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(54) HOT-STAMP-FORMED ARTICLE

(57) This hot-stamping formed body has a predetermined chemical composition, in a surface layer region, an area ratio of bainite of more than 10%, a maximum value of pole density of a texture of 4.0 or less, and a deboronization index of 0.05 or more.

Description

[Technical Field of the Invention]

[0001] The present invention relates to a hot-stamping formed body.

[0002] Priority is claimed on Japanese Patent Application No. 2022-067023, filed April 14, 2022, the content of which is incorporated herein by reference.

[Background Art]

[0003] In recent years, there has been a demand for a reduction in a weight of a vehicle body for a vehicle in terms of environmental protection and resource saving, and a high-strength steel sheet has been applied to vehicle members. Vehicle members are manufactured by press forming, but not only a forming load is increased but also the formability deteriorates as the strength of a steel sheet is increased. For this reason, the formability of a high-strength steel sheet into a member having a complicated shape becomes an issue.

[0004] In order to solve this issue, the application of a hot stamping technique in which press forming is performed after a steel sheet is heated up to a high temperature of an austenite range where the steel sheet softens is in progress. Hot stamping is attracting attention as a technique that achieves both the formability of a steel sheet into a vehicle member and strength of a vehicle member by performing hardening of the steel sheet in a die at the same time as press working.

[0005] For example, Patent Document 1 discloses an electrolytic zinc-based plated steel sheet having a high yield ratio and excellent bendability, in which the critical hydrogen amount in the steel is 0.20 mass ppm or less.

[Prior Art Document]

[Patent Document]

[0006] [Patent Document 1] PCT International Publication No. WO2020/079925

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0007] In order to make vehicle members lighter, it is effective to make the microstructure of steel sheets a microstructure in which martensite with a high dislocation density is a main phase. However, in a microstructure whose main phase is martensite with a high dislocation density, since a trap amount of hydrogen irrupting from the outside increases, hydrogen embrittlement cracking more likely to be occurred in vehicle members.

[0008] Hydrogen embrittlement cracking is a phenomenon in which a steel member, to which high stress is applied in use, suddenly fractures due to hydrogen which is irrupted into the steel from an external environment. This phenomenon is also called delayed fracture due to the mode of the occurrence of fracture. It is generally known that hydrogen embrittlement cracking is more likely to occur in the steel sheet as tensile strength of the steel sheet increases. It is considered that this is because the higher tensile strength of the steel sheet, the greater residual stress in the steel sheet after a component is formed. This susceptibility to hydrogen embrittlement cracking (delayed fracture) is called hydrogen embrittlement resistance.

[0009] In Patent Document 1, bendability is considered, but hydrogen embrittlement resistance are not considered.

[0010] The present invention has been made in view of the above-mentioned problem. An object of the present invention is to provide a hot-stamping formed body having high strength and excellent hydrogen embrittlement resistance.

[Means for Solving the Problem]

[0011] The gist of the present invention is as follows.

[1] A hot-stamping formed body according to an aspect of the present invention comprising, as a chemical composition, by mass%:

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 3.000%;
Mn: 0.10% or more and less than 0.60%;
P: 0.100% or less;

S: 0.0100% or less;
N: 0.0200% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.5000%;
Nb: 0.0010% to 0.1000%;
Ti: 0.010% to 0.200%;
Cr: 0.010% to 0.800%;
Mo: 0.0010% to 1.0000%;
B: 0.0005% to 0.0200%;
Co: 0% to 4.00%;
Ni: 0% to 3.00%;
Cu: 0% to 3.00%;
V: 0% to 3.00%;
W: 0% to 3.00%;
Ca: 0% to 1.0000%;
Mg: 0% to 1.0000%;
REM: 0% to 1.0000%;
Sb: 0% to 1.000%;
Sn: 0% to 1.000%;
Zr: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder: Fe and impurities,
in a surface layer region, which is a region from a surface of the hot-stamping formed body to 1/25 depth of a sheet thickness from the surface,
an area ratio of bainite is more than 10%,
a maximum value of pole density of a texture is 4.0 or less, and
a deboronization index is 0.05 or more.

[2] The hot-stamping formed body according to [1] may comprise, as the chemical composition, by mass%, one or more selected from the group consisting of:

Co: 0.01% to 4.00%;
Ni: 0.01% to 3.00%;
Cu: 0.01% to 3.00%;
V: 0.01% to 3.00%;
W: 0.01% to 3.00%;
Ca: 0.0001% to 1.0000%;
Mg: 0.0001% to 1.0000%;
REM: 0.0001% to 1.0000%;
Sb: 0.001% to 1.000%;
Sn: 0.001% to 1.000%;
Zr: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

[Effects of the Invention]

[0012] According to the above-described aspects of the present invention, it is possible to provide a hot-stamping formed body having high strength and excellent hydrogen embrittlement resistance.

[Brief Description of the Drawings]

[0013] [Fig. 1] A figure explaining the method to obtain a deboronization index.

[Embodiments of the Invention]

[0014] The present inventors found that in a surface layer region, by generating a desired amount of bainite, creating a texture with a desired crystal orientation, and achieving a desired deboronization index, hydrogen embrittlement resistance of the hot-stamping formed body can be improved.

[0015] The present inventors found that in order to obtain a hot-stamping formed body having the above features, it is particularly effective to perform annealing under a desired condition during manufacturing a steel sheet for hot stamping.

[0016] Hereinafter, the hot-stamping formed body according to the present embodiment will be described in detail. First, the reason the chemical composition of the hot-stamping formed body according to the present embodiment is limited will be described.

[0017] 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 percentages (%) related to the chemical composition mean mass%.

[0018] The hot-stamped formed body according to the present embodiment comprises, as a chemical composition, by mass%, C: more than 0.40% and 0.70% or less, Si: 0.010% to 3.000%, Mn: 0.10% or more and less than 0.60%, P: 0.100% or less, S: 0.0100% or less, N: 0.0200% or less, O: 0.0200% or less, Al: 0.0010% to 0.5000%, Nb: 0.0010% to 0.1000%, Ti: 0.010% to 0.200%, Cr: 0.010% to 0.800%, Mo: 0.0010% to 1.0000%, B: 0.0005% to 0.0200%, and a remainder: Fe and impurities. Each element will be described below.

C: more than 0.40% and 0.70% or less

[0019] C is an element that improves the strength of the hot-stamping formed body. When the C content is 0.40% or less, a desired strength of the hot-stamping formed body cannot be obtained. For this reason, the C content is set to more than 0.40%. The C content is preferably 0.42% or more or 0.44% or more.

[0020] Meanwhile, when the C content is more than 0.70%, since an amount of hydrogen trapped in martensite increases, a desired hydrogen embrittlement resistance cannot be obtained. For this reason, the C content is set to 0.70% or less. The C content is preferably 0.65% or less or 0.60% or less.

Si: 0.010% to 3.000%

[0021] Si is an element that improves strength of the hot-stamping formed body by solid-solution strengthening. When the Si content is less than 0.010%, a desired strength cannot be obtained. For this reason, the Si content is set to 0.010% or more. The Si content is preferably 0.050% or more, 0.100% or more or 0.150% or more.

[0022] Meanwhile, when the Si content is more than 3.000%, the amount of ferrite increases and a desired microstructure cannot be obtained. For this reason, the Si content is set to 3.000% or less. The Si content is preferably 2.000% or less, 1.000% or less or 0.600% or less.

Mn: 0.10% or more and less than 0.60%

[0023] Mn is an element that increases strength of the hot-stamping formed body by increasing the hardenability of steel. In order to obtain a desired strength, the Mn content is set to 0.10% or more. The Mn content is preferably 0.20% or more or 0.25% or more.

[0024] Meanwhile, when the Mn content is 0.60% or more, a desired texture cannot be obtained. For this reason, the Mn content is set to less than 0.60%. The Mn content is preferably 0.55% or less, 0.50% or less or 0.45% or less.

P: 0.100% or less

[0025] P is an impurity element, and decreases strength of the grain boundaries by segregating in the grain boundaries. This deteriorates hydrogen embrittlement resistance of the hot-stamping formed body. When the P content is more than 0.100%, the above effects become significant. For this reason, the P content is set to 0.100% or less. The P content is preferably 0.050% or less or 0.010% or less.

[0026] The lower limit of the P content is not particularly limited, but may be 0%. However, when the P content is reduced to less than 0.0001%, the dephosphorization cost increases significantly, which is not preferable economically. For this reason, the P content may be set to 0.0001% or more, 0.001% or more or 0.005% or more.

S: 0.0100% or less

[0027] S is an impurity element, and forms inclusions in steel. The inclusions trap a large amount of hydrogen and form a region with locally high hydrogen concentration, and thereby deteriorate hydrogen embrittlement resistance of the hot-stamping formed body. When the S content is more than 0.100%, the above effects become significant. For this reason, the S content is set to 0.0100% or less. The S content is preferably 0.0080% or less, 0.0050% or less or 0.0030% or less.

[0028] The lower limit of the S content is not particularly limited, but may be 0%. However, when the S content is reduced to less than 0.0001%, the desulfurization cost increases significantly, which is not preferable economically. For this reason, the S content may be set to 0.0001% or more, 0.0002% or more, 0.0003% or more or 0.0010% or more.

N: 0.0200% or less

[0029] N is an impurity element, and forms nitrides in steel. The nitrides trap a large amount of hydrogen and form a region with locally high hydrogen concentration, and thereby deteriorate hydrogen embrittlement resistance of the hot-stamping formed body. When the N content is more than 0.0200%, the above effects become significant. For this reason, the N content is set to 0.0200% or less. The N content is preferably 0.0150% or less, 0.0100% or less, 0.0060% or less or 0.0040% or less.

[0030] The lower limit of the N content is not particularly limited, but may be 0%. However, when the N content is reduced to less than 0.0001%, the denitrification cost increases significantly, which is not preferable economically. For this reason, the N content may be set to 0.0001% or more or 0.0010% or more.

O: 0.0200% or less

[0031] O forms coarse oxides when a large amount of O is comprised in steel. The oxides trap a large amount of hydrogen and form a region with locally high hydrogen concentration, and thereby deteriorate hydrogen embrittlement resistance of the hot-stamping formed body. When the O content is more than 0.0200%, the above effects become significant. For this reason, the O content is set to 0.0200% or less. The O content is preferably 0.0100% or less, 0.0070% or less or 0.0040% or less.

[0032] The O content may be 0%, in order to disperse many oxides during deoxidizing of molten steel, the O content may be set to 0.0005% or more or 0.0010% or more.

Al: 0.0010% to 0.5000%

[0033] Al is an element having an effect of deoxidizing molten steel and achieving soundness of the steel. When the Al content is less than 0.0010%, deoxidation is not sufficiently performed, and coarse oxides are generated. The oxides trap a large amount of hydrogen and form a region with locally high hydrogen concentration, and thereby deteriorate hydrogen embrittlement resistance of the hot-stamping formed body. For these reasons, the Al content is set to 0.0010% or more. The Al content is preferably 0.0050% or more, 0.0100% or more or 0.0300% or more.

[0034] Meanwhile, when the Al content is more than 0.5000%, coarse oxides are generated in steel. The oxides trap a large amount of hydrogen and form a region with locally high hydrogen concentration, and thereby deteriorate hydrogen embrittlement resistance of the hot-stamping formed body. For this reason, the Al content is set to 0.5000% or less. The Al content is preferably 0.4000% or less, 0.3000% or less, or 0.2000% or less or 0.1000% or less.

Nb: 0.0010% to 0.1000%

[0035] Nb is an element that forms carbonitride in steel and improves strength of the hot-stamping formed body by precipitation strengthening. When the Nb content is less than 0.0010%, a desired strength cannot be obtained. For this reason, the Nb content is set to 0.0010% or more. The Nb content is preferably 0.0050% or more, 0.0090% or more or 0.0150% or more.

[0036] Meanwhile, when the Nb content is more than 0.1000%, many carbonitrides are generated in steel, and hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the Nb content is set to 0.1000% or less. The Nb content is preferably 0.0800% or less or 0.0600% or less.

Ti: 0.010% to 0.200%

[0037] Ti is an element that forms carbonitride in steel and improves strength of the hot-stamping formed body by precipitation strengthening. When the Ti content is less than 0.010%, a desired strength cannot be obtained. For this reason, the Ti content is set to 0.010% or more. The Ti content is preferably 0.020% or more or 0.025% or more.

[0038] Meanwhile, when the Ti content is more than 0.200%, many coarse carbonitrides are generated in steel, the carbonitrides become sites with local increase of hydrogen concentration, and thereby hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the Ti content is set to 0.200% or less. The Ti content is preferably 0.150% or less, 0.090% or less, 0.080% or less, 0.070% or less, 0.060% or less or 0.050% or less.

Cr: 0.010% to 0.800%

[0039] Cr is an element that increases strength of the hot-stamping formed body by dissolving in prior austenite grains during heating before hot stamping. When the Cr content is less than 0.010%, a desired strength cannot be obtained. For this reason, the Cr content is set to 0.010% or more. The Cr content is preferably 0.100% or more, 0.150% or more or 0.200% or more.

[0040] Meanwhile, when the Cr content is more than 0.800%, a desired texture cannot be obtained in the hot-stamping formed body and hydrogen embrittlement resistance deteriorates. For this reason, the Cr content is set to 0.800% or less. The Cr content is preferably 0.700% or less, 0.500% or less or 0.400% or less.

Mo: 0.0010% to 1.0000%

[0041] Mo is an element that increases strength of the hot-stamping formed body by dissolving in prior austenite grains during heating before hot stamping. When the Mo content is less than 0.0010%, a desired strength cannot be obtained. For this reason, the Mo content is set to 0.0010% or more. The Mo content is preferably 0.0100% or more, 0.0500% or more or 0.1000% or more.

[0042] Meanwhile, when the Mo content is more than 1.0000%, a desired texture cannot be obtained in the hot-stamping formed body and hydrogen embrittlement resistance deteriorates. For this reason, the Mo content is set to 1.0000% or less. The Mo content is preferably 0.8000% or less, 0.6000% or less or 0.4000% or less.

B: 0.0005% to 0.0200%

[0043] B is an element that improves the hardenability of steel. When the B content is less than 0.0005%, a desired strength cannot be obtained. For this reason, the B content is set to 0.0005% or more. The B content is preferably 0.0010% or more or 0.0015% or more.

[0044] Meanwhile, when the B content is more than 0.0200%, coarse intermetallic compounds are generated in the hot-stamping formed body, the intermetallic compounds become sites with local increase of hydrogen concentration, and thereby hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the B content is set to 0.0200% or less. The B content is preferably 0.0150% or less, 0.0100% or less, 0.0080% or less, 0.0040% or less or 0.0030% or less.

[0045] The remainder of the chemical composition of the hot-stamping formed body 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-stamping formed body according to the present embodiment do not deteriorate are exemplary examples of the impurities.

[0046] The hot-stamping formed body may comprise the following elements as optional elements. The content of the following optional elements obtained in a case where the following optional elements are not contained is 0%.

Co: 0% to 4.00%

[0047] Co is an element that improves strength of the hot-stamping formed body by solid-solution strengthening. In order to reliably obtain the effect, it is preferable that the Co content be set to 0.01% or more. The Co content is more preferably set to 0.05% or more.

[0048] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Co content is set to 4.00% or less. If necessary, the upper limit of Co content may be set to 1.00%, 0.50%, 0.10%, 0.05% or 0.02%.

Ni: 0% to 3.00%

[0049] Ni has an effect of increasing strength of the hot-stamping formed body by dissolving in prior austenite grains during heating before hot stamping. In order to reliably obtain the effect, the Ni content is preferably set to 0.01% or more.

[0050] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Ni content is preferably set to 3.00% or less. If necessary, the upper limit of Ni content may be set to 1.50%, 1.00%, 0.50%, 0.10%, 0.05% or 0.02%.

Cu: 0% to 3.00%

[0051] Cu has an effect of increasing strength of the hot-stamping formed body by dissolving in prior austenite grains during heating before hot stamping. In order to reliably obtain the effect, the Cu content is preferably set to 0.01% or more. The Cu content is more preferably set to 0.05% or more.

[0052] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Cu content is preferably set to 3.00% or less. If necessary, the upper limit of Cu content may be set to 1.50%, 1.00%, 0.50%, 0.10%, 0.05% or 0.02%.

V: 0% to 3.00%

[0053] V has an effect of forming carbonitride in steel and improves strength of the hot-stamping formed body by precipitation strengthening. In order to reliably obtain the effect, the V content is preferably set to 0.01% or more. The V content is more preferably set to 0.05% or more.

[0054] Meanwhile, when the V content is more than 3.00%, many coarse carbonitrides are generated in steel. The carbonitrides become sites with local increase in hydrogen concentration, and thereby hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the V content is set to 3.00% or less. If necessary, the upper limit of V content may be set to 1.50%, 1.00%, 0.50%, 0.10%, 0.05% or 0.02%.

W: 0% to 3.00%

[0055] W has an effect of improving strength of the hot-stamping formed body. In order to reliably obtain the effects, the W content is preferably set to 0.01% or more. The W content is preferably set to 0.05% or more.

[0056] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the W content is preferably set to 3.00% or less. If necessary, the upper limit of W content may be set to 1.50%, 1.00%, 0.50%, 0.10%, 0.05% or 0.02%.

Ca: 0% to 1.0000%

[0057] Ca is an element that suppresses generation of carbides that become starting points for fracture, and contributes to improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the Ca content is preferably set to 0.0001% or more.

[0058] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Ca content is set to 1.0000% or less. If necessary, the upper limit of Ca content may be set to 0.1000%, 0.0100%, 0.0050%, 0.0010%, 0.0005% or 0.0002%.

Mg: 0% to 1.000%

[0059] Mg forms oxides and sulfides in molten steel, suppresses formation of a coarse MnS, disperses a lot of fine oxides, miniaturizes the microstructure. This contributes to improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain these effects, the Mg content is preferably set to 0.0001% or more.

[0060] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Mg content is set to 1.0000% or less. If necessary, the upper limit of Mg content may be set to 0.1000%, 0.0100%, 0.0050%, 0.0010%, 0.0005% or 0.0002%.

REM: 0% to 1.000%

[0061] REM suppresses generation of coarse oxides that become sites with local increase of hydrogen concentration. This contributes improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the REM content is preferably set to 0.0001% or more.

[0062] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the REM content is set to 1.0000% or less. If necessary, the upper limit of REM content may be set to 0.1000%, 0.0100%, 0.0050%, 0.0010%, 0.0005% or 0.0002%.

[0063] 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.

Sb: 0% to 1.000%

[0064] Sb suppresses generation of coarse oxides that become sites with local increase of hydrogen concentration. This contributes improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the Sb content is preferably set to 0.001% or more.

[0065] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Sb content is set to 1.000% or less. If necessary, the upper limit of Sb content may be set to 0.100%, 0.050%, 0.020%, 0.010%, 0.005% or 0.002%.

Sn: 0% to 1.000%

[0066] Sn suppresses generation of coarse oxides that become sites with local increase of hydrogen concentration. This contributes improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the Sn content is preferably set to 0.001% or more.
[0067] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Sn content is set to 1.000% or less. If necessary, the upper limit of Sn content may be set to 0.100%, 0.050%, 0.020%, 0.010%, 0.005% or 0.002%.

Zr: 0% to 1.000%

[0068] Zr suppresses generation of coarse oxides that become sites with local increase of hydrogen concentration. This contributes improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the Zr content is preferably set to 0.001% or more.
[0069] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the Zr content is set to 1.000% or less. If necessary, the upper limit of Zr content may be set to 0.100%, 0.050%, 0.020%, 0.010%, 0.005% or 0.002%.

As: 0% to 0.100%

[0070] As refines the prior austenite grains by lowering an austenite single-phase transformation temperature. This contributes improvement of hydrogen embrittlement resistance of the hot-stamping formed body. In order to reliably obtain the effect, the As content is preferably set to 0.001% or more.
[0071] Meanwhile, since the above effect will be saturated even if a large amount is comprised, the As content is set to 0.100% or less. If necessary, the upper limit of As content may be set to 0.100%, 0.050%, 0.020%, 0.010%, 0.005% or 0.002%.
[0072] The above-mentioned chemical composition of the hot-stamping formed body may be measured by a standard analysis method. For example, the chemical composition may be measured using inductively coupled plasma-atomic emission spectrometry (ICP-AES). C and S may be measured using a combustion-infrared absorption method, N may be measured using an inert gas fusion-thermal conductivity method, and O may be measured using an inert gas fusion-nondispersive infrared absorption method.
[0073] When a plating layer or a coating film is provided on the surface of the hot-stamping formed body, the chemical composition is analyzed after the plating layer or the coating film is removed by mechanical grinding.
[0074] Next, the microstructure of the hot-stamping formed body according to the present embodiment will be described.
[0075] In the hot-stamping formed body according to the present embodiment, in a surface layer region, which is a region from a surface of the hot-stamping formed body to 1/25 depth of a sheet thickness (thickness of the hot-stamping formed body) from the surface, the area ratio of bainite is more than 10%, the maximum value of pole density of the texture is 4.0 or less, and the deboronization index is 0.05 or more.
[0076] The surface layer region in the present embodiment refers to a region between the surface of the hot-stamping formed body and 1/25 depth of the sheet thickness (thickness of the hot-stamping formed body) from the surface.
[0077] When the hot-stamping formed body has the plating layer or the coating film on the surface thereof, the "surface" refers to the interface of the plating layer or the coating film and the base steel sheet, and for convenience, the plating layer or the coating film is excluded from the hot-stamping formed body. Specifically, when the hot-stamping formed body has the plating layer or the coating film on the surface thereof, as described below, for convenience, a region where the Fe concentration is less than 90% by mass in GD-OES measurement, that is, the plating layer or the coating film is excluded from the hot-stamping formed body, the measuring point where the Fe concentration is 90% by mass (the interface of the base steel sheet and the plating layer) is regarded as the surface of the hot-stamping formed body. As described above, the plating layer or the coating film is excluded from the hot-stamping formed body, when the thickness of the plating layer or the coating film is very small compared to the sheet thickness (thickness) of the hot-stamping formed body and can be ignored (however, when only the plating layer is formed, the thickness of the plating layer is often very small and can be ignored in most cases), when measuring the sheet thickness (thickness) of the hot-stamping formed body, the sheet thickness (thickness) of the hot-stamping formed body may be regarded as the sheet thickness (thickness) including the plating layer or the coating film.

"Surface Layer Region"

Area ratio of bainite: more than 10%

[0078] By generating bainite in the surface layer region, dislocation density of the surface layer region can be decreased. As a result, irruption of hydrogen from the external environment can be suppressed, and hydrogen embrittlement resistance of the hot-stamping formed body can be improved. Furthermore, by generating bainite in the surface layer region, since excessive softening of the surface layer can be suppressed, hydrogen embrittlement resistance can be further improved while maintaining a load bearing of the member. When the area ratio of bainite in the surface layer region is 10% or less, hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the area ratio of bainite is set to more than 10%, preferably 20% or more, 40% or more or 60% or more.

[0079] The upper limit of the area ratio of bainite is not particularly limited, but may be set to 100%, 90% or 80%.

[0080] In the microstructure of the surface layer region, except for bainite, martensite of 0% to 90% (0% or more and 90% or less), ferrite and residual austenite of 0% to 65% (0% or more and 65% or less) may be included. Martensite in the present embodiment includes untempered martensite (fresh martensite) and tempered martensite.

[0081] The area ratio of the microstructure is calculated for the surface layer region (the region from the surface to 1/25 depth of the sheet thickness from the surface) by the following method.

[0082] A sample is cut out from an arbitrary position away from an end surface of the hot-stamping formed body by a distance of 50 mm or more (a position that avoids an end portion in a case where a sample cannot be collected at this position) so that a sheet thickness cross section parallel to the rolling direction can be observed. The size of the sample depends on a measurement device, but is set to a size that can be observed by about 10 mm in the rolling direction.

[0083] After polishing the cross section of the sample using silicon carbide paper of #600 to #1500, the cross section is mirror-finished using liquid in which diamond powder having a grain size in the range of 1 μm to 6 μm is dispersed in a diluted solution of alcohol or the like or pure water. Next, the observation surface is finished by electrolytic polishing. At an arbitrary position on the cross section of the sample in a longitudinal direction, a region which has a length of 50 μm and is present between the surface of the hot-stamping formed body and 1/25 depth of the sheet thickness from the surface is measured at a measurement interval of 0.1 μm by an electron backscatter diffraction method, and thus, crystal orientation information is obtained. An EBSD analyzer composed of a Schottky emission scanning electron microscope and an EBSD detector may be used for measurement, for example, an EBSD analyzer composed of JSM-7001F manufactured by JEOL Ltd. and DVC 5-type detector manufactured by TSL Solutions may be used for measurement. In this case, the degree of vacuum in the EBSD analyzer may be set to 9.6×10^{-5} Pa or less, an accelerating voltage may be set to 15 kV, and an irradiation current level may be set to 13.

[0084] In the obtained crystal structure information, using the "Phase Map" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer, a region where a crystal structure is fcc is determined as residual austenite. The ratio of the residual austenite is calculated, thereby the area ratio of the residual austenite is obtained. Next, in the regions where the crystal structure is bcc, under the condition that boundary with 5° is regarded as the grain boundary, using the "Grain Average Misorientation" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer, regions where a grain average misorientation is more than 0.50° and 0.75° or lower are extracted as bainite. By calculating the area ratio of the extracted bainite, the area ratio of bainite is obtained.

[0085] Subsequently, the region where "Grain Average Misorientation" is 0.5° or lower is extracted as ferrite. By calculating the area ratio of the extracted ferrite, the area ratio of ferrite is obtained. The remaining region (the region where "Grain Average Misorientation" is more than 0.75°) is extracted as martensite, and the area ratio thereof is calculated, thereby the area ratio of martensite is obtained.

[0086] In addition, in the present embodiment, the rolling direction of the hot-stamping formed body is determined by the following method.

[0087] First, a sample is cut out from an arbitrary position away from an end surface of the hot-stamping formed body by a distance of 50 mm or more so that a sheet thickness cross section parallel to a rolling direction can be observed. After finishing the cross section of the collected sample by mirror polishing, observations with an optical microscope at 100, 200, 500, and 1000 magnifications are performed respectively. Depending on the size of the inclusion, an observation result with an appropriate magnification that the size of the inclusion can be measured is selected. The observation area is width of 500 μm or more and full of the sheet thickness, and the areas with low brightness are determined to be inclusions. The observation may be performed at multiple fields when observing. Next, using the sheet thickness cross section initially observed by the above method as a reference, in the range of 0° to 180° with the sheet thickness direction as the axis, the cross-sectional observation of the plane parallel to the plane rotated in 5° increments is performed in the same way as the above method. The average values of the lengths of the long axes of the plurality of inclusions in each cross section are calculated respectively. The cross section in which the obtained average value of the length of the long axes of the inclusions is maximum is specified. A direction parallel to the longitudinal direction of the inclusion in the cross section is determined as the rolling direction.

"Surface Layer Region"

[0088] Crystal orientation in surface layer region: Maximum value of pole density of texture is 4.0 or less

[0089] By controlling the texture in the surface layer region, irruption of hydrogen from the external environment can be suppressed, and hydrogen embrittlement resistance of the hot-stamping formed body can be improved. When the maximum value of pole density of the texture in the surface layer region is more than 4.0, hydrogen embrittlement resistance of the hot-stamping formed body deteriorates. For this reason, the maximum value of pole density of the texture in the surface layer region is set to 4.0 or less, preferably 3.5 or less, 3.0 or less or 2.5 or less.

[0090] The lower limit of the pole density of the texture in the surface layer region is not particularly limited, but may be set to 1.0 or 1.2.

[0091] In the surface layer region (the region between the surface and 1/25 depth of the sheet thickness from the surface), the texture in the surface layer region is obtained by the following method.

[0092] A sample is cut out from an arbitrary position away from an end surface of the hot-stamping formed body by a distance of 50 mm or more (a position that avoids an end portion in a case where the sample cannot be collected at this position) so that a sheet thickness cross section parallel to a rolling direction can be observed. The size of the sample depends on a measurement device, but is set to a size that can be observed by about 10 mm in the rolling direction.

[0093] After polishing the cross section of the sample using silicon carbide paper of #600 to #1500, the cross section of the sample is mirror-finished using liquid in which diamond powder having a grain size in the range of 1 μm to 6 μm is dispersed in a diluted solution of alcohol or the like or pure water. Next, the observation surface is finished by electrolytic polishing. At an arbitrary position on the cross section of the sample in a longitudinal direction, a region which has a length of 1000 μm and is present between the surface and 1/25 depth of the sheet thickness from the surface is measured at a measurement interval of 5.0 μm by an electron backscatter diffraction method, and thus, crystal orientation information is obtained. An EBSD analyzer composed of a Schottky emission scanning electron microscope and an EBSD detector may be used for measurement, for example, an EBSD analyzer composed of JSM-7001F manufactured by JEOL Ltd. and DVC 5-type detector manufactured by TSL Solutions may be used for measurement. In this case, the degree of vacuum in the EBSD analyzer may be set to 9.6×10^{-5} Pa or less, an accelerating voltage may be set to 15 kV, and an irradiation current level may be set to 13.

[0094] By using the obtained crystal orientation information, using the "Texture" function installed in the software "OIM Analysis (registered trademark)" which is attached to the EBSD analyzer, intensity calculation is performed using a Harmonic Series Expansion for grains whose crystal structure is bcc. At this time, the expansion order is set to 16, and a half width when applied to a Gaussian distribution is set to 5°. Next, the "Texture Plot" function is used for the output file after the intensity calculation to output a $\varphi2=45°$ cross section in the orientation distribution function (ODF). The maximum value of the pole density in the $\varphi2=45°$ cross section is regarded as the maximum value of pole density of the texture in the surface layer region.

"Surface Layer Region"

Deboronization index: 0.05 or more

[0095] The deboronization index is an index that quantitatively represents the amount of decrease of the B concentration in the surface layer region. By decreasing the B concentration in the surface layer region, deformability of prior austenite grain is improved by reducing strength of prior austenite before transformation, and the generation of grains having random orientation is facilitated in the surface layer region. When the deboronization index in the surface layer region is less than 0.05, grains having a desired texture cannot be obtained in the surface layer region. For this reason, the deboronization index is set to 0.05 or more, preferably 0.20 or more, 0.30 or more or 0.35 or more.

[0096] The upper limit of the deboronization index is not particularly limited, but may be set to 1.00, 0.80 or 0.60.

[0097] The deboronization index in the surface layer region is obtained by the following method.

[0098] An element concentration distribution in the sheet thickness direction in the hot-stamping formed body is measured using glow discharge optical emission spectrometry (GD-OES: Manufactured by Horiba, Ltd., Marcus type high-frequency glow discharge optical emission spectrometer, GD-PROFILER-HR). The measurement conditions are an analysis diameter of 4 mmφ, a sputtering rate of 4 μm/min, an argon pressure of 600 Pa, an RF output of 35 W, and a measurement interval of 0.02 μm or less. All elements that are comprised in the hot-stamping formed body are measured.

[0099] In a case where the hot-stamping formed body has the plating layer on the surface, the "surface" refers to the interface of the plating layer and the base steel sheet. In a case where the hot-stamping formed body has the plating layer or the coating film on the surface, GD-OES measurement is performed after removing a part or all of the plating layer or the coating film by mechanical polishing or chemical polishing such that measurement to 200 μm depth from the surface of the base steel sheet (the interface of the plating layer and the base steel sheet) can be performed. In the GD-OES measurement, a measuring point where the Fe concentration becomes 90 mass% is regarded as the surface of the hot-stamping formed body. In addition, in the following description, for ease of explanation, the hot-stamping formed body may be referred to as a base steel sheet.

[0100] Next, B concentrations from the surface of the hot-stamping formed body to at least 100 μm depth from the surface are measured. After measuring the B concentration at a position of 100 μm depth from the surface, in a case where the absolute value of the difference between the average value of the B concentration in a region from 80 μm to 100 μm and the maximum value of the measured value of the B concentration in the region from 80 μm to 100 μm is 0.0006% by mass or less, and, in a case where the absolute value of the difference between the average value of the B concentration in the region from 80 μm to 100 μm and the minimum value of the measured value of the B concentration in the region from 80 μm to 100 μm is 0.0006% by mass or less, the measurement in the depth direction of the B concentration is finished at the position of 100 μm depth from the surface.

[0101] In a case where the requirements for ending the measurement are not satisfied, the measurement of the B concentration in the depth direction is continued. Then, each time a new B concentration measurement value is obtained in the depth direction, the average value of the B concentration in the region between the deepest part and 20 μm from the deepest part to the surface side is calculated. In a case where the absolute value of the difference between the average value of the B concentration in the region between the deepest part and 20 μm from the deepest part to the surface side and the maximum value of the measured value of the B concentration in the region between the deepest part and 20 μm from the deepest part to the surface side is 0.0006 mass% or less, and, in a case where the absolute value of the difference between the average value of the B concentration in the region between the deepest part and 20 μm from the deepest part to the surface side and the minimum value of the measured value of the B concentration in the region between the deepest part and 20 μm from the deepest part to the surface side is 0.0006 mass% or less, the measurement of the B concentration in the depth direction is finished at the position. For example, when the measured value of the B concentration at 150 μm depth from the surface is obtained, in a case where the absolute value of the difference between the average value of the B concentration in the region between 130 μm depth from the surface and 150 μm depth from the surface and the maximum value of the measured value of the B concentration in the region between 130 μm depth from the surface and 150 μm depth from the surface is 0.0006 mass% or less, and, in a case where the absolute value of the difference between the average value of the B concentration in the region between 130 μm depth from the surface and 150 μm depth from the surface and the minimum value of the measured value of the B concentration in the region between 130 μm depth from the surface and 150 μm depth from the surface is 0.0006 mass% or less, the measurement of the B concentration in the depth direction is finished at the position of 150 μm depth from the surface.

[0102] Even if the requirements for ending the measurement described above are not satisfied and the measurement of the B concentration in the depth direction cannot be finished, the measurement of the B concentration in the depth direction is finished when the measurement of the B concentration at the position of 200 μm depth from the surface is completed. Then, at the time when the measurement of the B concentration in the depth direction is finished, the average value of the B concentration in the region between the deepest part (the deepest position where the B concentration used for calculating the deboronization index was obtained) and the position of 20 μm from the deepest part to the surface side is used for the below calculation of the deboronization index (hereinafter, the average value of the B concentration in the region will be referred to as the average B concentration at the deepest part of 20 μm).

[0103] For convenience of measurement, for example, after measuring the B concentration to 200 μm depth from the surface, in a region between 100 μm and 200 μm from the surface, the shallowest depth position that satisfies the ending condition for the B concentration measurement in the depth direction is searched for, and in a case where the depth position is found, the deboronization index may be calculated without using the measurement results of the B concentration at the position deeper than the shallowest depth position. For example, the B concentration may be measured from the surface to 200 μm depth from the surface, in this case, in a case where a shallowest depth position that satisfies the ending condition for B concentration measurement in the depth direction exists in a region of 100 μm or more depth from the surface, the measurement is regarded as ending at the depth position, and the deboronization index is calculated.

[0104] In the region between the deepest part and 20 μm from the deepest part to the surface side of the hot-stamping formed body, the amount of decrease in the B concentration per unit depth (the value obtained by subtracting the B concentration at each measurement point from the average B concentration at the deepest part of 20 μm) is calculated, the integrated value of the product of the unit depth and the amount of decrease in the B concentration is calculated and determined as the area of the B-depletion region (area of region A in FIG. 1). However, when the value obtained by subtracting the B concentration at each measurement point from the average B concentration at the deepest part of 20 μm is negative, it is integrated as 0 (due to the B removal phenomenon near the surface, the B concentration at each measurement point is in most cases lower than the average B concentration at the deepest part of 20 μm, and the integrated value becomes positive). Next, the product of the average B concentration at the deepest part of 20 μm and the length of 200 μm is calculated as a reference area (area of rectangular region B in Fig. 1). The value obtained by dividing a B-depletion area (area of region A) by the reference area (area of region B) is defined as the deboronization index (area of region A/area of region B). Even in a case where the above-mentioned requirement for ending the measurement is satisfied in a region from the surface to 200 μm, the reference area (area of region B) is calculated by assuming that the length by which the average B concentration at the deepest part of 20 μm is multiplied is 200 μm.

[0105] The microstructure of a region other than the surface layer region (for example, the region between 4/16 depth of the sheet thickness from the surface of the hot-stamping formed body and 5/16 depth of the sheet thickness from the surface) is not particularly limited as long as a desired strength and hydrogen embrittlement resistance can be obtained, for example, in area%, the microstructure may consist of martensite and bainite of 90% to 100% (90% or more and 100% or less) in total, and ferrite and residual austenite of 0% to 10% (0% or more and 10% or less) in total.

[0106] The microstructure of a region other than the surface layer region is measured by the following method. Note that the microstructure in the region other than the surface layer region is measured from 1/8 depth of the sheet thickness from the surface to 3/8 depth of the sheet thickness from the surface. The reason is that the microstructure in this region shows a typical microstructure of the hot-stamping formed body.

[0107] A sample is cut out from an arbitrary position away from an end surface of the hot-stamping formed body by a distance of 50 mm or more (a position that avoids an end portion in a case where the sample cannot be collected at this position) so that a sheet thickness cross section parallel to the rolling direction can be observed. The size of the sample depends on a measurement device, but is set to a size that can be observed by about 10 mm in the rolling direction.

[0108] After polishing the cross section of the sample using silicon carbide paper of #600 to #1500, the cross section is mirror-finished using liquid in which diamond powder having a grain size in the range of 1 μm to 6 μm is dispersed in a diluted solution of alcohol or the like or pure water. Next, the observation surface is finished by electrolytic polishing. At an arbitrary position on the cross section of the sample in a longitudinal direction, a region which has a length of 50 μm and is present between 1/8 depth of the sheet thickness from the surface and 3/8 depth of the sheet thickness from the surface is measured at a measurement interval of 0.1 μm by an electron backscatter diffraction method, and thus, crystal orientation information is obtained. An EBSD analyzer composed of a Schottky emission scanning electron microscope and an EBSD detector may be used for measurement, for example, an EBSD analyzer composed of JSM-7001F manufactured by JEOL Ltd. and DVC 5-type detector manufactured by TSL Solutions may be used for measurement. In this case, the degree of vacuum in the EBSD analyzer may be set to 9.6×10^{-5} Pa or less, an accelerating voltage may be set to 15 kV, and an irradiation current level may be set to 13.

[0109] In the obtained crystal structure information, using "Phase Map" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer, a region where a crystal structure is fcc is determined as residual austenite. The area ratio of the residual austenite is calculated, thereby the area ratio of the residual austenite is obtained. Next, regions where the crystal structure is bcc is determined as bainite, martensite, and ferrite. In these regions, under the condition that boundary with 5° is regarded as the grain boundary, using "Grain Average Misorientation" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer, regions where a grain average misorientation is 0.5° or lower are extracted as ferrite. By calculating the area ratio of the extracted ferrite, the area ratio of ferrite is obtained.

[0110] Subsequently, the area ratio of the remaining region (the region where "Grain Average Misorientation" is more than 0.5°) is calculated, and this area ratio is determined as the total area ratio of martensite and bainite.

[0111] The hot-stamping formed body may have a plating layer on the surface. By having the plating layer on the surface, corrosion resistance can be improved after hot stamping. Examples of the plating layer include an aluminum plating layer, aluminum-galvanized layer, aluminum-silicon plating layer, hot-dip galvanized layer, electrogalvanized layer, galvannealed layer, zinc-nickel plating layer, aluminum-magnesium-zinc-based plating layer.

[0112] Next, a steel sheet for hot stamping for obtaining the hot-stamping formed body according to the present embodiment will be described.

[0113] The steel sheet for hot stamping has the above-described chemical composition. The microstructure of the steel sheet for hot stamping is not particularly limited as long as a desired strength and hydrogen embrittlement resistance are obtained after hot stamping, for example, in area%, the microstructure may consist of ferrite: 5% to 90%, bainite and martensite: 0% to 100%, pearlite: 10% to 95%, and residual austenite: 0% to 5%. In addition to these, iron carbides, alloy carbides, intermetallic compounds, and inclusions may be included.

[0114] Further, the steel sheet for hot stamping may have a plating layer on the surface. By having the plating layer on the surface, corrosion resistance can be improved after hot stamping. Examples of the plating layer include an aluminum plating layer, aluminum-galvanized layer, aluminum-silicon plating layer, hot-dip galvanized layer, electrogalvanized layer, galvannealed layer, zinc-nickel plating layer, aluminum-magnesium-zinc-based plating layer.

Manufacturing method of steel sheet for hot stamping

[0115] A manufacturing method to obtain the steel sheet for hot stamping for obtaining the hot-stamping formed body according to the present embodiment will be described. In order to obtain the above-described hot-stamping formed body, it is particularly effective to control the annealing condition in the manufacturing method of the steel sheet for hot stamping.

[0116] The casting method of molten steel, the conditions of heating before hot rolling, rough rolling, finish rolling, coiling, and cold rolling are not particularly limited, and may be standard conditions.

[0117] Furthermore, for the purpose of softening the hot-rolled steel sheet, a softening heat treatment may be performed on the coil after coiling. The softening heat treatment method is not particularly limited, and standard conditions may be adopted.

Annealing

[0118] After cold rolling, it is preferable to perform annealing to heat for 15 seconds or more in an oxidizing atmosphere. Generally, it is preferable to perform annealing in a reducing atmosphere in order to suppress formation of scale. However, in the present embodiment, formation of scale on the steel sheet surface is promoted by performing annealing in the oxidizing atmosphere. During heating of hot stamping, the scale formed on the steel sheet surface becomes an oxidation source, and C and B in the surface layer region are oxidized. Since oxidized C and B leave the surface layer of the steel sheet, the amounts of C and B are reduced in the surface layer region. As a result, the strength of the prior austenite grains decreases and they become easily deformed, and grains having random orientation are likely to be generated. Thereby, grains having a desired texture can be generated in the surface layer region.

[0119] The heating temperature during annealing may be set to a temperature range of 730°C to 900°C, and by staying in this heating temperature range for 15 seconds or more, formation of scale can be promoted while suppressing peeling of scale. The time for annealing is preferably 100 seconds or more, more preferably 200 seconds or more, and even more preferably 300 seconds or more. On the other hand, annealing for more than 3600 seconds is not preferable since the prior austenite grain sizes become coarser, the grain boundary diffusion rate of B decreases, removal of B does not proceed, and the deboronization index cannot be 0.05 or more. For this reason, the annealing time is preferably 3600 seconds or less.

[0120] After annealing in the oxidizing atmosphere, the annealing step may be performed again in an oxidizing atmosphere or a non-oxidizing atmosphere unless a treatment for removing oxide scale (for example, pickling) is performed.

[0121] In the present embodiment, the oxidizing atmosphere may be any heating atmosphere that generates oxide scale on the surface layer of the steel sheet, and may be a standard condition. For example, in a gas combustion atmosphere, it is preferable to create an atmosphere in which the mixture ratio of air and fuel (air-fuel ratio) is controlled to 1.00 or more, and more preferably controlled to 1.10 or more. It is preferable to generate an oxide scale of 15 μm or more on the steel sheet surface by annealing in the oxidizing atmosphere.

[0122] It is preferable that the oxide scale on the steel sheet surface remain in subsequent processes. That is, it is preferable to perform hot stamping, which will be described later, with the oxide scale remaining. Oxide scale is removed by shot blasting after hot stamping.

[0123] Furthermore, even when the plating layer is formed on the surface of the steel sheet for hot stamping, oxide scale remains at the interface between the base steel sheet and the plating layer. When the plating layer is formed, the oxide scale disappears after hot stamping due to an alloying reaction during heating before hot stamping.

Hot stamping

[0124] A hot-stamping formed body according to the present embodiment is obtained by hot stamping the steel sheet for hot stamping manufactured by the above-described method. The hot stamping conditions are not particularly limited. However, for example, it is preferable to heat the steel sheet for hot stamping to a temperature range of 800°C to 1000°C and hold in this temperature range for 60 to 1200 seconds.

[0125] When the heating temperature is lower than 800°C, austenitization becomes insufficient, and hydrogen embrittlement resistance may deteriorate or a desired strength may not be obtained in the hot-stamping formed body. On the other hand, when the heating temperature is higher than 1000°C, the grains of prior austenite grow excessively, and hydrogen embrittlement resistance may deteriorate or a desired strength may not be obtained in the hot-stamping formed body. When the holding time is shorter than 60 seconds, austenitization becomes insufficient, and hydrogen embrittlement resistance may deteriorate or a desired strength may not be obtained in the hot-stamping formed body. When the holding time is longer than 1200 seconds, grains of prior austenite grow excessively, and hydrogen embrittlement resistance may deteriorate or a desired strength may not be obtained in the hot-stamping formed body.

[0126] A heating atmosphere is not particularly limited, and may be standard conditions, for example, such as the atmosphere, a gas combustion atmosphere with a controlled ratio of air and fuel, or a nitrogen atmosphere, and the dew point of these gases may be controlled.

[0127] After holding in the temperature range, hot stamping is performed. After hot stamping, cooling may be performed to a temperature range of 250°C or lower at an average cooling rate of 20°C/s or faster.

[0128] Examples of heating methods before hot stamping include heating using an electric furnace and gas furnace, flame heating, electrical heating, high-frequency heating, and induction heating.

[0129] By the above methods, the hot-stamping formed body according to the present embodiment is obtained. A tempering treatment at 130°C to 600°C may be performed for softening after hot stamping, or a baking hardening treatment after painting may be performed. In addition, a portion of the hot-stamping formed body may be tempered by laser irradiation or the like to provide a partially softened region.

[Example]

[0130] 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.

[0131] Slabs manufactured by casting molten steel having a chemical composition shown in Tables 1A to 2C were heated, held in a temperature range of 1200°C or higher for 20 minutes or longer, and then subjected to rough rolling, finish rolling, cold rolling and coiling under standard conditions. And then, annealing was performed under the conditions shown in Tables 3A to 3C. Annealing was performed in an oxidizing atmosphere. In annealing in the oxidizing atmosphere, the mixture ratio of air and fuel (air-fuel ratio) was controlled to 1.05 in the gas combustion atmosphere.

[0132] The obtained steel sheets for hot stamping were heated to a temperature range shown in Tables 3A to 3C in a furnace continuously supplied with nitrogen gas (hot stamp heating), held in the temperature range, subjected to hot stamping, and then cooled to 250°C or lower at an average cooling rate of 20°C/s or faster. As a result, the hot-stamping formed bodies shown in Tables 4A to 4C were obtained.

[0133] However, for some examples, as described in the tables, re-annealing, plating, or heating treatment for softening were performed.

[0134] The underlines in the tables indicate that it is outside the scope of the present invention, falls outside the preferable manufacturing conditions, or the characteristic value is not preferable. In addition, other than bainite, the microstructure of the surface layer region of the hot-stamping formed bodies according to the present invention examples included, in area%, martensite of 90% or more, and ferrite and residual austenite of 65% or less in total. Furthermore, the microstructure in the region other than the surface layer region of the hot-stamping formed body according to the present invention examples consisted of, in area%, martensite and bainite of 90% or more in total, and ferrite and residual austenite of 10% or less in total.

[0135] Measurements of the microstructure, deboronization index, and pole density of the texture of the hot-stamping formed body were performed by the above-described methods. In addition, the mechanical properties of the hot-stamping formed body were evaluated by the following methods.

Tensile strength

[0136] The tensile (maximum) strength TS of the hot-stamping formed body was obtained, in accordance with JIS Z 2241:2011, by preparing a No. 5 test piece from an arbitrary position of the hot-stamping formed body and conducting a tensile test. The crosshead speed was set to 1 mm/min. When the tensile strength TS was 2200 MPa or more, it was determined as having high strength and successful, and when the tensile strength TS was less than 2200 MPa, it was determined as not having high strength and not successful.

Hydrogen embrittlement resistance

[0137] Hydrogen embrittlement resistance of the hot-stamping formed body was evaluated by the following method. A test piece with a length of 68 mm and a width of 6 mm was taken from an arbitrary position of the hot-stamping formed body, and the edges of the test piece were polished using silicon carbide paper of #200 to #1500, and then mirror finishing was performed using a liquid in which diamond powder with a particle size of 1 μm to 6 μm was dispersed in a diluent such as alcohol and pure water. Furthermore, the corners of the test piece were chamfered using silicon carbide paper of #200 to #1500. A stress of 800 MPa or more was applied to the test piece, the test piece was immersed in a liter of hydrochloric acid adjusted to pH 4 at room temperature for 48 hours, and the presence or absence of cracks was determined.

[0138] When no crack occurred under the load stress of 800 MPa or more, it was determined as successful. When no crack occurred at 800MPa, an evaluation of "Fair" was used in the tables, when no crack occurred at 900MPa, an evaluation of "Good" was used in the tables, when no crack occurred at 1000MPa, an evaluation of "Very Good" was used in the tables, and when no crack occurred at 1100MPa or higher, an evaluation of "Excellent" was used in the tables. On the other hand, when a crack occurred at a load stress of 800 MPa, it was determined as not successful and "Bad" was described in the tables.

[Table 1A]

Steel	Chemical composition (mass%) remainder being Fe and impurities													Notes
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	Cr	Mo	B	
1	0.46	0.430	0.42	0.009	0.0003	0.0035	0.0016	0.0440	0.0180	0.020	0.270	0.1900	0.0025	Steel of present invention
2	0.47	0.330	0.40	0.009	0.0008	0.0031	0.0017	0.0290	0.0470	0.020	0.410	0.1000	0.0019	Steel of present invention
3	0.41	0.282	0.46	0.013	0.0003	0.0030	0.0017	0.0424	0.0600	0.019	0.500	0.0500	0.0020	Steel of present invention
4	0.55	0.322	0.44	0.013	0.0002	0.0023	0.0020	0.0330	0.0286	0.015	0.500	0.0200	0.0025	Steel of present invention
5	0.69	0.400	0.46	0.012	0.0002	0.0030	0.0015	0.0600	0.0500	0.025	0.461	0.1500	0.0020	Steel of present invention
6	039	0.361	0.40	0.013	0.0005	0.0026	0.0019	0.0365	0.0600	0.025	0.230	0.1800	0.0027	Steel of present invention
7	0.72	0.200	0.42	0.013	0.0004	0.0024	0.0025	0.0600	0.0290	0.020	0.300	0.0500	0.0028	Comparative steel
8	0.47	0.015	0.50	0.012	0.0003	0.0024	0.0019	0.0424	0.0500	0.025	0.422	0.0950	0.0019	Comparative steel
9	0.47	1.290	0.50	0.010	0.0003	0.0026	0.0016	0.0482	0.0450	0.018	0.460	0.1000	0.0018	Steel of present invention
10	0.47	2.980	0.40	0.013	0.0004	0.0022	0.0017	0.0600	0.0290	0.015	0.304	0.0980	0.0021	Steel of present invention
11	0.41	0.004	0.42	0.013	0.0004	0.0034	0.0010	0.0380	0.0330	0.021	0.200	0.0200	0.0014	Comparative steel
12	0.47	3.050	0.40	0.011	0.0003	0.0024	0.0021	0.0420	0.0450	0.015	0.200	0.1000	0.0027	Comparative steel
13	0.47	0.322	0.10	0.014	0.0004	0.0024	0.0025	0.0365	0.0300	0.019	0.400	0.3000	0.0026	Steel of present invention
14	0.46	0.361	0.59	0.013	0.0003	0.0024	0.0021	0.0541	0.0208	0.023	0.500	0.1000	0.0024	Steel of present invention
15	0.42	0.420	0.05	0.008	0.0005	0.0037	0.0015	0.0330	0.0200	0.024	0.100	0.0300	0.0020	Comparative steel
16	0.45	0.280	0.65	0.013	0.0003	0.0030	0.0017	0.0420	0.0600	0.019	0.300	0.1500	0.0030	Comparative steel
17	0.46	0.361	0.42	0.095	0.0003	0.0028	0.0017	0.0365	0.0300	0.019	0.500	0.1900	0.0015	Steel of present invention
18	0.46	0.420	0.41	0.115	0.0004	0.0035	0.0014	0.0400	0.0200	0.020	0.280	0.1900	0.0025	Comparative steel
19	0.47	0.282	0.42	0.014	0.0098	0.0022	0.0023	0.0365	0.0290	0.023	0.200	0.1900	0.0020	Steel of present invention
20	0.46	0.430	0.40	0.010	0.0135	0.0033	0.0015	0.0400	0.0210	0.020	0.300	0.1900	0.0024	Comparative steel
21	0.45	0.400	0.44	0.014	0.0003	0.0193	0.0017	0.0541	0.0340	0.021	0.300	0.2000	0.0025	Steel of present invention
22	0.45	0.240	0.44	0.010	0.0003	0.0210	0.0015	0.0600	0.0520	0.021	0.460	0.1900	0.0027	Comparative steel
23	0.46	0.361	0.48	0.012	0.0003	0.0022	0.0194	0.0541	0.0522	0.019	0.500	0.2100	0.0021	Steel of present invention
24	0.46	0.400	0.46	0.010	0.0003	0.0020	0.0210	0.0300	0.0200	0.015	0.420	0.2000	0.0015	Comparative steel
25	0.45	0.322	0.40	0.013	0.0004	0.0020	0.0021	0.0018	0.0365	0.020	0.304	0.1900	0.0019	Steel of present invention

[0139] The underline indicates that it is outside the scope of the present invention.

[Table 1B]

Steel	Chemical composition (mass%) remainder being Fe and impurities													Notes
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	Cr	Mo	B	
26	0.46	0.330	0.50	0.012	0.0004	0.0033	0.0017	0.2950	0.0440	0.019	0.290	0.2000	0.0020	Steel of present invention
27	0.47	0.204	0.50	0.011	0.0005	0.0026	0.0021	0.4910	0.0350	0.020	0.300	0.2000	0.0023	Steel of present invention
28	0.46	0.330	0.48	0.011	0.0004	0.0035	0.0050	0.0006	0.0450	0.021	0.270	0.1900	0.0024	Comparative steel
29	0.45	0.280	0.48	0.011	0.0003	0.0022	0.0021	0.5200	0.0280	0.020	0.380	0.1950	0.0021	Comparative steel
30	0.45	0.282	0.44	0.013	0.0003	0.0028	0.0025	0.0424	0.0050	0.023	0.100	0.2000	0.0018	Steel of present invention
31	0.46	0.420	0.40	0.010	0.0004	0.0034	0.0018	0.0450	0.0950	0.020	0.290	0.1900	0.0027	Steel of present invention
32	0.41	0.300	0.40	0.011	0.0003	0.0028	0.0020	0.0330	0.0006	0.021	0.270	0.0600	0.0019	Comparative steel
33	0.46	0.400	0.42	0.011	0.0004	0.0027	0.0020	0.0330	0.1200	0.020	0.300	0.1000	0.0024	Comparative steel
34	0.46	0.282	0.48	0.014	0.0002	0.0020	0.0019	0.0541	0.0350	0.011	0.300	0.2000	0.0019	Steel of present invention
35	0.46	0.400	0.42	0.011	0.0004	0.0028	0.0020	0.0390	0.0190	0.064	0.270	0.1900	0.0028	Steel of present invention
36	0.45	0.361	0.48	0.012	0.0002	0.0026	0.0023	0.0310	0.0290	0.180	0.340	0.1800	0.0015	Steel of present invention
37	0.41	0.300	0.39	0.012	0.0005	0.0030	0.0025	0.0320	0.0200	0.006	0.300	0.0500	0.0023	Comparative steel
38	0.46	0.390	0.41	0.012	0.0006	0.0031	0.0018	0.0300	0.0410	0.210	0.300	0.2000	0.0027	Comparative steel
39	0.47	0.243	0.48	0.015	0.0004	0.0030	0.0017	0.0482	0.0500	0.020	0.015	0.2000	0.0025	Steel of present invention
40	0.46	0.361	0.44	0.012	0.0004	0.0030	0.0021	0.0430	0.0300	0.023	0.780	0.1900	0.0018	Steel of present invention
41	0.41	0.400	0.42	0.012	0.0005	0.0030	0.0023	0.0320	0.0190	0.020	0.004	0.0500	0.0019	Comparative steel
42	0.45	0.280	0.46	0.014	0.0002	0.0024	0.0025	0.0420	0.0200	0.020	0.870	0.1800	0.0025	Comparative steel
43	0.46	0.400	0.42	0.010	0.0003	0.0035	0.0016	0.0400	0.0220	0.022	0.400	0.0040	0.0020	Steel of present invention
44	0.46	0.400	0.43	0.011	0.0004	0.0034	0.0020	0.0380	0.0210	0.022	0.370	0.5000	0.0021	Steel of present invention
45	0.46	0.410	0.40	0.011	0.0003	0.0018	0.0019	0.0380	0.0210	0.022	0.380	0.9700	0.0015	Steel of present invention
46	0.42	0.350	0.42	0.010	0.0004	0.0026	0.0020	0.0330	0.0200	0.021	0.100	0.0008	0.0024	Comparative steel
47	0.46	0.420	0.40	0.010	0.0005	0.0023	0.0019	0.0300	0.0200	0.020	0.350	1.1000	0.0025	Comparative steel
48	0.46	0.322	0.40	0.012	0.0003	0.0026	0.0015	0.0482	0.0360	0.017	0.460	0.2000	0.0005	Steel of present invention
49	0.46	0.300	0.41	0.010	0.0003	0.0030	0.0017	0.0350	0.0270	0.020	0.400	0.1900	0.0105	Steel of present invention
50	0.46	0.300	0.42	0.010	0.0004	0.0031	0.0018	0.0340	0.0280	0.020	0.400	0.1900	0.0198	Steel of present invention

[0140] The underline indicates that it is outside the scope of the present invention.

[Table 1C]

Steel	Chemical composition (mass%) remainder being Fe and impurities													Notes
	C	Si	Mn	P	S	N	0	Al	Nb	Ti	Cr	Mo	B	
51	0.42	0.240	0.30	0.011	0.0005	0.0029	0.0018	0.0300	0.0290	0.020	0.100	0.1000	0.0002	Comparative steel
52	0.46	0.250	0.42	0.012	0.0005	0.0036	0.0019	0.0310	0.0300	0.021	0.300	0.2000	0.0210	Comparative steel
53	0.46	0.420	0.43	0.010	0.0003	0.0035	0.0016	0.0440	0.0180	0.020	0.270	0.1900	0.0029	Steel of present invention
54	0.46	0.420	0.43	0.011	0.0004	0.0034	0.0018	0.0400	0.0190	0.020	0.280	0.1900	0.0028	Steel of present invention
55	0.46	0.420	0.43	0.010	0.0003	0.0034	0.0019	0.0410	0.0200	0.020	0.280	0.1900	0.0027	Steel of present invention
56	0.46	0.430	0.43	0.010	0.0003	0.0034	0.0018	0.0400	0.0190	0.020	0.280	0.1900	0.0025	Steel of present invention
57	0.46	0.420	0.41	0.011	0.0004	0.0030	0.0020	0.0320	0.0200	0.020	0.290	0.1950	0.0023	Steel of present invention
58	0.46	0.420	0.41	0.011	0.0004	0.0030	0.0020	0.0330	0.0200	0.020	0.290	0.2000	0.0023	Steel of present invention
59	0.46	0.420	0.41	0.011	0.0004	0.0025	0.0020	0.0320	0.0200	0.020	0.290	0.2000	0.0024	Steel of present invention
60	0.46	0.420	0.41	0.011	0.0005	0.0024	0.0023	0.0330	0.0200	0.020	0.290	0.2000	0.0023	Steel of present invention
61	0.46	0.420	0.42	0.010	0.0004	0.0030	0.0020	0.0320	0.0200	0.020	0.290	0.2000	0.0025	Steel of present invention
62	0.46	0.400	0.41	0.010	0.0004	0.0030	0.0021	0.0330	0.0210	0.021	0.300	0.2000	0.0023	Steel of present invention
63	0.46	0.400	0.41	0.011	0.0003	0.0032	0.0020	0.0320	0.0200	0.020	0.290	0.1950	0.0027	Steel of present invention
64	0.46	0.420	0.41	0.011	0.0004	0.0029	0.0020	0.0320	0.0200	0.020	0.290	0.1950	0.0023	Steel of present invention

[0141] The underline indicates that it is outside the scope of the present invention.

[Table 2A]

Steel	Chemical composition (mass%) remainder being Fe and impurities												Notes
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Sn	Zr	As	
1													Steel of present invention
2													Steel of present invention
3													Steel of present invention
4													Steel of present invention
5													Steel of present invention
6													Comparative steel
7													Comparative steel
8													Steel of present invention
9													Steel of present invention
10													Steel of present invention
11													Comparative steel
12													Comparative steel
13													Steel of present invention
14													Steel of present invention
15													Comparative steel
16													Comparative steel
17													Steel of present invention
18													Comparative steel
19													Steel of present invention
20													Comparative steel
21													Steel of present invention
22													Comparative steel
23													Steel of present invention
24													Comparative steel
25													Steel of present invention

[Table 2B]

Steel	Chemical composition (mass%) remainder being Fe and impurities												Notes
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Sn	Zr	As	
26													Steel of present invention
27													Steel of present invention
28													Comparative steel
29													Comparative steel
30													Steel of present invention
31													Steel of present invention
32													Comparative steel
33													Comparative steel

(continued)

Steel	Chemical composition (mass%) remainder being Fe and impurities												Notes
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Sn	Zr	As	
34													Steel of present invention
35													Steel of present invention
36													Steel of present invention
37													Comparative steel
38													Comparative steel
39													Steel of present invention
40													Steel of present invention
41													Comparative steel
42													Comparative steel
43													Steel of present invention
44													Steel of present invention
45													Steel of present invention
46													Comparative steel
47													Comparative steel
48													Steel of present invention
49													Steel of present invention
50													Steel of present invention

[Table 2C]

Steel	Chemical composition (mass%) remainder being Fe and impurities												Notes
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Sn	Zr	As	
51													Comparative steel
52													Comparative steel
53	3.00												Steel of present invention
54		0.20											Steel of present invention
55			0.30										Steel of present invention
56				0.09									Steel of present invention
57					0.50								Steel of present invention
58						0.0055							Steel of present invention
59							0.0032						Steel of present invention
60								0.0046					Steel of present invention

(continued)

Steel	Chemical composition (mass%) remainder being Fe and impurities												Notes
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Sn	Zr	As	
61									0.050				Steel of present invention
62										0.051			Steel of present invention
63											0.080		Steel of present invention
64												0.004	Steel of present invention

[Table 3A]

Examination No.	Steel	Annealing		Hot stamping		Notes	Notes
		Annealing temperature °C	Annealing time s	Heating temperature °C	Holding time s		
1	1	800	600	900	120		Present invention example
2	2	800	600	900	120		Present invention example
3	3	800	600	900	120		Present invention example
4	4	800	600	900	120	Softening heat treatment on coil after coiling	Present invention example
5	5	780	200	850	120	Softening heat treatment on coil after coiling	Present invention example
6	6	800	650	900	150		Comparative example
7	7	780	200	850	120		Comparative example
8	8	800	600	900	120	Galvannealed plating	Present invention example
9	9	800	600	900	120		Present invention example
10	10	840	600	990	200		Present invention example
11	11	800	600	900	120		Comparative example
12	12	800	600	900	120		Comparative example
13	13	800	600	900	120		Present invention example
14	14	800	600	900	120	Re-annealing	Present invention example
15	15	800	600	900	120		Comparative example
16	16	800	600	900	120		Comparative example
17	17	800	600	900	120		Present invention example
18	18	800	600	900	120		Comparative example
19	19	800	600	900	120		Present invention example
20	20	800	600	900	120		Comparative example
21	21	800	600	900	120		Present invention example
22	22	800	600	900	120		Comparative example
23	23	800	600	900	120	Electrogalvanized plating	Present invention example
24	24	800	600	900	120		Comparative example
25	25	800	600	900	120		Present invention example

The underline indicates that it falls outside the preferable manufacturing conditions.

[Table 3B]

Examination No.	Steel	Annealing		Hot stamping		Notes	Notes
		Annealing temperature °C	Annealing time s	Heating temperature °C	Holding time s		
26	26	800	600	900	120		Present invention example
27	27	800	600	900	120		Present invention example
28	28	800	600	900	120		Comparative example
29	29	800	300	900	120		Comparative example
30	30	800	600	900	120		Present invention example
31	31	800	600	900	120		Present invention example
32	32	800	600	900	120		Comparative example
33	33	800	600	900	120		Comparative example
34	34	800	600	900	120		Present invention example
35	35	800	600	900	120		Present invention example
36	36	800	600	900	120		Present invention example
37	37	800	600	900	120		Comparative example
38	38	800	600	900	120		Comparative example
39	39	800	600	900	120		Present invention example
40	40	800	600	900	120	Softening heat treatment on coil after coiling	Present invention example
41	41	800	600	900	120		Comparative example
42	42	800	600	900	120		Comparative example
43	43	800	600	900	120		Present invention example
44	44	800	600	900	120		Present invention example
45	45	800	600	900	120	Softening heat treatment on coil after coiling	Present invention example
46	46	800	600	900	120		Comparative example
47	47	800	600	900	120		Comparative example
48	48	800	600	900	120		Present invention example
49	49	800	600	900	120	Aluminum-galvanized plating	Present invention example
50	50	800	600	900	120		Present invention example

The underline indicates that it falls outside the preferable manufacturing conditions.

[Table 3C]

Examination No.	Steel	Annealing		Hot stamping		Notes	Notes
		Annealing temperature °C	Annealing time s	Heating temperature °C	Holding time s		
51	51	800	600	900	120		Comparative example
52	52	800	600	900	120		Comparative example
53	53	800	600	900	120		Present invention example
54	54	800	600	900	120	Aluminum-silicon plating	Present invention example
55	55	800	600	900	120	Aluminum plating	Present invention example
56	56	800	600	900	120		Present invention example
57	57	800	600	900	120	Aluminum-magnesium-zinc plating	Present invention example
58	58	800	600	900	120		Present invention example
59	59	800	600	900	120		Present invention example
60	60	800	600	900	120		Present invention example
61	61	800	600	900	120	Galvannealed plating	Present invention example
62	62	800	600	900	120		Present invention example
63	63	800	600	900	120	Zinc-nickel plating	Present invention example
64	64	800	600	900	120		Present invention example
65	1	750	600	900	120		Present invention example
66	1	900	600	900	120		Present invention example
67	1	680	600	900	120		Comparative example
68	1	1000	600	900	120		Comparative example
69	1	800	20	900	120		Present invention example
70	1	780	10	900	120		Comparative example
71	1	800	300	820	120		Present invention example
72	1	800	600	1000	120		Present invention example
73	1	800	600	750	120		Comparative example
74	1	800	600	1100	120		Comparative example
75	1	800	600	900	60		Present invention example
76	1	800	600	900	1100		Present invention example
77	1	800	300	900	30		Comparative example
78	1	800	600	900	1300		Comparative example
79	1	800	600	900	120	Annealing in reducing atmosphere, Hot-stamping in atmosphere	Comparative example
80	56	800	600	900	120	Annealing in reducing atmosphere, Hot-stamping in atmosphere	Comparative example
81	1	800	600	900	120	Hot-stamping in atmosphere	Present invention example
82	56	800	600	900	120	Hot-stamping in atmosphere	Present invention example
83	1	800	3700	900	120		Comparative example

The underline indicates that it falls outside the preferable manufacturing conditions.

[Table 4A]

Examination No.	Steel	Surface layer region			Tensile strength MPa	Evaluation of hydrogen embrittlement resistance	Notes
		Bainite area %	Maximum value of pole density of texture -	Deboronization index -			
1	1	22	2.6	0.45	2412	Excellent	Present invention example
2	2	30	2.4	0.47	2426	Excellent	Present invention example
3	3	68	1.7	0.47	2245	Excellent	Present invention example
4	4	72	2.7	0.45	2705	Good	Present invention example
5	5	85	3.2	0.40	3136	Fair	Present invention example
6	6	35	1.6	0.48	2124	Excellent	Comparative example
7	7	90	4.1	0.30	2458	Bad	Comparative example
8	8	25	2.2	0.46	2374	Excellent	Present invention example
9	9	45	2.4	0.44	2463	Excellent	Present invention example
10	10	60	1.2	0.64	2404	Excellent	Present invention example
11	11	9	2.0	0.45	2098	Excellent	Comparative example
12	12	5	1.9	0.48	2178	Bad	Comparative example
13	13	50	2.0	0.48	2228	Excellent	Present invention example
14	14	65	3.8	0.47	2478	Good	Present invention example
15	15	15	1.5	0.48	2011	Excellent	Comparative example
16	16	70	4.8	0.45	2407	Bad	Comparative example
17	17	38	3.2	0.44	2439	Fair	Present invention example
18	18	35	3.0	0.44	2412	Bad	Comparative example
19	19	47	2.5	0.46	2451	Fair	Present invention example
20	20	45	2.4	0.46	2430	Bad	Comparative example
21	21	42	2.3	0.47	2409	Good	Present invention example
22	22	40	2.5	0.45	2387	Bad	Comparative example
23	23	38	2.9	0.44	2439	Fair	Present invention example
24	24	35	2.7	0.45	2411	Bad	Comparative example
25	25	40	3.0	0.42	2451	Good	Present invention example

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

[Table 4B]

Examination No.	Steel	Surface layer region			Tensile strength MPa	Evaluation of hydrogen embrittlement resistance	Notes
		Bainite area %	Maximum value of pole density of texture -	Deboronization index -			
26	26	29	2.8	0.46	2426	Excellent	Present invention example
27	27	30	3.0	0.45	2437	Very Good	Present invention example
28	28	41	3.1	0.40	2460	Bad	Comparative example
29	29	25	3.1	0.35	2444	Bad	Comparative example
30	30	38	2.0	0.34	2380	Good	Present invention example
31	31	25	2.9	0.48	2452	Very Good	Present invention example
32	32	60	1.6	0.45	2155	Excellent	Comparative example
33	33	32	3.2	0.49	2478	Bad	Comparative example
34	34	28	2.8	0.45	2440	Excellent	Present invention example
35	35	31	2.9	0.45	2456	Excellent	Present invention example
36	36	30	2.7	0.46	2418	Very Good	Present invention example
37	37	60	1.5	0.46	2178	Excellent	Comparative example
38	38	45	3.2	0.45	2432	Bad	Comparative example
39	39	40	2.8	0.47	2450	Excellent	Present invention example
40	40	60	3.7	0.44	2479	Good	Present invention example
41	41	8	1.6	0.45	2021	Excellent	Comparative example
42	42	65	4.3	0.44	2490	Bad	Comparative example
43	43	14	1.9	0.46	2325	Excellent	Present invention example
44	44	48	2.8	0.45	2468	Very Good	Present invention example
45	45	70	3.9	0.44	2508	Fair	Present invention example
46	46	10	1.5	0.45	2048	Excellent	Comparative example
47	47	75	4.2	0.44	2522	Bad	Comparative example
48	48	19	2.5	0.32	2419	Excellent	Present invention example
49	49	28	2.7	0.46	2434	Excellent	Present invention example
50	50	35	2.9	0.48	2452	Good	Present invention example

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

[Table 4C]

Examination No.	Steel	Surface layer region			Tensile strength MPa	Evaluation of hydrogen embrittlement resistance	Notes
		Bainite area %	Maximum value of pole density of texture -	Deboronization index -			
51	51	11	2.2	0.19	2189	Excellent	Comparative example
52	52	40	3.4	0.46	2421	Bad	Comparative example
53	53	24	2.6	0.46	2425	Excellent	Present invention example
54	54	28	2.4	0.46	2439	Very Good	Present invention example
55	55	26	2.5	0.47	2418	Very Good	Present invention example
56	56	27	2.7	0.45	2449	Excellent	Present invention example
58	58	25	2.8	0.45	2426	Very Good	Present invention example
59	59	23	2.5	0.45	2408	Excellent	Present invention example
60	60	20	2.3	0.46	2403	Excellent	Present invention example
61	61	22	2.5	0.44	2415	Excellent	Present invention example
62	62	25	2.5	0.45	2422	Excellent	Present invention example
63	63	26	2.4	0.44	2420	Excellent	Present invention example
64	64	26	2.4	0.45	2421	Excellent	Present invention example
65	65	28	2.5	0.46	2437	Excellent	Present invention example
65	1	20	2.7	0.28	2423	Very Good	Present invention example
66	1	15	2.4	0.54	2355	Excellent	Present invention example
67	1	6	5.4	0.10	2427	Bad	Comparative example
68	1	5	2.4	0.60	2179	Bad	Comparative example
69	1	15	3.7	0.11	2439	Good	Present invention example
70	1	9	4.2	0.03	2450	Bad	Comparative example
71	1	13	2.8	0.12	2473	Very Good	Present invention example
72	1	14	2.7	0.48	2258	Very Good	Present invention example
73	1	8	4.5	0.04	2185	Bad	Comparative example
74	1	7	2.7	0.49	2193	Bad	Comparative example
75	1	20	2.7	0.43	2459	Very Good	Present invention example
76	1	16	2.4	0.49	2238	Excellent	Present invention example
77	1	5	4.1	0.04	2178	Bad	Comparative example
78	1	6	2.6	0.48	2164	Bad	Comparative example
79	1	15	4.3	0.03	2455	Bad	Comparative example
80	56	20	4.5	0.04	2461	Bad	Comparative example
81	1	19	3.1	0.30	2426	Excellent	Present invention example
82	56	29	2.9	0.47	2463	Excellent	Present invention example
83	1	11	4.5	0.03	2302	Bad	Comparative example

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

[0142] From Tables 4A to 4C, it can be seen that the hot-stamping formed bodies according to the present invention examples had high strength and excellent hydrogen embrittlement resistance. On the other hand, it can be seen that in the hot-stamping formed bodies according to comparative examples, one of the properties deteriorated.

[Industrial Applicability]

[0143] According to the above-described aspects of the present invention, it is possible to provide a hot-stamping formed body having high strength and excellent hydrogen embrittlement resistance.

Claims

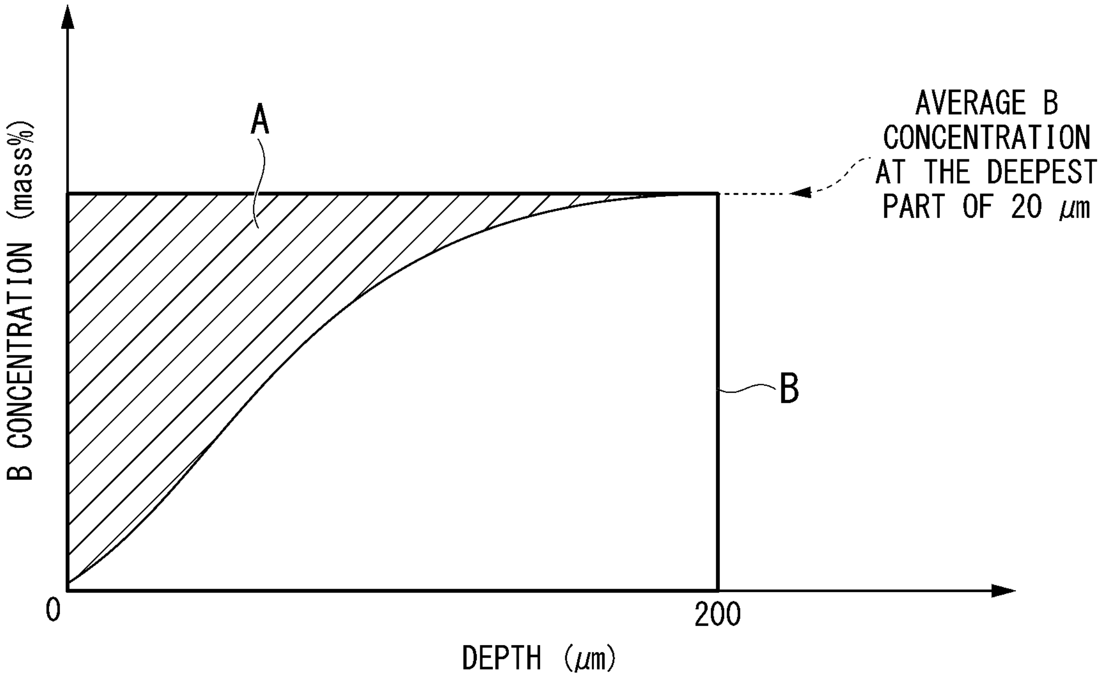
1. A hot-stamping formed body comprising, as a chemical composition, by mass%:

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 3.000%;
Mn: 0.10% or more and less than 0.60%;
P: 0.100% or less;
S: 0.0100% or less;
N: 0.0200% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.5000%;
Nb: 0.0010% to 0.1000%;
Ti: 0.010% to 0.200%;
Cr: 0.010% to 0.800%;
Mo: 0.0010% to 1.0000%;
B: 0.0005% to 0.0200%;
Co: 0% to 4.00%;
Ni: 0% to 3.00%;
Cu: 0% to 3.00%;
V: 0% to 3.00%;
W: 0% to 3.00%;
Ca: 0% to 1.0000%;
Mg: 0% to 1.0000%;
REM: 0% to 1.0000%;
Sb: 0% to 1.000%;
Sn: 0% to 1.000%;
Zr: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder: Fe and impurities,
in a surface layer region, which is a region from a surface of the hot-stamping formed body to 1/25 depth of a sheet thickness from the surface,
an area ratio of bainite is more than 10%,
a maximum value of pole density of a texture is 4.0 or less, and
a deboronization index is 0.05 or more.

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

Co: 0.01% to 4.00%;
Ni: 0.01% to 3.00%;
Cu: 0.01% to 3.00%;
V: 0.01% to 3.00%;
W: 0.01% to 3.00%;
Ca: 0.0001% to 1.0000%;
Mg: 0.0001% to 1.0000%;
REM: 0.0001% to 1.0000%;
Sb: 0.001% to 1.000%;
Sn: 0.001% to 1.000%;
Zr: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

FIG. 1


B CONCENTRATION (mass%)
A
AVERAGE B CONCENTRATION AT THE DEEPEST PART OF 20 μm
B
0
200
DEPTH (μm)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/007780

A. CLASSIFICATION OF SUBJECT MATTER

B21D 22/20(2006.01)i; ***C21D 9/00***(2006.01)i; ***C21D 9/46***(2006.01)i; ***C22C 38/00***(2006.01)i; ***C22C 38/60***(2006.01)i; ***C21D 1/18***(2006.01)i
FI: C22C38/00 301Z; C22C38/00 301S; C22C38/60; B21D22/20 E; B21D22/20 H; C21D1/18 C; C21D9/00 A; C21D9/46 G

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D22/20; C21D9/00; C21D9/46; C22C38/00; C22C38/60; C21D1/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2021/230150 A1 (NIPPON STEEL CORP.) 18 November 2021 (2021-11-18)	1-2
A	WO 2021/230149 A1 (NIPPON STEEL CORP.) 18 November 2021 (2021-11-18)	1-2
A	WO 2020/213179 A1 (NIPPON STEEL CORP.) 22 October 2020 (2020-10-22)	1-2

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

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"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
"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	"&" document member of the same patent family

Date of the actual completion of the international search **25 April 2023**	Date of mailing of the international search report **16 May 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/007780

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2021/230150 A1	18 November 2021	KR 10-2022-0129060 A CN 115135790 A EP 4151758 A1	
WO 2021/230149 A1	18 November 2021	KR 10-2022-0129061 A CN 115151669 A EP 4151757 A1	
WO 2020/213179 A1	22 October 2020	TW 202039881 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2022067023 A **[0002]**
- WO 2020079925 A **[0006]**