Mo	Ti	Nb			Others
A	0.31	0.23	0.94	0.010	0.0006	0.048	0.0044	0.0013	0.0021	0.33	-	0.022	0.045		805	Comparative steel
B	0.36	0.50	0.48	0.008	0.0006	0.043	0.0039	0.0012	0.0026	0.54	-	0.024	0.026		815	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	0.49	0.38	0.40	0.008	0.0006	0.045	0.0032	0.0017	0.0023	0.34	0.20	0.020	0.019		800	Steel of pre-sent invention
E	0.50	0.15	0.79	0.009	0.0005	0.043	0.0028	0.0013	0.0025	-	0.11	0.018	0.020		777	Steel of pre-sent invention
F	0.50	0.17	1.29	0.010	0.0006	0.042	0.0036	0.0015	0.0023	0.22	0.13	0.026	0.040		767	Comparative steel
G	0.72	0.01	0.45	0.008	0.0007	0.043	0.0018	0.0016	0.0020	-	0.05	-	-		741	Comparative steel
H	0.45	0.13	0.52	0.010	0.0006	0.047	0.0046	0.0015	0.0002	-	-	-	0.048		783	Comparative steel
I	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
J	0.46	0.26	0.78	0.011	0.0004	0.045	0.0032	0.0015	0.0026	0.20	0.20	0.020	-	V:0.044 Zr:0.020	802	Steel of pre-sent invention
K	0.49	0.37	0.38	0.009	0.0005	0.045	0.0032	0.0015	0.0025	-	0.25	0.021	0.019	Cu:0.31 Ni:0.17	801	Steel of pre-sent invention
L	0.49	0.17	0.79	0.009	0.0004	0.048	0.0037	0.0014	0.0023	0.19	0.12	0.019	0.019	Ca:0.0006 Mg:0.0003 REM:0.0007	783	Steel of pre-sent invention
M	0.50	0.01	0.78	0.008	0.0006	0.049	0.0036	0.0017	0.0023	0.20	0.16	0.019	0.018	Bi:0.0025	773	Steel of pre-sent invention
N	0.49	0.28	0.44	0.010	0.0007	0.052	0.0030	0.0013	0.0025	0.17	0.21	0.020	0.018	W:0.29	804	Steel of pre-sent invention

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Steel	Chemical composition (mass%) remainder: Fe and impurities											Ac <sub>3</sub> point (°C)	Notes			
	C*	Si	Mn	P	S	sol. Al	N	O	B	Cr	Mo			Ti	Nb	Others
O	0.50	0.07	0.92	0.011	0.0006	0.050	0.0039	0.0012	0.0024	0.09	0.10	0.018	0.021	Sr:0.175 As:0.003	772	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.

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[Table 2A]

5	Test No.	Steel	Annealing conditions			B concentration distribution in steel sheet for hot stamping			Notes
			Soaking temperature (°C)	Residence time in temperature range of 700 °C or higher and lower than "Ac <sub>3</sub> 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	
10	1	A	750	376	-5	0.0016	0.0021	0.762	Comparative example
15	2	B	740	373	-10	0.0021	0.0026	0.808	Present invention example
20	3	B	740	433	-10	0.0020	0.0026	0.769	Present invention example
25	4	B	740	373	-15	0.0022	0.0026	0.846	Present invention example
30	5	B	705	<u>342</u>	<u>-25</u>	0.0023	0.0026	<u>0.885</u>	Comparative example
35	6	B	740	<u>713</u>	-5	0.0017	0.0026	0.654	Comparative example
40	7	C	750	376	-5	0.0016	0.0020	0.800	Present invention example
45	8	C	750	376	-10	0.0017	0.0020	0.850	Present invention example
50	9	C	750	376	<u>15</u>	0.0018	0.0020	<u>0.900</u>	Comparative example
55	10	D	730	370	-5	0.0016	0.0023	0.696	Present invention example
	11	D	730	370	-15	0.0018	0.0023	0.783	Present invention example
	12	D	730	370	-20	0.0019	0.0023	0.826	Present invention example
	13	D	<u>680</u>	<u>0</u>	-15	0.0020	0.0023	<u>0.870</u>	Comparative example
	14	E	730	370	-5	0.0018	0.0025	0.720	Present invention example

The underline indicates that the manufacturing condition is not preferable.

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[Table 2B]

5	Test No.	Steel	Annealing conditions			B concentration distribution in steel sheet for hot stamping			Notes
			Soaking temperature (°C)	Residence time in temperature range of 700 °C or higher and lower than "Ac <sub>3</sub> 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	
15	15	E	730	370	-10	0.0020	0.0025	0.800	Present invention example
20	16	E	730	370	<u>-40</u>	0.0023	0.0025	<u>0.920</u>	Comparative example
25	17	<u>F</u>	730	370	-10	0.0019	0.0023	0.826	Comparative example
30	18	<u>G</u>	710	363	-15	0.0017	0.0020	0.850	Comparative example
35	19	<u>H</u>	740	403	-5	0.0001	0.0002	0.500	Comparative example
40	20	<u>I</u>	740	373	-10	0.0017	0.0020	0.850	Comparative example
45	21	J	740	403	-10	0.0019	0.0026	0.731	Present invention example
50	22	K	740	403	-10	0.0018	0.0025	0.720	Present invention example
55	23	L	740	403	-10	0.0017	0.0023	0.739	Present invention example
	24	M	740	403	-10	0.0017	0.0023	0.739	Present invention example
	25	N	740	403	-10	0.0018	0.0025	0.720	Present invention example
	26	O	740	403	-10	0.0019	0.0024	0.792	Present invention example
	27	K	710	363	-10	0.0021	0.0025	0.840	Present invention example
	28	N	740	403	-10	0.0018	0.0025	0.720	Present invention example

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(continued)

Test No.	Steel	Annealing conditions			B concentration distribution in steel sheet for hot stamping			Notes
		Soaking temperature (°C)	Residence time in temperature range of 700 °C or higher and lower than "Ac <sub>3</sub> 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	
29	N	710	363	<u>5</u>	0.0022	0.0025	<u>0.880</u>	Comparative example

The underline indicates that the manufacturing condition is not preferable.

[Table 3]

Test No.	Steel	Hot stamping conditions			Blasting conditions	Notes
		Heating temperature (°C)	Retention time (s)	Air ratio	Almen arc height value (mmN)	
<u>1</u>	<u>A</u>	970	380	0.83	0.25	Comparative example
2	B	960	<u>60</u>	0.83	0.25	Comparative example
3	B	960	390	0.83	0.25	Present invention example
4	B	960	390	0.83	<u>0.10</u>	Comparative example
<u>5</u>	B	960	390	0.83	0.25	Comparative example
<u>6</u>	B	970	390	0.83	0.25	Comparative example
7	C	960	370	0.83	0.25	Present invention example
8	C	960	370	<u>1.10</u>	0.25	Comparative example
<u>9</u>	C	960	370	0.83	0.25	Comparative example
10	D	960	370	0.83	0.25	Present invention example
11	D	<u>870</u>	390	0.83	0.25	Comparative example
12	D	960	390	0.83	<u>0.15</u>	Comparative example
<u>13</u>	D	960	390	0.83	0.25	Comparative example
14	E	970	390	0.83	0.25	Present invention example
15	E	970	390	<u>1.10</u>	0.25	Comparative example
<u>16</u>	E	970	390	0.83	0.25	Comparative example
<u>17</u>	<u>F</u>	960	370	0.83	0.25	Comparative example
<u>18</u>	<u>G</u>	960	370	0.83	0.25	Comparative example
<u>19</u>	H	960	370	0.83	0.25	Comparative example
<u>20</u>	I	<u>960</u>	370	0.83	0.25	Comparative example
21	J	960	370	0.83	0.22	Present invention example
22	K	960	370	0.83	0.25	Present invention example
23	L	960	370	0.83	0.22	Present invention example
24	M	960	370	0.83	0.22	Present invention example
25	N	960	370	0.83	0.25	Present invention example

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(continued)

Test No.	Steel	Hot stamping conditions			Blasting conditions	Notes
		Heating temperature (°C)	Retention time (s)	Air ratio	Almen arc height value (mmN)	
26	O	960	370	0.83	0.22	Present invention example
27	K	960	<u>330</u>	0.83	0.25	Comparative example
28	N	960	370	0.81	0.25	Present invention example
29	N	960	370	0.83	0.25	Comparative example

The underline indicates that the manufacturing condition is not preferable.

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[Table 4A]

Test No.	Steel	Hot-stamp formed body							Notes	
		Chemical composition C content (mass%)	C: Average B concentration in surface layer region (mass%)	Average O concentration in region vicinity surface (mass%)	D: B concentration at position of depth of 100 μm from surface (mass%)	C/E	Tensile strength (MPa)	VDA bending angle (°)		Hydrogen embrittlement resistance
1	A	<u>0.30</u>	0.0003	2.383	0.0019	0.158	<u>1820</u>	78	OK	Comparative example
2	B	0.35	0.0019	2.864	0.0025	<u>0.760</u>	2059	<u>55</u>	NG	Comparative example
3	B	0.33	0.0004	3.323	0.0023	0.174	1987	74	OK	Present invention example
4	B	0.34	0.0005	5.504	0.0023	0.217	1995	71	NG	Comparative example
5	B	0.34	0.0018	2.995	0.0024	<u>0.750</u>	2050	<u>58</u>	NG	Comparative example
6	B	<u>0.31</u>	0.0002	3.367	0.0022	0.091	<u>1861</u>	79	OK	Comparative example
7	C	0.35	0.0005	2.251	0.0019	0.263	2092	67	OK	Present invention example
8	C	0.35	0.0016	2.069	0.0020	<u>0.800</u>	2122	<u>59</u>	NG	Comparative example
9	C	0.36	0.0017	1.838	0.0020	<u>0.850</u>	2170	<u>56</u>	NG	Comparative example
10	D	0.45	0.0005	2.656	0.0020	0.250	2459	47	OK	Present invention example
11	D	0.46	0.0015	2.412	0.0021	<u>0.714</u>	2485	<u>38</u>	NG	Comparative example
<u>12</u>	D	0.42	0.0006	<u>4.982</u>	0.0020	0.300	2467	45	NG	Comparative example
<u>13</u>	D	0.47	0.0016	2.337	0.0022	<u>0.727</u>	2503	<u>31</u>	NG	Comparative example
14	E	0.47	0.0005	1.854	0.0023	0.217	2516	46	OK	Present invention example

The underline indicates that it is outside the scope of the present invention, or me characteristic value is not preferable.

[Table 4B]

Test No.	Steel	Hot-stamp formed body							Notes	
		Chemical composition C content (mass%)	C: Average B concentration in surface layer region (mass%)	Average O concentration in region vicinity surface (mass%)	D: B concentration at position of depth of 100 μm from surface (mass%)	C/E	Tensile strength (MPa)	VDA bending angle (°)		Hydrogen embrittlement resistance
15	E	0.48	0.0017	1.602	0.0024	0.708	2544	36	NG	Comparative example
16	E	0.49	0.0019	1.688	0.0024	0.792	2568	29	NG	Comparative example
17	F	0.48	0.0015	1.523	0.0022	0.682	2524	42	NG	Comparative example
18	G	0.71	0.0012	1.804	0.0019	0.632	-	16	NG	Comparative example
19	H	0.44	0.0001	2.311	0.0002	0.500	1852	68	OK	Comparative example
20	I	0.35	0.0007	2.637	0.0019	0.368	1883	66	OK	Comparative example
21	J	0.43	0.0006	2.463	0.0024	0.250	2378	49	OK	Present invention example
22	K	0.46	0.0004	2.435	0.0023	0.174	2488	46	OK	Present invention example
23	L	0.46	0.0005	2.499	0.0021	0.238	2502	44	OK	Present invention example
24	M	0.47	0.0007	2.212	0.0022	0.318	2514	43	OK	Present invention example
25	N	0.46	0.0005	2.506	0.0023	0.217	2480	46	OK	Present invention example
26	O	0.48	0.0012	1.933	0.0023	0.522	2551	42	OK	Present invention example
27	K	0.47	0.0017	2.548	0.0024	0.708	2513	37	NG	Comparative example
28	N	0.46	0.0004	2.322	0.0022	0.182	2462	47	OK	Present invention example
29	N	0.48	0.0018	2.415	0.0024	0.750	2510	30	NG	Comparative example

The underline indicates that it is outside the scope of the present invention, or the characteristic value is not preferable.

[0167] 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 O concentration in region vicinity the surface was low, and the hydrogen embrittlement resistance and the deformability were excellent. Note that 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] On the other hand, in the comparative examples (Test Nos. 1, 6, 19 and 20) 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, B 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.

[0169] In Test No. 17, since the Mn content was too high, the hydrogen embrittlement resistance of the hot-stamp formed body was inferior.

[0170] In Test No. 18, since the C content was too high, the hydrogen embrittlement resistance and the deformability of the hot-stamp formed body were 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 Nos. 2, 4, 5, 8, 9, 11 to 13, 15, 16, 27 and 29 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, the average B concentration in the surface layer region or the average O concentration in the region vicinity the surface became outside the invention range. Therefore, the hydrogen embrittlement resistance and/or the deformability was inferior.

[Industrial Applicability]

[0172] 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 hydrogen embrittlement resistance and deformability.

## 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% or more and less than 1.00%;

P: 0.200% or less;

S: 0.0200% or less;

sol. Al: 0.001% to 1.000%;

N: 0.0200% or less;

O: 0.0200% or less;

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,

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an average B concentration in a region from a depth of 5  $\mu\text{m}$  from a surface of the steel sheet to a depth of 25  $\mu\text{m}$  from the surface is 0.700 times or less than a B concentration at a position of a depth of 100  $\mu\text{m}$  from the surface, an average O concentration in a region from the surface to a depth of 0.5  $\mu\text{m}$  from the surface is 4.000 mass% or less.

- 5
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:

10 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%;  
15 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%;  
20 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%.

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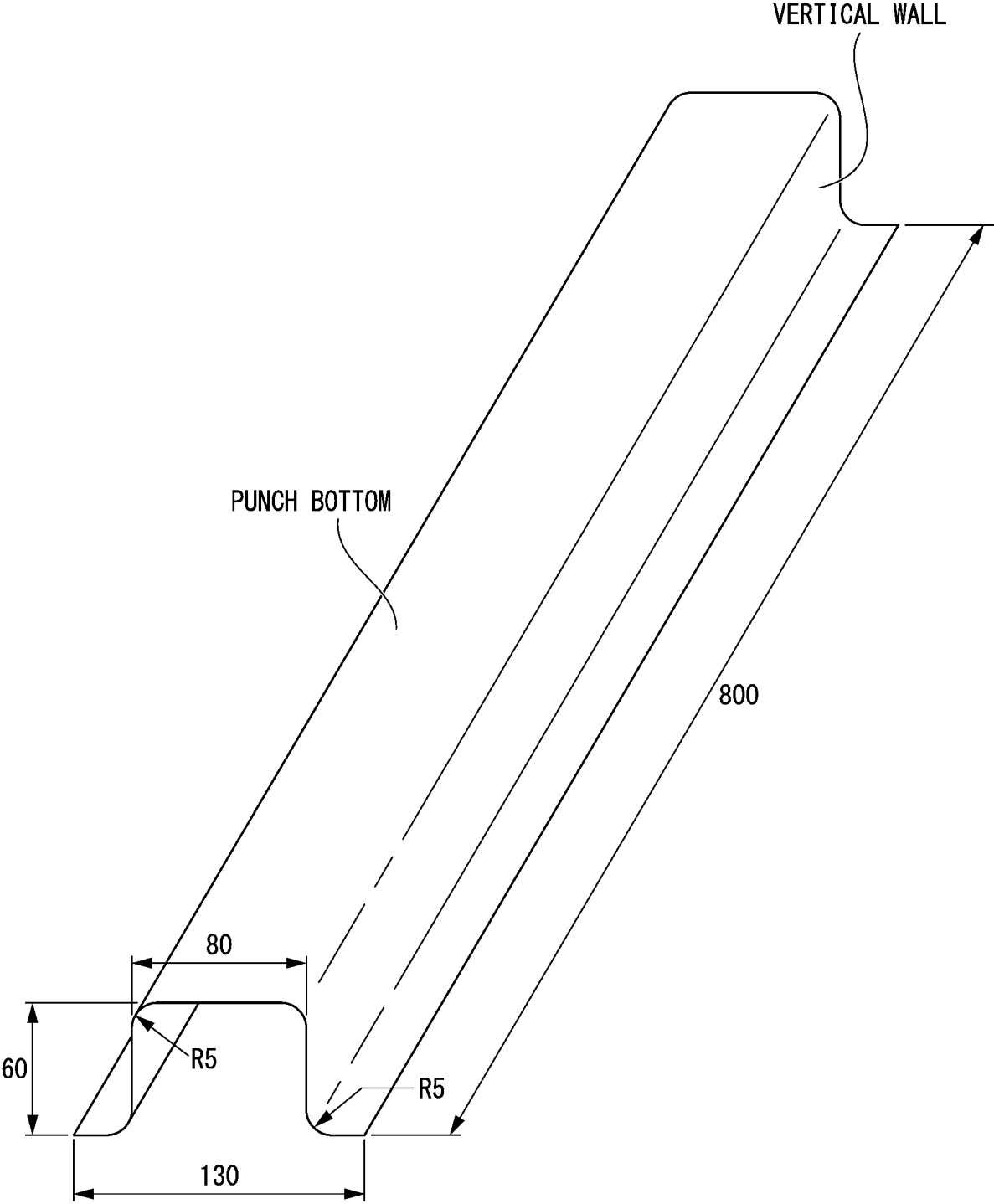
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FIG. 1



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/013800

5	<b>A. CLASSIFICATION OF SUBJECT MATTER</b>	
	<p><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 38/54</i>(2006.01)i            FI: C22C38/00 301Z; C21D1/18 C; C21D9/00 A; C21D9/46 G; C22C38/00 301S; C22C38/54; B21D22/20 E; B21D22/20 H</p>	
10	According to International Patent Classification (IPC) or to both national classification and IPC	
	<b>B. FIELDS SEARCHED</b>	
	Minimum documentation searched (classification system followed by classification symbols) C22C38/00-38/60; B21D22/20; C21D1/18; C21D9/00; C21D9/46	
15	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	
20	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)	
	<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>	
	Category*	Citation of document, with indication, where appropriate, of the relevant passages
25	A	WO 2022/044510 A1 (JFE STEEL CORP.) 03 March 2022 (2022-03-03) claims, paragraphs [0011], [0012]
	A	JP 2014-118613 A (NIPPON STEEL & SUMITOMO METAL CORP.) 30 June 2014 (2014-06-30) claims, paragraph [0018], tables 1-4
30	A	JP 2006-152427 A (SUMITOMO METAL INDUSTRIES, LTD.) 15 June 2006 (2006-06-15) claims, paragraphs [0006]-[0008], [0035]
	A	JP 2009-228134 A (NIPPON STEEL CORP.) 08 October 2009 (2009-10-08) claims, paragraphs [0011]-[0013], tables 1, 2
35	A	WO 2019/003449 A1 (JFE STEEL CORP.) 03 January 2019 (2019-01-03) claims
40	<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.	
45	* 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
50	Date of the actual completion of the international search <b>15 June 2023</b>	Date of mailing of the international search report <b>27 June 2023</b>
55	Name and mailing address of the ISA/JP <b>Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan</b>	Authorized officer  Telephone No.

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INTERNATIONAL SEARCH REPORT  
Information on patent family members

International application No.  
**PCT/JP2023/013800**

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		JP 7028378 B1	
JP 2014-118613 A	30 June 2014	(Family: none)	
JP 2006-152427 A	15 June 2006	(Family: none)	
JP 2009-228134 A	08 October 2009	(Family: none)	
WO 2019/003449 A1	03 January 2019	EP 3647447 A1 claims	
		US 2020/0131597 A1	
		CN 110799662 A	
		WO 2019/003541 A1	

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**REFERENCES CITED IN THE DESCRIPTION**

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- JP 2010150612 A [0009]
- WO 2019003445 A [0009]