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(54) STEEL SHEET FOR HOT STAMPING AND HOT STAMPING MOLDED BODY

(57) This steel sheet for hot stamping has a predetermined chemical composition and has a microstructure in which $S_\alpha + S_{GB}$, which is a total of an area ratio S_α of ferrite and an area ratio S_{GB} of a granular bainite, is 10% or more and less than 50% and S_{GB}/S_α, which is a ratio between the area ratio S_{GB} of the granular bainite and the area ratio S_α of the ferrite, is 0.30 to 0.70. In addition, a hot-stamping formed body manufactured using this steel sheet for hot stamping has a predetermined chemical composition and a microstructure in which an average grain size of prior austenite grains is 5 to 25 μm, and a standard deviation of grain sizes of the prior austenite grains is 0.1 to 2.0 μm, and a tensile strength of the hot-stamping formed body is 2,200 MPa or more.

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Description

[Technical Field of the Invention]

[0001] The present invention relates to a steel sheet for hot stamping and a hot-stamping formed body.

[0002] Priority is claimed on Japanese Patent Application No. 2021-081620, filed May 13, 2021, the content of which is incorporated herein by reference.

[Background Art]

[0003] In the related art, from the viewpoint of global environmental problems and collision safety performance, thinning and high-strengthening of vehicle members have been required. In order to meet these demands, the number of vehicle members made of a high strength steel sheet as a material is increasing. In addition, as a forming method of a high strength steel sheet, a method called hot stamping is known. In the hot stamping, a high strength steel sheet is press-formed in a high temperature range of 700°C or higher and quenched inside or outside a press die. According to the hot stamping, since forming is performed in a high temperature range in which the strength of the steel sheet decreases, it is possible to suppress forming defects that occur in cold pressing. In addition, since a structure having martensite as a primary phase is obtained by quenching after forming, high strength can be obtained. For this reason, hot-stamping formed bodies having a tensile strength of about 1,500 MPa are widely used worldwide.

[0004] In order to obtain a higher effect of reducing the weight of a vehicle body from a vehicle member into which a high strength steel sheet is formed by hot stamping, it is necessary to obtain a member that has high strength and is also excellent in collision characteristics. In order to improve the collision characteristics of vehicle members, particularly, vehicle members are required to have excellent bendability.

[0005] Patent Document 1 discloses a hot-stamping formed body having a tensile strength of 1,900 MPa or more and capable of suppressing low-stress fracture and a manufacturing method thereof.

[0006] The present inventors found that, in a vehicle member having an improved tensile strength, it is necessary to further improve the bendability in order to obtain a higher effect of reducing the weight of a vehicle body.

[Prior Art Document]

[Patent Document]

[0007] [Patent Document 1] PCT International Publication No. WO2018/134874

[Non-Patent Document]

[0008] Non-Patent Document 1: Acta Materialia, 58 (2010), 6393-6403

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0009] 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 bendability, and a steel sheet for hot stamping capable of manufacturing this hot-stamping formed body.

[Means for Solving the Problem]

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

[1] A steel sheet for hot stamping according to an aspect of the present invention includes, as a chemical composition, by mass%:

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 1.30%;
Mn: more than 0.60% and 3.00% or less;
P: 0.100% or less;
S: 0.0100% or less;

N: 0.0130% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.500%;
Cr: 0.010% to 0.80%;
Nb: 0% to 0.100%;
Ti: 0% to 0.100%;
B: 0% to 0.0100%;
Mo: 0% to 1.00%;
Co: 0% to 2.00%;
Ni: 0% or more and less than 3.00%;
Cu: 0% to 1.00%;
V: 0% to 1.00%;
W: 0% to 1.000%;
Ca: 0% to 0.010%;
Mg: 0% to 1.000%;
REM: 0% to 1.000%;
Sb: 0% to 1.000%;
Zr: 0% to 1.000%;
Sn: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder including Fe and impurities,
in which the steel sheet for hot stamping has a microstructure in which $S_{\alpha} + S_{GB}$, which is a total of an area ratio S_{α} of ferrite and an area ratio S_{GB} of a granular bainite, is 10% or more and less than 50%, and S_{GB}/S_{α}, which is a ratio between the area ratio S_{GB} of the granular bainite and the area ratio S_{α} of the ferrite, is 0.30 to 0.70.

[2] The steel sheet for hot stamping according to [1], in which the steel sheet for hot stamping may contain, as the chemical composition, by mass%, one or more selected from the group consisting of:

Nb: 0.001 % to 0.100%;
Ti: 0.010% to 0.100%;
B: 0.0015% to 0.0100%;
Mo: 0.05% to 1.00%;
Co: 0.05% to 2.00%;
Ni: 0.01% or more and less than 3.00%;
Cu: 0.01% to 1.00%;
V: 0.01% to 1.00%;
W: 0.001 % to 1.000%;
Ca: 0.001% to 0.010%;
Mg: 0.001% to 1.000%;
REM: 0.001% to 1.000%;
Sb: 0.005% to 1.000%;
Zr: 0.001% to 1.000%;
Sn: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

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

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 1.30%;
Mn: more than 0.60% and 3.00% or less;
P: 0.100% or less;
S: 0.0100% or less;
N: 0.0130% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.500%;
Cr: 0.010% to 0.80%;

Nb: 0% to 0.100%;
Ti: 0% to 0.100%;
B: 0% to 0.0100%;
Mo: 0% to 1.00%;
Co: 0% to 2.00%;
Ni: 0% or more and less than 3.00%;
Cu: 0% to 1.00%;
V: 0% to 1.00%;
W: 0% to 1.000%;
Ca: 0% to 0.010%;
Mg: 0% to 1.000%;
REM: 0% to 1.000%;
Sb: 0% to 1.000%;
Zr: 0% to 1.000%;
Sn: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder including Fe and impurities,
in which the hot-stamping formed body has a microstructure in which an average grain size of prior austenite grains is 5 to 25 μm,
a standard deviation of grain sizes of the prior austenite grains is 0.1 to 2.0 μm, and
a tensile strength of the hot-stamping formed body is 2,200 MPa or more.

[4] The hot-stamping formed body according to [3], in which the hot-stamping formed body may contain, as the chemical composition, by mass%, one or more selected from the group consisting of:

Nb: 0.001% to 0.100%;
Ti: 0.010% to 0.100%;
B: 0.0015% to 0.0100%;
Mo: 0.05% to 1.00%;
Co: 0.05% to 2.00%;
Ni: 0.01% or more and less than 3.00%;
Cu: 0.01% to 1.00%;
V: 0.01% to 1.00%;
W: 0.001 % to 1.000%;
Ca: 0.001% to 0.010%;
Mg: 0.001% to 1.000%;
REM: 0.001% to 1.000%;
Sb: 0.005% to 1.000%;
Zr: 0.001% to 1.000%;
Sn: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

[5] In the hot-stamping formed body according to [3] or [4], an area ratio of the prior austenite grains having an average grain size of 0.5 to 3.0 μm may be 60% or less.

[Effects of the Invention]

[0011] 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 bendability, and a steel sheet for hot stamping capable of manufacturing this hot-stamping formed body.

[Embodiments of the Invention]

[0012] The present inventors examined bendability of a hot-stamping formed body. As a result, the present inventors found that in a microstructure of the hot-stamping formed body, the bendability deteriorates when a large amount of fine prior austenite grains are present. In addition, the present inventors found that, in the microstructure of the hot-stamping formed body, when prior austenite grains are set to a desired size and unevenness in the size of the prior austenite grains is suppressed, that is, the prior austenite grains are grain-sized, the bendability of the hot-stamping formed body can be further improved.

[0013] Next, the present inventors examined a method for obtaining the above-described hot-stamping formed body. As a result, the present inventors found that the above-described hot-stamping formed body can be obtained by controlling an area ratio of ferrite and an area ratio of granular bainite so as to form a desired amount of ferrite and granular bainite in a microstructure of a steel sheet for hot stamping and to have a desired relationship.

[0014] Hereinafter, the steel sheet for hot stamping and the hot-stamping formed body according to the present embodiment made based on the above-described findings will be described. First, the reason why the chemical composition of the steel sheet for hot stamping according to the present embodiment is to be limited will be described.

[0015] A limited numerical range described using "to" to be 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%.

[0016] The steel sheet for hot stamping according to the present embodiment includes, as a chemical composition, by mass%, C: more than 0.40% and 0.70% or less, Si: 0.010% to 1.30%, Mn: more than 0.60% and 3.00% or less, P: 0.100% or less, S: 0.0100% or less, N: 0.0130% or less, O: 0.0200% or less, Al: 0.0010% to 0.500%, Cr: 0.010% to 0.80%, and a remainder including Fe and impurities. Each element will be described below.

C: more than 0.40% and 0.70% or less

[0017] C greatly contributes to improvement in the strength of the hot-stamping formed body. When the C content is 0.40% or less, it becomes difficult to obtain sufficient strength in the hot-stamping formed body. For this reason, the C content is set to more than 0.40%. The C content is preferably 0.42% or more, more preferably 0.45% or more, and still more preferably 0.47% or more.

[0018] Meanwhile, when the C content is more than 0.70%, coarse carbides are generated and the bendability of the hot-stamping formed body deteriorates. Therefore, the C content is set to 0.70% or less. The C content is preferably 0.65% or less and more preferably 0.60% or less.

Si: 0.010% to 1.30%

[0019] Si is an element that improves distortion capability of the hot-stamping formed body by suppressing the formation of an oxide which is combined with oxygen and becomes an origin of fracture. When the Si content is less than 0.010%, a coarse oxide is formed in the hot-stamping formed body, and desired bendability cannot be obtained. Therefore, the Si content is set to 0.010% or more. The Si content is preferably 0.05% or more and more preferably 0.10% or more.

[0020] Meanwhile, when the Si content is more than 1.30%, a coarse oxide is formed, and the bendability of the hot-stamping formed body deteriorates. For this reason, the Si content is set to 1.30% or less. The Si content is preferably less than 1.00% and more preferably 0.50% or less.

Mn: more than 0.60% and 3.00% or less

[0021] Mn stabilizes austenite and improves the hardenability of the steel sheet. When the Mn content is 0.60% or less, sufficient hardenability cannot be obtained. Therefore, the Mn content is set to more than 0.60%. The Mn content is preferably 0.80% or more and more preferably 1.20% or more.

[0022] Meanwhile, when the Mn content is more than 3.00%, coarse inclusions are generated and the bendability of the hot-stamping formed body deteriorates. Therefore, the Mn content is set to 3.00% or less. The Mn content is preferably 2.20% or less and more preferably 1.80% or less.

P: 0.100% or less

[0023] P segregates in the grain boundaries of the steel sheet and deteriorates the bendability of the hot-stamping formed body. Therefore, the lower P content is more preferable. In particular, when the P content is more than 0.100%, the workability of the steel sheet and the bendability of the hot-stamping formed body significantly deteriorate. For this reason, the P content is set to 0.100% or less. The P content is preferably 0.080% or less and more preferably 0.020% or less.

[0024] The lower limit of the P content is not particularly limited and 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.

S: 0.0100% or less

[0025] S forms coarse inclusions and deteriorates the bendability of the hot-stamping formed body. Accordingly, the lower S content is more preferable. In particular, when the S content is more than 0.0100%, the formability of the steel sheet and the bendability of the hot-stamping formed body significantly deteriorate. Therefore, the S content is set to 0.0100% or less. The S content is preferably 0.0050% or less and more preferably 0.0010% or less.
[0026] The lower limit of the S content is not particularly limited and 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.

N: 0.0130% or less

[0027] N forms a coarse nitride and deteriorates the bendability of the hot-stamping formed body. Therefore, the lower N content is more preferable. In particular, when the N content is more than 0.0130%, the formability of the steel sheet significantly deteriorates. Therefore, the N content is set to 0.0130% or less. The C content is preferably 0.0100% or less or 0.0070% or less and more preferably 0.0040% or less.
[0028] The lower limit of the N content is not particularly limited and 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.

O: 0.0200% or less

[0029] O forms a coarse oxide in steel and deteriorates the bendability of the hot-stamping formed body. Therefore, the lower O content is more preferable. In particular, when the O content is more than 0.0200%, the bendability of the hot-stamping formed body significantly deteriorates. Therefore, the O content is set to 0.0200% or less. The O content is preferably 0.0100% or less and more preferably 0.0060% or less.
[0030] The lower limit of the O content is not particularly limited and may be 0%. However, when the O content is reduced to less than 0.0001%, the manufacturing cost increases significantly, which is not preferable economically. Therefore, the O content may be set to 0.0001% or more.

Al: 0.0010% to 0.500%"

[0031] Al is an element that improves the distortion capability by deoxidizing molten steel to suppress the formation of oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In a case where the Al content is less than 0.0010%, deoxidation is not sufficiently performed and a coarse oxide is generated. As a result, the above-mentioned effects cannot be obtained. For this reason, the Al content is set to 0.001 0% or more. The Al content is preferably 0.010% or more and more preferably 0.030% or more.
[0032] Meanwhile, when the Al content is more than 0.500%, a coarse oxide is formed in steel, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Al content is set to 0.500% or less. The Al content is preferably 0.450% or less and more preferably 0.350% or less.

Cr: 0.010% to 0.80%

[0033] Cr increases the strength of the hot-stamping formed body by dissolving in prior austenite grains during heating at the time of hot stamping. When the Cr content is less than 0.010%, this effect cannot be obtained. Therefore, the Cr content is set to 0.010% or more. The Cr content is preferably 0.10% or more and more preferably 0.20% or more.
[0034] Meanwhile, when the Cr content is more than 0.80%, a coarse carbide is formed and the bendability of the hot-stamping formed body deteriorates. Therefore, the Cr content is set to 0.80% or less. The Cr content is preferably 0.60% or less and more preferably 0.40% or less.
[0035] The remainder of the chemical composition of the steel sheet for hot stamping according to the present embodiment may be Fe and impurities. An example of the impurities includes an element that is unavoidably incorporated from a steel raw material or scrap and/or during a steelmaking process and is allowed in a range in which properties of the hot-stamping formed body according to the present embodiment are not inhibited.
[0036] The steel sheet for hot stamping according to the present embodiment may contain the following elements as arbitrary elements instead of a part of Fe. The contents of the following arbitrary elements, which are obtained in a case where the following arbitrary elements are not contained, are 0%.

Nb: 0% to 0.100%

[0037] Nb forms carbonitride in steel to improve the strength of the hot-stamping formed body by precipitation hardening. In order to obtain this effect, the Nb content is preferably set to 0.001% or more.
[0038] Meanwhile, when the Nb content is more than 0.100%, a large amount of carbonitride is formed in steel, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Nb content is set to 0.100% or less.

Ti: 0% to 0.100%

[0039] Similar to Nb, Ti forms carbonitride in steel to improve the strength of the hot-stamping formed body by precipitation hardening. In order to obtain the effects, a Ti content is preferably set to 0.010% or more.
[0040] Meanwhile, when the Ti content is more than 0.100%, a large amount of carbonitride is formed in steel, and the bendability of the hot-stamping formed body deteriorates. For this reason, the Ti content is set to 0.100% or less.

B: 0% to 0.0100%

[0041] B improves the hardenability of the steel and improves the strength of the hot-stamping formed body. In order to obtain the effects, the B content is preferably set to 0.0015% or more.
[0042] Meanwhile, when the B content is more than 0.0100%, a coarse carbide is generated and the bendability of the hot-stamping formed body deteriorates. Therefore, the B content is set to 0.0100% or less.

Mo: 0% to 1.00%

[0043] Mo improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to obtain the effects, the Mo content is preferably set to 0.05% or more.
[0044] Meanwhile, when the Mo content is more than 1.00%, a coarse carbide is generated and the bendability of the hot-stamping formed body deteriorates. Therefore, the Mo content is set to be 1.00% or less.

Co: 0% to 2.00%

[0045] Co improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to reliably exert the effects, it is preferable that the Co content is set to 0.05% or more.
[0046] Meanwhile, when the Co content is more than 2.00%, a coarse carbide is generated and the bendability of the hot-stamping formed body deteriorates. For this reason, the Co content is set to 2.00% or less.

Ni: 0% or more and less than 3.00%

[0047] Ni improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to obtain the effects, the Ni content is preferably set to 0.01% or more.
[0048] Meanwhile, when the Ni content is 3.00% or more, segregation is promoted and the bendability of the hot-stamping formed body deteriorates. Therefore, the Ni content is set to less than 3.00%.

Cu: 0% to 1.00%

[0049] Similar to Ni, Cu improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to obtain the effects, the Cu content is preferably set to 0.01% or more.
[0050] Meanwhile, when the Cu content is more than 1.00%, segregation is promoted and the bendability of the hot-stamping formed body deteriorates. Therefore, the Cu content is set to 1.00% or less.

V: 0% to 1.00%

[0051] V improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to obtain the effects, the V content is preferably set to 0.01% or more.
[0052] Meanwhile, when the V content is more than 1.00%, coarse carbides are generated and the bendability of the hot-stamping formed body deteriorates. Therefore, the V content is set to 1.00% or less.

W: 0% to 1.000%

[0053] W improves the hardenability of the steel sheet and improves the strength of the hot-stamping formed body. In order to obtain the effects, the W content is preferably set to 0.001 % or more.
[0054] Meanwhile, when the W content is more than 1.000%, segregation is promoted and the bendability of the hot-stamping formed body deteriorates. Therefore, the W content is set to 1.000% or less.

Ca: 0% to 0.010%

[0055] Ca improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improve the bendability of the hot-stamping formed body. In order to reliably obtain the effects, the Ca content is preferably set to 0.001% or more.
[0056] Meanwhile, when the Ca content is more than 0.010%, a coarse oxide is formed, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Ca content is set to 0.010% or less.

Mg: 0% to 1.000%

[0057] Mg improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In order to obtain the effects, the Mg content is preferably set to 0.001% or more.
[0058] Meanwhile, when the Mg content is more than 1.000%, a coarse oxide is generated, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Mg content is set to 1.000% or less.

REM: 0% to 1.000%

[0059] REM improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In order to obtain the effects, the REM content is preferably set to 0.001% or more.
[0060] Meanwhile, when the REM content is more than 1.000%, a coarse oxide is generated, and the bendability of the hot-stamping formed body deteriorates. Therefore, the REM content is set to 1.000% or less.
[0061] 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%

[0062] Sb improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In order to obtain the effects, the Sb content is preferably set to 0.005% or more.
[0063] Meanwhile, when the Sb content is more than 1.000%, a coarse oxide is generated, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Sb content is set to 1.000% or less.

Zr: 0% to 1.000%

[0064] Zr improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In order to obtain the effects, the Zr content is preferably set to 0.001% or more.
[0065] Meanwhile, when the Zr content is more than 1.000%, a coarse oxide is generated, and the bendability of the hot-stamping formed body deteriorates. Therefore, the Zr content is set to 1.000% or less.

Sn: 0% to 1.000%

[0066] Sn improves the distortion capability by suppressing the formation of an oxide which becomes the origin of fracture and improves the bendability of the hot-stamping formed body. In the case of reliably obtaining the effects, the Sn content is preferably set to 0.001% or more.
[0067] Meanwhile, since the above effects are saturated even when a large amount of Sn is contained, the Sn content is set to 1.000% or less.

As: 0% to 0.100%; and

[0068] As refines the prior austenite grains by lowering an austenite single-phase formation temperature and improve the bendability of the hot-stamping formed body. In the case of reliably obtaining the effects, the As content is preferably set to 0.001% or more.
[0069] Meanwhile, since the above effects are saturated even when a large amount of As is contained, the As content is set to 0.100% or less.
[0070] The above-mentioned chemical composition of the steel sheet for hot stamping may be measured by an ordinary analysis method. For example, the chemical composition of the steel sheet for hot stamping 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. In a case where a plating layer is provided on the surface of the steel sheet for hot stamping, the chemical composition may be analyzed after the plating layer is removed by mechanical grinding.
[0071] Next, the microstructure of the steel sheet for hot stamping according to the present embodiment will be described.
[0072] The steel sheet for hot stamping according to the present embodiment has a microstructure in which $S_\alpha + S_{GB}$, which is a total of an area ratio S_α of ferrite and an area ratio S_{GB} of granular bainite, is 10% or more and less than 50%, and S_{GB}/S_α which is a ratio between the area ratio S_{GB} of the granular bainite and the area ratio S_α of the ferrite is 0.30 to 0.70. Hereinafter, each specification will be described.
[0073] In addition, in the present embodiment, it should be noted that, in a sheet thickness cross section parallel to a rolling direction, the microstructure is specified at a 1/4 depth position of the sheet thickness from the surface (in a region from a 1/8 depth of the sheet thickness from the surface to a 3/8 depth of the sheet thickness from the surface). The reason therefor is that the microstructure at this position indicates a typical microstructure of the steel sheet.
[0074] "$S_\alpha + S_{GB}$, which is total of area ratio S_α of ferrite and area ratio S_{GB} of a granular bainite, is 10% or more and less than 50%"
When $S_\alpha + S_{GB}$, which is the total of the area ratio S_α of the ferrite and the area ratio S_{GB} of the granular bainite, is less than 10%, the prior austenite grains cannot be grain-sized in the hot-stamping formed body, and as a result, it is not possible to obtain a hot-stamping formed body having excellent bendability. Since the solid solubility limits of carbon in ferrite and granular bainite are low, by setting $S_\alpha + S_{GB}$ to 10% or more and setting S_{GB}/S_α to be described below within a desired range, carbon diffuses into ferrite grain boundaries, and a segregation region of carbon is formed at ferrite grain boundaries. During hot stamping, the segregation region of carbon becomes the origin of the prior austenite grains, so that the prior austenite grains are uniformly dispersed and formed. As a result, it is presumed that prior austenite grains can be grain-sized in the hot-stamping formed body. $S_\alpha + S_{GB}$ is preferably 20% or more and more preferably 30% or more.
[0075] Meanwhile, when $S_\alpha + S_{GB}$ is 50% or more, segregation of carbon into ferrite grain boundaries is excessively promoted, the generation density of carbides at ferrite grain boundaries increases, and the prior austenite grains cannot be uniformly dispersed and generated after the hot stamping. $S_\alpha + S_{GB}$ is preferably 40% or less.
[0076] "S_{GB}/S_α which is a ratio between area ratio S_{GB} of granular bainite and area ratio S_α of ferrite is 0.30 to 0.70"
S_{GB}/S_α is set to 0.30 to 0.70. Since ferrite does not include subgrain boundaries, carbon is less likely to be segregated in the grains than granular bainite. Therefore, by controlling the area ratio of the ferrite and granular bainite to the above range, the amount of segregation of carbon at ferrite grain boundaries can increase. The subgrain boundaries contained in the grains of granular bainite can serve as the segregation origins of carbon and thus function as the origins of prior austenite during hot stamping heating. Accordingly, the average grain size of the prior austenite grains in the hot-stamping formed body can be controlled to 25 μm or less. S_{GB}/S_α is preferably 0.40% or more.
[0077] Meanwhile, when S_{GB}/S_α is more than 0.70, the segregation of carbon to subgrain boundaries is excessively promoted, and the distance between the austenite grains becomes short during hot stamping heating. Therefore, the average grain size of the prior austenite grains cannot be controlled to 5 μm or more. Therefore, S_{GB}/S_α is set to 0.70 or less. S_{GB}/S_α is preferably 0.50 or less.
[0078] In the microstructure of the steel sheet for hot stamping according to the present embodiment, the remainder in microstructure is one or more of pearlite, martensite, lower bainite, residual austenite, and tempered martensite. The area ratio of the remainder in the microstructure may be set to more than 50% and 90% or less in consideration of the relationship with $S_\alpha + S_{GB}$.

Measurement method of microstructure of steel sheet for hot stamping

[0079] A sample is cut out from an arbitrary position (a position that avoids an end portion in a case where the sample cannot be collected at this position) away from an end surface of the steel sheet for hot stamping by a distance of 50 mm or more so that a sheet thickness cross section parallel to a rolling direction can be observed. The size of the sample also depends on a measurement device, but is set to a size that can be observed by about 10 mm in the rolling direction.

[0080] The cross section of the sample is polished using silicon carbide paper having a grit of #600 to #1500, then, is finished as a mirror surface using liquid in which diamond powder having a grain size of 1 to 6 μm is dispersed in diluted solution of alcohol or the like or pure water and finish-polished by electrolytic polishing. Next, in a region that has a length of 100 μm and between the 1/8 depth of the sheet thickness from the surface and the 3/8 depth of the sheet thickness from the surface at an arbitrary position on the cross section of the sample in a longitudinal direction so that the 1/4 depth position of the sheet thickness from the surface can be observed, the structure is observed using a device including a thermal field emission type scanning electron microscope (JSM-7001F manufactured by JEOL Ltd.) and an EBSD detector (DVC5-type detector manufactured by TSL Solutions). The scanning electron microscope used is equipped with a secondary electron detector. In a vacuum of 9.6×10^{-5} Pa or less, the sample is irradiated with an electron beam at an acceleration voltage of 15 kV and an irradiation current level of 13, and a secondary electron image is photographed with the scanning electron microscope.

[0081] In the obtained photographed photograph, a region where cementite is precipitated in a lamellar shape in the grains is determined as pearlite. Lath-shaped grains are determined as lower bainite, martensite, and tempered martensite. Next, EBSD analysis is performed on the same visual field at an analysis speed of 200 to 300 points/sec using an EBSD analyzer. The area ratio S_α of the ferrite and the area ratio S_{GB} of the granular bainite are calculated using the "Grain Average Misorientation" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer. With this function, for grains having a body-centered structure, it is possible to calculate an orientation difference between adjacent measurement points and then obtain an average value of all measurement points in the grains. For the crystal orientation information obtained by the EBSD analysis, a region surrounded by grain boundaries having an average crystal orientation difference of 5° or more is defined as a grain, and a map is drawn by the "Grain Average Misorientation" function. In a region where regions determined to be pearlite, lower bainite, martensite, and tempered martensite are excluded from the map, a region where an average crystal orientation difference in grains is less than 0.4° is determined as ferrite, and a region where the average crystal orientation difference in grains is 0.4° or more and 3.0° or less is determined as granular bainite. An area ratio of the region determined as ferrite is calculated, so that the area ratio of ferrite is obtained. The area ratio of the granular bainite is obtained by calculating the area ratio of the region determined to be the granular bainite.

[0082] The steel sheet for hot stamping according to the present embodiment may have a plating layer formed on the surface for the purpose of improving corrosion resistance after hot stamping. The plating layer may be any of an electroplating layer and a hot-dip plating layer. The electroplating layer includes, for example, an electrogalvanized layer, an electrolytic Zn-Ni alloy plating layer, and the like. The hot-dip plating layer includes, for example, a hot-dip galvanized layer, a hot-dip galvannealed layer, a hot-dip aluminum plating layer, a hot-dip Zn-Al alloy plating layer, a hot-dip Zn-Al-Mg alloy plating layer, a hot-dip Zn-Al-Mg-Si alloy plating layer, and the like. An adhesion amount of a plating layer is not particularly limited and may be a general adhesion amount.

[0083] The sheet thickness of the steel sheet for hot stamping according to the present embodiment is not particularly limited, but is preferably 0.5 to 3.5 mm from the viewpoint of a reduction in the weight of the vehicle body or the like.

[0084] Next, a hot-stamping formed body according to the present embodiment that is obtained by hot-stamping the above-described steel sheet for hot stamping will be described. The hot-stamping formed body according to the present embodiment has the same chemical composition as the above-described steel sheet for hot stamping. A measurement method of the chemical composition may be the same as that for the steel sheet for hot stamping. In addition, in the hot-stamping formed body according to the present embodiment, the prior austenite grains are grain-sized in the microstructure. That is, the hot-stamping formed body according to the present embodiment has a microstructure in which the average grain size of the prior austenite grains is 5 to 25 μm and the standard deviation of the grain sizes of the prior austenite grains is 0.1 to 2.0 μm.

[0085] In addition, in the present embodiment, the microstructure is specified at the 1/4 depth position (the region from the 1/8 depth of the sheet thickness from the surface to the 3/8 depth of the sheet thickness from the surface) of the sheet thickness from the surface of the cross section perpendicular to the sheet surface. The reason therefor is that the microstructure at this position indicates a typical microstructure of the hot-stamping formed body. Hereinafter, the microstructure will be described.

[0086]

"Average grain size of prior austenite grains is 5 to 25 μm"
"Standard deviation of grain size of prior austenite grains is 0.1 to 2.0 μm"

[0087] In the microstructure of the hot-stamping formed body, by setting the average grain size of the prior austenite grains to be 5 to 25 μm and setting the standard deviation of the grain sizes of the prior austenite grains to 0.1 to 2.0 μm, the bendability of the hot-stamping formed body can be improved. When the average grain size of the prior austenite grains or the standard deviation of the grain sizes of the prior austenite grains is outside the above range, it is not possible to obtain excellent bendability in the hot-stamping formed body.

[0088] The average grain size of the prior austenite grains is preferably 10 μm or more and more preferably 15 μm or more. The average grain size of the prior austenite grains is preferably 20 μm or less.

[0089] By setting the standard deviation of the grain sizes of the prior austenite grains to 2.0 μm or less, excellent bendability in the hot-stamping formed body can be obtained. Therefore, the standard deviation of the grain sizes of the prior austenite grains is set to 2.0 μm or less. The standard deviation is preferably 1.2 μm or less, more preferably 1.1 μm or less, and still more preferably 0.4 μm or less.

[0090] In an actual operation, since it is difficult to set the standard deviation of the grain sizes of the prior austenite grains to less than 0.1 μm, the substantial lower limit is set to 0.1 μm or more.

[0091] When the area ratio of the prior austenite grains having the average grain size of 0.5 to 3.0 μm is 60% or less, more excellent bendability can be obtained in the hot-stamping formed body. Therefore, the area ratio of the prior austenite grains having the average grain size of 0.5 to 3.0 μm may be set to 60% or less. The area ratio is more preferably 50% or less and still more preferably 40% or less.

Measurement method of average grain size and standard deviation of grain size of prior austenite grains

[0092] Next, the measurement method of the average grain size of the prior austenite grains will be described. A sample is cut out from an arbitrary position (a position that avoids an end portion in a case where the sample cannot be collected at this 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. The size of the sample also depends on a measurement device, but is set to a size that can be observed by about 10 mm in the rolling direction. The cross section of the sample is polished using silicon carbide paper having a grit of #600 to #1500, then, is finished as a mirror surface using liquid in which diamond powder having a grain size of 1 to 6 μm is dispersed in diluted solution of alcohol or the like or pure water and finish-polished by electrolytic polishing.

[0093] Next, in a region from the 1/8 depth of the sheet thickness from the surface to the 3/8 depth of the sheet thickness from the surface at an arbitrary position of the sample cross section in the longitudinal direction so that the 1/4 depth position of the sheet thickness from the surface can be observed and in a region having 100 μm in the length and 100 μm in the sheet thickness direction, a sample is irradiated with an electron beam at an acceleration voltage of 15 kV and an irradiation current level of 13 in a vacuum of 9.6×10^{-5} Pa or less using the device including a thermal field emission type scanning electron microscope (JSM-7001F manufactured by JEOL Ltd.) and an EBSD detector (DVC5-type detector manufactured by TSL Solutions), and the EBSD analysis is performed at an analysis speed of 200 to 300 points/sec. Using the obtained crystal orientation information, the crystal orientation of the prior austenite grains is calculated from a crystal orientation relationship between the general prior austenite grains and grains having a body-centered structure after transformation, and the average grain size of the prior austenite grains is calculated using the calculated crystal orientation.

[0094] The method for calculating the crystal orientation of the prior austenite grains is not particularly limited, and for example, the calculation may be performed using the following method. First, the crystal orientation of the prior austenite grains is calculated by the method described in Non-Patent Document 1, and the crystal orientation of the prior austenite in each coordinate of the EBSD-measured region is specified. Next, a crystal orientation map of the prior austenite grain is created using the "Inverse Pole Figure" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer. For one of the prior austenite grains included in the observed visual field, an average value of a shortest diameter and a longest diameter is calculated, and the average value is used as the grain size of the prior austenite grains. The above operation is performed on all the prior austenite grains except for the prior austenite grains which are not entirely included in the photographed visual fields, such as grains in an end portion of the photographed visual field, and the grain sizes of all the prior austenite grains in the photographed visual fields are obtained. The average grain size of the prior austenite grains in the photographed visual fields is obtained by calculating a value obtained by dividing the sum of the obtained grain sizes of the prior austenite grains by the total number of prior austenite grains of which grain sizes are measured. This operation is performed on all the photographed visual fields, and the average grain size of the prior austenite grains of all the photographed visual fields is calculated, thereby obtaining the average grain size of the prior austenite grains.

[0095] By calculating the standard deviation from the grain sizes of the prior austenite grains, the standard deviation of the grain sizes of the prior austenite grains is obtained. At this time, in order to eliminate the influence of locally generated fine grains or coarse grains, the standard deviation is calculated by excluding the minimum value and the maximum value of the prior austenite grain sizes.

[0096] By calculating a value obtained by dividing the area of the prior austenite grains having an average grain size of 0.5 to 3.0 μm by the area of the entire measurement visual field, the area ratio of the prior austenite grains having an average grain size of 0.5 to 3.0 μm is obtained.

[0097] The microstructure of the hot-stamping formed body is not particularly limited as long as desired strength and desired bendability can be obtained after hot stamping. However, the microstructure may include, for example, by area%, ferrite: 0% to 50%, bainite and martensite: 0% to 100%, pearlite: 0% to 30%, and residual austenite: 0% to 5%. The microstructure of the hot-stamping formed body may be measured by the following method.

Measurement method of microstructure of hot-stamping formed body

[0098] A sample is cut out from an arbitrary position (a position that avoids an end portion in a case where the sample cannot be collected at this position) away from an end surface of the hot-stamping formed body by a distance of 50 mm or more so that the cross section perpendicular to the sheet surface can be observed. The cross section of the sample is polished using silicon carbide paper having a grit of #600 to #1500, then, is finished as a mirror surface using liquid in which diamond powder having a grain size of 1 to 6 μm is dispersed in diluted solution of alcohol or the like or pure water and is performed on Nital etching. In a region that has a length of 50 μm and between the 1/8 depth of the sheet thickness from the surface and the 3/8 depth of the sheet thickness from the surface at an arbitrary position on the cross section of the sample in a longitudinal direction so that the 1/4 depth position of the sheet thickness from the surface can be observed, photographs having a plurality of visual fields are taken using a thermal field emission type scanning electron microscope (JSM-7001F manufactured by JEOL Ltd.). Evenly spaced grids are drawn in the taken photographs, and structures at grid points are identified. The number of grid points corresponding to each structure is obtained and is divided by the total number of grid points, so that the area ratio of each structure is obtained. The area ratio can be more accurately obtained as the total number of grid points is larger. In the present embodiment, grid spacings are set to 2 μm $\times$ 2 μm and the total number of grid points is set to 1500.

[0099] A region where cementite is precipitated in a lamellar shape in the grains is determined as pearlite. A region in which brightness is low and no sub-microstructure is observed is determined as ferrite. A region in which the brightness is high and the sub-microstructure is not exposed by etching is determined as "martensite or residual austenite". A region that does not correspond to any of the above-described microstructures is determined as bainite.

[0100] The area ratio of martensite is obtained by subtracting the area ratio of residual austenite obtained by EBSD analysis described later from the area ratio of martensite and residual austenite obtained from the taken photographs.

[0101] The area ratio of residual austenite is measured using an electron backscatter diffraction method (EBSD). In the analysis by EBSD, a sample collected at the same sample collection position as in the measurement using the above-described taken photograph is used, and the analysis is performed on the region between the 1/8 depth of the sheet thickness from the surface and the 3/8 depth of the sheet thickness from the surface. The sample is polished using silicon carbide paper having a grit of #600 to #1500, then, finished into a mirror surface using liquid in which diamond powder having a grain size of 1 to 6 μm is dispersed in diluted solution of alcohol or the like or pure water, and then finished by electrolytic polishing for the purpose of sufficiently removing strain in a cross section to be measured. In the electrolytic polishing, in order to remove mechanical polishing strain on the observed section, the sample may be polished a minimum of 20 μm and polished a maximum of 50 μm. The sample is preferably polished 30 μm or less in consideration of rollover at the end portion.

[0102] With regard to the measurement in EBSD, an acceleration voltage is set to 15 to 25 kV, the measurement is performed at intervals of at least 0.25 μm or less, and the crystal orientation information about each measurement point in a range of 150 μm or more in the sheet thickness direction and 250 μm or more in the rolling direction is obtained. In the obtained crystal structure, a measurement point at which a crystal structure is fcc is determined as residual austenite using "Phase Map" function installed in the software "OIM Analysis (registered trademark)" attached to the EBSD analyzer. The ratio of measurement points determined as the residual austenite is obtained, thereby obtaining the area ratio of the residual austenite. Here, the larger the number of the measurement points, the more preferable, and thus it is preferable that the measurement intervals are narrow and the measurement range is wide. However, in a case where the measurement intervals are less than 0.01 μm, adjacent points interfere with the expansion width of an electron beam. For this reason, the measurement interval is set to 0.01 μm or more. In addition, the measurement range may be set to 200 μm in the sheet thickness direction and 400 μm in the sheet width direction at a maximum. An EBSD device including a thermal field emission type scanning electron microscope (JSM-7001F manufactured by JEOL Ltd.) and an EBSD detector (DVC5-type detector manufactured by TSL Solutions) is used for measurement. In this case, a degree of vacuum in the device is set to 9.6×10^{-5} Pa or less, the irradiation current level is set to 13, and the irradiation level of the electron beam is set to 62.

[0103] The hot-stamping formed body according to the present embodiment may have a plating layer formed on the surface for the purpose of improving corrosion resistance after the hot stamping or the like. The plating layer may be any of an electroplating layer and a hot-dip plating layer. The electroplating layer includes, for example, an electrogalvanized layer, an electrolytic Zn-Ni alloy plating layer, and the like. The hot-dip plating layer includes, for example, a hot-dip galvanized layer, a hot-dip galvannealed layer, a hot-dip aluminum plating layer, a hot-dip Zn-Al alloy plating layer, a hot-dip Zn-Al-Mg alloy plating layer, a hot-dip Zn-Al-Mg-Si alloy plating layer, and the like. An adhesion amount of a plating layer is not particularly limited and may be a general adhesion amount.

[0104] The sheet thickness of the hot-stamping formed body according to the present embodiment is not particularly limited. However, in terms of reducing the weight of a vehicle body or the like, it is preferable that the sheet thickness of the hot-stamping formed body according to the present embodiment is set to 0.5 to 3.5 mm.

[0105] The hot-stamping formed body according to the present embodiment has a tensile (maximum) strength of 2,200 MPa or more. The tensile strength is preferably 2,400 MPa or more and more preferably 2,550 MPa or more. The tensile strength is obtained according to the test method described in JIS Z 2241:2011 by producing a No. 5 test piece described in JIS Z 2241:2011 from a position as flat as possible in the hot-stamping formed body.

[0106] In addition, in the hot-stamping formed body according to the present embodiment, the maximum bending angle that is obtained by a bending test based on the VDA standard (VDA238-100) specified by the German Association of the Automotive Industry is preferably 20° or more. The maximum bending angle is more preferably 30° or more or 40° or more. The conditions in the bending test were as described below.

Dimensions of test piece: 60 mm (rolling direction) × 30 mm (direction parallel to sheet width direction)

Test piece sheet thickness: 1.6 mm
Bending ridge: direction parallel to sheet width direction
Test method: roll support and punch pressing
Roll diameter: φ 30 mm
Punch shape: tip end R=0.4 mm
Distance between rolls: 2.0 × sheet thickness (mm) + 0.5 mm
Pressing speed: 20 mm/min
Tester: SHIMADZU AUTOGRAPH 20 kN

[0107] Next, a manufacturing method of the steel sheet for hot stamping according to the present embodiment will be described.

[0108] In the manufacturing method of the steel sheet for hot stamping according to the present embodiment, in order to obtain the steel sheet for hot stamping having the above-described microstructure, the final rolling reduction of the finish rolling in the hot rolling is preferably set to 40% to 80%. Normally, the final rolling reduction of the finish rolling is less than 10%, but in the present embodiment, it is preferable to set the final rolling reduction to be higher than a normal final rolling reduction.

[0109] A steel piece (steel material) to be subjected to hot rolling may be a steel piece manufactured by an ordinary method, and may be, for example, a steel piece manufactured by a general method such as a continuous cast slab or a thin slab caster. In addition, in a casting step, the steel piece after solidification may be rolled at a rolling reduction of 30% to 70% in a temperature range in which a center temperature of a slab is 1,200°C or higher and equal to or lower than a solidus temperature. As a result, the segregation of Mn is relaxed, which makes it possible to improve the bendability of the hot-stamping formed body. The solidus temperature can be obtained from Expression (1).

$$\text{Solidus temperature (°C)} = 1536 - (415.5 \times \%C + 12.3 \times \%Si + 6.8 \times \%Mn + 124.5 \times \%P + 183.9 \times \%S + 4.3 \times \%Ni + 1.4 \times \%Cr + 4.1 \times \%Al) \ldots (1)$$

[0110] In Expression (1), %C, %Si, %Mn, %P, %S, %Ni, %Cr, and %Al mean the content (mass%) of each element.

[0111] In the hot rolling, rough rolling and finish rolling are performed. In the finish rolling, the slab after the rough rolling is rolled by a plurality of finishing mills. In the present embodiment, the finish rolling is preferably performed so that the rolling reduction (final rolling reduction) in the final pass of the finish rolling becomes 40% or more. When the sheet thickness before the final pass of the finish rolling is t_0 and the sheet thickness after the final pass of the finish rolling is t_1, the final rolling reduction can be represented by $\{(t_0 - t_1)/t_0\} \times 100$ (%).

[0112] By setting the final rolling reduction of the finish rolling to 40% to 80%, the prior austenite grains are refined, and the origins of ferrite and granular bainite increase. As a result, in the microstructure of the steel sheet for hot stamping, $S_\alpha + S_{GB}$ and S_{GB}/S_α can be set within desired ranges. When the final rolling reduction of the finish rolling is less than 40%, in the microstructure of the steel sheet for hot stamping, $S_\alpha + S_{GB}$ and S_{GB}/S_α cannot be set within desired ranges. Therefore, the final rolling reduction of the finish rolling is preferably set to 40% or more. The final rolling reduction of the finish rolling is preferably 50% or more. Meanwhile, when the final rolling reduction of the finish rolling is more than

80%, S_{GB}/S_{α} cannot be controlled to 0.70 or less. Therefore, the final rolling reduction of the finish rolling is preferably set to 80% or less. The final rolling reduction is more preferably less than 70%.

[0113] The heating temperature and holding time of the steel piece before hot rolling are not particularly limited, but it is preferable that the steel piece is held in a temperature range of 1,200°C or higher for 20 minutes or longer.

[0114] After the finish rolling, the steel sheet is preferably coiled in the temperature range of 400°C to 750°C. When the coiling temperature is higher than 750°C, ferritic transformation is excessively promoted, and $S_{GB} + S_{\alpha}$ becomes 50% or more and S_{GB}/S_{α} becomes less than 0.30. The coiling temperature is preferably 700°C or lower and more preferably 660°C or lower.

[0115] In addition, the coiling temperature is preferably 400°C or higher. When the coiling temperature is lower than 400°C, the formation of granular bainite is suppressed, and S_{GB} / S_{α} becomes less than 0.30. The coiling temperature is preferably 450°C or higher and more preferably 530°C or higher.

[0116] In addition, after the finish rolling (after the completion of hot rolling), the cooling is preferably performed after 2.5 seconds or longer elapses. The cooling mentioned here is cooling that does not include air cooling and has an average cooling rate of 50 to 200 °C/s. When the time from the finish rolling to the start of cooling is shorter than 2.5 seconds, a desired amount of $S_{\alpha} + S_{GB}$ may not be obtained.

[0117] After the coiling, cold rolling may be performed as necessary. In addition, the above-mentioned plating may be formed after finish rolling or after cold rolling. Pickling may be performed between the hot rolling and the cold rolling. In the cold rolling, a normal cumulative rolling reduction, for example, 30% to 90% may be set. In addition, temper rolling may be performed under normal conditions. In addition, for the purpose of softening the hot-rolled steel sheet, hot-rolled sheet annealing in which the hot-rolled steel sheet is heated to a temperature range of 730°C or lower may be performed.

[0118] The steel sheet for hot stamping according to the present embodiment can be manufactured by the above method. Next, a manufacturing method of the hot-stamping formed body according to the present embodiment that can be manufactured using the above-described steel sheet for hot stamping will be described. The manufacturing method of the hot-stamping formed body according to the present embodiment is not particularly limited, and for example, the following manufacturing method may be used.

[0119] First, the above-mentioned steel sheet for hot stamping is heated in a temperature range of 800°C or higher. When the heating temperature is lower than 800°C, there are cases where coarse carbides that are being heated remain and the bendability of the hot-stamping formed body decreases. The heating temperature is preferably 820°C or higher and more preferably 860°C or higher.

[0120] The upper limit of the heating temperature is not particularly limited. However, when the heating temperature is too high, decarburization is promoted in the surface layer of the steel sheet, and the strength of the hot-stamping formed body decreases. Therefore, the heating temperature is preferably 1,000°C or lower, more preferably 960°C or lower, and even more preferably 930°C or lower.

[0121] The holding time at the heating temperature is preferably 1.0 to 10.0 minutes. When the holding time is shorter than 1.0 minutes, there are cases where coarse carbides remain and the bendability of the hot-stamping formed body decreases. Meanwhile, when the holding time is more than 10.0 minutes, decarburization is promoted in the surface layer of the steel sheet, and the strength of the hot-stamping formed body may decrease.

[0122] In addition, the average heating rate up to the heating temperature is preferably set to 1.0 °C/s or faster. When the average heating rate is slower than 1.0 °C/s, decarburization is promoted in the surface layer of the steel sheet, and the strength of the hot-stamping formed body decreases. Although the upper limit of the average heating rate is not particularly determined, since it is difficult to set the upper limit to faster than 1,000 °C/s in actual operation, the actual upper limit is 1,000 °C/s or slower.

[0123] Hot stamping is performed after the heating and the holding described above. After the hot stamping, it is preferable to perform cooling to a temperature range of, for example, 300°C or lower at an average cooling rate of 10 °C/s or faster. When the average cooling rate is slower than 10 °C/s, the strength may be insufficient. Although the upper limit of the average heating rate is not particularly determined, since it is difficult to set the upper limit to faster than 1,000 °C/s in actual operation, the actual upper limit is 1,000 °C/s or slower.

[0124] In the heating during hot stamping, it is not preferable to perform preheating, that is, to perform two-stage heating. The segregation region of carbon in the grain boundaries created in the stage of the steel sheet for hot stamping is eliminated, it is not possible to uniformly disperse and form the prior austenite grains, and as a result, the standard deviation of the prior austenite grains cannot be controlled within a desired range.

[0125] The hot-stamping formed body according to the present embodiment can be obtained by the preferable manufacturing method described above. After the hot stamping, a tempering treatment may be performed at 150°C to 600°C. In addition, a part of the hot-stamping formed body may be tempered by laser irradiation or the like to partially provide a softened region. Weldability improves in the softened region. For example, when spot welding is performed after softening the end portion of the hot-stamping formed body, it is possible to reduce a difference in strength between the softened end portion and the spot-welding portion of the end portion, and thus, the fracture from the interface between the end portion and the spot-welding portion can be suppressed. In addition, for example, in a case where the hot-stamping formed body is applied to a high strength member of an automobile, it is possible to control a fracture or deformation mode of the high strength member in the time of a collision by providing a softened region in a part of the high strength member.

[Example]

[0126] Next, examples of the present invention will be described. Conditions in the examples are one condition example that is employed to confirm the feasibility and effects of the present invention, and the present invention is not limited to this condition example. The present invention may employ various conditions to achieve the object of the present invention without departing from the scope of the present invention.

[0127] A steel piece manufactured by casting molten steel having a chemical composition shown in Tables 1A to 1D was heated, held in a temperature range of 1,200°C or higher and lower than 1,350°C for 20 minutes or longer, and then subjected to hot rolling, cooling, and coiling under conditions shown in Tables 2A to 2F, and subjected to cold rolling, hot-rolled sheet annealing, pickling, and plating as necessary. Therefore, steel sheets for hot stamping shown in Table 2A to Table 2F were obtained. The average cooling rate of cooling after the finish rolling to coiling was set to 50 to 200 °C/s. In addition, cooling was performed at the above-described average cooling rate after a lapse of 2.5 seconds or longer after the finish rolling. Note that, for Steel sheet No. 172 marked with "*", after the finish rolling, cooling was performed after 2.0 seconds elapsed.

[0128] In addition, for Steel sheet No. 107, in the casting step, the steel piece after solidification was rolled with a rolling reduction of 30% to 70% in a temperature range in which the center temperature of a slab was the solidus temperature or lower.

[0129] For Steel sheet No. 108, the heating temperature before the hot rolling was set to 1,350°C.

[0130] Steel sheet No. 125 was subjected to hot-rolled sheet annealing of heating and holding in a temperature range of 730°C or lower.

For Steel sheet No. 126, the cold rolling was not performed.

[0131] An electrogalvanized layer was formed on the surface of Steel sheet No. 127.

[0132] An electrolytic Zn-Ni alloy plating layer was formed on the surface of Steel sheet No. 128.

[0133] A hot-dip galvanized layer was formed on the surface of Steel sheet No. 129.

[0134] A hot-dip galvannealed layer was formed on the surface of Steel sheet No. 130.

[0135] A hot-dip aluminum plating layer was formed on the surface of Steel sheet No. 131.

[0136] A hot-dip Zn-Al alloy plating layer was formed on the surface of Steel sheet No. 132.

[0137] A hot-dip Zn-Al-Mg alloy plating layer was formed on the surface of Steel sheet No. 133.

[0138] A hot-dip Zn-Al-Mg-Si alloy plating layer was formed on the surface of Steel sheet No. 134.

[0139] The obtained steel sheets for hot stamping were subjected to hot stamping under the conditions shown in Tables 3A to 3F to obtain hot-stamping formed bodies shown in Tables 3A to 3F.

[0140] For Manufacturing No. 161, a tempering treatment was performed at 150°C to 600°C after hot stamping.

[0141] For Manufacturing No. 162, a partially softened region was formed by irradiating a portion of the hot-stamping formed body with a laser and tempering the portion.

[0142] After Manufacturing No. 163 was heated to a heating temperature shown in Table 3F, Manufacturing No. 163 was cooled to a temperature range of 250°C or lower. Thereafter, Manufacturing No. 163 was heated to 900°C and hot-stamped, and then cooled at the average cooling rate in Table 3D.

[0143] In the examples of the present invention shown in Tables 2A to 2F, the remainder in the microstructure was one or more of pearlite, martensite, lower bainite, residual austenite, and tempered martensite, and the total area ratio of these was more than 50% and 90% or less. In addition, in the examples of the present invention shown in Tables 3A to 3F, the microstructures included, by area%, ferrite: 0% to 50%, bainite and martensite: 0% to 100%, pearlite: 0% to 30%, and residual austenite: 0% to 5%.

[0144] In addition, a method for measuring the microstructure of the steel sheet for hot stamping and a method for measuring the microstructure and mechanical properties of the hot-stamping formed body were as described above. In a case where the tensile strength of the hot-stamping formed body was 2,200 MPa or more, the hot-stamping formed body was determined to be acceptable for having high strength, and, in a case where the tensile strength of the hot-stamping formed body was less than 2,200 MPa, the hot-stamping formed body was determined to be unacceptable for not having high strength.

[0145] In addition, in a case where the maximum bending angle was 20° or more, it was determined to be acceptable for having excellent bendability, and, in a case where the maximum bending angle was less than 20°, it was determined to be unacceptable for not having excellent bendability.

[Table 1A]

Steel No.	Chemical composition (mass%) remainder Fe and impurity																									Remark
	C	Si	Mn	P	S	N	O	Al	Cr	Nb	Ti	B	Mo	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
1	0.46	0.43	1.27	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
2	0.44	0.43	1.27	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
3	0.46	0.43	2.00	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
4	0.46	0.43	0.80	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
5	0.36	0.36	1.35	0.009	0.0005	0.0033	0.0008	0.044	0.18	0.015	0.026	0.0023														Comparative steel
6	0.41	0.33	1.17	0.012	0.0014	0.0026	0.0014	0.035	0.29	0.022	0.033	0.0025														Present invention steel
7	0.43	0.30	1.39	0.011	0.0019	0.0021	0.0010	0.038	0.30	0.017	0.032	0.0021														Present invention steel
8	0.46	0.25	1.40	0.008	0.0006	0.0023	0.0009	0.043	0.22																	Present invention steel
9	0.48	0.29	1.19	0.012	0.0006	0.0031	0.0011	0.035	0.20	0.024	0.027	0.0018														Present invention steel
10	0.55	0.31	1.12	0.008	0.0015	0.0030	0.0014	0.033	0.27	0.021	0.033	0.0020														Present invention steel
11	0.62	0.27	1.40	0.010	0.0020	0.0021	0.0012	0.038	0.19	0.019	0.039	0.0019														Present invention steel
12	0.67	0.39	1.22	0.012	0.0006	0.0035	0.0011	0.030	0.25	0.025	0.037	0.0027														Present invention steel
13	0.73	0.28	1.36	0.008	0.0018	0.0016	0.0010	0.045	0.22	0.027	0.028	0.0025														Comparative steel
14	0.44	0.006	1.16	0.009	0.0017	0.0015	0.0008	0.025	0.21	0.028	0.028	0.0023														Comparative steel
15	0.44	0.02	1.28	0.011	0.0020	0.0029	0.0010	0.043	0.23	0.023	0.022	0.0024														Present invention steel
16	0.44	0.07	1.39	0.011	0.0004	0.0019	0.0008	0.041	0.26	0.028	0.038	0.0028														Present invention steel
17	0.44	0.20	1.42	0.010	0.0010	0.0021	0.0011	0.045	0.21	0.016	0.029	0.0023														Present invention steel
18	0.46	0.40	1.38	0.008	0.0021	0.0028	0.0011	0.029	0.18	0.029	0.035	0.0019														Present invention steel
19	0.44	0.90	1.33	0.008	0.0018	0.0032	0.0012	0.032	0.29	0.020	0.036	0.0021														Present invention steel
20	0.44	1.10	1.25	0.012	0.0016	0.0033	0.0009	0.028	0.25	0.027	0.035	0.0026														Present invention steel
21	0.46	1.40	1.32	0.009	0.0003	0.0016	0.0008	0.035	0.25	0.027	0.037	0.0023														Comparative steel
22	0.45	0.22	0.40	0.009	0.0020	0.0030	0.0012	0.035	0.25	0.019	0.040	0.0018														Comparative steel
23	0.44	0.26	0.65	0.009	0.0017	0.0032	0.0010	0.035	0.29	0.025	0.022	0.0022														Present invention steel
24	0.44	0.35	1.00	0.010	0.0012	0.0029	0.0012	0.036	0.20	0.020	0.020	0.0024														Present invention steel
25	0.45	0.29	1.30	0.012	0.0020	0.0033	0.0015	0.026	0.18	0.026	0.028	0.0020														Present invention steel
26	0.44	0.40	1.70	0.012	0.0016	0.0016	0.0011	0.039	0.19	0.020	0.034	0.0023														Present invention steel
27	0.45	0.26	2.00	0.008	0.0021	0.0019	0.0009	0.043	0.24	0.030	0.021	0.0019														Present invention steel
28	0.45	0.23	2.70	0.009	0.0017	0.0019	0.0013	0.027	0.19	0.016	0.036	0.0025														Present invention steel

Underscores indicate scope outside present invention.

[Table 1B]

Steel No.	Chemical composition (mass%) remainder Fe and impurity																									Remark
	C	Si	Mn	P	S	N	O	Al	Cr	Nb	Ti	B	Mo	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
29	0.46	0.40	3.20	0.011	0.0004	0.0019	0.0013	0.035	0.22	0.021	0.024	0.0028														Comparative steel
30	0.46	0.24	1.30	0.150	0.0022	0.0030	0.0014	0.034	0.29	0.021	0.028	0.0024														Comparative steel
31	0.46	0.35	1.32	0.090	0.0020	0.0028	0.0008	0.036	0.20	0.016	0.032	0.0028														Present invention steel
32	0.44	0.32	1.35	0.050	0.0020	0.0018	0.0014	0.029	0.21	0.025	0.024	0.0028														Present invention steel
33	0.44	0.29	1.26	0.010	0.0021	0.0016	0.0015	0.028	0.21	0.021	0.029	0.0021														Present invention steel
34	0.47	0.38	1.44	0.009	0.0150	0.0016	0.0010	0.035	0.18	0.028	0.028	0.0024														Comparative steel
35	0.45	0.29	1.13	0.011	0.0080	0.0018	0.0011	0.025	0.23	0.028	0.027	0.0019														Present invention steel
36	0.47	0.32	1.41	0.008	0.0030	0.0021	0.0009	0.032	0.22	0.022	0.020	0.0028														Present invention steel
37	0.47	0.31	1.31	0.008	0.0008	0.0030	0.0012	0.033	0.25	0.025	0.022	0.0021														Present invention steel
38	0.44	0.40	1.24	0.010	0.0014	0.0140	0.0013	0.045	0.26	0.030	0.021	0.0024														Comparative steel
39	0.47	0.25	1.22	0.011	0.0011	0.0080	0.0008	0.034	0.25	0.030	0.021	0.0028														Present invention steel
40	0.45	0.40	1.43	0.010	0.0003	0.0050	0.0013	0.045	0.29	0.028	0.027	0.0018														Present invention steel
41	0.45	0.31	1.16	0.008	0.0011	0.0030	0.0010	0.031	0.21	0.029	0.028	0.0019														Present invention steel
42	0.47	0.23	1.19	0.010	0.0008	0.0030	0.0250	0.040	0.18	0.026	0.036	0.0023														Comparative steel
43	0.46	0.29	1.29	0.008	0.0009	0.0019	0.0150	0.037	0.18	0.026	0.035	0.0026														Present invention steel
44	0.45	0.21	1.25	0.008	0.0017	0.0033	0.0080	0.041	0.29	0.027	0.022	0.0022														Present invention steel
45	0.46	0.26	1.12	0.010	0.0016	0.0025	0.0030	0.041	0.26	0.020	0.036	0.0021														Present invention steel
46	0.44	0.26	1.25	0.012	0.0008	0.0028	0.0015	0.0008	0.22	0.020	0.020	0.0019														Comparative steel
47	0.44	0.27	1.28	0.011	0.0008	0.0022	0.0011	0.005	0.29	0.018	0.032	0.0027														Present invention steel
48	0.47	0.32	1.14	0.012	0.0016	0.0028	0.0010	0.020	0.30	0.023	0.030	0.0023														Present invention steel
49	0.45	0.20	1.18	0.010	0.0004	0.0015	0.0014	0.040	0.20	0.018	0.030	0.0027														Present invention steel
50	0.44	0.35	1.37	0.012	0.0019	0.0034	0.0013	0.100	0.26	0.015	0.039	0.0025														Present invention steel
51	0.47	0.37	1.20	0.009	0.0012	0.0024	0.0013	0.250	0.29	0.017	0.036	0.0020														Present invention steel
52	0.47	0.32	1.32	0.010	0.0021	0.0020	0.0008	0.390	0.24	0.025	0.028	0.0019														Present invention steel
53	0.44	0.28	1.14	0.012	0.0015	0.0019	0.0010	0.510	0.29	0.030	0.031	0.0028														Comparative steel
54	0.45	0.35	1.19	0.010	0.0016	0.0027	0.0011	0.030	0.008	0.023	0.034	0.0018														Comparative steel
55	0.45	0.31	1.35	0.008	0.0007	0.0032	0.0008	0.035	0.012	0.016	0.039	0.0027														Present invention steel
56	0.46	0.26	1.22	0.010	0.0022	0.0019	0.0014	0.039	0.18	0.023	0.030	0.0019														Present invention steel

Underscores indicate scope outside present invention.

[Table 1C]

Steel No.	Chemical composition (mass%) remainder Fe and impurity																									Remark
	C	Si	Mn	P	S	N	O	Al	Cr	Nb	Ti	B	Mo	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
57	0.46	0.20	1.36	0.010	0.0003	0.0020	0.0009	0.030	0.27	0.026	0.040	0.0020														Present invention steel
58	0.46	0.25	1.35	0.011	0.0008	0.0026	0.0009	0.044	0.34	0.027	0.026	0.0025														Present invention steel
59	0.47	0.29	1.36	0.008	0.0021	0.0031	0.0014	0.038	0.55	0.019	0.027	0.0027														Present invention steel
60	0.45	0.29	1.13	0.012	0.0019	0.0034	0.0014	0.044	0.67	0.022	0.033	0.0020														Present invention steel
61	0.47	0.28	1.12	0.009	0.0018	0.0029	0.0008	0.028	0.85	0.021	0.038	0.0026														Comparative steel
62	0.44	0.33	1.41	0.008	0.0017	0.0017	0.0010	0.043	0.28	0.130	0.028	0.0025														Comparative steel
63	0.45	0.22	1.12	0.011	0.0015	0.0031	0.0013	0.036	0.29	0.080	0.036	0.0022														Present invention steel
64	0.47	0.39	1.19	0.008	0.0008	0.0022	0.0010	0.028	0.21	0.019	0.039	0.0020														Present invention steel
65	0.46	0.36	1.32	0.012	0.0015	0.0015	0.0009	0.034	0.24		0.028	0.0026														Present invention steel
66	0.44	0.34	1.39	0.010	0.0022	0.0026	0.0009	0.030	0.19	0.015	0.150	0.0020														Comparative steel
67	0.47	0.34	1.25	0.012	0.0007	0.0022	0.0015	0.036	0.25	0.024	0.090	0.0020														Present invention steel
68	0.46	0.37	1.12	0.011	0.0021	0.0022	0.0008	0.029	0.27	0.027	0.028	0.0026														Present invention steel
69	0.46	0.21	1.32	0.010	0.0005	0.0033	0.0011	0.033	0.28	0.025		0.0025														Present invention steel
70	0.46	0.36	1.39	0.010	0.0012	0.0032	0.0013	0.027	0.27	0.015	0.020	0.0170														Comparative steel
71	0.44	0.30	1.17	0.011	0.0017	0.0034	0.0009	0.039	0.22	0.015	0.037	0.0090														Present invention steel
72	0.47	0.35	1.40	0.010	0.0014	0.0026	0.0015	0.026	0.18	0.018	0.024	0.0020														Present invention steel
73	0.45	0.20	1.16	0.011	0.0015	0.0034	0.0008	0.041	0.28	0.021	0.038															Present invention steel
74	0.45	0.28	1.33	0.012	0.0009	0.0035	0.0013	0.032	0.27	0.022	0.038	0.0019	1.20													Comparative steel
75	0.45	0.29	1.41	0.010	0.0007	0.0024	0.0015	0.041	0.28	0.018	0.037	0.0022	0.88													Present invention steel
76	0.45	0.39	1.25	0.008	0.0014	0.0032	0.0015	0.033	0.26	0.015	0.039	0.0021	0.10													Present invention steel
77	0.47	0.38	1.23	0.012	0.0017	0.0028	0.0009	0.040	0.26	0.018	0.032	0.0027		2.20												Comparative steel
78	0.46	0.38	1.31	0.009	0.0022	0.0028	0.0012	0.030	0.26	0.028	0.023	0.0024		1.87												Present invention steel
79	0.45	0.23	1.36	0.008	0.0022	0.0020	0.0011	0.042	0.18	0.026	0.040	0.0025		0.20												Present invention steel
80	0.46	0.37	1.43	0.009	0.0006	0.0029	0.0010	0.038	0.22	0.026	0.025	0.0026			3.20											Comparative steel
81	0.46	0.40	1.43	0.008	0.0014	0.0017	0.0012	0.042	0.20	0.024	0.025	0.0027			2.77											Present invention steel
82	0.47	0.36	1.20	0.010	0.0005	0.0026	0.0012	0.037	0.24	0.029	0.028	0.0028			0.20											Present invention steel
83	0.46	0.20	1.26	0.012	0.0004	0.0015	0.0012	0.034	0.22	0.026	0.037	0.0026				1.30										Comparative steel

Underscores indicate scope outside present invention.

[Table 1D]

Steel No.	Chemical composition (mass%) remainder Fe and impurity																									Remark
	C	Si	Mn	P	S	N	O	Al	Cr	Nb	Ti	B	Mo	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
84	0.47	0.25	1.21	0.009	0.0018	0.0027	0.0013	0.025	0.28	0.020	0.022	0.0020				0.85										Present invention steel
85	0.45	0.39	1.42	0.010	0.0004	0.0033	0.0011	0.028	0.23	0.028	0.036	0.0018				0.10										Present invention steel
86	0.45	0.36	1.11	0.012	0.0005	0.0019	0.0011	0.029	0.20	0.030	0.032	0.0025					1.10									Comparative steel
87	0.44	0.37	1.42	0.009	0.0012	0.0029	0.0010	0.035	0.23	0.020	0.026	0.0028					0.79									Present invention steel
88	0.46	0.33	1.16	0.009	0.0021	0.0021	0.0014	0.039	0.22	0.015	0.027	0.0023					0.05									Present invention steel
89	0.46	0.24	1.12	0.012	0.0018	0.0024	0.0011	0.043	0.20	0.028	0.021	0.0027						1.300								Comparative steel
90	0.45	0.26	1.20	0.008	0.0014	0.0018	0.0008	0.039	0.20	0.022	0.028	0.0026						0.910								Present invention steel
91	0.45	0.20	1.18	0.010	0.0010	0.0023	0.0013	0.040	0.26	0.015	0.037	0.0027						0.006								Present invention steel
92	0.46	0.34	1.12	0.011	0.0004	0.0029	0.0010	0.044	0.28	0.030	0.039	0.0025							0.016							Comparative steel
93	0.44	0.35	1.36	0.008	0.0003	0.0034	0.0012	0.039	0.30	0.022	0.035	0.0022							0.001							Present invention steel
94	0.46	0.38	1.35	0.011	0.0008	0.0027	0.0008	0.026	0.29	0.015	0.034	0.0025							0.003							Present invention steel
95	0.44	0.29	1.45	0.011	0.0017	0.0025	0.0008	0.034	0.28	0.016	0.031	0.0019								1.300						Comparative steel
96	0.45	0.32	1.34	0.009	0.0022	0.0033	0.0013	0.031	0.25	0.025	0.035	0.0024								0.950						Present invention steel
97	0.47	0.34	1.43	0.011	0.0017	0.0030	0.0009	0.032	0.18	0.025	0.027	0.0025								0.005						Present invention steel
98	0.44	0.24	1.32	0.008	0.0019	0.0030	0.0012	0.039	0.22	0.028	0.020	0.0026									1.300					Comparative steel
99	0.47	0.25	1.38	0.012	0.0011	0.0024	0.0012	0.036	0.24	0.015	0.022	0.0018									0.860					Present invention steel
100	0.44	0.22	1.20	0.008	0.0009	0.0023	0.0015	0.029	0.30	0.028	0.039	0.0025									0.003					Present invention steel
101	0.45	0.26	1.12	0.008	0.0013	0.0033	0.0010	0.027	0.22	0.023	0.036	0.0021										1.300				Comparative steel
102	0.44	0.40	1.32	0.009	0.0006	0.0035	0.0008	0.043	0.21	0.028	0.037	0.0021										0.920				Present invention steel
103	0.47	0.32	1.44	0.011	0.0010	0.0016	0.0008	0.032	0.21	0.030	0.024	0.0018										0.010				Present invention steel
104	0.44	0.24	1.35	0.010	0.0022	0.0015	0.0011	0.026	0.29	0.021	0.034	0.0018											1.200			Comparative steel
105	0.47	0.29	1.45	0.009	0.0015	0.0018	0.0015	0.043	0.22	0.021	0.023	0.0020											0.890			Present invention steel
106	0.47	0.38	1.21	0.009	0.0012	0.0028	0.0015	0.039	0.19	0.015	0.029	0.0022											0.020			Present invention steel
107	0.46	0.43	2.90	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
108	0.44	0.43	2.92	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
109	0.45	0.43	2.91	0.007	0.0003	0.0029	0.0010	0.030	0.27	0.019	0.028	0.0021														Present invention steel
110	0.47	0.24	1.21	0.011	0.0011	0.0081	0.0008	0.034	0.25	0.030	0.021	0.0028														Present invention steel
111	0.46	0.32	1.42	0.010	0.0010	0.0017	0.0008	0.032	0.21	0.028	0.024	0.0017												0.100		Present invention steel
112	0.46	0.39	1.21	0.009	0.0012	0.0028	0.0015	0.039	0.19	0.015	0.029	0.0022													0.011	Present invention steel

Underscores indicate scope outside present invention.

[Table 2A]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
1	1	43	631	13	9	22	0.43	Present invention example
2	2	45	637	19	15	34	0.44	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
3	3	54	593	12	11	23	0.48	Present invention example
4	4	55	569	17	16	33	0.47	Present invention example
5	5	45	551	10	4	14	0.32	Comparative example
6	6	42	585	6	4	10	0.36	Present invention example
7	7	45	565	9	5	14	0.33	Present invention example
8	8	54	630	10	6	16	0.37	Present invention example
9	9	46	659	11	6	17	0.35	Present invention example
10	10	45	570	12	6	18	0.33	Present invention example
11	11	46	565	10	5	15	0.36	Present invention example
12	12	45	540	8	4	12	0.33	Present invention example
13	<u>13</u>	49	608	10	4	14	0.32	Comparative example
14	14	47	597	11	7	18	0.37	Comparative example
15	15	50	590	7	4	11	0.36	Present invention example
16	16	53	591	6	4	10	0.38	Present invention example
17	17	54	617	8	5	13	0.39	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
18	18	42	556	12	7	19	0.38	Present invention example
19	19	55	570	10	6	16	0.35	Present invention example
20	20	49	597	9	5	14	0.37	Present invention example
21	<u>21</u>	55	599	12	6	18	0.34	Comparative example
22	22	46	549	8	5	13	0.36	Comparative example
23	23	56	544	13	7	20	0.37	Present invention example
24	14	50	581	10	6	16	0.38	Present invention example
25	25	44	646	8	4	12	0.32	Present invention example
26	26	53	622	12	6	18	0.31	Present invention example
27	27	51	545	11	7	18	0.38	Present invention example
28	28	45	623	9	5	14	0.33	Present invention example
29	29	52	542	10	6	16	0.36	Comparative example
30	<u>30</u>	56	548	8	4	12	0.31	Comparative example
Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.								

[Table 2B]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheeL for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
31	31	44	565	7	4	11	0.35	Present invention example
32	32	52	647	11	6	17	0.38	Present invention example
33	33	46	604	7	4	11	0.35	Present invention example
34	34	43	614	7	4	11	0.34	Comparative example
35	35	56	582	7	4	11	0.34	Present invention example
36	36	47	567	7	3	10	0.32	Present invention example
37	37	42	586	8	5	13	0.38	Present invention example
38	38	44	637	11	6	17	0.37	Comparative example
39	39	46	632	7	5	12	0.39	Present invention example
40	40	53	628	11	6	17	0.33	Present invention example
41	41	54	615	10	4	14	0.32	Present invention example
42	42	51	566	7	3	10	0.33	Comparative example
43	43	55	544	7	3	10	0.33	Present invention example
44	44	44	656	12	7	19	0.39	Present invention example
45	45	55	555	8	4	12	0.35	Present invention example
46	46	47	652	7	4	11	0.34	Comparative example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheeL for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_{α} (area%)	S_{GB} (area%)	$S_{\alpha} + S_{GB}$ (area%)	S_{GB}/S_{α}	
47	47	42	541	13	7	20	0.34	Present invention example
48	48	44	627	12	8	20	0.38	Present invention example
49	49	46	594	8	4	12	0.37	Present invention example
50	50	43	564	10	5	15	0.31	Present invention example
51	51	54	617	12	8	20	0.38	Present invention example
52	52	49	554	12	6	18	0.31	Present invention example
53	53	52	563	11	6	17	0.34	Comparative example
54	54	54	654	13	6	19	0.32	Comparative example
55	55	53	656	7	4	11	0.36	Present invention example
56	56	48	595	8	5	13	0.35	Present invention example
57	57	52	621	7	4	10	0.35	Present invention example
58	58	47	621	11	6	17	0.34	Present invention example
59	59	54	593	9	6	15	0.37	Present invention example
60	60	49	654	9	5	14	0.33	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 2C]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_{α} (area%)	S_{GB} (arca%)	S_{α} + S_{GB} (area%)	S_{GB}/S_{α}	
61	21	44	565	12	5	17	0.31	Comparative example
62	62	43	554	13	7	20	0.37	Comparative example
63	63	56	615	9	5	14	0.38	Present invention example
64	64	42	638	12	6	18	0.35	Present invention example
65	65	49	606	13	6	19	0.32	Present invention example
66	66	42	545	9	6	15	0.39	Comparative example
67	67	56	596	11	6	17	0.35	Present invention example
68	68	45	587	10	5	15	0.31	Present invention example
69	69	42	583	12	6	18	0.33	Present invention example
70	<u>70</u>	47	580	8	3	11	0.31	Comparative example
71	71	42	605	12	7	19	0.39	Present invention example
72	72	49	616	8	4	12	0.31	Present invention example
73	73	43	541	8	4	12	0.36	Present invention example
74	74	53	595	8	4	12	0.32	Comparative example
75	75	45	642	12	6	18	0.32	Present invention example
76	76	48	594	7	4	11	0.34	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_{α} (area%)	S_{GB} (arca%)	S_{α} + S_{GB} (area%)	S_{GB}/S_{α}	
77	12	53	568	13	7	20	0.37	Comparative example
78	78	52	540	12	8	20	0.38	Present invention example
79	79	53	540	11	6	17	0.34	Present invention example
80	80	42	635	10	6	16	0.36	Comparative example
81	81	52	643	10	6	16	0.37	Present invention example
82	82	49	561	II	7	18	0.39	Present invention example
as	83	47	585	9	6	15	0.37	Comparative example
84	84	42	570	7	4	11	0.35	Present invention example
85	85	54	652	7	4	11	0.35	Present invention example
86	86	44	584	8	3	11	0.31	Comparative example
87	87	43	560	10	6	16	0.39	Present invention example
88	88	54	631	8	4	12	0.32	Present invention example
89	89	44	651	8	3	11	0.31	Comparative example
90	90	50	645	7	5	12	0.39	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 2D]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (arca%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
91	91	55	624	8	4	12	0.34	Present invention example
92	92	52	598	8	5	13	0.37	Comparative example
93	93	50	648	8	4	12	0.37	Present invention example
94	94	49	555	8	5	13	0.38	Present invention example
95	95	51	557	12	8	20	0.39	Comparative example
96	96	48	578	12	7	19	0.35	Present invention example
97	97	44	611	10	6	16	0.35	Present invention example
98	98	51	570	13	7	20	0.35	Comparative example
99	99	52	556	7	3	10	0.33	Present invention example
100	100	47	545	12	5	17	0.32	Present invention example
101	101	50	560	12	6	18	0.35	Comparative example
102	102	50	579	10	5	15	0.32	Present invention example
103	103	49	594	7	4	10	0.35	Present invention example
104	104	51	619	11	5	16	0.31	Comparative example
105	105	56	631	10	5	15	0.36	Present invention example
106	106	55	628	10	6	16	0.38	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (arca%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
107	1	43	589	7	4	10	0.35	Present invention example
108	1	45	614	12	7	19	0.39	Present invention example
109	1	<u>84</u>	550	3	40	43	<u>0.94</u>	Comparative example
110	1	75	629	19	27	46	0.59	Present invention example
111	1	62	638	21	23	44	0.53	Present invention example
112	1	58	640	19	15	34	0.43	Present invention example
113	1	51	549	12	9	21	0.41	Present invention example
114	1	46	586	12	8	20	0.39	Present invention example
115	1	42	659	8	4	12	0.32	Present invention example
116	1	<u>35</u>	640	6	2	<u>8</u>	<u>0.21</u>	Comparative example
117	1	46	<u>770</u>	43	17	<u>60</u>	<u>0.29</u>	Comparative example
118	1	50	741	31	16	47	0.35	Present invention example
119	1	54	678	30	15	45	0.33	Present invention example
120	1	43	641	13	13	26	0.49	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 2E]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_{α} (area%)	S_{GB} (arcao/c)	S_{α} + S_{GB} (arca%)	S_{GB}/S_{α}	
121	1	46	556	18	13	31	0.43	Present invention example
122	1	46	473	4	7	11	0.66	Present invention example
123	1	52	411	4	6	10	0.58	Present invention example
124	1	44	376	14	3	17	0.20	Comparative example
125	1	50	624	11	6	17	0.33	Present invention example
126	1	55	550	8	5	13	0.36	Present invention example
127	1	45	594	8	5	13	0.35	Present invention example
128	1	46	564	8	4	12	0.35	Present invention example
129	1	48	586	8	5	13	0.38	Present invention example
130	1	51	649	12	7	19	0.38	Present invention example
131	1	43	631	12	5	17	0.32	Present invention example
132	1	43	630	13	6	19	0.33	Present invention example
133	1	53	558	7	4	11	0.33	Present invention example
134	1	54	547	12	8	an	0.39	Present invention example
135	1	50	597	10	5	15	0.35	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_{α} (area%)	S_{GB} (arcao/c)	$S_{\alpha} + S_{GB}$ (arca%)	S_{GB}/S_{α}	
136	1	44	577	7	3	10	0.33	Present invention example
137	1	42	600	7	3	10	0.33	Present invention example
138	1	48	549	9	5	14	0.34	Present invention example
139	1	52	607	11	6	17	0.37	Present invention example
140	1	47	656	6	4	10	0.37	Present invention example
141	1	44	625	9	4	13	0.32	Present invention example
142	I	43	590	8	4	12	0.35	Present invention example
143	1	45	646	8	4	12	0.31	Present invention example
144	1	45	633	8	5	13	0.34	Present invention example
145	1	51	565	8	4	12	0.36	Present invention example
116	1	42	650	11	6	17	0.38	Present invention example
147	1	50	621	7	4	11	0.32	Present invention example
148	1	47	644	12	5	17	0.31	Present invention example
149	1	52	638	12	7	19	0.36	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot stamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (arcao/c)	$S_\alpha + S_{GB}$ (arca%)	S_{GB}/S_α	
150	1	49	637	11	6	17	0.33	Present invention example
Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.								

[Table 2F]

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot slamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
151	1	56	626	10	5	15	0.34	Present invention example
152	1	50	622	11	6	17	0.35	Present invention example
153	1	42	652	7	3	10	0.34	Present invention example
154	1	53	542	9	4	13	0.31	Present invention example
155	1	48	628	13	6	19	0.31	Present invention example
156	1	42	635	13	7	20	0.33	Present invention example
157	1	44	659	8	5	13	0.37	Present invention example
158	1	55	659	6	4	10	0.38	Present invention example
159	1	45	575	6	4	10	0.37	Present invention example
160	1	49	627	12	6	18	0.36	Present invention example
161	1	52	553	11	6	17	0.35	Present invention example

(continued)

Steel sheet No.	Steel No.	Finish rolling	Coiling	Steel sheet for hot slamping				Remark
		Final rolling reduction (%)	Coiling temperature (°C)	S_α (area%)	S_{GB} (area%)	$S_\alpha + S_{GB}$ (area%)	S_{GB}/S_α	
162	1	51	596	9	5	14	0.34	Present invention example
163	1	53	631	10	5	15	0.31	Present invention example
164	1	44	622	13	7	20	0.35	Present invention example
165	107	48	652	13	7	20	0.35	Present invention example
166	108	56	621	9	4	13	0.31	Present invention example
167	109	52	633	12	7	19	0.36	Present invention example
168	110	44	627	7	4	11	0.55	Present invention example
169	111	44	590	8	4	12	0.44	Present invention example
170	112	51	630	9	5	14	0.56	Present invention example
171	1	22	636	7	3	6	0.18	Comparative example
172*	1	24	640	8	2	10	0.21	Comparative example
Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.								

[Table 3A]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (um)	Standard deviation of grain sizes of prior y grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
1	1	1	7	892	4.5	258	5	0.4	39	2558	31	Present invention example
2	2	2	5	906	4.6	195	6	0.3	35	2572	39	Present invention example
3	3	3	5	894	3.7	188	5	0.2	32	2561	47	Present invention example
4	4	4	8	898	3.9	267	7	0.3	31	2630	34	Present invention example
5	5	5	6	917	4.6	349	24	1.4	55	2149	44	Comparative example
6	6	6	8	908	3.9	367	22	1.4	56	2402	41	Present invention example
7	7	7	6	915	4.1	250	24	1.4	56	2569	37	Present invention example
8	8	8	10	910	3.5	474	25	1.5	51	2481	34	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (um)	Standard deviation of grain sizes of prior y grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
9	9	9	9	895	3.8	217	24	1.8	54	2598	35	Present invention example
10	10	10	5	920	4.5	280	25	1.8	59	2583	30	Present invention example
11	11	11	10	894	4.4	465	23	1.3	58	2556	21	Present invention example
12	12	12	8	913	4.3	175	25	1.6	50	2640	25	Present invention example
13	13	13	5	890	4.1	456	22	1.5	59	2630	16	Comparative example
14	14	14	7	917	3.7	290	21	1.5	55	2592	12	Comparative example
15	15	15	7	913	43	398	23	1.4	51	2586	22	Present invention example
16	16	16	6	898	5.0	481	22	1.4	57	2567	45	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (um)	Standard deviation of grain sizes of prior y grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
17	17	17	9	905	4.9	241	21	1.8	57	2589	46	Present invention example
18	18	18	7	916	4.8	442	23	1.3	57	2555	44	Present invention example
19	19	19	10	904	4.4	311	21	1.4	56	2586	32	Present invention example
20	20	20	7	891	3.7	335	21	1.7	58	2561	23	Present invention example
21	21	21	5	917	4.2	203	22	1.4	59	2565	17	Comparative example
22	22	22	9	902	4.9	389	22	1.6	55	2005	47	Comparative example
23	23	23	7	895	4.7	163	24	1.8	54	2467	43	Present invention example
24	24	24	5	918	4.9	217	25	1.5	57	2564	46	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (um)	Standard deviation of grain sizes of prior y grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
25	25	25	5	912	3.7	266	24	1.7	58	2598	47	Present invention example
26	26	26	8	907	4.2	383	24	1.7	55	2602	33	Present invention example
27	27	27	5	892	3.6	463	21	1.3	54	2642	39	Present invention example
28	28	28	10	896	4.7	259	24	1.5	55	2649	29	Present invention example
29	29	29	5	909	4.4	395	23	1.9	52	2625	15	Comparative example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 3B]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
30	30	30	9	899	43	405	23	1.5	53	2556	16	Comparative example
31	31	31	6	892	4.6	190	22	1.5	54	2598	23	Present invention example
32	32	32	5	915	3.7	340	21	1.4	59	2590	40	Present invention example
33	33	33	10	890	4.5	402	21	1.7	57	2553	45	Present invention example
34	34	34	7	897	3.8	471	21	1.8	54	2590	16	Comparative example
35	35	35	8	902	5.0	351	21	1.8	59	2596	27	Present invention example
36	36	36	5	895	3.8	331	25	1.8	56	2561	37	Present invention example
37	37	37	7	890	3.5	299	25	1.5	53	2581	50	Present invention example
38	38	38	7	911	3.5	414	23	1.9	53	2586	12	Comparative example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
39	39	39	7	920	3.6	477	21	1.3	51	2587	27	Present invention example
40	40	40	7	906	5.0	321	21	1.4	51	2566	37	Present invention example
41	41	41	8	913	3.9	251	22	1.9	54	2578	50	Present invention example
42	42	42	10	894	3.8	395	21	1.6	53	2594	14	Comparative example
43	43	43	7	914	3.6	394	25	1.9	52	2573	28	Present invention example
44	44	44	10	899	4.9	340	22	1.4	54	2584	38	Present invention example
45	45	45	7	896	3.5	296	24	1.4	50	2597	47	Present invention example
46	46	46	7	896	4.5	350	22	1.7	58	2557	15	Comparative example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
47	47	47	8	895	4.5	227	24	1.5	53	2553	24	Present invention example
48	48	48	8	901	4.1	187	22	1.8	56	2555	46	Present invention example
49	49	49	10	890	4.3	279	25	1.6	58	2571	42	Present invention example
50	50	50	7	900	3.9	399	22	1.7	59	2593	47	Present invention example
51	51	51	9	909	4.0	286	22	1.6	54	2590	34	Present invention example
52	52	52	5	894	3.7	340	24	1.7	57	2579	30	Present invention example
53	53	53	5	903	4.6	448	25	1.3	58	2569	18	Comparative example
54	54	54	6	900	4.0	437	25	1.4	52	2188	47	Comparative example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
55	55	55	5	901	4.5	429	22	1.3	56	2523	47	Present invention example
56	56	56	6	897	4.6	472	21	1.4	57	2571	42	Present invention example
57	57	57	7	897	4.5	418	24	1.8	52	2599	48	Present invention example
58	58	58	8	920	4.1	321	23	1.8	53	2609	37	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 3C]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
59	59	59	5	908	4.4	285	25	1.6	52	2620	32	Present invention example
60	60	60	5	894	4.0	418	23	1.3	59	2630	25	Present invention example
61	<u>61</u>	<u>21</u>	5	913	3.5	412	21	1.3	59	2629	<u>12</u>	Comparative example
62	<u>62</u>	<u>62</u>	9	894	4.4	325	21	1.7	58	2602	<u>17</u>	Comparative example
63	63	63	5	893	4.8	424	21	1.6	50	2609	27	Present invention example
64	64	64	8	890	4.6	196	24	1.8	58	2638	35	Present invention example
65	65	65	5	890	5.0	388	25	1.4	51	2490	40	Present invention example
66	<u>66</u>	<u>66</u>	7	907	4.8	371	24	1.5	54	2603	<u>13</u>	Comparative example
67	67	67	8	897	4.6	486	25	1.8	53	2649	21	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
68	68	68	5	895	4.6	255	23	1.5	53	2634	36	Present invention example
69	69	69	9	902	3.7	429	21	1.7	51	2410	32	Present invention example
70	70	70	5	913	4.4	199	23	1.6	52	2615	15	Comparative example
71	71	71	7	907	3.7	268	24	1.7	59	2602	24	Present invention example
72	72	72	5	914	4.6	395	23	1.8	53	2639	40	Present invention example
73	73	73	6	890	3.7	324	21	1.7	50	2441	32	Present invention example
74	74	74	9	901	3.7	402	25	1.5	55	2620	13	Comparative example
75	75	75	9	915	4.7	307	25	1.6	59	2623	23	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
76	76	76	8	904	4.3	237	21	1.3	50	2636	39	Present invention example
77	<u>77</u>	<u>77</u>	10	897	3.5	213	22	1.4	55	2627	12	Comparative example
78	78	78	7	906	3.8	466	22	1.8	50	2602	23	Present invention example
79	74	79	5	901	4.6	352	24	1.5	54	2630	34	Present invention example
80	<u>80</u>	<u>80</u>	10	901	4.5	247	23	1.9	51	2619	<u>16</u>	Comparative example
81	81	81	5	899	3.5	304	25	1.8	52	2618	23	Present invention example
82	82	82	5	919	4.5	277	22	1.4	50	2606	38	Present invention example
83	<u>83</u>	<u>83</u>	10	898	4.8	190	24	1.8	58	2618	<u>19</u>	Comparative example
84	84	84	8	898	4.9	478	25	1.3	51	2627	30	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
85	85	85	8	897	5.0	460	25	1.9	55	2620	39	Present invention example
86	86	86	5	891	4.1	325	25	1.8	54	2616	15	Comparative example
87	87	87	7	916	3.9	309	22	1.4	56	2642	29	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 3D]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding lime (minutes)	Average cooling rate (°C/s)	Average grain size ofprior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of0.5to3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (")	
88	88	88	9	890	4.2	288	25	1.8	51	2623	34	Present invention example
89	89	89	5	912	3.6	345	22	1.9	55	2604	15	Comparative example
90	90	90	9	898	3.6	296	22	1.5	55	2613	30	Present invention example
91	91	91	9	905	4.1	434	25	1.4	58	2631	38	Present invention example
92	92	92	8	915	3.9	307	21	1.6	58	2636	13	Comparative example
93	93	93	10	917	4.4	288	22	1.7	51	2613	25	Present invention example
94	94	94	5	914	5.0	358	24	1.3	53	2631	40	Present invention example
95	95	95	7	894	4.8	228	24	1.8	52	2629	18	Comparative example
96	96	96	9	915	4.0	426	22	1.8	54	2633	28	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding lime (minutes)	Average cooling rate (°C/s)	Average grain size ofprior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (")	
97	97	97	8	905	3.5	300	24	1.6	59	2628	35	Present invention example
98	98	98	7	891	5.0	285	25	1.5	59	2642	17	Comparative example
99	99	99	7	903	3.5	310	25	1.3	52	2604	21	Present invention example
100	100	100	9	920	3.6	362	25	1.9	52	2630	33	Present invention example
101	101	101	5	904	4.8	355	24	1.6	57	2634	17	Comparative example
102	102	102	6	920	4.8	261	22	1.3	56	2643	27	Present invention example
103	103	103	8	895	4.9	480	25	1.7	56	2612	31	Present invention example
104	104	104	6	901	3.6	457	25	1.3	53	2630	15	Comparative example
105	105	105	8	908	4.7	210	23	1.3	54	2607	26	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding lime (minutes)	Average cooling rate (°C/s)	Average grain size ofprior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (")	
106	106	106	9	893	4.3	418	24	1.4	54	2650	37	Present invention example
107	107	1	9	901	4.0	291	21	1.7	57	2561	49	Present invention example
108	108	1	10	914	4,4	298	22	1.5	59	2582	42	Present invention example
109	<u>109</u>	1	10	919	4.9	287	<u>2</u>	0.5	44	2578	<u>13</u>	Comparative example
110	110	1	6	904	5.0	468	17	0.8	44	2582	40	Present invention example
111	111	1	7	909	4.1	355	19	0.6	49	2571	50	Present invention example
112	112	1	8	915	3.8	408	5	0.3	33	2558	48	Present invention example
113	113	1	7	915	4.8	323	5	0.2	34	2554	49	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding lime (minutes)	Average cooling rate (°C/s)	Average grain size ofprior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of0.5to3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (")	
114	114	1	8	897	3.9	471	25	1.8	54	2553	37	Present invention example
115	115	1	6	899	4.4	249	23	1.7	51	2550	26	Present invention example
116	116	1	9	913	3.8	446	36	2.0	85	2571	14	Comparative example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 3E]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
117	117	1	6	894	4.7	402	35	2.3	61	2568	12	Comparative example
118	118	1	6	904	4.9	280	23	0.5	41	2558	27	Present invention example
119	119	1	6	893	4.8	194	21	0.9	48	2554	31	Present invention example
120	120	1	10	895	3.9	217	7	0.2	33	2575	44	Present invention example
121	121	1	6	897	4.5	172	5	0.4	38	2585	45	Present invention example
122	122	1	6	905	4.1	164	12	1.8	52	2586	32	Present invention example
123	123	1	9	898	3.5	302	17	1.3	59	2566	24	Present invention example
124	124	1	5	907	4.3	494	29	1.5	57	2586	14	Comparative example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
125	125	1	8	912	4.8	318	24	1.9	55	2582	39	Present invention example
126	126	1	6	909	4.8	478	25	1.3	56	2571	35	Present invention example
127	127	1	5	919	3.9	434	21	1.7	58	2566	40	Present invention example
128	128	1	8	903	3.5	344	21	1.9	52	2591	39	Present invention example
129	129	1	6	911	4.5	302	25	1.5	52	2593	34	Present invention example
130	130	1	6	901	4.8	168	24	1.5	57	2551	33	Present invention example
131	131	1	8	890	3.9	491	24	1.4	56	2561	35	Present invention example
132	132	1	5	897	5.0	208	23	1.9	55	2569	36	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
133	133	1	6	904	4.9	404	23	1.3	53	2579	34	Present invention example
134	134	1	10	915	4.3	210	25	1.6	50	2585	33	Present invention example
135	135	1	950	911	3.8	176	22	1.3	53	2611	31	Present invention example
136	136	1	500	910	3.9	311	23	1.9	58	2640	35	Present invention example
137	137	1	120	904	4.7	324	25	1.5	57	2560	36	Present invention example
138	138	1	50	919	4.7	298	24	1.5	56	2558	32	Present invention example
139	139	1	10	904	5.0	261	21	1.4	50	2596	36	Present invention example
140	140	1	4	903	4.2	203	25	1.4	58	2429	32	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average heating rate (°C/s)	Healing temperature (°C)	Holding time (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 30 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
141	141	1	<u>0.5</u>	905	3.5	472	22	1.6	51	<u>2099</u>	39	Comparative example
142	142	1	5	<u>1022</u>	4.2	354	23	1.6	55	<u>2009</u>	38	Comparative example
143	143	1	5	997	4.8	289	25	1.7	54	2439	44	Present invention example
144	144	1	9	971	4.6	456	25	1.9	53	2578	49	Present invention example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[Table 3F]

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding Lime (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
145	145	1	6	938	4.9	402	23	1.6	57	2567	41	Present invention example
146	146	1	6	905	46	383	23	1.8	53	2566	42	Present invention example
147	147	1	8	870	4.3	229	24	1.3	52	2594	50	Present invention example
148	148	1	10	831	4.9	188	24	1.4	55	2586	33	Present invention example
149	149	1	7	810	4.9	386	23	1.5	55	2560	30	Present invention example
150	150	1	5	902	11.0	405	22	1.8	50	2038	47	Comparative example
151	151	1	9	919	8.5	325	22	1.3	56	2407	48	Present invention example
152	152	1	10	896	7.8	290	25	1.5	57	2564	48	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding Lime (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
153	153	1	9	913	6.2	443	24	1.3	55	2642	46	Present invention example
154	154	1	10	919	4.1	321	25	1.8	57	2649	47	Present invention example
155	155	1	8	894	23	312	23	1.4	55	2555	35	Present invention example
156	156	1	6	891	1.5	276	25	1.6	51	2551	30	Present invention example
157	157	1	7	897	3.6	980	23	1.4	55	2638	36	Present invention example
158	158	1	7	914	4.4	560	24	1.9	52	2608	39	Present invention example
159	159	1	5	906	4,2	120	24	1.9	59	2552	39	Present invention example
160	160	1	8	910	3.8	18	23	1.8	59	2471	39	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding Lime (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of 0.5 to 3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
161	161	1	7	919	4.1	4	24	1.9	52	<u>2188</u>	39	Comparative example
162	162	1	10	895	4.0	330	22	1.7	50	2576	34	Present invention example
163	163	1	7	902	4.4	344	25	1.6	57	2580	31	Present invention example
164	164	1	5	895	4.1	371	24	<u>3.3</u>	71	2559	<u>18</u>	Comparative example
165	165	107	6	870	4.2	402	25	1.8	71	2610	23	Present invention example
166	166	108	7	919	4.9	345	23	1.7	77	2601	25	Present invention example
167	167	109	5	891	7.8	321	25	1.8	81	2598	24	Present invention example
168	168	110	7	921	3.7	460	22	1.2	55	2577	26	Present invention example

(continued)

Manufacturing No.	Steel sheet No.	Steel No.	Hot stamping				Hot-stamping formed body					Remark
			Average healing rate (°C/s)	Heating temperature (°C)	Holding Lime (minutes)	Average cooling rate (°C/s)	Average grain size of prior γ grains (μm)	Standard deviation of grain sizes of prior γ grains (μm)	Prior γ grains having average grain size of0.5to3.0 μm (area%)	Tensile strength (MPa)	Maximum bending angle (°)	
169	169	111	8	900	4.9	477	25	1.7	56	2613	30	Present invention example
170	170	112	9	899	4.1	420	24	1.3	51	2644	34	Present invention example
171	171	1	10	907	3.6	437	33	1.9	77	2566	13	Comparative example
172	172*	1	9	900	3.8	444	34	1.9	80	2566	14	Comparative example

Underscores indicate scope outside present invention and indicate that manufacturing conditions are not preferable.

[0146] From Table 3A to Table 3F, it is found that the hot-stamping formed bodies according to the examples of the present invention have high strength and excellent bendability. Meanwhile, it can be seen that in the hot-stamping formed bodies according to comparative examples, one of the properties deteriorated.

[Industrial Applicability]

[0147] 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 bendability, and a steel sheet for hot stamping capable of manufacturing this hot-stamping formed body.

Claims

1. A steel sheet for hot stamping consisting of, as a chemical composition, by mass%:

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 1.30%;
Mn: more than 0.60% and 3.00% or less;
P: 0.100% or less;
S: 0.0100% or less;
N: 0.0130% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.500%;
Cr: 0.010% to 0.80%;
Nb: 0% to 0.100%;
Ti: 0% to 0.100%;
B: 0% to 0.0100%;
Mo: 0% to 1.00%;
Co: 0% to 2.00%;
Ni: 0% or more and less than 3.00%;
Cu: 0% to 1.00%;
V: 0% to 1.00%;
W: 0% to 1.000%;
Ca: 0% to 0.010%;
Mg: 0% to 1.000%;
REM: 0% to 1.000%;
Sb: 0% to 1.000%;
Zr: 0% to 1.000%;
Sn: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder of Fe and impurities,
wherein the steel sheet for hot stamping has a microstructure in which $S_\alpha + S_{GB}$, which is a total of an area ratio S_α of ferrite and an area ratio S_{GB} of a granular bainite, is 10% or more and less than 50%, and S_{GB}/S_α, which is a ratio between the area ratio S_{GB} of the granular bainite and the area ratio S_α of the ferrite, is 0.30 to 0.70.

2. The steel sheet for hot stamping according to claim 1, wherein the steel sheet for hot stamping contains, as the chemical composition, by mass%, one or more selected from the group consisting of:

Nb: 0.001 % to 0.100%;
Ti: 0.010% to 0.100%;
B: 0.0015% to 0.0100%;
Mo: 0.05% to 1.00%;
Co: 0.05% to 2.00%;
Ni: 0.01% or more and less than 3.00%;
Cu: 0.01% to 1.00%;
V: 0.01% to 1.00%;
W: 0.001% to 1.000%;

Ca: 0.001% to 0.010%;
Mg: 0.001% to 1.000%;
REM: 0.001% to 1.000%;
Sb: 0.005% to 1.000%;
Zr: 0.001% to 1.000%;
Sn: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

3. A hot-stamping formed body consisting of, as a chemical composition, by mass%:

C: more than 0.40% and 0.70% or less;
Si: 0.010% to 1.30%;
Mn: more than 0.60% and 3.00% or less;
P: 0.100% or less;
S: 0.0100% or less;
N: 0.0130% or less;
O: 0.0200% or less;
Al: 0.0010% to 0.500%;
Cr: 0.010% to 0.80%;
Nb: 0% to 0.100%;
Ti: 0% to 0.100%;
B: 0% to 0.0100%;
Mo: 0% to 1.00%;
Co: 0% to 2.00%;
Ni: 0% or more and less than 3.00%;
Cu: 0% to 1.00%;
V: 0% to 1.00%;
W: 0% to 1.000%;
Ca: 0% to 0.010%;
Mg: 0% to 1.000%;
REM: 0% to 1.000%;
Sb: 0% to 1.000%;
Zr: 0% to 1.000%;
Sn: 0% to 1.000%;
As: 0% to 0.100%; and
a remainder of Fe and impurities,
wherein the hot-stamping formed body has a microstructure in which an average grain size of prior austenite grains is 5 to 25 μm,
a standard deviation of grain sizes of the prior austenite grains is 0.1 to 2.0 μm, and
a tensile strength of the hot-stamping formed body is 2,200 MPa or more.

4. The hot-stamping formed body according to claim 3, wherein the hot-stamping formed body contains, as the chemical composition, by mass%, one or more selected from the group consisting of:

Nb: 0.001% to 0.100%;
Ti: 0.010% to 0.100%;
B: 0.0015% to 0.0100%;
Mo: 0.05% to 1.00%;
Co: 0.05% to 2.00%;
Ni: 0.01% or more and less than 3.00%;
Cu: 0.01% to 1.00%;
V: 0.01% to 1.00%;
W: 0.001% to 1.000%;
Ca: 0.001% to 0.010%;
Mg: 0.001% to 1.000%;
REM: 0.001% to 1.000%;
Sb: 0.005% to 1.000%;
Zr: 0.001% to 1.000%;

Sn: 0.001% to 1.000%; and
As: 0.001% to 0.100%.

5. The hot-stamping formed body according to claim 3 or 4, wherein an area ratio of the prior austenite grains having an average grain size of 0.5 to 3.0 μm is 60% or less.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/019656

A. CLASSIFICATION OF SUBJECT MATTER

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 301S; C22C38/00 301W; C22C38/00 301Z; C22C38/60; C21D9/46 G; C21D9/46 T; C21D9/00 A; C21D1/18 C; C21D9/46 J; C21D9/46 U

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)

C21D9/00; C21D9/46; C22C38/00-38/60; 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 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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 2020/195012 A1 (NIPPON STEEL CORPORATION) 01 October 2020 (2020-10-01) entire text	1-5
A	WO 2020/241764 A1 (NIPPON STEEL CORPORATION) 03 December 2020 (2020-12-03) entire text	1-5
A	JP 2014-118613 A (NIPPON STEEL & SUMITOMO METAL CORP) 30 June 2014 (2014-06-30) entire text	1-5
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Date of the actual completion of the international search	Date of mailing of the international search report
06 July 2022	**19 July 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/019656

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REFERENCES CITED IN THE DESCRIPTION

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