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

(57) Provided is a steel sheet for hot stamping having a predetermined chemical composition and a metallographic structure comprising, by area ratio, ferrite: 10% or more and pearlite: 10% or more, wherein a total of ferrite and pearlite is 80% or more, and a dispersion index of pearlite is 0.50 or more. Further, provided is a hot

stamped part having a predetermined chemical composition and a metallographic structure comprising, by area ratio, at least one of martensite, bainite, and tempered martensite in a total of 90% or more, wherein a standard deviation in a hardness distribution of prior austenite grains at a sheet thickness 1/4 position is 150 Hv or less.

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Description

FIELD

[0001] The present invention relates to a steel sheet for hot stamping and a hot stamped part produced using the same.

BACKGROUND

[0002] In recent years, in the automobile industry, lighter weight of car bodies has been sought from the viewpoint of improvement of fuel economy. To achieve both lighter weight of car bodies and collision safety, one effective method is to increase the strength of the steel sheet used. A high strength steel sheet is being developed due to such a background. On the other hand, if making a steel sheet high in strength, the formability falls, and therefore it is generally difficult to achieve both strength and formability in the steel sheet.

[0003] In relation to this, PTL 1 describes a cold rolled steel sheet having a predetermined chemical composition and a metallographic structure comprising, by area ratio, polygonal ferrite in 40.0% or more and less than 60.0%, bainitic ferrite in 30.0% or more, retained austenite in 10.0% or more and 25.0% or less, and martensite in 15.0% or less, wherein in the retained austenite, a ratio of the retained austenite, in which an aspect ratio is 2.0 or less, a length of a long axis is 1.0 μm or less, and a length of a short axis is 1.0 μm or less, is 80.0% or more, wherein in the bainitic ferrite, a ratio of the bainitic ferrite, in which an aspect ratio is 1.7 or less and an average value of crystal orientation difference of a region surrounded by grain boundaries with a crystal orientation difference of 15° or more is 0.5° or more and less than 3.0°, is 80.0% or more, and wherein a connectivity D value of the martensite, bainitic ferrite, and retained austenite is 0.70 or less. Further, PTL 1 describes that according to the above constitution, it is possible to provide a high strength cold rolled steel sheet having a tensile strength of 980 MPa or more, a 0.2% yield strength of 600 MPa or more, and excellent punching fatigue properties, elongation, and hole expandability suitable as a structural member of an automobile, etc.

[CITATIONS LIST]

[PATENT LITERATURE]

[0004] [PTL 1] WO 2016/136810

SUMMARY

[TECHNICAL PROBLEM]

[0005] Hot stamping (hot pressing) is known as a technique for press-forming a material, which is difficult to form, such as a high strength steel sheet. Hot stamping is a technique of hot forming which heats then forms a material to be formed. This technique heats then forms the material, and therefore at the time of forming, the steel material is soft and has good formability. Therefore, even a high strength steel material can be formed into a complex shape with a good precision. Further, it is hardened at the same time as being formed by the press dies, and therefore a formed steel material is known to have sufficient strength.

[0006] In a hot stamped part having such a high strength, sometimes hydrogen embrittlement cracking (also referred to as "delayed fracture", etc.) becomes a problem. "Hydrogen embrittlement cracking" is the phenomenon where a steel member which is acted on by a high stress under conditions of use suddenly fractures due to hydrogen penetrating the steel from the environment. In general, it is known that hydrogen embrittlement cracking occurs more easily the higher the strength of the steel material. On the other hand, in the automobile industry, etc., further reduction of weight of the steel material is sought. To achieve such lighter weight, a need arises to raise the strength of the steel material more than the past. Therefore, there is a great need for a steel material, more specifically a hot stamped part, able to solve the problem of hydrogen embrittlement even if raising the strength equal to the past or more than the same.

[0007] Therefore, the present invention has as its object to provide a hot stamped part which is high in strength and able to suppress hydrogen embrittlement and a steel sheet for hot stamping for producing such a hot stamped part by a novel constitution.

[SOLUTION TO PROBLEM]

[0008] The inventors engaged in studies focusing on the metallographic structures at a steel sheet before hot stamping and a hot stamped part after hot stamping so as to achieve the above object. As a result, the inventors discovered that by making the pearlite forming starting points of austenite grains at the time of heating in hot stamping homogeneously

disperse in a steel sheet before hot stamping, the prior austenite grains are made uniform at the finally obtained hot stamped part, and accordingly it is possible to reduce the variation in hardness of the prior austenite grains at the metallographic structure of the hot stamped part. Further, the inventors discovered that by reducing the variation in hardness of prior austenite grains at the metallographic structure of the hot stamped part, it is possible to suppress a rise in local hardness and as a result possible to remarkably improve the hydrogen embrittlement resistance regardless of having a high tensile strength and thereby completed the present invention.

[0009] The present invention able to achieve this object is as follows:

(1) A steel sheet for hot stamping having a chemical composition comprising, by mass%,

C: 0.40 to 0.70%,
 Si: 0.010 to 1.300%,
 Mn: 0.60 to 3.00%,
 P: 0.100% or less,
 S: 0.0100% or less,
 N: 0.0200% or less,
 O: 0.0200% or less,
 Al: 0.0010 to 0.5000%,
 Nb: 0.0010 to 0.100%,
 Ti: 0.010 to 0.200%,
 B: 0.0005 to 0.0200%,
 Cr: 0.010 to 0.80%,
 Mo: 0.0010 to 1.000%,
 Co: 0 to 2.00%,
 Ni: 0 to 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
 balance: Fe and impurities, and
 a metallographic structure comprising, by area ratio,
 ferrite: 10% or more and
 pearlite: 10% or more, wherein
 a total of ferrite and pearlite is 80% or more, and
 a dispersion index of pearlite is 0.50 or more.

(2) The steel sheet for hot stamping according to the above (1), wherein the chemical composition contains, by mass%, one or more selected from the group consisting of

Co: 0.001 to 2.00%,
 Ni: 0.001 to 3.00%,
 Cu: 0.001 to 1.00%,
 V: 0.001 to 1.00%,
 W: 0.001 to 1.000%,
 Ca: 0.0001 to 0.010%,
 Mg: 0.0001 to 1.000%,
 REM: 0.0001 to 1.000%,
 Sb: 0.001 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 stamped part having a chemical composition comprising, by mass%,

C: 0.40 to 0.70%,
 Si: 0.010 to 1.300%,
 Mn: 0.60 to 3.00%,
 P: 0.100% or less,
 S: 0.0100% or less,
 N: 0.0200% or less,
 O: 0.0200% or less,
 Al: 0.0010 to 0.5000%,
 Nb: 0.0010 to 0.100%,
 Ti: 0.010 to 0.200%,
 B: 0.0005 to 0.0200%,
 Cr: 0.010 to 0.80%,
 Mo: 0.0010 to 1.000%,
 Co: 0 to 2.00%,
 Ni: 0 to 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
 balance: Fe and impurities, and
 a metallographic structure comprising, by area ratio, at least one of martensite, bainite, and tempered martensite
 in a total of 90% or more, wherein
 a standard deviation in a hardness distribution of prior austenite grains at a sheet thickness 1/4 position is 150 Hv
 or less.

(4) The hot stamped part according to the above (3), wherein the chemical composition contains, by mass%, one or more selected from the group consisting of

Co: 0.001 to 2.00%,
 Ni: 0.001 to 3.00%,
 Cu: 0.001 to 1.00%,
 V: 0.001 to 1.00%,
 W: 0.001 to 1.000%,
 Ca: 0.0001 to 0.010%,
 Mg: 0.0001 to 1.000%,
 REM: 0.0001 to 1.000%,
 Sb: 0.001 to 1.000%,
 Zr: 0.001 to 1.000%,
 Sn: 0.001 to 1.000%, and
 As: 0.001 to 0.100%.

[ADVANTAGEOUS EFFECTS OF INVENTION]

[0010] According to the present invention, it is possible to provide a hot stamped part which is high in strength and able to suppress hydrogen embrittlement and a steel sheet for hot stamping for producing such a hot stamped part.

DESCRIPTION OF EMBODIMENTS

<Steel Sheet for Hot Stamping>

5 **[0011]** The steel sheet for hot stamping according to an embodiment of the present invention has a chemical composition comprising, by mass%,

10 C: 0.40 to 0.70%,
Si: 0.010 to 1.300%,
Mn: 0.60 to 3.00%,
P: 0.100% or less,
S: 0.0100% or less,
N: 0.0200% or less,
O: 0.0200% or less,
15 Al: 0.0010 to 0.5000%,
Nb: 0.0010 to 0.100%,
Ti: 0.010 to 0.200%,
B: 0.0005 to 0.0200%,
Cr: 0.010 to 0.80%,
20 Mo: 0.0010 to 1.000%,
Co: 0 to 2.00%,
Ni: 0 to 3.00%,
Cu: 0 to 1.00%,
V: 0 to 1.00%,
25 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%,
30 Zr: 0 to 1.000%,
Sn: 0 to 1.000%,
As: 0 to 0.100%, and
balance: Fe and impurities, and
a metallographic structure comprising, by area ratio,
35 ferrite: 10% or more and
pearlite: 10% or more, wherein
a total of ferrite and pearlite is 80% or more, and
a dispersion index of pearlite is 0.50 or more.

40 **[0012]** As stated above, it is known that hydrogen embrittlement cracking occurs more easily the higher the strength of the steel material. Therefore, the inventors engaged in studies focusing on the metallographic structures of a steel sheet before hot stamping and a hot stamped part after hot stamping from the viewpoint of reducing or suppressing regions which could form starting points of hydrogen embrittlement cracking in such a high strength steel material. More specifically, first,
45 the inventors discovered that if the variation in prior austenite grain size in the metallographic structure of a hot stamped part is large, the hardness rises in regions with smaller prior austenite grain size and that such local high hardness regions can form starting points of hydrogen embrittlement cracking. As opposed to this, the inventors discovered that by reducing the variation in prior austenite grain size and as a result reducing the variation in hardness at the prior austenite grains, more specifically controlling the standard deviation in hardness distribution of prior austenite grains to 150 Hv or less, it is possible to reliably suppress such a rise in local hardness.

50 **[0013]** While not intending to be bound to any specific theory, it is believed that at the time of hot stamping, the starting temperature of martensite transformation changes in accordance with the size of the austenite grains. If explained in more detail, it is believed that austenite grains having a larger grain size become lower in hardness since the starting temperature of martensite transformation is higher compared with austenite grains having a smaller grain size. Austenite grains having a smaller grain size rise in hardness due to martensite transformation at a lower temperature than large
55 grains. Therefore, to suppress or reduce such a rise in local hardness, it is important to reduce the variation in austenite grain size before martensite transformation. In other words, it is believed that by reducing the variation in austenite grain size before martensite transformation, it is possible to reduce the variation in prior austenite grain size after martensite transformation and as a result possible to reduce the variation in hardness of prior austenite grains in the metallographic

structure of the hot stamped part. From such a reason, it is believed that by controlling the standard deviation in hardness distribution of prior austenite grains in the metallographic structure of the hot stamped part to 150 Hv or less to reduce the variation in hardness of the prior austenite grains, it is possible to remarkably suppress the rise in local hardness based on the difference in timing of martensite transformation. If there are regions with high hardness locally, it is believed that there would be a high possibility of causing hydrogen embrittlement cracking particularly at the interfaces of prior austenite grains with differences in hardness, and therefore in the metallographic structure of the hot stamped part, reducing the variation in hardness of the prior austenite grains is extremely effective in improving the hydrogen embrittlement resistance.

[0014] In relation to this, as explained later in detail regarding the method of production of a steel sheet for hot stamping, the inventors focused on the metallographic structure of a steel sheet before hot stamping, for example, a hot rolled steel sheet, and discovered that by making the pearlite homogeneously disperse in the metallographic structure, it is possible to reduce the variation in prior austenite grain size at the final metallographic structure of the hot stamped part and in relation to this is possible to control the standard deviation in hardness distribution of prior austenite grains to 150 Hv or less. Along with the higher strength of steel materials, sometimes a relatively large amount of Mn is added for improving the hardenability of the steel material, but this time, in research by the inventors, it was learned that with such a high Mn content (for example, 0.60 mass% or more), pearlite forms relatively easily, and therefore it is extremely difficult to make the pearlite formed in larger amounts in the metallographic structure of a hot rolled steel sheet compared with the case of low Mn content homogeneously disperse and as a result the variation in prior austenite grain size becomes greater in the metallographic structure after hot stamping. However, the inventors discovered, in relation to such a problem, that by applying relatively high reduction at the final stage of finish rolling and further by suitably controlling the cooling after that, it is possible to homogeneously disperse pearlite in the metallographic structure of the hot rolled steel sheet and as a result possible to reduce the variation in prior austenite grain size in the final metallographic structure of the hot stamped part and thereby remarkably reduce the variation in hardness distribution of prior austenite grains. More specifically, the inventors discovered that controlling a dispersion index of pearlite, obtained by dividing the number of A/B boundaries (boundaries of ferrite phases and pearlite phases) in an electron micrograph of the metallographic structure of the steel sheet for hot stamping mainly comprised of ferrite and pearlite by the total of the number of A/A boundaries (boundaries of ferrite phases and ferrite phases), the number of B/B boundaries (boundaries of pearlite phases and pearlite phases), and the number of A/B boundaries (boundaries of ferrite phases and pearlite phases), to 0.5 or more is important and further that controlling the dispersion index of pearlite to 0.5 or more enables achievement of a standard deviation in hardness distribution of prior austenite grains of 150 Hv or less in the final metallographic structure of the hot stamped part due to homogeneous dispersion of pearlite.

[0015] The fact that by hot stamping a steel sheet for hot stamping in which pearlite is homogeneously dispersed in a predetermined range, it is possible to control the variation in the hardness distribution of the prior austenite grains in the metallographic structure of the obtained hot stamped part to within a predetermined range was first clarified this time by the inventors. In addition, according to the hot stamped part according to an embodiment of the present invention, by controlling the variation in the hardness distribution of the prior austenite grains to within a predetermined range, it is possible to remarkably suppress a rise in local hardness, and therefore it is possible to remarkably improve the hydrogen embrittlement resistance regardless of having a high tensile strength, for example a high tensile strength of 2200 MPa or more.

[0016] Below, the steel sheet for hot stamping according to the embodiment of the present invention will be explained in more detail. In the following explanation, the "%" of the units of content of the elements, unless otherwise indicated, means "mass%". Further, in this Description, "to" showing a numerical range, unless otherwise indicated, is used in the sense including the numerical values described before and after it as the lower limit value and upper limit value.

[C: 0.40 to 0.70%]

[0017] C is an element improving the strength of a hot stamped part. If the C content is less than 0.40%, it is not possible to obtain the desired strength at the hot stamped part. For this reason, the C content is 0.40% or more. The C content is preferably more than 0.40%, 0.42% or more, 0.43% or more, 0.44% or more, 0.45% or more, or 0.46% or more.

[0018] On the other hand, if the C content is more than 0.70%, the strength becomes too high and sometimes excellent hydrogen embrittlement resistance cannot be obtained. For this reason, the C content is 0.70% or less. Preferably, the C content is 0.68% or less, 0.67% or less, 0.65% or less, or 0.60% or less.

[Si: 0.010 to 1.300%]

[0019] Si is an element improving the strength of a hot stamped part by solid solution strengthening. If the Si content is less than 0.010%, the desired strength cannot be obtained. For this reason, the Si content is 0.010% or more. The Si content is preferably 0.050% or more, 0.100% or more, 0.200% or more, more than 0.250%, 0.255% or more, 0.260% or

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more, 0.270% or more, 0.280% or more, 0.300% or more, or 0.400% or more.

[0020] On the other hand, if the Si content is more than 1.300%, in the steel sheet for hot stamping, the amount of ferrite increases and sometimes the desired metallographic structure cannot be obtained. For this reason, the Si content is 1.300% or less. The Si content is preferably 1.200% or less, 1.000% or less, 0.800% or less, 0.600% or less, or 0.500% or less.

[Mn: 0.60 to 3.00%]

[0021] Mn is an element promoting transformation of austenite to pearlite in a hot rolled steel sheet in the process of production of the hot stamped part and contributing to control of the dispersion index of pearlite in a steel sheet for hot stamping and further the hardness distribution of prior austenite grains in a hot stamped part. To control the dispersion index of pearlite and standard deviation in hardness distribution of prior austenite grains to the desired ranges, the Mn content is 0.60% or more. The Mn content is preferably more than 0.60%, 0.70% or more, 0.80% or more, 1.00% or more, or 1.30% or more.

[0022] On the other hand, if the Mn content is more than 3.00%, in the hot rolled steel sheet, transformation from austenite to pearlite is promoted too much and the dispersion index of pearlite and standard deviation in hardness distribution of prior austenite grains cannot be rendered the desired ranges. For this reason, the Mn content is 3.00% or less. Preferably, the Mn content is 2.90% or less, 2.70% or less, 2.50% or less, 2.30% or less, or 2.00% or less.

[P: 0.100% or Less]

[0023] P is an impurity element and segregates at the grain boundaries to cause the hydrogen embrittlement resistance to deteriorate. For this reason, the P content is 0.100% or less. The P content is preferably 0.070% or less, 0.050% or less, or 0.010% or less.

[0024] The lower limit of the P content is not particularly prescribed, but if less than 0.0001%, the dephosphorization cost greatly rises making this not preferable economically. For this reason, the P content may also be 0.0001% or more.

[S: 0.0100% or Less]

[0025] S is an impurity element and forms inclusions in the steel. The inclusions cause the hydrogen embrittlement resistance to deteriorate, and therefore the S content is 0.0100% or less. The S content is preferably 0.0080% or less, 0.0050% or less, 0.0030% or less, or 0.0020% or less.

[0026] The lower limit of the S content is not particularly prescribed, but if less than 0.0001%, the desulfurization cost greatly rises making this not preferable economically. For this reason, the S content may also be 0.0001% or more.

[N: 0.0200% or Less]

[0027] N is an impurity element and forms nitrides in the steel. The nitrides cause the hydrogen embrittlement resistance to deteriorate, and therefore the N content is 0.0200% or less. The N content is preferably 0.0180% or less, 0.0150% or less, 0.0100% or less, 0.0060% or less, or 0.0040% or less.

[0028] The lower limit of the N content is not particularly prescribed, but if reducing this to less than 0.0001%, the denitridation cost greatly rises making this not preferable economically. For this reason, the N content may also be 0.0001% or more.

[O: 0.0200% or Less]

[0029] O, if contained in a large amount in the steel, forms coarse oxides and causes the hydrogen embrittlement resistance to deteriorate. For this reason, the O content is 0.0200% or less. The O content is preferably 0.0150% or less, 0.0100% or less, 0.0070% or less, or 0.0040% or less.

[0030] From the viewpoint of reducing the refining costs, the O content may also be 0.0001% or more. To make a large number of fine oxides disperse at the time of deoxidation of the molten steel, the O content may be 0.0005% or more.

[Al: 0.0010 to 0.5000%]

[0031] Al is an element having the action of deoxidizing the molten steel and making the steel sounder. If the Al content is less than 0.0010%, the deoxidation will not sufficiently proceed and coarse oxides will be formed causing the hydrogen embrittlement resistance to deteriorate. For this reason, the Al content is 0.0010% or more. The Al content is preferably 0.0030% or more, 0.0050% or more, 0.0100% or more, or 0.0300% or more.

[0032] On the other hand, if the Al content is more than 0.5000%, coarse oxides will form in the steel causing the hydrogen embrittlement resistance of the hot stamped part to fall. For this reason, the Al content is 0.5000% or less. The Al content is preferably 0.4000% or less, 0.3000% or less, 0.2000% or less, 0.1500% or less, or 0.1000% or less.

[Nb: 0.0010 to 0.100%]

[0033] Nb is an element forming carbonitrides in steel and improving the strength of the hot stamped part by precipitation strengthening. If the Nb content is less than 0.0010%, the desired strength cannot be obtained. For this reason, the Nb content is 0.0010% or more. The Nb content is preferably 0.005% or more, 0.009% or more, or 0.015% or more.

[0034] On the other hand, if the Nb content is more than 0.100%, carbonitrides are formed in the steel in a large amount and the hydrogen embrittlement resistance of the hot stamped part falls. For this reason, the Nb content is 0.100% or less. The Nb content is preferably 0.080% or less, 0.060% or less, or 0.050% or less.

[Ti: 0.010 to 0.200%]

[0035] Ti is an element forming carbonitrides in steel and improving the strength of the hot stamped part by precipitation strengthening. If the Ti content is less than 0.010%, the desired strength cannot be obtained. For this reason, the Ti content is 0.010% or more. The Ti content is preferably 0.015% or more, 0.020% or more, or 0.025% or more.

[0036] On the other hand, if the Ti content is more than 0.200%, carbonitrides are formed in large amounts in the steel and the hydrogen embrittlement resistance of the hot stamped part falls. For this reason, the Ti content is 0.200% or less. The Ti content is preferably 0.180% or less, 0.150% or less, 0.100% or less, 0.080% or less, 0.060% or less, or 0.050% or less.

[B: 0.0005 to 0.0200%]

[0037] B is an element improving the hardenability of steel. If the B content is less than 0.0005%, the desired strength cannot be obtained. For this reason, the B content is 0.0005% or more. The B content is preferably 0.0010% or more, 0.0015% or more, or 0.0020% or more.

[0038] On the other hand, if the B content is more than 0.0200%, coarse intermetallic compounds are formed at the hot stamped part and the hydrogen embrittlement resistance of the hot stamped part falls. For this reason, the B content is 0.0200% or less. The B content is preferably 0.0150% or less, 0.0100% or less, 0.0080% or less, 0.0060% or less, or 0.0040% or less.

[Cr: 0.010 to 0.80%]

[0039] Cr is an element raising the strength of the hot stamped part by dissolving in the prior austenite grains at the time of heating before hot stamping. If the Cr content is less than 0.010%, the desired strength cannot be obtained. For this reason, the Cr content is 0.010% or more. The Cr content is preferably 0.05% or more, 0.10% or more, 0.15% or more, or 0.20% or more.

[0040] On the other hand, if the Cr content is more than 0.80%, coarse intermetallic compounds are formed in the hot stamped part and the hydrogen embrittlement resistance of the hot stamped part deteriorates. For this reason, the Cr content is 0.80% or less. The Cr content is preferably 0.70% or less, 0.60% or less, 0.50% or less, or 0.40% or less.

[Mo: 0.0010 to 1.000%]

[0041] Mo is an element improving the hardenability of steel. If the Mo content is less than 0.0010%, the desired strength cannot be obtained. For this reason, the Mo content is 0.0010% or more. The Mo content is preferably 0.005% or more, 0.010% or more, 0.050% or more, or 0.100% or more.

[0042] On the other hand, if the Mo content is more than 1.000%, coarse intermetallic compounds are formed in the hot stamped part and the hydrogen embrittlement resistance of the hot stamped part deteriorates. For this reason, the Mo content is 1.000% or less. The Mo content is preferably 0.800% or less, 0.600% or less, 0.500% or less, or 0.300% or less.

[0043] The basic chemical composition of the steel sheet for hot stamping according to an embodiment of the present invention is as explained above. Furthermore, the steel sheet for hot stamping may, in accordance with need, contain at least one of the following optional elements in place of part of the Fe of the balance. For example, the steel sheet for hot stamping may contain at least one element selected from the group consisting of Co: 0 to 2.00%, Ni: 0 to 3.00%, Cu: 0 to 1.00%, V: 0 to 1.00%, and W: 0 to 1.000%. Further, the steel sheet for hot stamping may contain at least one selected from the group consisting of Ca: 0 to 0.010%, Mg: 0 to 1.000%, and REM: 0 to 1.000%. Further, the steel sheet for hot stamping may contain at least one selected from the group consisting of Sb: 0 to 1.000%, Zr: 0 to 1.000%, and Sn: 0 to 1.000%.

Further, the steel sheet for hot stamping may contain As: 0 to 0.100%. Below, these optional elements will be explained in detail.

[Co: 0 to 2.00%]

[0044] Co is an element improving the strength of the hot stamped part by solid solution strengthening. The Co content may be 0.001% or more, but to reliably obtain this effect, the Co content is preferably 0.01% or more or 0.05% or more.

[0045] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Co content is preferably 2.00% or less. The Co content may also be 1.80% or less, 1.50% or less, 1.00% or less, 0.80% or less, or 0.60% or less.

[Ni: 0 to 3.00%]

[0046] Ni has the action of dissolving in the austenite grains at the time of heating in the hot stamping step and thereby raising the strength of the hot stamped part. The Ni content may be 0.001% or more, but to reliably obtain this effect, the Ni content is preferably 0.01% or more.

[0047] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Ni content is preferably 3.00% or less. The Ni content may also be less than 3.00%, 2.80% or less, 2.50% or less, 2.00% or less, 1.50% or less, 1.00% or less, or 0.80% or less.

[Cu: 0 to 1.00%]

[0048] Cu has the action of dissolving in the austenite grains at the time of heating in the hot stamping step and thereby raising the strength of the hot stamped part. The Cu content may be 0.001% or more, but to reliably obtain this effect, the Cu content is preferably 0.01% or more or 0.05% or more.

[0049] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Cu content is preferably 1.00% or less. The Cu content may also be 0.80% or less, 0.60% or less, 0.50% or less, or 0.30% or less.

[V: 0 to 1.00%]

[0050] V has the effect of forming carbonitrides in the steel to thereby improve the strength of the hot stamped part by precipitation strengthening. The V content may be 0.001% or more, but to reliably obtain this effect, the V content is preferably 0.01% or more or 0.05% or more.

[0051] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the V content is preferably 1.00% or less. The V content may also be 0.80% or less, 0.60% or less, 0.50% or less, or 0.30% or less.

[W: 0 to 1.000%]

[0052] W is an element improving the hardenability of steel. The W content may be 0.001% or more, but to reliably obtain this effect, the W content is preferably 0.005% or more or 0.010% or more.

[0053] On the other hand, even if included in a large amount, the above effect becomes saturated, and therefore the W content is preferably 1.000% or less. The W content may also be 0.800% or less, 0.600% or less, 0.500% or less, or 0.300% or less.

[Ca: 0 to 0.010%]

[0054] Ca is an element able to suppress the formation of oxides. The Ca content may be 0.0001% or more, but to reliably obtain this effect, the Ca content is preferably 0.0005% or more or 0.001% or more.

[0055] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Ca content is preferably 0.010% or less. The Ca content may also be 0.008% or less, 0.006% or less, 0.004% or less, 0.003% or less, or 0.002% or less.

[Mg: 0 to 1.000%]

[0056] Mg forms oxides and sulfides in the molten steel to suppress the formation of coarse MnS, causes dispersion of large number of fine oxides, and contributes to increased fineness of the metallographic structure. The Mg content may be 0.0001% or more, but to reliably obtain this effect, the Mg content is preferably 0.0005% or more or 0.001% or more.

[0057] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Mg content is preferably 1.000% or less. The Mg content may also be 0.500% or less, 0.100% or less, 0.050% or less, 0.010% or less, 0.005% or less, or 0.002% or less.

[REM: 0 to 1.000%]

[0058] REM is an element suppressing the formation of oxides. The REM content may be 0.0001% or more, but to reliably obtain this effect, the REM content is preferably 0.0005% or more or 0.001% or more.

[0059] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the REM content is preferably 1.000% or less. The REM content may be 0.500% or less, 0.100% or less, 0.050% or less, 0.010% or less, 0.005% or less, or 0.002% or less.

[0060] In the present embodiment, "REM" is the general term for the 17 elements of atomic number 21 scandium (Sc), atomic number 39 yttrium (Y), and the lanthanoids of atomic number 57 lanthanum (La) to atomic number 71 lutetium (Lu). The REM content is the total content of these elements.

[Sb: 0 to 1.000%]

[0061] Sb is an element inhibiting the formation of oxides. To reliably obtain this effect, the Sb content is preferably 0.001% or more.

[0062] On the other hand, even if contained in a large amount, the effect becomes saturated, and therefore the Sb content is preferably 1.000% or less. The Sb content may also be 0.800% or less, 0.500% or less, 0.200% or less, or 0.100% or less.

[Zr: 0 to 1.000%]

[0063] Zr is an element suppressing the formation of oxides. If reliably obtaining this effect, the Zr content is preferably 0.001% or more.

[0064] On the other hand, even if included in a large amount, the above effect becomes saturated, and therefore the Zr content is preferably 1.000% or less. The Zr content may also be 0.800% or less, 0.500% or less, 0.200% or less, or 0.100% or less.

[Sn: 0 to 1.000%]

[0065] Sn is an element suppressing the formation of oxides. If reliably obtaining this effect, the Sn content is preferably 0.001% or more.

[0066] On the other hand, even if included in a large amount, the above effect becomes saturated, and therefore the Sn content is preferably 1.000% or less. The Sn content may also be 0.800% or less, 0.500% or less, 0.200% or less, or 0.100% or less.

[As: 0 to 0.100%]

[0067] As causes the temperature for forming an austenite single phase to fall and thereby contributes to refinement of the prior austenite grains. If reliably obtaining this effect, the As content is preferably 0.001% or more.

[0068] On the other hand, even if contained in a large amount, the above effect is saturated, and therefore the As content is preferably 0.100% or less. The As content may be 0.080% or less, 0.050% or less, 0.020% or less, or 0.010% or less.

[0069] In the steel sheet for hot stamping according to an embodiment of the present invention, the balance besides the above elements is comprised of Fe and impurities. The "impurities" are constituents, etc., entering due to various factors in the production process starting from materials such as ore and scrap, etc., when industrially producing the steel sheet for hot stamping.

[0070] The chemical composition of the above-mentioned steel sheet for hot stamping may be measured by a general analysis method. For example, it may be measured using ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometry). C and S may be measured using the combustion-infrared absorption method, N may be measured using the inert gas melting-thermal conductivity method, and O may be measured by the inert gas melting-nondispersion type infrared absorption method.

[0071] If the surface of the steel sheet for above-mentioned hot stamping is provided with a plating layer, mechanical polishing may be used to remove the plating layer, then the chemical composition may be analyzed.

[Ferrite: 10% or More, Pearlite: 10% or More, Total of Ferrite and Pearlite: 80% or More]

[0072] The metallographic structure of the steel sheet for hot stamping according to an embodiment of the present invention contains, by area ratio, ferrite: 10% or more and pearlite: 10% or more. The total of ferrite and pearlite is 80% or more. Pearlite forms the starting points of austenite grains at the time of heating in hot stamping, and therefore has to be present in the metallographic structure by an area ratio of 10% or more. Further, in the present embodiment, inclusion of pearlite in combination with ferrite enables homogeneous dispersion of pearlite. The area ratios of ferrite and pearlite may respectively be any values of 10% or more in the range where the total of the same becomes 80% or more. For example, they may respectively independently be 20% or more, 30% or more, 40% or more, 50% or more, or 60% or more. The upper limit is not particularly prescribed, but the area ratios of ferrite and pearlite may, for example, be respectively independently 85% or less, 80% or less, or 70% or less. The total of the area ratios of ferrite and pearlite may be 85% or more, 90% or more, or 95% or more. The upper limit is not particularly prescribed, but the total of the area ratios of ferrite and pearlite may be 100%, for example, may be 99% or less or 98% or less. The remaining structure is not particularly limited, but may be comprised of at least one of bainite, martensite, retained austenite, and carbides. The carbides are, for example, Fe carbides. Sometimes trace amounts are formed at the boundaries of the ferrite phases and ferrite phases. The area ratio of the remaining structure is 20% or less, for example, may be 17% or less, 15% or less, 12% or less, 10% or less, 8% or less, 5% or less, or 3% or less.

[Dispersion Index of Pearlite: 0.50 or More]

[0073] In the metallographic structure of the steel sheet for hot stamping according to an embodiment of the present invention, pearlite has to be homogeneously dispersed. In the present embodiment, such a homogeneous dispersion of pearlite is achieved by controlling the dispersion index of pearlite to become 0.50 or more. The dispersion index of pearlite is obtained by dividing the number of A/B boundaries (boundaries of ferrite phases and pearlite phases) in an electron micrograph of the metallographic structure of the steel sheet for hot stamping mainly comprised of ferrite and pearlite by the total of the number of A/A boundaries (boundaries of ferrite phases and ferrite phases), the number of B/B boundaries (boundaries of pearlite phases and pearlite phases), and the number of A/B boundaries (boundaries of ferrite phases and pearlite phases). The dispersion index of pearlite being high means that in the metallographic structure mainly comprised of ferrite and pearlite, the ratio of the A/B boundaries is high, i.e., the number of boundaries of ferrite phases and pearlite phases is large. Therefore, by controlling the dispersion index of pearlite to a high value, it is possible to reduce more the parts where pearlite is present connected and possible to achieve more homogeneous dispersion of pearlite. According to the present embodiment, by controlling the dispersion index of pearlite to 0.50 or more, it is possible to achieve a standard deviation in hardness distribution of prior austenite grains of 150 Hv or less in the final metallographic structure of the hot stamped part due to such homogeneous dispersion of pearlite. As a result, it is possible to reduce the variation in hardness of the prior austenite grains in the metallographic structure of the hot stamped part and in turn possible to remarkably suppress a rise in local hardness, and therefore it is possible to remarkably improve the hydrogen embrittlement resistance despite having a high tensile strength, for example, a high tensile strength of 2200 MPa or more. The higher the dispersion index of pearlite, the more preferable. For example, it may be 0.52 or more, 0.55 or more, 0.58 or more, 0.60 or more, 0.62 or more, or 0.65 or more. The upper limit is not particularly prescribed, but the dispersion index of pearlite may, for example, be 0.80 or less, 0.75 or less, or 0.70 or less.

[0074] The dispersion index of pearlite is determined in the following way. First, using a scan type electron microscope, an electron channeling contrast image centered at the sheet thickness 1/4 position in the cross-section vertical to the surface in a range of 35 μm in the direction vertical to the sheet thickness direction and 10 μm in the sheet thickness direction is obtained. For this measurement, specifically an EBSD analysis apparatus comprised of a thermal field emission type scan electron microscope and EBSD detector may be used. For example, an EBSD analysis apparatus comprised of a JSM-7001F made by JEOL and DVC5 type detector made by TSL may be used. Next, in the obtained electron channeling contrast image, 10 lines vertical to the sheet thickness direction are drawn at 1 μm intervals. Next, the phase boundaries where these lines cross are classified as A/A boundaries (boundaries of ferrite phases and ferrite phases), B/B boundaries (boundaries of pearlite phases and pearlite phases), and A/B boundaries (boundaries of ferrite phases and pearlite phases) and the intersecting points of the boundaries are calculated. Next, the number of intersecting points of the A/B boundaries are divided by the total number of intersecting points, i.e., the total of the number of intersecting points of the A/A boundaries, the number of intersecting points of the B/B boundaries, and the number of intersecting points of the A/B boundaries, to obtain the ratio of the A/B boundaries in the field. The same procedure is performed on the same sample at five fields and the average value of the ratios of the A/B boundaries at the five fields is determined as the dispersion index of pearlite.

[Sheet Thickness]

[0075] The steel sheet for hot stamping according to an embodiment of the present invention is not particularly limited, but, for example, has a sheet thickness of 0.1 to 4.0 mm. The sheet thickness may also be 0.2 mm or more, 0.4 mm or more, 0.6 mm or more, 0.8 mm or more, or 1.0 mm or more. Similarly, the sheet thickness may be 3.6 mm or less, 3.2 mm or less, 2.8 mm or less, 2.4 mm or less, or 2.0 mm or less. If the steel sheet for hot stamping is a hot rolled steel sheet, the sheet thickness may, for example, be 1.0 to 4.0 mm. On the other hand, if the steel sheet for hot stamping is a cold rolled steel sheet, the sheet thickness may, for example, be 0.1 to 2.0 mm.

[Plating]

[0076] The steel sheet for hot stamping according to an embodiment of the present invention may have a plating layer on its surface. By having a plating layer on its surface, it is possible to improve the corrosion resistance after hot stamping. As the plating layer, an aluminum plating layer, aluminum-zinc plating layer, aluminum-silicon plating layer, hot dip galvanized layer, electrogalvanized layer, hot dip galvanized layer, zinc-nickel plating layer, aluminum-magnesium-zinc plating layer, etc., may be illustrated.

<Hot Stamped Part>

[0077] In the present invention, in addition to the above steel sheet for hot stamping, a hot stamped part produced using the steel sheet for hot stamping is further provided. Therefore, below, a hot stamped part according to an embodiment of the present invention will be explained in more detail. The hot stamped part has a chemical composition comprising, by mass%,

C: 0.40 to 0.70%,

Si: 0.010 to 1.300%,

Mn: 0.60 to 3.00%,

P: 0.100% or less,

S: 0.0100% or less,

N: 0.0200% or less,

O: 0.0200% or less,

Al: 0.0010 to 0.5000%,

Nb: 0.0010 to 0.100%,

Ti: 0.010 to 0.200%,

B: 0.0005 to 0.0200%,

Cr: 0.010 to 0.80%,

Mo: 0.0010 to 1.000%,

Co: 0 to 2.00%,

Ni: 0 to 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

balance: Fe and impurities, and

a metallographic structure comprising, by area ratio, at least one of martensite, bainite, and tempered martensite in a total of 90% or more, wherein

a standard deviation in a hardness distribution of prior austenite grains at a sheet thickness 1/4 position is 150 Hv or less.

[Chemical Composition of Hot Stamped Part]

[0078] The chemical composition does not substantially change in hot stamping, and therefore the chemical composition

tion of the hot stamped part has the same chemical composition as the steel sheet for hot stamping described above. Therefore, the explanations of the elements and balance relating to the chemical composition of the steel sheet for hot stamping described above apply to not only the steel sheet for hot stamping, but also the hot stamped part.

5 [At Least One of Martensite, Bainite, and Tempered Martensite: Total of 90% or More]

10 **[0079]** The metallographic structure of the hot stamped part includes, by area ratio, at least one of martensite, bainite, and tempered martensite in a total of 90% or more. The remaining structure is not particularly limited, but may also be comprised of at least one of ferrite, retained austenite and pearlite in 10% or more. Martensite, bainite, and tempered martensite are extremely hard structures, and therefore by the hot stamped part containing at least one of martensite, bainite, and tempered martensite in an area ratio of a total of 90% or more, a high tensile strength, specifically a tensile strength of 2200 MPa or more, can be achieved. The total of the area ratios of the least one of martensite, bainite, and tempered martensite is preferably 92% or more or 94% or more, more preferably 95% or more or 97% or more. The upper limit of the total of the area ratios of the at least one of martensite, bainite, and tempered martensite is not particularly prescribed and may also be 100%.

[Identification of Metallographic Structure and Calculation of Area Ratios]

20 **[0080]** The metallographic structures in the hot stamped part and the previously explained steel sheet for hot stamping are identified and the area ratios are calculated in the following way. First, a sample is cut out from any position 50 mm or more away from the ends of the steel material (if not possible to obtain a sample from this position, a position away from the ends) so as to enable a cross-section of thickness vertical to the surface to be examined. The size of the sample depends on the measurement device, but is a size enabling 10 mm or so to be examined in a direction vertical to the thickness direction.

25 **[0081]** The cross-section of the sample is polished using #600 to #1500 silicon carbide paper, then a liquid comprised of particle size 1 to 6 μm diamond powder dispersed in alcohol or other diluent or pure water is used to polish the surface to a mirror finish. Next, the examined surface is finished by electrolytic polishing. An area of a length 50 μm and 50 μm in the sheet thickness direction centered at a 1/4 depth position of the sheet thickness at any position in the long direction of the sample cross-section is measured at 0.1 μm measurement intervals by electron backscatter diffraction to obtain crystal orientation information. For the measurement, an EBSD analysis apparatus comprised of a thermal field emission type scan electron microscope and EBSD detector may be used. For example, an EBSD analysis apparatus comprised of a JSM-7001F made by JEOL and a DVC5 model detector made by TSL may be used. At that time, the vacuum degree inside the EBSD analysis apparatus may be 9.6×10^{-5} Pa or less, the acceleration voltage may be 15 kV, and the beam current level may be 13.

30 **[0082]** The obtained crystal orientation information is analyzed using the "Phase Map" function included in the software "OIM Analysis[®]" attached to the EBSD analysis apparatus. Structures with fcc crystal structures are judged to be retained austenite. The area ratio of the retained austenite is obtained by calculating the area ratio of this retained austenite. Next, regions with bcc crystal structures are judged to be bainite, tempered martensite, martensite, and ferrite. In these regions, using the "Grain Average Misorientation" function included in the software "OIM Analysis[®]" attached to the EBSD analysis apparatus, under conditions deeming a 5° grain boundary as a crystal grain boundary, a region having a "Grain Average Misorientation" of 0.5° or less is extracted as ferrite. The area ratio of ferrite is obtained by calculating the area ratio of the extracted ferrite.

40 **[0083]** Next, the remaining region (region with "Grain Average Misorientation" of more than 0.5°) is made the area ratio of the total of martensite, tempered martensite, and bainite. As for the carbides, regions having grain-like shapes which are bright in contrast in the secondary electron image captured using a scan type electron microscope for the same field as the EBSD examination are judged to be carbides. The area ratio of the corresponding regions is calculated to obtain the area ratio of carbides. The area ratio of pearlite is calculated by subtracting from 100% the area ratio of the retained austenite, the area ratios of the bainite, tempered martensite, martensite, and ferrite, and the area ratio of the carbides.

50 [Standard Deviation in Hardness Distribution of Prior Austenite Grains at Sheet Thickness 1/4 Position: 150 Hv or Less]

55 **[0084]** In an embodiment of the present invention, the standard deviation in hardness distribution of prior austenite grains at the sheet thickness 1/4 position of the hot stamped part is 150 Hv or less. If the variation in hardness of the prior austenite grains is large, a rise in local hardness is invited and sometimes hydrogen embrittlement cracking is triggered. According to an embodiment of the present invention, by controlling the standard deviation in hardness distribution of prior austenite grains at the sheet thickness 1/4 position of the hot stamped part to 150 Hv or less and reducing the variation in hardness of the prior austenite grains, it is possible to reliably suppress a rise in local hardness forming starting points of

hydrogen embrittlement cracking. Preferably, the standard deviation is 140 Hv or less, 130 Hv or less, 120 Hv or less, or 110 Hv or less. The lower limit is not particularly prescribed, but the standard deviation in hardness distribution of prior austenite grains at the sheet thickness 1/4 position of the hot stamped part may, for example, be 50 Hv or more, 60 Hv or more, or 80 Hv or more.

[0085] In an embodiment of the present invention, as explained above, it is important to control the standard deviation in hardness distribution of prior austenite grains at the sheet thickness 1/4 position of the hot stamped part (not hardness distribution of metallographic structure as a whole at sheet thickness 1/4 position, but hardness distribution of prior austenite grains present in the metallographic structure) to 150 Hv or less to reduce the variation in hardness of the prior austenite grains. For this reason, it is not necessary to control the hardness itself of the prior austenite grains to a specific range. Therefore, the hardness of the prior austenite grains at the sheet thickness 1/4 position of the hot stamped part is not particularly limited, but, for example, may be 500 Hv or more and/or may be 1000 Hv or less. The "hardness of the prior austenite grains at the sheet thickness 1/4 position of the hot stamped part" means the average of all measured values of hardness measured in the method of determination of the standard deviation in hardness distribution of prior austenite grains explained below.

[0086] The standard deviation in hardness distribution of prior austenite grains is determined in the following way. First, a sample is cut out from any position 50 mm or more away from the end faces of the hot stamped part so that the cross-section vertical to the surface (sheet thickness cross-section) can be examined. The sample, while depending on the measurement apparatus, is made a size enabling examination of 10 mm in a direction vertical to the sheet thickness direction. The cross-section of the sample is polished using #600 to #1500 silicon carbide paper, then is finished to a mirror surface using a liquid comprised of diamond powder of a granularity of 1 to 6 μm dispersed in alcohol or other diluent and pure water. The cross-section finished to a mirror surface is measured for Vickers hardness at a 1/4 depth position of the sheet thickness from the surface using a micro Vickers hardness tester by a load of 1 gf at intervals of 3 times or more of the indentations in the direction parallel to the sheet surface. Measurement values of a total of 100 points or more are obtained. Next, an EBSD analysis apparatus was used to measure the same sample. Referring to the obtained results of analysis of the structure, only measurement points with indentations inside the prior austenite grains (i.e., where indentations do not cover the grain boundaries) are extracted. Finally, the standard deviation obtained based on the measurement values of Vickers hardness relating to 20 or more different prior austenite grains extracted is determined as the standard deviation in hardness distribution of prior austenite grains at the sheet thickness 1/4 position of the hot stamped part. For the EBSD measurement, an EBSD analysis apparatus comprised of a thermal field emission type scan electron microscope and EBSD detector may be used. For example, an EBSD analysis apparatus comprised of a JSM-7001F made by JEOL and DVC5 type detector made by TSL may be used. At that time, the vacuum degree inside the EBSD analysis apparatus may be 9.6×10^{-5} Pa or less, the acceleration voltage may be 15 kV, and the beam current level may be 13. The method described in Acta Materialia, 58(2010), 6393-6403 is used to prepare a crystal orientation map of the prior austenite grains and the prior austenite grains are identified based on this crystal orientation map.

[Plating]

[0087] The hot stamped part according to the present embodiment may have a plating layer on its surface. By having a plating layer on its surface, it is possible to improve the corrosion resistance. As the plating layer, an aluminum plating layer, aluminum-zinc plating layer, aluminum-silicon plating layer, hot dip galvanized layer, electrogalvanized layer, hot dip galvanized plating layer, zinc-nickel plating layer, aluminum-magnesium-zinc plating layer, etc., may be illustrated.

[Mechanical Properties]

[0088] According to the hot stamped part of an embodiment of the present invention, excellent mechanical properties, for example, a tensile strength of 2200 MPa or more, can be achieved. The tensile strength is preferably 2300 MPa or more, more preferably 2400 MPa or more, most preferably 2500 MPa or more or 2600 MPa or more. The upper limit is not particularly prescribed, but, for example, the tensile strength may be 3500 MPa or less, 3300 MPa or less, or 3000 MPa or less. The tensile strength of the hot stamped part is measured by preparing a No. 5 test piece and conducting a tensile test based on JIS Z 2241: 2011.

[0089] The hot stamped part according to an embodiment of the present invention, despite as explained above having a high tensile strength of, for example, 2200 MPa or more, is excellent in hydrogen embrittlement resistance, and therefore is extremely useful for use as, for example, a frame member or bumper of an automobile or other structural member and reinforcing member where strength is required.

<Method of Production>

[0090] Next, a preferable method of production of the steel sheet for hot stamping and the hot stamped part according to

an embodiment of the present invention will be explained. The following explanation is intended to illustrate the characteristic method for producing the steel sheet for hot stamping and the hot stamped part according to the embodiment of the present invention and is not intended to limit the steel sheet for hot stamping and hot stamped part to one produced by the method of production such as explained below.

<Method of Production of Steel Sheet for Hot Stamping>

[0091] In the method of production of steel sheet for hot stamping according to an embodiment of the present invention, in particular controlling the finish rolling conditions and later cooling conditions is effective. Specifically, the method of production of steel sheet for hot stamping according to an embodiment of the present invention comprises

hot rolling a slab having a chemical composition explained above in relation to the steel sheet for hot stamping, wherein the hot rolling includes heating the slab, then finish rolling it, and a rolling reduction of a final stage in the finish rolling is 40% or more (hot rolling step),

rapidly cooling the obtained hot rolled steel sheet within 1.0 second after the end of finish rolling, then cooling it by an average cooling speed of 90°C/s or more (cooling step), and coiling the hot rolled steel sheet at a temperature of 500 to 700°C (coiling step). Below, the steps will be explained in detail.

[Hot Rolling Step]

[Heating of Slab]

[0092] First, a slab having the chemical composition explained above in relation to the steel sheet for hot stamping is heated. The method of casting the molten steel is not particularly limited. The slab may be produced by continuous casting, ingot forming, or thin slab casting. The heating before the hot rolling is not particularly limited, but the slab used contains a relatively large amount of alloying elements for obtaining a high strength steel sheet. For this reason, the slab may also be heated before being sent on for hot rolling. For the purpose of making the alloying elements dissolve in the slab, the heating temperature may be 1100°C or more.

[Rough Rolling]

[0093] In the present method, for example, the heated slab may be rough rolled before the finish rolling so as to adjust the sheet thickness, etc. The rough rolling need only secure the desired sheet bar dimensions. The conditions are not particularly limited.

[Finish Rolling]

[0094] The heated slab, or the slab additionally rough rolled in accordance with need, is next finish rolled. In the present method, making the rolling reduction of the final stage at the finish rolling 40% or more is important. By making the rolling reduction of the final stage at the finish rolling 40% or more, pearlite is homogeneously dispersed in the hot rolled steel sheet after rolling. This pearlite forms starting points for austenite at the time of heating in hot stamping step explained in detail later relating to the method of production of the hot stamped part. For this reason, if pearlite is homogeneously dispersed, it is possible to reduce the variation in prior austenite grain size in the hot stamped part. As a result, it is possible to reduce the variation in hardness of the prior austenite grains in the metallographic structure of the hot stamped part and in turn possible to remarkably suppress a rise in local hardness. Therefore, it is possible to remarkably improve the hydrogen embrittlement resistance regardless of having a high tensile strength, for example a high tensile strength of 2200 MPa or more. More preferably, the rolling reduction of the final stage in the finish rolling is 45% or more or 50% or more.

[0095] In the steel sheet for hot stamping, the amount of Mn added tends to be increased for the purpose of securing a high hardenability. For example, 0.60% or more of Mn is added. In relation to this, in the current research of the inventors, it was learned that with such a high Mn content, pearlite tends to be arranged relatively connected at the hot rolled steel sheet, and therefore compared with the case of a low Mn content, it is extremely difficult to make the pearlite homogeneously disperse in the metallographic structure of the hot rolled steel sheet. Therefore, if finish rolling a steel material with such a high Mn content by a relatively low rolling reduction of less than 40%, it is believed that in the metallographic structure, the presence of parts where pearlite is connected will become particularly remarkable.

[0096] However, by making the rolling reduction of the final stage in the finish rolling 40% or more, despite the high Mn content of 0.60% or more, it is possible to arrange the pearlite sufficiently dispersed in the hot rolled steel sheet after the hot rolling step and the subsequent cooling step and coiling step. Therefore, in the metallographic structure of the hot rolled

steel sheet rolled in this way, either there will be no parts where pearlite is present connected or they will be sufficiently reduced, and therefore in the structure after hot stamping, the variation in prior austenite grain size can be reduced. As a result, it is possible to reduce the variation in hardness of the prior austenite grains in the metallographic structure of the hot stamped part. The upper limit of the rolling reduction of the final stage in the finish rolling is not particularly prescribed. In this way, even in a steel material having a high Mn content, by particularly suitably controlling the rolling reduction of the final stage in the finish rolling, it is possible to arrange the pearlite sufficiently dispersed in the metallographic structure of the hot rolled steel sheet and in turn possible to reduce the variation in prior austenite grain size and suppress a rise in local hardness.

[0097] In such a form of metallographic structure, the rolling reduction of the final stage in the finish rolling and the average cooling speed in the subsequent cooling step and coiling temperature in the coiling step are dominant factors. For example, no particularly great effect is affected even by an optional cold rolling or subsequent annealing, etc. This is because if making the rolling reduction of the final stage in the finish rolling 40% or more to form the hot rolled steel sheet, even if the hot rolled steel sheet is cold rolled and then annealed under a relatively high temperature, there is a high tendency that a metallographic structure will be formed in which carbides, grain boundaries and retained austenite forming starting points of austenite after cooling are arranged dispersed. In general, if overly increasing the rolling reduction of the final stage in the finish rolling, cracking of the steel sheet at the time of rolling will be a concern. In particular, in the case of a high strength steel sheet with a C content of 0.40% or more, if overly raising the rolling reduction of the final stage, in addition to the concern over cracking of the steel sheet, the rolling load of the rolling mill will also remarkably increase. For this reason, in a steel material having a chemical composition similar to that of the steel sheet for hot stamping according to an embodiment of the present invention, finish rolling resulting in a rolling reduction in the final stage of 40% or more has not been performed in the past. Therefore, the fact that by making the rolling reduction of the final stage in the finish rolling 40% or more and further suitably controlling the average cooling speed in the subsequent cooling step and coiling temperature in the coiling step and combining the same, it is possible to make the pearlite forming starting points of austenite grains at the time of heating in the hot stamping homogeneously disperse was not known in the past. Therefore, only naturally, in relation to this, the fact that in the finally obtained hot stamped part, the prior austenite grains are uniform, and accordingly the variation in hardness of the prior austenite grains in the metallographic structure of the hot stamped part can be reduced was not known in the past. These facts were first clarified this time by the inventors.

[Cooling Step]

[0098] Next, the finish rolled hot rolled steel sheet is rapidly cooled within 1.0 second after the end of the finish rolling. Ferrite is generally formed from the grain boundaries of austenite grains, and therefore if the austenite grains become large, the number of grain boundaries forming starting points of ferrite will be reduced. In such a case, preventing connection of pearlite and making it homogeneously disperse becomes difficult. Therefore, rapidly cooling the hot rolled steel sheet immediately after the end of finish rolling, specifically rapidly cooling the hot rolled steel sheet within 1.0 second after the end of the finish rolling, preferably within 0.8 second, to suppress the growth of austenite grains is extremely important in making pearlite form homogeneously dispersed in the hot rolled steel sheet. The average cooling speed and cooling time period at the time of rapid cooling are not particularly limited, but, for example, the average cooling speed is preferably 200 to 1000°C/s and the cooling time period is preferably 0.2 to 2.0 seconds.

[0099] Next, the rapidly cooled hot rolled steel sheet is cooled by an average cooling speed of 90°C/s or more. If the cooling speed is slow, bainite is greatly formed, austenite remains as retained austenite, and formation of a metallographic structure mainly comprised of ferrite and pearlite becomes no longer possible. As a result, controlling the arrangement of ferrite and pearlite becomes difficult. In particular, achieving homogeneous dispersion of pearlite becomes difficult. On the other hand, by cooling at an average cooling speed of 90°C/s or more, it is possible to form a metallographic structure comprised mainly of ferrite and pearlite, more specifically, possible to form a metallographic structure having a total of the area ratios of ferrite and pearlite of 80% or more. The average cooling speed is preferably 95°C/s or more. The upper limit is not particularly prescribed, but the average cooling speed may, for example, be 200°C/s or less or 150°C/s or less.

[Coiling Step]

[0100] Next, the finish rolled hot rolled steel sheet is coiled at a temperature of 500 to 700°C. If the coiling temperature is high, grain growth occurs and sometimes homogeneous dispersion of pearlite is obstructed. On the other hand, if the coiling temperature is low, bainite and martensite are formed and formation of a metallographic structure mainly comprised of ferrite and pearlite becomes no longer possible. As opposed to this, by controlling the coiling temperature to 500 to 700°C, it is possible to suppress grain growth and keep ferrite from being arranged connected at the hot rolled steel sheet after rolling and possible to make the pearlite homogeneously disperse. Preferably, the coiling temperature is 505 to 650°C or 550 to 650°C. Further, after coiling, the coil may be treated to soften it for the purpose of softening the hot rolled steel sheet. The method of heat treatment for softening is not particularly limited. General conditions may be used.

[Pickling Step]

[0101] After the coiling step and before the cold rolling step, pickling may be performed for removing the oxide scale formed on the surface of the hot rolled steel sheet. The pickling may be performed under conditions suitable for removing oxide scale. It may be performed at one time or may be performed divided into several times so as to reliably remove the oxide scale.

[Cold Rolling Step]

[0102] After the coiling step, the steel sheet may be optionally cold rolled. The cold rolling is not particularly limited and may be performed under any suitable conditions. For example, the rolling reduction of the cold rolling may be 30 to 80%. The number of rolling passes and the rolling reduction per pass are not particularly limited and may be suitable set so that the rolling reduction of the cold rolling as a whole becomes the above range.

[Annealing Step]

[0103] For example, after the cold rolling step, annealing may optionally be performed to adjust the metallographic structure and/or properties. The heating temperature of the annealing step is not particularly limited, but may for example be 800°C or less.

[Plating Step]

[0104] For the purpose of improving the corrosion resistance, etc., the surface of the hot rolled steel sheet or cold rolled steel sheet may be treated to plate it. The plating treatment may be hot dip coating, hot dip alloyed coating, electroplating, or other treatment. For example, the steel sheet may be hot dip galvanized as plating treatment or may be hot dip galvanized and then alloyed. As the plating layer, an aluminum plating layer, aluminum-zinc plating layer, aluminum-silicon plating layer, hot dip galvanized layer, electrogalvanized layer, hot dip galvanized layer, zinc-nickel plating layer, aluminum-magnesium-zinc plating layer, etc., may be illustrated. The specific conditions of the plating treatment and alloying treatment are not particularly limited and may be any suitable conditions known to persons skilled in the art.

[Temper Rolling Step]

[0105] To correct the shape of the steel sheet or adjust the surface roughness, etc., it is possible, for example, to temper roll the steel sheet after the annealing step, or after the plating step.

<Method of Production of Hot Stamped Part>

[0106] Next, the method of production of the hot stamped part according to an embodiment of the present invention will be explained. Specifically, this method of production includes hot stamping a steel sheet for hot stamping obtained by the method of production of a steel sheet for hot stamping explained above, wherein the hot stamping includes heating the steel sheet for hot stamping to a temperature range of 800°C to 1000°C, then holding it there for 60 to 600 seconds.

[Hot Stamping Step]

[0107] The steel sheet for hot stamping is hot stamped in the hot stamping step so as to produce a hot stamped part having the desired chemical composition and metallographic structure. In the present embodiment, at the time of heating in the hot stamping, the homogeneously dispersed pearlite in the metallographic structure of the steel sheet forms starting points for formation of austenite. In the subsequent forming and cooling operations, the desired hard structures are formed, the desired prior austenite grain size distribution with reduced variations is obtained, and therefore a hot stamped part having a metallographic structure in which variation in hardness of the prior austenite grains is reduced is produced. From the viewpoint of obtaining such desired hard structures and hardness distribution of prior austenite grains, it is preferable to heat the steel sheet for hot stamping to a temperature range of 800°C to 1000°C and hold it at the temperature range for 60 to 600 seconds. If the heating temperature is less than 800°C, sometimes the austenization will become insufficient, the desired area ratio of the hard structures (at least one of martensite, bainite, and tempered martensite) will not be able to be obtained, and the tensile strength will deteriorate. On the other hand, if the heating temperature is more than 1000°C, the austenite grains will excessively grow, the desired prior austenite grain size distribution will not be able to be obtained, and, as a result, sometimes the desired hardness distribution of the prior austenite grains will not be able to be obtained and the hydrogen embrittlement resistance will deteriorate. If the holding time period is less than 60 seconds, in the same way as

the case where the heating temperature is less than 800°C, sometimes the austenization will become insufficient, the desired area ratio of the hard structures (at least one of martensite, bainite, and tempered martensite) will not be able to be obtained, and the tensile strength will deteriorate. If the holding time period is more than 600 seconds, the austenite grains will excessively grow, the desired prior austenite grain size distribution will not be able to be obtained, and, as a result, sometimes the desired hardness distribution of the prior austenite grains will not be able to be obtained, and the hydrogen embrittlement resistance will deteriorate.

[0108] The heating atmosphere is not particularly limited. Usual conditions are enough. For example, it may be an air atmosphere, a gas combustion atmosphere controlled in ratio of air and fuel, and a nitrogen atmosphere. The dew points may also be controlled in these gases. The steel sheet is held at a temperature range of 800°C to 1000°C, then hot stamped. After hot stamping, it may be cooled down to a temperature region of 250°C or less by an average cooling speed of 20°C/s or more.

[0109] As the heating method before hot stamping, for example, furnace heating by an electric furnace, gas furnace, etc., flame heating, ohmic heating, high frequency heating, induction heating, etc., may be mentioned.

[0110] The hot stamped part according to the present embodiment is obtained by the above method. After hot stamping, it may be tempered at 130 to 600°C or coated, then bake hardened (BH). Further, part of the hot stamped part may be tempered by being irradiated by a laser, etc. to partially provide softened regions.

[0111] Below, examples will be used to explain the present invention in more detail, but the present invention is not limited to these examples in any way.

EXAMPLES

[0112] In the following examples, hot stamped parts according to an embodiment of the present invention were produced under various conditions and the tensile strength and hydrogen embrittlement resistance of the obtained hot stamped parts were investigated.

[0113] First, molten steels having the chemical compositions shown in Table 1 were cast by continuous casting to produce slabs. The balances besides the constituents shown in Table 1 were Fe and impurities. These slabs were heated to a temperature of 1100°C or more and rough rolled under predetermined conditions, then were finish rolled, cooled, and coiled under conditions shown in Table 2. In all of the invention examples and comparative examples, the average cooling speed at the time of rapid cooling after the end of finish rolling was within a range of 200 to 1000°C/s and the cooling time period was within a range of 0.2 to 2.0 seconds. Next, the obtained hot rolled steel sheets were cold rolled by predetermined rolling reductions of 30 to 80%. Next, some of the steel sheets were subjected to annealing, plating, or temper rolling under predetermined conditions. Next, the obtained steel sheets were hot stamped under the conditions shown in Table 2. The heating atmosphere and heating method in the hot stamping step, except when clearly indicated otherwise, were a gas combustion atmosphere (air-fuel ratio 0.85) and furnace heating. After the hot stamping, some of the hot stamped parts were tempered or partially softened.

[Table 1-1]

[0114]

Table 1-1

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
A1	0.37	0.440	1.30	0.007	0.0018	0.0022	0.0022	0.0410	0.020	0.034	0.0031	0.21	0.153
A2	0.41	0.410	1.32	0.005	0.0018	0.0033	0.0014	0.0610	0.041	0.027	0.0034	0.22	0.229
A3	0.43	0.450	1.32	0.005	0.0004	0.0021	0.0014	0.0540	0.019	0.045	0.0032	0.31	0.228
A4	0.44	0.410	1.36	0.010	0.0011	0.0026	0.0029	0.0550	0.016	0.044	0.0031	0.21	0.223
A5	0.45	0.400	1.27	0.005	0.0018	0.0028	0.0025	0.0530	0.031	0.032	0.0023	0.25	0.165
A6	0.46	0.410	1.24	0.004	0.0016	0.0023	0.0021	0.0480	0.018	0.040	0.0029	0.23	0.211
A7	0.48	0.450	1.34	0.005	0.0014	0.0036	0.0029	0.0600	0.019	0.025	0.0021	0.24	0.132
A8	0.50	0.420	1.24	0.008	0.0017	0.0040	0.0021	0.0430	0.021	0.024	0.0019	0.31	0.221
A9	0.55	0.410	1.36	0.005	0.0007	0.0028	0.0012	0.0560	0.029	0.036	0.0018	0.25	0.204
A10	0.61	0.410	1.25	0.005	0.0007	0.0022	0.0011	0.0470	0.041	0.048	0.0018	0.30	0.191
A11	0.66	0.430	1.25	0.006	0.0019	0.0040	0.0011	0.0480	0.036	0.044	0.0024	0.23	0.191
A12	0.68	0.440	1.26	0.010	0.0009	0.0033	0.0011	0.0530	0.034	0.041	0.0031	0.21	0.153
A13	0.73	0.400	1.30	0.004	0.0008	0.0031	0.0020	0.0590	0.019	0.029	0.0031	0.31	0.219
B1	0.45	0.007	1.32	0.004	0.0002	0.0023	0.0017	0.0600	0.019	0.041	0.0032	0.24	0.134
B2	0.44	0.014	1.33	0.006	0.0016	0.0026	0.0011	0.0550	0.029	0.036	0.0028	0.24	0.137
B3	0.47	0.060	1.27	0.010	0.0005	0.0035	0.0017	0.0540	0.033	0.023	0.0025	0.31	0.231
B4	0.47	0.150	1.27	0.006	0.0007	0.0029	0.0013	0.0430	0.031	0.032	0.0022	0.25	0.206
B5	0.47	0.240	1.32	0.009	0.0003	0.0023	0.0013	0.0450	0.022	0.046	0.0020	0.25	0.150
B6	0.45	0.370	1.28	0.010	0.0017	0.0039	0.0030	0.0510	0.030	0.038	0.0030	0.33	0.171
B7	0.44	0.560	1.36	0.009	0.0018	0.0035	0.0021	0.0440	0.032	0.044	0.0034	0.23	0.222
B8	0.44	0.750	1.36	0.004	0.0017	0.0027	0.0018	0.0600	0.031	0.048	0.0019	0.30	0.157
B9	0.46	0.940	1.28	0.008	0.0006	0.0033	0.0019	0.0520	0.036	0.035	0.0025	0.25	0.145
B10	0.46	1.080	1.36	0.006	0.0009	0.0025	0.0026	0.0420	0.025	0.035	0.0016	0.30	0.131
B11	0.47	1.250	1.27	0.008	0.0015	0.0028	0.0016	0.0530	0.024	0.036	0.0023	0.32	0.230

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
B12	0.44	1.400	1.24	0.007	0.0003	0.0030	0.0010	0.0590	0.015	0.028	0.0033	0.23	0.139
C1	0.46	0.470	0.55	0.007	0.0015	0.0033	0.0020	0.0570	0.014	0.045	0.0028	0.29	0.175
C2	0.45	0.400	0.62	0.004	0.0007	0.0034	0.0026	0.0540	0.027	0.021	0.0026	0.25	0.164
C3	0.44	0.450	0.69	0.006	0.0003	0.0031	0.0022	0.0520	0.023	0.035	0.0024	0.22	0.213
C4	0.46	0.400	0.75	0.010	0.0010	0.0022	0.0020	0.0550	0.038	0.027	0.0018	0.22	0.152
C5	0.44	0.440	0.88	0.008	0.0003	0.0023	0.0027	0.0470	0.034	0.039	0.0027	0.23	0.198
C6	0.44	0.390	1.10	0.010	0.0007	0.0030	0.0011	0.0410	0.041	0.037	0.0027	0.25	0.214
C7	0.45	0.390	1.30	0.006	0.0013	0.0026	0.0016	0.0410	0.016	0.042	0.0019	0.31	0.130
C8	0.44	0.470	1.60	0.007	0.0007	0.0033	0.0020	0.0390	0.020	0.037	0.0018	0.33	0.146
C9	0.45	0.470	1.70	0.009	0.0004	0.0024	0.0020	0.0470	0.028	0.043	0.0019	0.26	0.231
C10	0.45	0.450	1.90	0.010	0.0020	0.0036	0.0021	0.0610	0.033	0.028	0.0025	0.30	0.167
C11	0.45	0.440	2.20	0.009	0.0004	0.0027	0.0030	0.0470	0.019	0.029	0.0032	0.22	0.171
C12	0.44	0.430	2.40	0.008	0.0018	0.0030	0.0029	0.0450	0.031	0.037	0.0025	0.24	0.134
C13	0.44	0.440	2.60	0.006	0.0019	0.0039	0.0022	0.0600	0.035	0.040	0.0022	0.30	0.136
C14	0.45	0.420	2.80	0.010	0.0008	0.0038	0.0017	0.0600	0.022	0.022	0.0030	0.21	0.219
C15	0.45	0.420	2.90	0.007	0.0019	0.0034	0.0013	0.0400	0.037	0.025	0.0020	0.25	0.138
C16	0.46	0.420	3.10	0.007	0.0015	0.0033	0.0024	0.0520	0.014	0.024	0.0025	0.23	0.209
D1	0.45	0.410	1.25	0.001	0.0004	0.0026	0.0016	0.0500	0.022	0.032	0.0016	0.30	0.175
D2	0.47	0.470	1.29	0.002	0.0008	0.0021	0.0012	0.0550	0.032	0.041	0.0021	0.26	0.177
D3	0.44	0.390	1.36	0.009	0.0008	0.0022	0.0015	0.0480	0.015	0.042	0.0029	0.25	0.164
D4	0.46	0.410	1.25	0.017	0.0015	0.0035	0.0026	0.0490	0.041	0.042	0.0020	0.31	0.181
D5	0.46	0.470	1.36	0.032	0.0005	0.0032	0.0016	0.0600	0.022	0.027	0.0023	0.27	0.178
D6	0.45	0.450	1.36	0.046	0.0010	0.0029	0.0023	0.0420	0.017	0.021	0.0029	0.29	0.223
D7	0.47	0.440	1.36	0.065	0.0007	0.0031	0.0013	0.0600	0.033	0.020	0.0022	0.21	0.230
D8	0.47	0.390	1.26	0.083	0.0010	0.0038	0.0015	0.0460	0.029	0.042	0.0029	0.27	0.219

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
D9	0.44	0.460	1.26	0.130	0.0007	0.0036	0.0029	0.0570	0.033	0.031	0.0030	0.33	0.178
E1	0.47	0.420	1.26	0.010	0.0006	0.0025	0.0028	0.0440	0.019	0.036	0.0024	0.29	0.188
E2	0.44	0.440	1.33	0.005	0.0010	0.0029	0.0015	0.0410	0.028	0.025	0.0031	0.27	0.131
E3	0.44	0.430	1.34	0.005	0.0020	0.0028	0.0023	0.0560	0.021	0.031	0.0031	0.21	0.160
E4	0.47	0.390	1.31	0.009	0.0040	0.0030	0.0027	0.0480	0.016	0.044	0.0018	0.24	0.206
E5	0.45	0.420	1.28	0.008	0.0060	0.0034	0.0026	0.0450	0.032	0.036	0.0025	0.27	0.220
E6	0.46	0.400	1.34	0.010	0.0070	0.0035	0.0024	0.0400	0.041	0.040	0.0033	0.23	0.192
E7	0.44	0.430	1.32	0.008	0.0080	0.0026	0.0012	0.0510	0.024	0.032	0.0028	0.24	0.188
E8	0.45	0.400	1.30	0.009	0.0090	0.0026	0.0027	0.0430	0.028	0.028	0.0017	0.23	0.186
E9	0.47	0.440	1.30	0.010	0.0120	0.0030	0.0027	0.0580	0.026	0.021	0.0024	0.21	0.195
F1	0.47	0.420	1.36	0.004	0.0019	0.0008	0.0021	0.0420	0.029	0.034	0.0016	0.30	0.163
F2	0.47	0.460	1.28	0.004	0.0004	0.0020	0.0022	0.0550	0.025	0.022	0.0032	0.28	0.138
F3	0.47	0.460	1.26	0.006	0.0006	0.0030	0.0020	0.0420	0.029	0.031	0.0028	0.32	0.161
F4	0.45	0.420	1.28	0.007	0.0013	0.0050	0.0016	0.0520	0.034	0.038	0.0028	0.29	0.172
F5	0.46	0.390	1.24	0.004	0.0005	0.0080	0.0010	0.0570	0.039	0.025	0.0029	0.21	0.170
F6	0.44	0.450	1.24	0.008	0.0007	0.0130	0.0027	0.0500	0.036	0.040	0.0023	0.32	0.218
Underlines indicate outside scope of present invention.													

[Table 1-2]

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[0115]

Table 1-2

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
F7	0.46	0.410	1.32	0.004	0.0002	0.0170	0.0014	0.0590	0.026	0.045	0.0024	0.22	0.178
F8	0.47	0.450	1.32	0.005	0.0018	0.0180	0.0026	0.0420	0.019	0.024	0.0029	0.21	0.216
F9	0.47	0.430	1.32	0.009	0.0002	<u>0.0240</u>	0.0011	0.0600	0.014	0.035	0.0023	0.25	0.162
G1	0.44	0.400	1.31	0.009	0.0019	0.0028	0.0009	0.0390	0.023	0.028	0.0023	0.31	0.177
G2	0.47	0.400	1.26	0.004	0.0019	0.0022	0.0020	0.0490	0.017	0.038	0.0023	0.21	0.160
G3	0.45	0.430	1.32	0.008	0.0013	0.0026	0.0030	0.0570	0.020	0.041	0.0030	0.33	0.131
G4	0.46	0.460	1.29	0.010	0.0013	0.0023	0.0060	0.0560	0.014	0.042	0.0030	0.27	0.173
G5	0.47	0.450	1.31	0.004	0.0003	0.0023	0.0090	0.0570	0.017		0.0020	0.27	0.217
G6	0.47	0.400	1.36	0.010	0.0005	0.0027	0.0120	0.0600	0.027	0.048	0.0031	0.25	0.204
G7	0.46	0.470	1.36	0.010	0.0020	0.0027	0.0150	0.0480	0.034	0.040	0.0018	0.23	0.151
G8	0.45	0.450	1.24	0.007	0.0012	0.0027	0.0190	0.0610	0.037	0.044	0.0024	0.23	0.152
G9	0.45	0.470	1.24	0.005	0.0004	0.0035	<u>0.0220</u>	0.0400	0.027	0.032	0.0016	0.28	0.160
H1	0.45	0.420	1.32	0.009	0.0002	0.0031	0.0027	<u>0.0008</u>	0.031	0.021	0.0023	0.32	0.211
H2	0.45	0.460	1.28	0.010	0.0010	0.0040	0.0024	0.0018	0.028	0.023	0.0027	0.26	0.216
H3	0.47	0.400	1.31	0.006	0.0016	0.0024	0.0014	0.0039	0.027	0.032	0.0021	0.26	0.228
H4	0.45	0.460	1.32	0.009	0.0016	0.0028	0.0010	0.0058	0.031	0.031	0.0027	0.26	0.169
H5	0.44	0.420	1.34	0.010	0.0011	0.0037	0.0018	0.0120	0.026	0.032	0.0020	0.23	0.141
H6	0.44	0.460	1.30	0.005	0.0018	0.0024	0.0013	0.0330	0.024	0.023	0.0034	0.33	0.145
H7	0.46	0.400	1.24	0.006	0.0005	0.0032	0.0021	0.0820	0.037	0.041	0.0034	0.27	0.165
H8	0.47	0.410	1.32	0.009	0.0011	0.0024	0.0018	0.1100	0.036	0.039	0.0026	0.24	0.166
H9	0.47	0.450	1.25	0.005	0.0008	0.0040	0.0016	0.1600	0.036	0.029	0.0021	0.32	0.166
H10	0.46	0.390	1.36	0.010	0.0015	0.0035	0.0026	0.2900	0.030	0.036	0.0021	0.21	0.178
H11	0.47	0.390	1.33	0.007	0.0014	0.0023	0.0014	0.3500	0.025	0.038	0.0025	0.21	0.188
H12	0.46	0.390	1.24	0.009	0.0018	0.0039	0.0011	0.4400	0.021	0.041	0.0019	0.25	0.130

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
H13	0.45	0.410	1.26	0.005	0.0017	0.0032	0.0023	<u>0.5300</u>	0.016	0.034	0.0024	0.29	0.130
I1	0.44	0.450	1.32	0.004	0.0008	0.0038	0.0028	0.0440	<u>0.0007</u>	0.027	0.0017	0.24	0.178
I2	0.45	0.390	1.28	0.010	0.0019	0.0027	0.0023	0.0520	<u>0.002</u>	0.032	0.0026	0.24	0.154
I3	0.46	0.430	1.29	0.009	0.0012	0.0039	0.0020	0.0560	0.006	0.025	0.0021	0.29	0.136
I4	0.44	0.400	1.28	0.008	0.0010	0.0028	0.0025	0.0490	0.015	0.027	0.0016	0.21	0.178
I5	0.47	0.440	1.32	0.010	0.0002	0.0024	0.0011	0.0520	0.024	0.039	0.0032	0.29	0.195
I6	0.45	0.450	1.26	0.007	0.0018	0.0030	0.0017	0.0550	0.038	0.019	0.0019	0.25	0.165
I7	0.44	0.410	1.25	0.009	0.0006	0.0037	0.0030	0.0440	0.045	0.037	0.0030	0.28	0.176
I8	0.45	0.440	1.32	0.006	0.0008	0.0024	0.0026	0.0410	0.052	0.038	0.0031	0.28	0.180
I9	0.44	0.440	1.35	0.006	0.0002	0.0025	0.0021	0.0480	0.068	0.038	0.0033	0.24	0.167
I10	0.47	0.390	1.28	0.005	0.0014	0.0025	0.0011	0.0490	0.083	0.047	0.0033	0.33	0.188
I11	0.47	0.430	1.36	0.005	0.0015	0.0039	0.0014	0.0510	0.096	0.021	0.0033	0.33	0.173
I12	0.44	0.440	1.36	0.009	0.0011	0.0024	0.0019	0.0530	<u>0.121</u>	0.039	0.0025	0.29	0.186
J1	0.46	0.440	1.33	0.007	0.0002	0.0026	0.0029	0.0470	0.038	<u>0.008</u>	0.0024	0.24	0.228
J2	0.46	0.390	1.26	0.010	0.0003	0.0039	0.0015	0.0590	0.039	0.013	0.0023	0.33	0.208
J3	0.44	0.470	1.31	0.009	0.0003	0.0035	0.0015	0.0560	0.018	0.023	0.0033	0.29	0.138
J4	0.46	0.460	1.33	0.004	0.0015	0.0020	0.0014	0.0510	0.033	0.045	0.0030	0.23	0.150
J5	0.46	0.450	1.32	0.006	0.0013	0.0039	0.0013	0.0440	0.031	0.068	0.0030	0.33	0.152
J6	0.45	0.390	1.30	0.009	0.0011	0.0035	0.0023	0.0440	0.022	0.075	0.0017	0.24	0.174
J7	0.46	0.400	1.34	0.005	0.0009	0.0029	0.0022	0.0500	0.021	0.092	0.0022	0.22	0.204
J8	0.44	0.450	1.32	0.010	0.0014	0.0032	0.0029	0.0610	0.018	0.111	0.0023	0.27	0.169
J9	0.45	0.470	1.36	0.010	0.0012	0.0030	0.0013	0.0410	0.017	0.133	0.0030	0.28	0.150
J10	0.46	0.420	1.30	0.006	0.0016	0.0031	0.0015	0.0480	0.031	0.159	0.0023	0.32	0.158
J11	0.44	0.420	1.26	0.010	0.0011	0.0020	0.0024	0.0400	0.027	0.187	0.0025	0.27	0.142
J12	0.45	0.450	1.27	0.006	0.0016	0.0020	0.0016	0.0520	0.028	0.213	0.0025	0.22	0.195

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
K1	0.44	0.400	1.31	0.004	0.0017	0.0022	0.0026	0.0580	0.041	0.019	<u>0.0004</u>	0.32	0.225
K2	0.46	0.420	1.33	0.004	0.0011	0.0024	0.0010	0.0470	0.027	0.033	0.0009	0.33	0.130
K3	0.45	0.420	1.29	0.010	0.0008	0.0027	0.0018	0.0460	0.024	0.022	0.0012	0.31	0.218
K4	0.46	0.440	1.35	0.008	0.0015	0.0029	0.0012	0.0530	0.016	0.024	0.0028	0.29	0.136
K5	0.47	0.400	1.33	0.007	0.0007	0.0033	0.0016	0.0540	0.019	0.041	0.0039	0.30	0.193
K6	0.45	0.430	1.25	0.006	0.0009	0.0026	0.0014	0.0420	0.022	0.042	0.0051	0.31	0.149
K7	0.47	0.470	1.24	0.007	0.0005	0.0021	0.0026	0.0500	0.016	0.037	0.0067	0.30	0.230
K8	0.44	0.400	1.34	0.009	0.0006	0.0037	0.0010	0.0520	0.019	0.034	0.0089	0.25	0.198
K9	0.44	0.430	1.34	0.010	0.0015	0.0036	0.0022	0.0410	0.016	0.044	0.0123	0.26	0.148
K10	0.47	0.410	1.30	0.009	0.0003	0.0034	0.0022	0.0500	0.019	0.047	0.0149	0.28	0.216
K11	0.45	0.450	1.34	0.010	0.0004	0.0037	0.0028	0.0470	0.025	0.032	0.0186	0.29	0.179
K12	0.46	0.430	1.30	0.006	0.0016	0.0026	0.0013	0.0540	0.039	0.024	<u>0.0227</u>	0.22	0.222
L1	0.47	0.430	1.26	0.010	0.0014	0.0023	0.0012	0.0490	0.026	0.041	0.0020	<u>0.006</u>	0.213
L2	0.47	0.470	1.30	0.008	0.0004	0.0023	0.0027	0.0500	0.019	0.043	0.0030	0.02	0.174
L3	0.44	0.460	1.29	0.008	0.0014	0.0021	0.0010	0.0490	0.031	0.028	0.0029	0.08	0.179
L4	0.47	0.450	1.25	0.006	0.0016	0.0029	0.0024	0.0470	0.025	0.037	0.0021	0.13	0.202
Underlines indicate outside scope of present invention.													

[Table 1-3]

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Table 1-3

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
L5	0.47	0.420	1.32	0.005	0.0011	0.0022	0.0025	0.0570	0.031	0.028	0.0026	0.19	0.157
L6	0.44	0.450	1.26	0.006	0.0016	0.0036	0.0019	0.0590	0.031	0.026	0.0025	0.24	0.193
L7	0.45	0.390	1.27	0.007	0.0002	0.0021	0.0030	0.0410	0.037	0.028	0.0029	0.36	0.169
L8	0.47	0.460	1.35	0.010	0.0008	0.0039	0.0017	0.0570	0.027	0.020	0.0021	0.44	0.133
L9	0.45	0.400	1.33	0.008	0.0002	0.0031	0.0024	0.0490	0.034	0.037	0.0026	0.53	0.156
L10	0.46	0.410	1.29	0.009	0.0015	0.0028	0.0023	0.0470	0.014	0.041	0.0022	0.65	0.191
L11	0.45	0.410	1.27	0.004	0.0009	0.0028	0.0011	0.0410	0.021	0.033	0.0019	0.78	0.150
L12	0.45	0.400	1.34	0.008	0.0002	0.0036	0.0012	0.0500	0.021	0.040	0.0024	0.89	0.146
M1	0.45	0.410	1.24	0.004	0.0012	0.0022	0.0013	0.0540	0.034	0.030	0.0021	0.33	0.0008
M2	0.45	0.430	1.34	0.008	0.0009	0.0038	0.0023	0.0460	0.015	0.034	0.0024	0.26	0.002
M3	0.47	0.430	1.25	0.008	0.0013	0.0023	0.0011	0.0570	0.031	0.039	0.0018	0.24	0.005
M4	0.45	0.450	1.25	0.005	0.0007	0.0037	0.0012	0.0520	0.040	0.027	0.0024	0.31	0.018
M5	0.44	0.430	1.36	0.005	0.0012	0.0020	0.0026	0.0430	0.027	0.032	0.0029	0.22	0.056
M6	0.47	0.420	1.29	0.008	0.0006	0.0031	0.0022	0.0610	0.026	0.043	0.0017	0.32	0.085
M7	0.47	0.420	1.31	0.009	0.0005	0.0026	0.0015	0.0530	0.040	0.029	0.0027	0.22	0.213
M8	0.44	0.420	1.30	0.007	0.0020	0.0029	0.0030	0.0420	0.023	0.020	0.0034	0.23	0.441
M9	0.44	0.460	1.36	0.010	0.0009	0.0038	0.0026	0.0420	0.016	0.038	0.0034	0.26	0.592
M10	0.44	0.450	1.27	0.007	0.0005	0.0029	0.0024	0.0470	0.037	0.026	0.0022	0.32	0.773
M11	0.47	0.440	1.32	0.006	0.0009	0.0027	0.0015	0.0450	0.036	0.032	0.0017	0.31	0.938
M12	0.44	0.420	1.25	0.005	0.0019	0.0021	0.0022	0.0520	0.017	0.024	0.0034	0.27	1.227
N1	0.46	0.400	1.34	0.004	0.0016	0.0029	0.0028	0.0410	0.013	0.044	0.0031	0.25	0.225
N2	0.45	0.460	1.35	0.005	0.0010	0.0033	0.0016	0.0570	0.020	0.042	0.0017	0.22	0.184
N3	0.45	0.390	1.34	0.006	0.0002	0.0024	0.0027	0.0460	0.035	0.041	0.0031	0.24	0.227
N4	0.46	0.390	1.26	0.005	0.0018	0.0040	0.0018	0.0600	0.040	0.043	0.0022	0.30	0.185

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
N5	0.44	0.420	1.24	0.008	0.0008	0.0027	0.0018	0.0550	0.032	0.028	0.0032	0.30	0.193
N6	0.45	0.400	1.28	0.006	0.0009	0.0028	0.0013	0.0600	0.033	0.035	0.0032	0.21	0.156
N7	0.47	0.450	1.34	0.009	0.0009	0.0025	0.0021	0.0570	0.015	0.028	0.0030	0.32	0.206
N8	0.45	0.450	1.24	0.005	0.0005	0.0031	0.0030	0.0560	0.035	0.033	0.0019	0.32	0.230
N9	0.47	0.420	1.26	0.009	0.0001	0.0020	0.0025	0.0520	0.022	0.041	0.0022	0.27	0.195
N10	0.47	0.410	1.31	0.008	0.0002	0.0030	0.0021	0.0580	0.022	0.047	0.0022	0.30	0.186
N11	0.44	0.400	1.36	0.004	0.0007	0.0033	0.0028	0.0390	0.020	0.025	0.0023	0.29	0.190
N12	0.44	0.440	1.25	0.010	0.0008	0.0028	0.0018	0.0540	0.024	0.034	0.0020	0.22	0.213
O1	0.44	0.450	1.28	0.006	0.0007	0.0020	0.0026	0.0530	0.016	0.031	0.0021	0.21	0.147
O2	0.46	0.390	1.34	0.008	0.0015	0.0022	0.0014	0.0440	0.019	0.019	0.0025	0.33	0.190
O3	0.44	0.450	1.24	0.009	0.0015	0.0029	0.0013	0.0410	0.017	0.043	0.0033	0.24	0.221
O4	0.44	0.390	1.31	0.005	0.0005	0.0021	0.0027	0.0400	0.018	0.035	0.0016	0.29	0.169
O5	0.46	0.410	1.30	0.007	0.0014	0.0024	0.0020	0.0510	0.020	0.026	0.0017	0.24	0.199
O6	0.44	0.430	1.25	0.004	0.0018	0.0020	0.0012	0.0570	0.018	0.027	0.0017	0.25	0.188
O7	0.47	0.420	1.25	0.007	0.0020	0.0035	0.0024	0.0540	0.034	0.024	0.0025	0.32	0.212
O8	0.46	0.460	1.27	0.007	0.0010	0.0032	0.0017	0.0590	0.021	0.039	0.0026	0.24	0.228
O9	0.46	0.470	1.29	0.006	0.0005	0.0028	0.0022	0.0590	0.024	0.038	0.0023	0.28	0.145
O10	0.46	0.400	1.35	0.007	0.0005	0.0025	0.0025	0.0580	0.025	0.022	0.0028	0.26	0.219
O11	0.44	0.460	1.32	0.009	0.0009	0.0035	0.0016	0.0450	0.041	0.033	0.0032	0.28	0.135
P1	0.47	0.460	1.30	0.006	0.0008	0.0024	0.0013	0.0600	0.037	0.033	0.0022	0.27	0.199
P2	0.46	0.400	1.35	0.009	0.0017	0.0028	0.0024	0.0580	0.023	0.033	0.0028	0.26	0.185
P3	0.44	0.420	1.32	0.006	0.0009	0.0036	0.0018	0.0610	0.039	0.023	0.0025	0.21	0.189
P4	0.47	0.390	1.29	0.004	0.0016	0.0038	0.0016	0.0480	0.040	0.047	0.0030	0.22	0.224
P5	0.46	0.430	1.33	0.007	0.0012	0.0034	0.0013	0.0440	0.037	0.034	0.0026	0.32	0.206
P6	0.45	0.440	1.33	0.004	0.0003	0.0032	0.0025	0.0510	0.035	0.043	0.0021	0.26	0.178

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
P7	0.45	0.440	1.25	0.006	0.0015	0.0021	0.0019	0.0480	0.024	0.025	0.0017	0.29	0.206
P8	0.46	0.390	1.24	0.004	0.0011	0.0024	0.0023	0.0550	0.028	0.026	0.0033	0.29	0.171
Q1	0.45	0.460	1.24	0.010	0.0010	0.0035	0.0022	0.0440	0.031	0.045	0.0030	0.32	0.203
Q2	0.44	0.410	1.34	0.009	0.0003	0.0040	0.0021	0.0480	0.028	0.033	0.0024	0.31	0.171
Q3	0.45	0.420	1.29	0.005	0.0020	0.0022	0.0027	0.0600	0.037	0.027	0.0019	0.25	0.134
Q4	0.47	0.440	1.34	0.007	0.0003	0.0039	0.0013	0.0420	0.024	0.026	0.0033	0.30	0.194
Q5	0.46	0.410	1.30	0.004	0.0017	0.0033	0.0023	0.0560	0.015	0.040	0.0025	0.32	0.167
Q6	0.47	0.470	1.30	0.010	0.0010	0.0020	0.0011	0.0560	0.037	0.029	0.0028	0.23	0.217
Q7	0.44	0.450	1.31	0.005	0.0006	0.0038	0.0025	0.0560	0.032	0.041	0.0017	0.24	0.215
Q8	0.45	0.470	1.36	0.006	0.0020	0.0028	0.0021	0.0550	0.036	0.032	0.0021	0.30	0.219
Q9	0.46	0.410	1.33	0.010	0.0011	0.0025	0.0016	0.0510	0.026	0.027	0.0020	0.27	0.166
Q10	0.45	0.440	1.33	0.010	0.0012	0.0035	0.0027	0.0540	0.041	0.019	0.0028	0.31	0.201
R1	0.44	0.400	1.25	0.009	0.0004	0.0034	0.0023	0.0610	0.031	0.025	0.0030	0.32	0.203
R2	0.47	0.440	1.30	0.008	0.0003	0.0029	0.0025	0.0440	0.038	0.019	0.0028	0.30	0.194
R3	0.47	0.470	1.24	0.010	0.0004	0.0037	0.0018	0.0610	0.018	0.035	0.0027	0.28	0.144
R4	0.45	0.430	1.33	0.004	0.0011	0.0036	0.0017	0.0510	0.035	0.028	0.0024	0.24	0.136
Underlines indicate outside scope of present invention.													

[Table 1-4]

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Table 1-4

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
R5	0.44	0.410	1.35	0.004	0.0004	0.0020	0.0023	0.0410	0.030	0.027	0.0019	0.24	0.216
R6	0.44	0.460	1.24	0.009	0.0014	0.0031	0.0025	0.0480	0.018	0.047	0.0022	0.25	0.214
R7	0.46	0.390	1.34	0.007	0.0003	0.0022	0.0017	0.0590	0.023	0.029	0.0017	0.28	0.165
R8	0.46	0.440	1.34	0.005	0.0004	0.0021	0.0014	0.0600	0.020	0.029	0.0017	0.31	0.161
R9	0.45	0.460	1.36	0.006	0.0014	0.0028	0.0015	0.0540	0.021	0.036	0.0018	0.22	0.201
S1	0.46	0.460	1.30	0.004	0.0014	0.0030	0.0016	0.0400	0.031	0.029	0.0020	0.30	0.178
S2	0.46	0.420	1.36	0.004	0.0008	0.0027	0.0022	0.0490	0.017	0.033	0.0030	0.27	0.155
S3	0.45	0.410	1.35	0.008	0.0012	0.0039	0.0024	0.0390	0.031	0.045	0.0019	0.21	0.193
S4	0.45	0.460	1.31	0.005	0.0003	0.0040	0.0010	0.0520	0.013	0.019	0.0023	0.25	0.223
S5	0.46	0.430	1.29	0.008	0.0004	0.0024	0.0026	0.0440	0.037	0.026	0.0031	0.28	0.221
S6	0.47	0.460	1.24	0.009	0.0016	0.0032	0.0013	0.0470	0.020	0.028	0.0023	0.28	0.140
S7	0.46	0.430	1.34	0.010	0.0008	0.0028	0.0025	0.0600	0.036	0.033	0.0031	0.26	0.183
S8	0.46	0.470	1.35	0.009	0.0020	0.0034	0.0014	0.0420	0.032	0.048	0.0023	0.33	0.184
T1	0.46	0.400	1.29	0.009	0.0001	0.0038	0.0028	0.0580	0.040	0.040	0.0033	0.30	0.218
T2	0.47	0.430	1.35	0.004	0.0008	0.0025	0.0010	0.0440	0.032	0.043	0.0025	0.24	0.200
T3	0.47	0.410	1.28	0.009	0.0009	0.0022	0.0021	0.0490	0.024	0.026	0.0019	0.29	0.231
T4	0.47	0.470	1.36	0.007	0.0015	0.0040	0.0018	0.0420	0.027	0.020	0.0034	0.24	0.215
T5	0.45	0.420	1.28	0.006	0.0014	0.0022	0.0017	0.0400	0.030	0.030	0.0029	0.22	0.150
T6	0.47	0.450	1.31	0.010	0.0013	0.0028	0.0020	0.0560	0.020	0.033	0.0019	0.24	0.152
T7	0.45	0.460	1.31	0.007	0.0017	0.0034	0.0017	0.0400	0.040	0.039	0.0027	0.27	0.167
T8	0.47	0.410	1.26	0.007	0.0005	0.0028	0.0010	0.0390	0.039	0.030	0.0017	0.24	0.204
T9	0.46	0.420	1.33	0.005	0.0013	0.0025	0.0022	0.0460	0.013	0.035	0.0021	0.30	0.192
T10	0.45	0.440	1.28	0.009	0.0014	0.0031	0.0024	0.0590	0.028	0.023	0.0024	0.32	0.178
U1	0.46	0.440	1.27	0.009	0.0011	0.0022	0.0010	0.0570	0.030	0.028	0.0030	0.31	0.146

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
U2	0.47	0.420	1.26	0.005	0.0017	0.0026	0.0029	0.0600	0.041	0.030	0.0024	0.27	0.142
U3	0.45	0.430	1.24	0.005	0.0014	0.0029	0.0019	0.0600	0.031	0.042	0.0018	0.23	0.135
U4	0.44	0.420	1.32	0.008	0.0012	0.0039	0.0027	0.0580	0.029	0.029	0.0022	0.25	0.135
U5	0.46	0.450	1.35	0.004	0.0015	0.0021	0.0014	0.0390	0.016	0.025	0.0024	0.30	0.131
U6	0.44	0.460	1.24	0.004	0.0017	0.0021	0.0029	0.0430	0.014	0.031	0.0018	0.21	0.149
U7	0.44	0.390	1.28	0.009	0.0015	0.0024	0.0021	0.0610	0.039	0.044	0.0017	0.22	0.152
U8	0.46	0.460	1.25	0.010	0.0006	0.0023	0.0025	0.0480	0.019	0.019	0.0028	0.33	0.205
V1	0.46	0.400	1.28	0.004	0.0010	0.0040	0.0017	0.0430	0.029	0.019	0.0026	0.30	0.213
V2	0.47	0.390	1.25	0.005	0.0018	0.0035	0.0013	0.0420	0.017	0.027	0.0026	0.22	0.168
V3	0.44	0.420	1.31	0.010	0.0006	0.0021	0.0027	0.0600	0.019	0.028	0.0034	0.27	0.204
V4	0.44	0.440	1.24	0.010	0.0003	0.0036	0.0025	0.0530	0.027	0.038	0.0020	0.28	0.184
V5	0.44	0.460	1.27	0.007	0.0007	0.0035	0.0018	0.0520	0.039	0.023	0.0024	0.24	0.171
V6	0.45	0.430	1.32	0.006	0.0002	0.0024	0.0017	0.0580	0.036	0.037	0.0032	0.21	0.210
V7	0.44	0.430	1.25	0.007	0.0018	0.0027	0.0030	0.0600	0.016	0.042	0.0023	0.28	0.230
V8	0.44	0.430	1.32	0.008	0.0020	0.0035	0.0026	0.0390	0.018	0.024	0.0027	0.32	0.220
W1	0.45	0.470	1.30	0.004	0.0006	0.0021	0.0012	0.0550	0.017	0.031	0.0018	0.24	0.193
W2	0.47	0.470	1.29	0.005	0.0017	0.0025	0.0029	0.0490	0.023	0.032	0.0019	0.28	0.145
W3	0.47	0.460	1.27	0.007	0.0015	0.0036	0.0010	0.0460	0.024	0.031	0.0029	0.22	0.135
W4	0.46	0.430	1.33	0.010	0.0010	0.0035	0.0018	0.0590	0.029	0.023	0.0026	0.25	0.206
W5	0.45	0.470	1.30	0.005	0.0003	0.0020	0.0023	0.0560	0.020	0.032	0.0021	0.23	0.206
W6	0.47	0.430	1.36	0.008	0.0019	0.0021	0.0018	0.0390	0.015	0.034	0.0030	0.29	0.136
W7	0.44	0.390	1.31	0.008	0.0008	0.0023	0.0014	0.0560	0.024	0.042	0.0027	0.26	0.214
W8	0.45	0.420	1.28	0.004	0.0005	0.0035	0.0017	0.0530	0.041	0.030	0.0016	0.23	0.184
X1	0.44	0.470	1.30	0.004	0.0008	0.0022	0.0015	0.0600	0.016	0.030	0.0032	0.29	0.131
X2	0.46	0.430	1.35	0.006	0.0010	0.0040	0.0021	0.0490	0.024	0.048	0.0031	0.32	0.148

(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												
	C	Si	Mn	P	S	N	O	Al	Nb	Ti	B	Cr	Mo
X3	0.47	0.470	1.36	0.007	0.0016	0.0026	0.0023	0.0570	0.030	0.030	0.0025	0.22	0.184
X4	0.44	0.410	1.26	0.004	0.0010	0.0032	0.0030	0.0440	0.041	0.037	0.0029	0.33	0.224
X5	0.45	0.470	1.26	0.008	0.0001	0.0033	0.0021	0.0400	0.015	0.032	0.0018	0.30	0.181
X6	0.47	0.440	1.26	0.006	0.0015	0.0040	0.0020	0.0500	0.041	0.035	0.0018	0.22	0.207
X7	0.45	0.450	1.24	0.007	0.0015	0.0037	0.0022	0.0470	0.030	0.030	0.0030	0.27	0.138
X8	0.45	0.450	1.24	0.006	0.0016	0.0035	0.0011	0.0410	0.019	0.030	0.0032	0.22	0.165
Y1	0.47	0.390	1.36	0.007	0.0020	0.0037	0.0013	0.0470	0.015	0.023	0.0028	0.23	0.207
Y2	0.47	0.410	1.34	0.007	0.0017	0.0021	0.0013	0.0470	0.026	0.044	0.0033	0.30	0.219
Y3	0.45	0.390	1.35	0.010	0.0003	0.0039	0.0023	0.0420	0.015	0.047	0.0029	0.27	0.216
Y4	0.46	0.460	1.24	0.008	0.0012	0.0035	0.0028	0.0530	0.017	0.020	0.0022	0.24	0.206
Y5	0.47	0.430	1.32	0.005	0.0002	0.0036	0.0030	0.0450	0.019	0.019	0.0025	0.24	0.188
Y6	0.47	0.410	1.36	0.007	0.0019	0.0031	0.0020	0.0480	0.019	0.037	0.0025	0.27	0.153
Y7	0.47	0.440	1.24	0.008	0.0006	0.0024	0.0014	0.0510	0.026	0.035	0.0027	0.33	0.147
Y8	0.47	0.430	1.34	0.010	0.0004	0.0034	0.0023	0.0610	0.015	0.046	0.0019	0.29	0.149
Z1	0.46	0.420	1.24	0.009	0.0015	0.0037	0.0018	0.0580	0.018	0.027	0.0025	0.22	0.131
Underlines indicate outside scope of present invention.													

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[Table 1-5]

[0118]

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Table 1-5

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Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
A1													Comp. steel
A2													Inv. steel
A3													Inv. steel
A4													Inv. steel
A5													Inv. steel
A6													Inv. steel
A7													Inv. steel
A8													Inv. steel
A9													Inv. steel
A10													Inv. steel
A11													Inv. steel
A12													Inv. steel
A13													Comp. steel
B1													Comp. steel
B2													Inv. steel
B3													Inv. steel
B4													Inv. steel
B5													Inv. steel
B6													Inv. steel
B7													Inv. steel
B8													Inv. steel
B9													Inv. steel
B10													Inv. steel
B11													Inv. steel
B12													Comp. steel
C1													Comp. steel
C2													Inv. steel
C3													Inv. steel
C4													Inv. steel
C5													Inv. steel
C6													Inv. steel
C7													Inv. steel
C8													Inv. steel
C9													Inv. steel
C10													Inv. steel

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(continued)

	Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
		Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
5	C11													Inv. steel
	C12													Inv. steel
	C13													Inv. steel
	C14													Inv. steel
10	C15													Inv. steel
	C16													Comp. steel
	D1													Inv. steel
	D2													Inv. steel
15	D3													Inv. steel
	D4													Inv. steel
	D5													Inv. steel
	D6													Inv. steel
20	D7													Inv. steel
	D8													Inv. steel
	D9													Comp. steel
	E1													Inv. steel
25	E2													Inv. steel
	E3													Inv. steel
	E4													Inv. steel
	E5													Inv. steel
30	E6													Inv. steel
	E7													Inv. steel
	E8													Inv. steel
	E9													Comp. steel
35	F1													Inv. steel
	F2													Inv. steel
	F3													Inv. steel
	F4													Inv. steel
40	F5													Inv. steel
	F6													Inv. steel
45														
Underlines indicate outside scope of present invention.														

50 [Table 1-6]

[0119]

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Table 1-6

	Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
		Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
5	F7													Inv. steel
	F8													Inv. steel
	F9													Comp. steel
10	G1													Inv. steel
	G2													Inv. steel
	G3													Inv. steel
	G4													Inv. steel
15	G5													Inv. steel
	G6													Inv. steel
	G7													Inv. steel
20	G8													Inv. steel
	G9													Comp. steel
	H1													Comp. steel
	H2													Inv. steel
25	H3													Inv. steel
	H4													Inv. steel
	H5													Inv. steel
	H6													Inv. steel
30	H7													Inv. steel
	H8													Inv. steel
	H9													Inv. steel
35	H10													Inv. steel
	H11													Inv. steel
	H12													Inv. steel
	H13													Comp. steel
40	I1													Comp. steel
	I2													Inv. steel
	I3													Inv. steel
45	I4													Inv. steel
	I5													Inv. steel
	I6													Inv. steel
	I7													Inv. steel
50	I8													Inv. steel
	I9													Inv. steel
	I10													Inv. steel
55	I11													Inv. steel
	I12													Comp. steel
	J1													Comp. steel

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(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
5	J2												Inv. steel
	J3												Inv. steel
	J4												Inv. steel
10	J5												Inv. steel
	J6												Inv. steel
	J7												Inv. steel
	J8												Inv. steel
15	J9												Inv. steel
	J10												Inv. steel
	J11												Inv. steel
20	J12												Comp. steel
	K1												Comp. steel
	K2												Inv. steel
	K3												Inv. steel
25	K4												Inv. steel
	K5												Inv. steel
	K6												Inv. steel
30	K7												Inv. steel
	K8												Inv. steel
	K9												Inv. steel
	K10												Inv. steel
35	K11												Inv. steel
	K12												Comp. steel
	L1												Comp. steel
	L2												Inv. steel
40	L3												Inv. steel
	L4												Inv. steel
Underlines indicate outside scope of present invention.													

[Table 1-7]

[0120]

Table 1-7

Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Me	REM	Sb	Zr	Sn	As	
55	L5												Inv. steel
	L6												Inv. steel
	L7												Inv. steel

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(continued)

	Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
		Co	Ni	Cu	V	W	Ca	Me	REM	Sb	Zr	Sn	As	
5	L8													Inv. steel
	L9													Inv. steel
	L10													Inv. steel
	L11													Inv. steel
10	L12													Comp. steel
	M1													Comp. steel
15	M2													Inv. steel
	M3													Inv. steel
	M4													Inv. steel
	M5													Inv. steel
20	M6													Inv. steel
	M7													Inv. steel
	M8													Inv. steel
	M9													Inv. steel
25	M10													Inv. steel
	M11													Inv. steel
	M12													Comp. steel
	N1	0.001												Inv. steel
35	N2	0.003												Inv. steel
	N3	0.01												Inv. steel
	N4	0.02												Inv. steel
	N5	0.05												Inv. steel
40	N6	0.09												Inv. steel
	N7	0.20												Inv. steel
	N8	0.50												Inv. steel
	N9	0.70												Inv. steel
45	N10	0.90												Inv. steel
	N11	1.30												Inv. steel
	N12	1.80												Inv. steel
	O1		0.001											Inv. steel
50	O2		0.004											Inv. steel
	O3		0.07											Inv. steel
	O4		0.20											Inv. steel
	O5		0.40											Inv. steel
55	O6		0.60											Inv. steel
	O7		0.90											Inv. steel

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(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Me	REM	Sb	Zr	Sn	As	
5	O8	1.30											Inv. steel
	O9	1.90											Inv. steel
	O10	2.30											Inv. steel
10	O11	2.80											Inv. steel
	P1		0.001										Inv. steel
	P2		0.003										Inv. steel
	P3		0.03										Inv. steel
15	P4		0.12										Inv. steel
	P5		0.38										Inv. steel
	P6		0.54										Inv. steel
	P7		0.71										Inv. steel
20	P8		0.93										Inv. steel
	Q1			0.001									Inv. steel
	Q2			0.002									Inv. steel
25	Q3			0.01									Inv. steel
	Q4			0.03									Inv. steel
	Q5			0.07									Inv. steel
	Q6			0.25									Inv. steel
30	Q7			0.44									Inv. steel
	Q8			0.58									Inv. steel
	Q9			0.77									Inv. steel
35	Q10			0.89									Inv. steel
	R1				0.001								Inv. steel
	R2				0.005								Inv. steel
	R3				0.030								Inv. steel
40	R4				0.110								Inv. steel
Underlines indicate outside scope of present invention.													

[Table 1-8]

[0121]

Table 1-8

Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
50	R5				0.280								Inv. steel
	R6				0.530								Inv. steel
55	R7				0.650								Inv. steel
	R8				0.740								Inv. steel

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(continued)

	Steel type	Chemical composition (mass%, balance: Fe and impurities)											Remarks	
		Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn		As
5	R9					0.910								Inv. steel
	S1						0.0001							Inv. steel
	S2						0.0004							Inv. steel
10	S3						0.002							Inv. steel
	S4						0.004							Inv. steel
	S5						0.006							Inv. steel
	S6						0.007							Inv. steel
15	S7						0.009							Inv. steel
	S8						0.010							Inv. steel
20	T1							0.0001						Inv. steel
	T2							0.0005						Inv. steel
	T3							0.001						Inv. steel
	T4							0.004						Inv. steel
	T5							0.008						Inv. steel
25	T6							0.040						Inv. steel
	T7							0.080						Inv. steel
	T8							0.280						Inv. steel
	T9							0.510						Inv. steel
30	T10							0.730						Inv. steel
35	U1								0.0006					Inv. steel
	U2								0.002					Inv. steel
	U3								0.003					Inv. steel
	U4								0.007					Inv. steel
	U5								0.030					Inv. steel
	U6								0.080					Inv. steel
40	U7								0.210					Inv. steel
	U8								0.620					Inv. steel
45	V1													Inv. steel
	V2									0.001				Inv. steel
	V3									0.009				Inv. steel
	V4									0.060				Inv. steel
	V5									0.180				Inv. steel
50	V6									0.480				Inv. steel
	V7									0.750				Inv. steel
	V8									0.920				Inv. steel
55	W1										0.001			Inv. steel
	W2										0.003			Inv. steel
	W3										0.008			Inv. steel

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(continued)

Steel type	Chemical composition (mass%, balance: Fe and impurities)												Remarks
	Co	Ni	Cu	V	W	Ca	Mg	REM	Sb	Zr	Sn	As	
W4										0.040			Inv. steel
W5										0.130			Inv. steel
W6										0.440			Inv. steel
W7										0.710			Inv. steel
W8										0.950			Inv. steel
X1											0.001		Inv. steel
X2											0.009		Inv. steel
X3											0.030		Inv. steel
X4											0.080		Inv. steel
X5											0.140		Inv. steel
X6											0.310		Inv. steel
X7											0.640		Inv. steel
X8											0.880		Inv. steel
Y1												0.001	Inv. steel
Y2												0.003	Inv. steel
Y3												0.007	Inv. steel
Y4												0.021	Inv. steel
Y5												0.038	Inv. steel
Y6												0.055	Inv. steel
Y7												0.073	Inv. steel
Y8												0.082	Inv. steel
Z1													Inv. steel
Underlines indicate outside scope of present invention.													

[Table 2-1]

[0122]

Table 2-1

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
1	A1	48	0.66	118	582	913	488		Comp. ex.
2	A2	50	0.54	112	667	886	481		Inv. ex.
3	A3	52	0.73	97	666	898	483		Inv. ex.
4	A4	52	0.65	102	654	905	491		Inv. ex.

(continued)

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
39	C14	52	0.39	110	614	908	478		Inv. ex.
40	C15	48	0.25	103	580	886	472		Inv. ex.
41	C16	52	0.72	109	538	904	470		Comp. ex.
42	D1	45	0.59	106	610	891	472		Inv. ex.
43	D2	48	0.34	111	592	892	478		Inv. ex.
44	D3	48	0.64	117	581	886	489		Inv. ex.
45	D4	50	0.63	102	540	886	483		Inv. ex.
46	D5	45	0.35	116	610	894	465		Inv. ex.
47	D6	50	0.33	105	591	915	490		Inv. ex.
48	D7	49	0.67	99	573	882	485		Inv. ex.
49	D8	52	0.74	106	666	894	472		Inv. ex.
50	D9	50	0.72	119	530	904	488		Comp. ex.
51	E1	52	0.62	103	584	918	488		Inv. ex.
52	E2	49	0.71	96	606	912	475		Inv. ex.
53	E3	47	0.75	119	636	887	478		Inv. ex.
54	E4	52	0.35	107	574	883	466		Inv. ex.
55	E5	51	0.42	103	592	893	484		Inv. ex.
56	E6	50	0.8	104	606	916	469		Inv. ex.
Underlines indicate production conditions not preferable.									

[Table 2-2]

[0123]

Table 2-2

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
57	E7	48	0.52	112	646	904	473		Inv. ex.
58	E8	51	0.35	107	666	892	476		Inv. ex.
59	E9	51	0.69	108	612	913	473		Comp. ex.
60	F1	47	0.4	101	584	910	483		Inv. ex.

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(continued)

5	No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamp ing step		Others	Remarks
			Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
10	61	F2	46	0.68	107	669	893	475		Inv. ex.
	62	F3	51	0.44	114	577	886	489		Inv. ex.
15	63	F4	46	0.34	117	574	913	493		Inv. ex.
	64	F5	45	0.3	96	624	886	487		Inv. ex.
	65	F6	50	0.26	107	545	917	484		Inv. ex.
	66	F7	50	0.68	101	635	889	492		Inv. ex.
20	67	F8	50	0.57	111	623	913	490		Inv. ex.
	68	F9	49	0.5	118	544	904	482		Comp. ex.
	69	G1	52	0.36	105	632	916	475		Inv. ex.
25	70	G2	50	0.57	105	625	880	492		Inv. ex.
	71	G3	51	0.36	99	638	890	494		Inv. ex.
	72	G4	46	0.25	95	593	914	470		Inv. ex.
	73	G5	47	0.35	120	544	881	492		Inv. ex.
30	74	G6	50	0.29	96	651	905	491		Inv. ex.
	75	G7	48	0.41	105	615	901	473		Inv. ex.
	76	G8	51	0.33	99	612	911	485		Inv. ex.
	77	G9	45	0.45	103	600	913	487		Comp. ex.
35	78	H1	51	0.43	95	655	886	468		Comp. ex.
	79	H2	45	0.53	98	545	881	484		Inv. ex.
	80	H3	47	0.6	99	643	911	487		Inv. ex.
40	81	H4	52	0.5	114	559	893	465		Inv. ex.
	82	H5	52	0.54	114	603	890	484		Inv. ex.
	83	H6	47	0.64	114	630	905	479		Inv. ex.
	84	H7	49	0.64	117	648	896	481		Inv. ex.
45	85	H8	52	0.55	106	539	892	486		Inv. ex.
	86	H9	46	0.22	115	637	913	491		Inv. ex.
	87	H10	45	0.78	105	594	889	468		Inv. ex.
50	88	H11	51	0.58	95	533	918	483		Inv. ex.
	89	H12	51	0.49	105	573	915	494		Inv. ex.
	90	H13	50	0.34	102	664	919	483		Comp. ex.
	91	I1	52	0.55	101	634	906	493		Comp. ex.
55	92	I2	51	0.76	117	607	899	474		Inv. ex.
	93	I3	48	0.57	113	611	914	482		Inv. ex.
	94	I4	47	0.57	117	621	881	471		Inv. ex.

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
95	I5	50	0.28	112	557	890	489		Inv. ex.
96	I6	52	0.58	110	635	880	478		Inv. ex.
97	I7	45	0.62	119	646	919	465		Inv. ex.
98	I8	51	0.58	108	638	899	483		Inv. ex.
99	I9	48	0.43	108	588	894	480		Inv. ex.
100	I10	45	0.32	110	667	916	495		Inv. ex.
101	I11	46	0.42	111	663	897	473		Inv. ex.
102	I12	45	0.79	103	610	903	493		Comp. ex.
103	J1	48	0.59	116	612	915	475		Comp. ex.
104	J2	49	0.54	105	596	918	492		Inv. ex.
105	J3	50	0.48	104	579	901	486		Inv. ex.
106	J4	52	0.3	106	659	915	467		Inv. ex.
107	J5	51	0.47	106	640	903	475		Inv. ex.
108	J6	50	0.36	109	572	905	493		Inv. ex.
109	J7	45	0.6	120	598	886	495		Inv. ex.
110	J8	48	0.34	111	569	915	467		Inv. ex.
111	J9	45	0.35	102	614	906	486		Inv. ex.
112	J10	46	0.55	97	665	916	477		Inv. ex.
Underlines indicate production conditions not preferable.									

[Table 2-3]

[0124]

Table 2-3

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
113	J11	47	0.22	115	613	914	490		Inv. ex.
114	J12	45	0.8	110	607	912	472		Comp. ex.
115	K1	45	0.68	101	606	915	490		Comp. ex.
116	K2	51	0.7	116	666	910	470		Inv. ex.

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(continued)

5	No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
			Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
10	117	K3	50	0.8	101	568	912	495		Inv. ex.
	118	K4	50	0.62	107	634	901	482		Inv. ex.
15	119	K5	51	0.66	113	587	905	490		Inv. ex.
	120	K6	52	0.47	109	653	918	494		Inv. ex.
	121	K7	51	0.49	108	594	903	466		Inv. ex.
	122	K8	46	0.62	105	583	883	486		Inv. ex.
20	123	K9	50	0.54	100	568	897	495		Inv. ex.
	124	K10	47	0.51	113	612	897	482		Inv. ex.
	125	K11	47	0.39	103	670	908	488		Inv. ex.
	126	K12	47	0.36	104	601	898	492		Comp. ex.
25	127	L1	52	0.4	100	578	890	495		Comp. ex.
	128	L2	48	0.28	113	626	898	490		Inv. ex.
	129	L3	49	0.48	101	546	902	483		Inv. ex.
30	130	L4	49	0.71	105	622	913	482		Inv. ex.
	131	L5	45	0.4	112	556	904	484		Inv. ex.
	132	L6	47	0.53	101	659	906	474		Inv. ex.
	133	L7	50	0.21	105	657	892	494		Inv. ex.
35	134	L8	48	0.37	117	645	887	473		Inv. ex.
	135	L9	52	0.45	111	598	893	480		Inv. ex.
	136	L10	45	0.43	100	582	911	474		Inv. ex.
40	137	L11	45	0.24	101	532	914	495		Inv. ex.
	138	L12	52	0.38	118	652	884	478		Comp. ex.
	139	M1	47	0.66	106	533	906	483		Comp. ex.
	140	M2	48	0.74	103	668	903	473		Inv. ex.
45	141	M3	52	0.44	115	669	899	487		Inv. ex.
	142	M4	50	0.34	97	585	906	469		Inv. ex.
	143	M5	49	0.64	95	643	910	493		Inv. ex.
50	144	M6	45	0.36	113	610	909	467		Inv. ex.
	145	M7	48	0.27	108	597	915	479		Inv. ex.
	146	M8	50	0.53	112	618	880	465		Inv. ex.
	147	M9	46	0.26	119	572	888	494		Inv. ex.
55	148	M10	48	0.57	98	584	904	494		Inv. ex.
	149	M11	52	0.58	100	561	914	488		Inv. ex.
	150	M12	47	0.34	105	597	893	468		Comp. ex.

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
151	N1	49	0.73	115	605	909	483		Inv. ex.
152	N2	47	0.75	95	630	894	465		Inv. ex.
153	N3	48	0.71	107	547	900	465		Inv. ex.
154	N4	51	0.35	110	538	907	490		Inv. ex.
155	N5	48	0.31	100	546	899	487		Inv. ex.
156	N6	47	0.56	114	650	919	489		Inv. ex.
157	N7	49	0.58	115	537	880	469		Inv. ex.
158	N8	51	0.68	104	573	897	476		Inv. ex.
159	N9	47	0.71	105	668	896	489		Inv. ex.
160	N10	50	0.37	106	530	915	495		Inv. ex.
161	N11	47	0.41	108	550	892	484		Inv. ex.
162	N12	51	0.68	97	561	895	470		Inv. ex.
163	O1	48	0.23	109	635	907	483		Inv. ex.
164	O2	47	0.32	113	630	918	480		Inv. ex.
165	O3	50	0.79	107	582	916	492		Inv. ex.
166	O4	50	0.63	104	642	908	474		Inv. ex.
167	O5	45	0.75	102	565	895	485		Inv. ex.
168	O6	49	0.2	120	570	881	485		Inv. ex.
Underlines indicate production conditions not preferable.									

[Table 2-4]

[0125]

Table 2-4

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
169	O7	52	0.26	113	559	885	470		Inv. ex.
170	O8	48	0.26	120	589	907	473		Inv. ex.
171	O9	46	0.43	98	578	896	492		Inv. ex.
172	O10	47	0.74	116	584	901	473		Inv. ex.

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(continued)

5	No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
			Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
10	173	O11	52	0.21	115	531	889	484		Inv. ex.
	174	P1	45	0.75	95	665	880	473		Inv. ex.
15	175	P2	52	0.45	107	664	888	490		Inv. ex.
	176	P3	48	0.72	110	567	901	469		Inv. ex.
	177	P4	45	0.55	109	613	895	482		Inv. ex.
	178	P5	52	0.66	96	544	920	468		Inv. ex.
20	179	P6	45	0.35	104	657	881	484		Inv. ex.
	180	P7	49	0.35	118	561	886	470		Inv. ex.
	181	P8	52	0.45	114	534	909	485		Inv. ex.
25	182	Q1	48	0.27	114	532	915	489		Inv. ex.
	183	Q2	47	0.74	103	668	905	473		Inv. ex.
	184	Q3	47	0.71	112	621	913	468		Inv. ex.
	185	Q4	50	0.43	113	573	913	489		Inv. ex.
30	186	Q5	47	0.67	115	606	882	471		Inv. ex.
	187	Q6	51	0.73	98	614	918	473		Inv. ex.
	188	Q7	49	0.31	108	633	885	485		Inv. ex.
	189	Q8	47	0.64	109	587	888	493		Inv. ex.
35	190	Q9	49	0.37	112	580	907	468		Inv. ex.
	191	Q10	47	0.25	103	597	905	482		Inv. ex.
	192	R1	45	0.2	103	630	880	490		Inv. ex.
40	193	R2	52	0.29	110	621	890	490		Inv. ex.
	194	R3	50	0.52	110	602	903	468		Inv. ex.
	195	R4	51	0.74	95	543	883	466		Inv. ex.
	196	R5	49	0.69	110	591	887	484		Inv. ex.
45	197	R6	45	0.76	96	531	881	485		Inv. ex.
	198	R7	50	0.22	106	549	893	466		Inv. ex.
	199	R8	51	0.77	98	652	884	479		Inv. ex.
50	200	R9	48	0.31	101	647	892	493		Inv. ex.
	201	S1	51	0.34	112	577	908	492		Inv. ex.
	202	S2	52	0.39	111	545	898	489		Inv. ex.
	203	S3	45	0.69	108	646	914	492		Inv. ex.
55	204	S4	47	0.55	97	636	904	494		Inv. ex.
	205	S5	45	0.69	112	550	916	481		Inv. ex.
	206	S6	49	0.26	114	532	919	492		Inv. ex.

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
207	S7	49	0.75	109	610	889	478		Inv. ex.
208	S8	47	0.62	108	622	911	475		Inv. ex.
209	T1	50	0.66	116	636	884	481		Inv. ex.
210	T2	47	0.36	115	539	885	492		Inv. ex.
211	T3	51	0.65	116	532	917	465		Inv. ex.
212	T4	49	0.23	111	565	916	487		Inv. ex.
213	T5	51	0.41	100	546	908	472		Inv. ex.
214	T6	50	0.61	114	582	901	480		Inv. ex.
215	T7	50	0.4	103	583	892	485		Inv. ex.
216	T8	50	0.49	96	605	898	488		Inv. ex.
217	T9	47	0.8	119	572	914	491		Inv. ex.
218	T10	45	0.38	115	650	902	490		Inv. ex.
219	U1	46	0.68	110	658	885	470		Inv. ex.
220	U2	51	0.62	95	617	888	468		Inv. ex.
221	U3	48	0.61	118	653	903	466		Inv. ex.
222	U4	47	0.42	102	622	899	493		Inv. ex.
223	U5	47	0.2	116	559	912	468		Inv. ex.
224	U6	51	0.53	104	624	909	491		Inv. ex.
Underlines indicate production conditions not preferable.									

[Table 2-5]

[0126]

Table 2-5

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
225	U7	45	0.22	110	641	901	492		Inv. ex.
226	U8	46	0.79	105	626	919	471		Inv. ex.
227	V1	49	0.6	98	575	899	495		Inv. ex.
228	V2	51	0.67	100	532	881	493		Inv. ex.

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(continued)

5	No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
			Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
10	229	V3	46	0.22	105	570	915	488		Inv. ex.
	230	V4	48	0.72	104	543	896	487		Inv. ex.
15	231	V5	47	0.54	96	647	896	495		Inv. ex.
	232	V6	51	0.6	114	648	900	490		Inv. ex.
	233	V7	45	0.55	99	538	905	489		Inv. ex.
	234	V8	50	0.32	102	623	895	489		Inv. ex.
20	235	W1	47	0.27	103	632	899	485		Inv. ex.
	236	W2	49	0.45	117	613	909	469		Inv. ex.
	237	W3	46	0.77	109	600	889	470		Inv. ex.
	238	W4	52	0.36	95	569	882	469		Inv. ex.
25	239	W5	45	0.62	98	594	903	481		Inv. ex.
	240	W6	50	0.52	102	618	915	473		Inv. ex.
	241	W7	49	0.53	100	653	884	465		Inv. ex.
30	242	W8	46	0.68	106	606	910	478		Inv. ex.
	243	X1	48	0.48	109	651	919	480		Inv. ex.
	244	X2	47	0.63	115	645	885	483		Inv. ex.
	245	X3	48	0.56	103	614	907	484		Inv. ex.
35	246	X4	50	0.39	101	545	912	482		Inv. ex.
	247	X5	46	0.38	106	557	882	481		Inv. ex.
	248	X6	46	0.45	109	648	881	481		Inv. ex.
40	249	X7	46	0.3	100	566	882	479		Inv. ex.
	250	X8	48	0.34	118	605	891	491		Inv. ex.
	251	Y1	49	0.79	111	536	892	471		Inv. ex.
	252	Y2	51	0.78	109	570	911	473		Inv. ex.
45	253	Y3	48	0.28	110	568	904	470		Inv. ex.
	254	Y4	45	0.49	105	582	919	489		Inv. ex.
	255	Y5	46	0.8	111	594	899	478		Inv. ex.
50	256	Y6	48	0.38	96	531	886	489		Inv. ex.
	257	Y7	49	0.5	111	628	916	489		Inv. ex.
	258	YS	49	0.38	99	582	910	471		Inv. ex.
	259	Z1	35	0.74	117	637	914	484		Comp. ex.
55	260	Z1	40	0.25	119	662	914	469		Inv. ex.
	261	Z1	41	0.26	103	533	919	485		Inv. ex.
	262	Z1	43	0.42	118	592	892	479		Inv. ex.

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
263	Z1	46	0.69	110	577	896	482		Inv. ex.
264	Z1	52	0.34	118	651	905	485		Inv. ex.
265	Z1	50	0.22	105	641	913	489		Inv. ex.
266	Z1	52	0.41	100	594	896	473		Inv. ex.
267	Z1	45	0.59	110	583	917	490		Inv. ex.
268	Z1	52	0.83	104	585	908	471		Inv. ex.
269	Z1	47	0.98	101	602	889	481		Inv. ex.
270	Z1	46	<u>1.23</u>	112	544	889	487		Comp. ex.
271	Z1	49	0.22	<u>72</u>	605	887	494		Comp. ex.
272	Z1	48	0.22	91	600	880	490		Inv. ex.
273	Z1	50	0.38	93	542	917	488		Inv. ex.
274	Z1	52	0.44	99	670	900	474		Inv. ex.
275	Z1	45	0.43	121	557	903	482		Inv. ex.
276	Z1	51	0.2	109	<u>485</u>	900	480		Comp. ex.
277	Z1	47	0.7	98	506	912	495		Inv. ex.
278	Z1	47	0.29	97	538	904	483		Inv. ex.
279	Z1	50	0.63	111	577	887	486		Inv. ex.
280	Z1	51	0.57	109	615	908	465		Inv. ex.
Underlines indicate production conditions not preferable.									

[Table 2-6]

[0127]

Table 2-6

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
281	Z1	47	0.28	99	642	881	476		Inv. ex.
282	Z1	49	0.49	101	678	916	478		Inv. ex.
283	Z1	50	0.8	114	695	883	477		Inv. ex.
284	Z1	52	0.21	115	<u>731</u>	885	491		Comp. ex.

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(continued)

5	No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
			Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
10	285	Z1	49	0.79	95	607	906	478	Pickling	Inv. ex.
	286	Z1	47	0.8	112	616	919	474	No cold rolling	Inv. ex.
15	287	Z1	50	0.64	107	632	908	493	Annealing	Inv. ex.
	288	Z1	51	0.7	110	547	906	478	Al plating	Inv. ex.
	289	Z1	47	0.46	116	628	883	475	Al-Zn plating	Inv. ex.
	290	Z1	48	0.27	101	598	918	466	Al-Si plating	Inv. ex.
20	291	Z1	51	0.57	98	607	880	466	Hot dip galvanization	Inv. ex.
	292	Z1	49	0.59	107	579	900	467	Electroalvanization	Inv. ex.
	293	Z1	46	0.78	97	588	894	484	Hot dip galvannealing	Inv. ex.
25	294	Z1	48	0.39	118	645	915	480	Zn-Ni plating	Inv. ex.
	295	Z1	51	0.68	115	551	883	478	Al-Mg-Zn plating	Inv. ex.
	296	Z1	45	0.24	115	604	880	490	Temper rolling	Inv. ex.
	297	Z1	51	0.59	98	669	805	478		Inv. ex.
30	298	Z1	47	0.25	107	656	813	475		Inv. ex.
	299	Z1	46	0.78	112	596	832	494		Inv. ex.
	300	Z1	51	0.34	107	665	845	488		Inv. ex.
	301	Z1	45	0.49	117	649	876	466		Inv. ex.
35	302	Z1	51	0.57	119	615	903	483		Inv. ex.
	303	Z1	50	0.38	120	597	924	467		Inv. ex.
	304	Z1	50	0.43	107	567	951	471		Inv. ex.
40	305	Z1	45	0.71	114	570	975	472		Inv. ex.
	306	Z1	52	0.56	111	574	993	490		Inv. ex.
	307	Z1	49	0.23	107	534	897	64		Inv. ex.
	308	Z1	51	0.4	117	551	893	91		Inv. ex.
45	309	Z1	48	0.51	105	563	890	146		Inv. ex.
	310	Z1	45	0.69	106	594	912	195		Inv. ex.
	311	Z1	46	0.25	114	629	904	287		Inv. ex.
50	312	Z1	46	0.63	98	665	909	366		Inv. ex.
	313	Z1	49	0.37	104	647	913	425		Inv. ex.
	314	Z1	50	0.46	115	621	881	496		Inv. ex.
	315	Z1	47	0.22	111	594	896	521		Inv. ex.
55	316	Z1	52	0.21	117	544	902	563		Inv. ex.
	317	Z1	48	0.56	95	550	892	595		Inv. ex.

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(continued)

No.	Steel type	Hot rolling step	Cooling step		Coiling step	Hot stamping step		Others	Remarks
		Finish rolling final stage rolling reduction %	Time period until rapid cooling start s	Average cooling speed °C/s	Coiling temp. °C	Heating temp. °C	Holding time period s		
318	Z1	47	0.8	115	648	894	489	Gas combustion atmosphere (air-fuel ratio 0.80)	Inv. ex.
319	Z1	46	0.41	111	612	898	495	Gas combustion atmosphere (air-fuel ratio 0.85)	Inv. ex.
320	Z1	52	0.4	113	608	899	481	Gas combustion atmosphere (air-fuel ratio 1.1)	Inv. ex.
321	Z1	51	0.72	96	641	884	475	Air	Inv. ex.
322	Z1	49	0.53	95	592	885	467	Nitrogen gas (dew point -30°C)	Inv. ex.
323	Z1	52	0.71	110	542	917	472	Nitrogen gas (dew point 0°C)	Inv. ex.
324	Z1	45	0.3	114	598	883	472	Nitrogen dew point +10°C)	Inv. ex.
325	Z1	47	0.36	102	584	887	490	Ohmic heating temp.	Inv. ex.
326	Z1	52	0.55	108	616	904	466	Tempering temp. 152°C	Inv. ex.
327	Z1	47	0.8	107	558	913	488	Tempering temp. 170°C	Inv. ex.
328	Z1	45	0.44	95	612	908	492	Tempering temp. 201°C	Inv. ex.
329	Z1	46	0.31	112	591	884	474	Tempering temp. 341°C	Inv. ex.
330	Z1	49	0.42	105	553	885	473	Tempering temp. 433°C	Inv. ex.
331	Z1	46	0.5	114	563	909	491	Tempering temp. 521°C	Inv. ex.
332	Z1	49	0.76	107	543	903	481	Tempering temp. 591°C	Inv. ex.
333	Z1	52	0.26	102	605	910	486	Partial softening treatment	Inv. ex.
Underlines indicate production conditions not preferable.									

[0128] The properties of the obtained hot stamped part were measured and evaluated by the following methods:

[Tensile Strength (TS)]

[0129] The tensile strength (TS) of the hot stamped part was obtained from any position of the hot stamped part by

preparing a No. 5 test piece and conducting a tensile test based on JIS Z 2241: 2011. The crosshead speed was 1 mm/min.

[Hydrogen Embrittlement Resistance]

[0130] The hydrogen embrittlement resistance of the hot stamped part was evaluated as follows. First, a 1.2t×7.0W×68L (mm) test piece was fabricated. A four-point bending jig was used to impart various strain (stress) to the test piece. Next, this was dipped in hydrochloric acid (room temperature, pH=4) for 48 hours and the limit amount of strain where cracking occurred was investigated. Cases where the limit amount of strain was 0.6% or more were evaluated as passing (P) and cases where the limit amount of strain was less than 0.6% were evaluated as failing (F).

[0131] Cases where the tensile strength was 2200 MPa or more and the hydrogen embrittlement resistance was evaluated as passing were evaluated as a hot stamped part which is high in strength and able to suppress hydrogen embrittlement. The results are shown in Table 3. In Table 3, the area ratios of ferrite and pearlite and the dispersion index of pearlite at the steel sheet for hot stamping after the coiling step are shown. The remaining structure besides ferrite and pearlite was comprised of bainite, martensite, retained austenite, and/or trace amounts of carbides. Similarly, in Table 3, the area ratio of hard structures at the hot stamped part and the standard deviation in hardness distribution of the prior austenite grains (former γ grains) at the sheet thickness 1/4 position are shown. The "area ratio of hard structures" means the total of the area ratios of martensite, bainite, and tempered martensite. Further, the remaining structure other than the hard structures was comprised of ferrite, retained austenite, and/or pearlite.

[Table 3-1]

[0132]

Table 3-1

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance		
			Pearlite area ratio %								
1	A1	52	43	95	0.62	97	113	2174	P	Comp. ex.	
2	A2	48	51	99	0.60	98	101	2220	P	Inv. ex.	
3	A3	32	58	90	0.65	95	128	2330	P	Inv. ex.	
4	A4	35	60	95	0.66	94	109	2464	P	Inv. ex.	
5	A5	38	53	91	0.64	96	111	2481	P	Inv. ex.	
6	A6	41	57	98	0.60	97	110	2540	P	Inv. ex.	
7	A7	30	61	91	0.65	95	125	2574	P	Inv. ex.	
8	A8	45	46	91	0.65	94	126	2727	P	Inv. ex.	
9	A9	24	65	89	0.65	98	121	2795	P	Inv. ex.	
10	A10	46	48	94	0.66	97	127	2897	P	Inv. ex.	
11	A11	54	42	96	0.66	95	108	2941	P	Inv. ex.	
12	A12	32	58	90	0.61	98	96	3043	P	Inv. ex.	
13	A13	51	44	95	0.65	96	122	3115	F	Comp. ex.	
14	B1	40	53	93	0.65	96	101	2192	P	Comp. ex.	
15	B2	40	59	99	0.66	99	126	2243	P	Inv. ex.	
16	B3	37	56	93	0.65	97	98	2305	P	Inv. ex.	
17	B4	54	43	97	0.63	97	118	2503	P	Inv. ex.	
18	B5	33	61	94	0.61	97	119	2523	P	Inv. ex.	
19	B6	47	50	97	0.62	99	130	2546	P	Inv. ex.	
20	B7	51	44	95	0.65	96	116	2470	P	Inv. ex.	
21	B8	55	42	97	0.60	98	121	2507	P	Inv. ex.	
22	B9	58	36	94	0.61	99	103	2534	P	Inv. ex.	

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance		
			Pearlite area ratio %								
23	B10	68	30	98	0.56	96	132	2534	P	Inv. ex.	
24	B11	78	18	96	0.52	94	147	2431	P	Inv. ex.	
25	B12	91	<u>7</u>	98	0.38	96	<u>188</u>	2476	F	Comp. ex.	
26	C1	51	47	98	<u>0.41</u>	94	<u>179</u>	2525	F	Comp. ex.	
27	C2	42	52	94	0.51	99	<u>146</u>	2445	P	Inv. ex.	
28	C3	52	45	97	0.57	95	134	2548	P	Inv. ex.	
29	C4	47	43	90	0.65	95	123	2527	P	Inv. ex.	
30	C5	38	61	99	0.65	96	117	2513	P	Inv. ex.	
31	C6	33	63	96	0.67	98	99	2452	P	Inv. ex.	
32	C7	39	41	80	0.65	98	118	2431	P	Inv. ex.	
33	C8	43	44	87	0.60	96	119	2541	P	Inv. ex.	
34	C9	41	45	86	0.60	99	111	2489	P	Inv. ex.	
35	C10	42	47	89	0.64	95	99	2425	P	Inv. ex.	
36	C11	38	53	91	0.63	99	107	2430	P	Inv. ex.	
37	C12	37	55	92	0.67	97	126	2462	P	Inv. ex.	
38	C13	33	58	91	0.63	96	105	2504	P	Inv. ex.	
39	C14	29	68	97	0.58	97	137	2512	P	Inv. ex.	
40	C15	16	82	98	0.53	95	146	2515	P	Inv. ex.	
41	C16	6	92	98	<u>0.43</u>	95	<u>201</u>	2447	F	Comp. ex.	
42	D1	53	46	99	0.64	98	125	2530	P	Inv. ex.	
43	D2	47	49	96	0.61	98	116	2470	P	Inv. ex.	
44	D3	52	40	92	0.66	96	105	2468	P	Inv. ex.	
45	D4	53	42	95	0.66	99	130	2486	P	Inv. ex.	

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance		
			Pearlite area ratio %								
46	D5	56	40	96	0.62	95	115	2476	P	Inv. ex.	
47	D6	28	65	93	0.62	99	99	2432	P	Inv. ex.	
48	D7	42	50	92	0.63	98	113	2548	P	Inv. ex.	
49	D8	49	45	94	0.64	96	119	2449	P	Inv. ex.	
50	D9	37	62	99	0.65	98	124	2517	F	Comp. ex.	
51	E1	36	54	90	0.60	98	100	2466	P	Inv. ex.	
52	E2	43	49	92	0.63	96	125	2424	P	Inv. ex.	
53	E3	34	55	89	0.63	95	109	2433	P	Inv. ex.	
54	E4	26	64	90	0.66	98	98	2474	P	Inv. ex.	
55	E5	30	60	90	0.65	94	114	2424	P	Inv. ex.	
56	E6	34	65	99	0.67	96	110	2432	P	Inv. ex.	
Underlines indicate outside scope of present invention or values of properties not preferable.											

[Table 3-2]

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[0133]

Table 3-2

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B		A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %	Pearlite area ratio %							
57	E7	42	50	92	0.61	99	109	2521	P	Inv. ex.	
58	E8	39	59	98	0.60	99	109	2521	P	Inv. ex.	
59	E9	43	55	98	0.61	99	110	2483	F	Comp. ex.	
60	F1	54	44	98	0.59	95	103	2423	P	Inv. ex.	
61	F2	27	63	90	0.59	96	124	2477	P	Inv. ex.	
62	F3	36	62	98	0.60	98	123	2500	P	Inv. ex.	
63	F4	46	48	94	0.66	99	105	2548	P	Inv. ex.	
64	F5	41	58	99	0.65	97	125	2488	P	Inv. ex.	
65	F6	56	41	97	0.62	97	101	2525	P	Inv. ex.	
66	F7	51	47	98	0.64	97	95	2501	P	Inv. ex.	
67	F8	43	51	94	0.63	94	110	2494	P	Inv. ex.	
68	F9	49	41	90	0.60	96	98	2495	F	Comp. ex.	
69	G1	48	45	93	0.65	94	122	2444	P	Inv. ex.	
70	G2	53	43	96	0.61	94	119	2517	P	Inv. ex.	
71	G3	57	42	99	0.64	98	108	2455	P	Inv. ex.	
72	G4	52	42	94	0.59	98	124	2518	P	Inv. ex.	
73	G5	29	61	90	0.65	98	129	2505	P	Inv. ex.	
74	G6	28	62	90	0.66	95	109	2454	P	Inv. ex.	
75	G7	55	43	98	0.63	95	106	2534	P	Inv. ex.	
76	G8	49	48	97	0.62	97	100	2538	P	Inv. ex.	
77	G9	42	54	96	0.64	95	99	2464	F	Comp. ex.	
78	H1	57	40	97	0.59	96	118	2488	F	Comp. ex.	

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
										Ferrite area ratio %	Pearlite area ratio %	
79	H2	29	63	92	0.64	99	116	2437	P	Inv. ex.		
80	H3	52	46	98	0.62	99	110	2488	P	Inv. ex.		
81	H4	59	40	99	0.60	94	99	2536	P	Inv. ex.		
82	H5	47	50	97	0.67	97	116	2533	P	Inv. ex.		
83	H6	51	44	95	0.67	96	109	2475	P	Inv. ex.		
84	H7	51	47	98	0.63	98	104	2453	P	Inv. ex.		
85	H8	39	52	91	0.66	97	116	2535	P	Inv. ex.		
86	H9	56	43	99	0.61	99	111	2484	P	Inv. ex.		
87	H10	50	42	92	0.65	95	115	2476	P	Inv. ex.		
88	H11	54	43	97	0.66	99	118	2496	P	Inv. ex.		
89	H12	36	59	95	0.63	94	115	2549	P	Inv. ex.		
90	H13	45	45	90	0.60	97	104	2484	F	Comp. ex.		
91	I1	36	56	92	0.65	95	130	2171	P	Comp. ex.		
92	I2	39	52	91	0.64	96	100	2203	P	Inv. ex.		
93	I3	56	43	99	0.63	99	121	2372	P	Inv. ex.		
94	I4	37	62	99	0.61	99	105	2543	P	Inv. ex.		
95	I5	46	44	90	0.63	97	110	2542	P	Inv. ex.		
96	I6	56	43	99	0.64	94	99	2480	P	Inv. ex.		
97	I7	50	45	95	0.59	94	106	2495	P	Inv. ex.		
98	I8	32	57	89	0.65	98	122	2526	P	Inv. ex.		
99	I9	42	53	95	0.65	98	102	2532	P	Inv. ex.		
100	I10	37	58	95	0.61	95	128	2466	P	Inv. ex.		
101	I11	43	53	96	0.65	95	102	2428	P	Inv. ex.		

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B	Pearlite area ratio %	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %								
102	I12	36	53		89	0.59	98	110	2493	F	Comp. ex.
103	J1	39	50		89	0.64	99	130	<u>2152</u>	P	Comp. ex.
104	J2	43	47		90	0.64	99	116	2234	P	Inv. ex.
105	J3	41	53		94	0.66	96	110	2377	P	Inv. ex.
106	J4	42	57		99	0.64	97	95	2430	P	Inv. ex.
107	JS	39	58		97	0.67	98	105	2505	P	Inv. ex.
108	J6	34	60		94	0.64	94	119	2467	P	Inv. ex.
109	J7	30	64		94	0.60	99	127	2466	P	Inv. ex.
110	J8	54	43		97	0.64	95	107	2431	P	Inv. ex.
111	J9	30	60		90	0.59	97	110	2480	P	Inv. ex.
112	J10	<u>50</u>	<u>46</u>		<u>96</u>	<u>0.61</u>	<u>94</u>	<u>127</u>	2429	P	Inv. ex.
Underlines indicate outside scope of present invention or values of properties not preferable.											

[Table 3-3]

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[0134]

Table 3-3

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B		A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %	Pearlite area ratio %							
113	J11	41		53	94	0.60	99	117	2428	P	Inv. ex.
114	J12	28		65	93	0.62	98	106	2499	F	Comp. ex.
115	K1	51		46	97	0.65	97	120	2190	P	Comp. ex.
116	K2	41		50	91	0.63	98	129	2207	P	Inv. ex.
117	K3	46		48	94	0.63	98	125	2351	P	Inv. ex.
118	K4	28		61	89	0.60	99	98	2546	P	Inv. ex.
119	K5	41		51	92	0.60	99	129	2494	P	Inv. ex.
120	K6	31		59	90	0.63	98	109	2504	P	Inv. ex.
121	K7	37		59	96	0.60	98	117	2501	P	Inv. ex.
122	K8	30		59	89	0.66	97	130	2466	P	Inv. ex.
123	K9	45		49	94	0.66	99	105	2465	P	Inv. ex.
124	K10	37		55	92	0.62	99	124	2521	P	Inv. ex.
125	K11	42		54	96	0.61	97	98	2520	P	Inv. ex.
126	K12	30		60	90	0.61	99	102	2454	F	Comp. ex.
127	L1	38		57	95	0.61	98	100	2191	P	Comp. ex.
128	L2	36		55	91	0.60	99	104	2218	P	Inv. ex.
129	L3	53		42	95	0.63	99	128	2309	P	Inv. ex.
130	L4	30		65	95	0.65	97	127	2442	P	Inv. ex.
131	L5	44		48	92	0.67	96	109	2540	P	Inv. ex.
132	L6	44		51	95	0.61	98	100	2510	P	Inv. ex.
133	L7	27		65	92	0.63	95	111	2523	P	Inv. ex.
134	L8	45		46	91	0.61	99	104	2522	P	Inv. ex.

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
										Ferrite area ratio %		
135	L9	57	41	98	0.64	99	95	2541	P	Inv. ex.		
136	L10	54	45	99	0.64	95	101	2482	P	Inv. ex.		
137	L11	41	49	90	0.62	97	103	2530	P	Inv. ex.		
138	L12	39	50	89	0.60	97	128	2487	F	Comp. ex.		
139	M1	48	46	94	0.66	99	123	<u>2176</u>	P	Comp. ex.		
140	M2	41	58	99	0.62	98	115	2230	P	Inv. ex.		
141	M3	45	51	96	0.67	99	126	2314	P	Inv. ex.		
142	M4	40	56	96	0.62	98	118	2423	P	Inv. ex.		
143	M5	35	58	93	0.66	98	98	2495	P	Inv. ex.		
144	M6	52	45	97	0.59	99	118	2454	P	Inv. ex.		
145	M7	44	55	99	0.61	98	98	2444	P	Inv. ex.		
146	M8	42	55	97	0.65	98	122	2541	P	Inv. ex.		
147	M9	48	45	93	0.65	97	109	2441	P	Inv. ex.		
148	M10	35	63	98	0.66	98	114	2423	P	Inv. ex.		
149	M11	38	58	96	0.59	98	115	2548	P	Inv. ex.		
150	M12	40	51	91	0.67	99	95	2460	F	Comp. ex.		
151	N1	49	41	90	0.59	98	98	2590	P	Inv. ex.		
152	N2	45	50	95	0.67	95	104	2580	P	Inv. ex.		
153	N3	44	49	93	0.59	98	98	2558	P	Inv. ex.		
154	N4	35	59	94	0.61	94	125	2582	P	Inv. ex.		
155	N5	41	50	91	0.63	97	119	2611	P	Inv. ex.		
156	N6	36	55	91	0.64	99	115	2570	P	Inv. ex.		
157	N7	34	62	96	0.62	97	120	2583	P	Inv. ex.		

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	Pearlite area ratio %	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former γ grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance		
			Ferrite area ratio %									
158	N8	46	50		96	0.65	95	109	2577	P	Inv. ex.	
159	N9	35	64		99	0.60	94	118	2592	P	Inv. ex.	
160	N10	29	63		92	0.59	96	102	2553	P	Inv. ex.	
161	N11	46	52		98	0.61	96	119	2583	P	Inv. ex.	
162	N12	44	51		95	0.64	95	102	2611	P	Inv. ex.	
163	O1	38	60		98	0.65	94	118	2583	P	Inv. ex.	
164	O2	43	55		98	0.62	94	117	2604	P	Inv. ex.	
165	O3	51	46		97	0.64	95	104	2603	P	Inv. ex.	
166	O4	43	46		89	0.64	97	105	2587	P	Inv. ex.	
167	O5	36	61		97	0.60	94	120	2594	P	Inv. ex.	
168	O6	48	41		89	0.59	95	117	2607	P	Inv. ex.	
Underlines indicate outside scope of present invention or values of properties not preferable.												

[Table 3-4]

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[0135]

Table 3-4

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
			Pearlite area ratio %									
169	O7	46	52	98	0.64	99	130	2591	P	Inv. ex.		
170	O8	38	52	90	0.60	94	99	2594	P	Inv. ex.		
171	O9	46	53	99	0.67	96	111	2574	P	Inv. ex.		
172	O10	53	41	94	0.64	99	113	2568	P	Inv. ex.		
173	O11	49	42	91	0.65	94	120	2567	P	Inv. ex.		
174	P1	52	47	99	0.60	99	98	2588	P	Inv. ex.		
175	P2	52	47	99	0.66	94	121	2567	P	Inv. ex.		
176	P3	43	49	92	0.59	94	109	2571	P	Inv. ex.		
177	P4	54	41	95	0.61	97	98	2568	P	Inv. ex.		
178	P5	46	53	99	0.60	96	104	2569	P	Inv. ex.		
179	P6	51	41	92	0.65	96	110	2552	P	Inv. ex.		
180	P7	47	44	91	0.61	95	126	2557	P	Inv. ex.		
181	P8	39	54	93	0.61	95	101	2603	P	Inv. ex.		
182	Q1	32	64	96	0.65	94	109	2565	P	Inv. ex.		
183	Q2	40	50	90	0.61	98	122	2562	P	Inv. ex.		
184	Q3	49	49	98	0.67	94	113	2575	P	Inv. ex.		
185	Q4	58	40	98	0.66	99	117	2570	P	Inv. ex.		
186	Q5	29	63	92	0.62	98	102	2559	P	Inv. ex.		
187	Q6	30	65	95	0.64	98	103	2572	P	Inv. ex.		
188	Q7	52	45	97	0.59	96	127	2589	P	Inv. ex.		
189	Q8	41	50	91	0.66	97	112	2583	P	Inv. ex.		
190	Q9	45	53	98	0.60	95	127	2590	P	Inv. ex.		

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	Pearlite area ratio %	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance		
											Ferrite area ratio %	
191	Q10	54	44		98	0.64	94	108	2553	P	Inv. ex.	
192	R1	41	56		97	0.59	97	126	2448	P	Inv. ex.	
193	R2	50	47		97	0.59	97	112	2503	P	Inv. ex.	
194	R3	33	65		98	0.62	98	96	2481	P	Inv. ex.	
195	R4	44	45		89	0.64	98	118	2467	P	Inv. ex.	
196	R5	40	53		93	0.60	98	120	2545	P	Inv. ex.	
197	R6	50	46		96	0.67	98	124	2424	P	Inv. ex.	
198	R7	27	62		89	0.59	99	108	2497	P	Inv. ex.	
199	R8	34	56		90	0.63	98	121	2503	P	Inv. ex.	
200	R9	52	44		96	0.67	97	117	2538	P	Inv. ex.	
201	S1	45	54		99	0.65	99	123	2441	P	Inv. ex.	
202	S2	33	61		94	0.61	99	129	2505	P	Inv. ex.	
203	S3	34	56		90	0.61	94	112	2450	P	Inv. ex.	
204	S4	36	63		99	0.63	98	113	2491	P	Inv. ex.	
205	S5	37	56		93	0.67	97	112	2497	P	Inv. ex.	
206	S6	45	52		97	0.62	96	99	2470	P	Inv. ex.	
207	S7	43	53		96	0.61	94	103	2453	P	Inv. ex.	
208	S8	33	57		90	0.60	99	102	2455	P	Inv. ex.	
209	T1	47	47		94	0.64	97	104	2581	P	Inv. ex.	
210	T2	55	43		98	0.63	96	117	2598	P	Inv. ex.	
211	T3	47	47		94	0.59	97	110	2559	P	Inv. ex.	
212	T4	41	58		99	0.65	99	122	2561	P	Inv. ex.	
213	T5	54	44		98	0.64	95	125	2554	P	Inv. ex.	

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
			Ferrite area ratio %									
214	T6	54	45	99	0.62	97	114	2613	P	Inv. ex.		
215	T7	39	56	95	0.65	94	111	2616	P	Inv. ex.		
216	T8	39	50	89	0.59	95	128	2601	P	Inv. ex.		
217	T9	39	57	96	0.61	96	104	2579	P	Inv. ex.		
218	T10	48	45	93	0.60	99	99	2611	P	Inv. ex.		
219	U1	33	58	91	0.64	98	122	2449	P	Inv. ex.		
220	U2	29	61	90	0.66	94	99	2530	P	Inv. ex.		
221	U3	44	49	93	0.65	95	116	2525	P	Inv. ex.		
222	U4	46	43	89	0.67	97	104	2424	P	Inv. ex.		
223	U5	36	58	94	0.60	99	102	2548	P	Inv. ex.		
<u>224</u>	<u>U6</u>	<u>48</u>	<u>46</u>	<u>94</u>	<u>0.63</u>	98	<u>112</u>	<u>2507</u>	P	<u>Inv. ex.</u>		
Underlines indicate outside scope of present invention or values of properties not preferable.												

[Table 3-5]

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[0136]

Table 3-5

No.	Steel type	Steel sheet for hot stamp ping				Hot stamped part					Remarks
		A	B		A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %	Pearlite area ratio %							
225	U7	30	63		93	0.61	97	125	2480	P	Inv. ex.
226	U8	36	57		93	0.60	98	118	2527	P	Inv. ex.
227	V1	39	55		94	0.64	95	97	2446	P	Inv. ex.
228	V2	35	56		91	0.59	94	108	2434	P	Inv. ex.
229	V3	38	51		89	0.60	96	95	2423	P	Inv. ex.
230	V4	49	42		91	0.67	99	126	2485	P	Inv. ex.
231	V5	39	51		90	0.61	96	124	2494	P	Inv. ex.
232	V6	41	51		92	0.65	96	107	2506	P	Inv. ex.
233	V7	28	62		90	0.59	96	106	2437	P	Inv. ex.
234	V8	36	56		92	0.60	95	127	2432	P	Inv. ex.
235	W1	26	64		90	0.66	95	112	2507	P	Inv. ex.
236	W2	54	43		97	0.61	96	126	2541	P	Inv. ex.
237	W3	43	53		96	0.61	96	109	2537	P	Inv. ex.
238	W4	34	62		96	0.60	96	121	2482	P	Inv. ex.
239	W5	39	55		94	0.63	95	107	2501	P	Inv. ex.
240	W6	38	51		89	0.65	94	113	2447	P	Inv. ex.
241	W7	43	53		96	0.59	94	119	2500	P	Inv. ex.
242	W8	48	50		98	0.64	98	101	2516	P	Inv. ex.
243	X1	45	52		97	0.67	97	104	2493	P	Inv. ex.
244	X2	44	45		89	0.67	96	119	2421	P	Inv. ex.
245	X3	42	54		96	0.64	95	124	2429	P	Inv. ex.
246	X4	33	59		92	0.61	99	112	2538	P	Inv. ex.

(continued)

No.	Steel type	Steel sheet for hot stamp ping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
			Pearlite area ratio %									
247	X5	55	41	96	0.59	97	95	2523	P	Inv. ex.		
248	X6	43	53	96	0.62	95	97	2457	P	Inv. ex.		
249	X7	40	50	90	0.66	94	102	2536	P	Inv. ex.		
250	X8	35	62	97	0.67	96	105	2478	P	Inv. ex.		
251	Y1	44	48	92	0.60	99	110	2551	P	Inv. ex.		
252	Y2	32	63	95	0.64	98	122	2595	P	Inv. ex.		
253	Y3	54	45	99	0.65	98	102	2591	P	Inv. ex.		
254	Y4	43	54	97	0.66	99	121	2585	P	Inv. ex.		
255	Y5	42	55	97	0.63	95	101	2566	P	Inv. ex.		
256	Y6	33	65	98	0.59	97	107	2560	P	Inv. ex.		
257	Y7	48	50	98	0.63	95	100	2599	P	Inv. ex.		
258	Y8	41	57	98	0.62	94	114	2600	P	Inv. ex.		
259	Z1	42	47	89	0.41	95	183	2517	F	Comp. ex.		
260	Z1	49	46	95	0.52	96	148	2437	P	Inv. ex.		
261	Z1	45	53	98	0.55	97	135	2447	P	Inv. ex.		
262	Z1	38	53	91	0.58	97	138	2523	P	Inv. ex.		
263	Z1	39	56	95	0.66	97	122	2441	P	Inv. ex.		
264	Z1	44	48	92	0.66	97	119	2510	P	Inv. ex.		
265	Z1	56	41	97	0.67	95	101	2534	P	Inv. ex.		
266	Z1	49	43	92	0.62	98	106	2490	P	Inv. ex.		
267	Z1	30	62	92	0.62	99	122	2486	P	Inv. ex.		
268	Z1	31	65	96	0.57	94	135	2539	P	Inv. ex.		
269	Z1	27	63	90	0.51	94	143	2513	P	Inv. ex.		

(continued)

No.	Steel type	Steel sheet for hot stamping					Hot stamped part				Remarks
		A	B	Pearlite area ratio %	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %								
270	Z1	35	61		96	<u>0.39</u>	98	<u>199</u>	2530	F	Comp. ex.
271	Z1	39	38		<u>77</u>	<u>0.42</u>	93	<u>202</u>	2518	F	Comp. ex.
272	Z1	51	46		97	0.52	98	147	2492	P	Inv. ex.
273	Z1	50	46		96	0.56	97	133	2487	P	Inv. ex.
274	Z1	42	53		95	0.59	99	111	2485	P	Inv. ex.
275	Z1	57	40		97	0.65	97	98	2428	P	Inv. ex.
276	Z1	27	36		<u>63</u>	0.59	94	<u>186</u>	2421	F	Comp. ex.
277	Z1	33	50		83	0.66	96	148	2546	P	Inv. ex.
278	Z1	31	57		88	0.62	97	133	2443	P	Inv. ex.
279	Z1	43	47		90	0.66	99	107	2481	P	Inv. ex.
280	Z1	40	57		97	0.66	94	98	2522	P	Inv. ex.
Underlines indicate outside scope of present invention or values of properties not preferable.											

[Table 3-6]

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[0137]

Table 3-6

No.	Steel type	Steel sheet for hot stamp ping				Hot stamped part					Remarks
		A	B		A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %	Pearlite area ratio %							
281	Z1	46	51	97	0.62	98	114	2448	P	Inv. ex.	
282	Z1	57	42	99	0.57	96	139	2448	P	Inv. ex.	
283	Z1	53	41	94	0.53	97	141	2536	P	Inv. ex.	
284	Z1	31	59	90	0.44	98	207	2474	F	Comp. ex.	
285	Z1	30	63	93	0.60	94	104	2462	P	Inv. ex.	
286	Z1	32	65	97	0.62	98	96	2509	P	Inv. ex.	
287	Z1	37	55	92	0.67	96	112	2544	P	Inv. ex.	
288	Z1	35	64	99	0.65	96	112	2474	P	Inv. ex.	
289	Z1	46	49	95	0.61	95	107	2462	P	Inv. ex.	
290	Z1	36	55	91	0.62	98	110	2517	P	Inv. ex.	
291	Z1	33	61	94	0.62	96	129	2465	P	Inv. ex.	
292	Z1	45	52	97	0.67	97	122	2466	P	Inv. ex.	
293	Z1	44	52	96	0.62	96	124	2494	P	Inv. ex.	
294	Z1	40	51	91	0.59	95	99	2471	P	Inv. ex.	
295	Z1	37	60	97	0.66	98	102	2498	P	Inv. ex.	
296	Z1	42	56	98	0.60	99	121	2451	P	Inv. ex.	
297	Z1	44	50	94	0.61	91	101	2247	P	Inv. ex.	
298	Z1	30	63	93	0.66	93	99	2367	P	Inv. ex.	
299	Z1	31	65	96	0.60	96	126	2529	P	Inv. ex.	
300	Z1	50	46	96	0.66	95	127	2459	P	Inv. ex.	
301	Z1	28	65	93	0.67	99	127	2468	P	Inv. ex.	
302	Z1	34	57	91	0.61	96	102	2480	P	Inv. ex.	

(continued)

No.	Steel type	Steel sheet for hot stamp ping					Hot stamped part					Remarks
		A	B	A+B %	Pearlite dispersion index	Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance			
			Ferrite area ratio %							Pearlite area ratio %		
303	Z1	50	44	94	0.67	98	128	2451	P	Inv. ex.		
304	Z1	53	42	95	0.62	98	111	2522	P	Inv. ex.		
305	Z1	57	41	98	0.59	98	136	2512	P	Inv. ex.		
306	Z1	45	46	91	0.63	94	143	2432	P	Inv. ex.		
307	Z1	40	53	93	0.61	98	142	2462	P	Inv. ex.		
308	Z1	52	43	95	0.67	99	137	2465	P	Inv. ex.		
309	Z1	46	45	91	0.65	96	95	2533	P	Inv. ex.		
310	Z1	54	42	96	0.59	97	123	2445	P	Inv. ex.		
311	Z1	47	45	92	0.61	94	129	2539	P	Inv. ex.		
312	Z1	45	47	92	0.59	96	102	2445	P	Inv. ex.		
313	Z1	35	58	93	0.59	96	103	2434	P	Inv. ex.		
314	Z1	48	45	93	0.63	96	95	2467	P	Inv. ex.		
315	Z1	34	59	93	0.64	95	120	2460	P	Inv. ex.		
316	Z1	55	44	99	0.66	94	137	2498	P	Inv. ex.		
317	Z1	41	56	97	0.63	99	142	2456	P	Inv. ex.		
318	Z1	38	52	90	0.60	96	125	2547	P	Inv. ex.		
319	Z1	27	62	89	0.62	98	100	2485	P	Inv. ex.		
320	Z1	48	51	99	0.66	94	111	2437	P	Inv. ex.		
321	Z1	46	46	92	0.63	94	126	2494	P	Inv. ex.		
322	Z1	44	50	94	0.65	95	112	2448	P	Inv. ex.		
323	Z1	45	53	98	0.63	98	109	2544	P	Inv. ex.		
324	Z1	44	48	92	0.65	98	126	2497	P	Inv. ex.		
325	Z1	48	47	95	0.65	96	99	2497	P	Inv. ex.		

(continued)

No.	Steel type	Steel sheet for hot stamping				Pearlite dispersion index	Hot stamped part				Remarks
		A	B		A+B %		Hard structure area ratio %	Former y grain hardness distribution standard deviation Hv	Tensile strength MPa	Hydrogen embrittlement resistance	
			Ferrite area ratio %	Pearlite area ratio %							
326	Z1	32	59		91	0.66	95	127	2470	P	Inv. ex.
327	Z1	28	62		90	0.66	98	122	2425	P	Inv. ex.
328	Z1	30	60		90	0.67	97	109	2471	P	Inv. ex.
329	Z1	49	44		93	0.66	98	98	2487	P	Inv. ex.
330	Z1	53	45		98	0.65	98	128	2546	P	Inv. ex.
331	Z1	30	62		92	0.62	94	96	2486	P	Inv. ex.
332	Z1	40	58		98	0.63	99	111	2440	P	Inv. ex.
333	Z1	34	55		89	0.63	99	127	2443	P	Inv. ex.
Underlines indicate outside scope of present invention or values of properties not preferable.											

[0138] Referring to Table 3, in Comparative Example 1, the C content was low, and therefore the tensile strength fell. In Comparative Example 13, the C content was high, and therefore the strength became too high and the hydrogen embrittlement resistance fell. In Comparative Example 14, the Si content was low, and therefore the tensile strength fell. In Comparative Example 25, the Si content was high, and therefore in the steel sheet for hot stamping, the amount of ferrite increased, the desired metallographic structure was not obtained, and the dispersion index of pearlite became less than 0.50. As a result, in the hot stamped part, it was not possible to control the standard deviation in hardness distribution of prior austenite grains to the desired range and the hydrogen embrittlement resistance fell. In Comparative Example 26, the Mn content was low, and therefore the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In Comparative Example 41, the Mn content was high, and therefore it is believed that in the hot rolled steel sheet, transformation from austenite to pearlite was promoted too much. As a result, the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In each of Comparative Examples 50, 59, 68, 77, 78, and 90, the P, S, N, O, or Al content was not suitable, and therefore the hydrogen embrittlement resistance fell. In each of Comparative Examples 91, 103, 115, 127, and 139, the respective Nb, Ti, B, Cr, and Mo contents were low, and therefore the strength could not be sufficiently improved and the tensile strength fell. In each of Comparative Examples 102, 114, 126, 138, and 150, the respective Nb, Ti, B, Cr, and Mo contents were high, and therefore it is believed that large amounts of carbonitrides were formed in the steel or coarse intermetallic compounds were formed. As a result, the hydrogen embrittlement resistance fell.

[0139] In Comparative Example 259, the rolling reduction of the final stage in the finish rolling of the hot rolling step was low, and therefore it is believed pearlite could not be made to homogeneously disperse in the hot rolled steel sheet after rolling. As a result, the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In Comparative Example 270, the time period from the end of the finish rolling to the start of rapid cooling was long, and therefore it is believed that growth of the austenite grains could not be sufficiently suppressed and ferrite was arranged connected and pearlite could not be made to homogeneously disperse. As a result, the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In Comparative Example 271, the average cooling speed after rapid cooling in the cooling step was slow, and therefore in the steel sheet for hot stamping, the desired metallographic structure could not be formed. As a result, the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In Comparative Example 276, the coiling temperature was low, and therefore in the steel sheet for hot stamping, the desired metallographic structure could not be formed. As a result, the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell. In Comparative Example 284, the coiling temperature was high, and therefore it is believed grain growth occurred and homogeneous dispersion of the pearlite was obstructed. As a result, the dispersion index of pearlite in the steel sheet for hot stamping and the standard deviation in hardness distribution of prior austenite grains in the hot stamped part could not be controlled to within the desired ranges and the hydrogen embrittlement resistance fell.

[0140] In contrast to this, in the steel sheet for hot stamping and hot stamped part of all of the invention examples, by having the predetermined chemical composition and metallographic structure, controlling the dispersion index of pearlite in the steel sheet for hot stamping to 0.50 or more, and, in the hot stamped part, controlling the standard deviation in hardness distribution of the prior austenite grains to 150 Hv or less, it was possible to reliably suppress hydrogen embrittlement regardless of having a high tensile strength of 2200 MPa or more. Further, in the hot stamped part of all of the invention examples, the hardness of the prior austenite grains at the sheet thickness 1/4 position (average of all measurement values of hardness in invention examples) was controlled to a range of 500 to 1000 Hv.

Claims

1. A steel sheet for hot stamping having a chemical composition comprising, by mass%,

C: 0.40 to 0.70%,
Si: 0.010 to 1.300%,
Mn: 0.60 to 3.00%,
P: 0.100% or less,
S: 0.0100% or less,

N: 0.0200% or less,
O: 0.0200% or less,
Al: 0.0010 to 0.5000%,
Nb: 0.0010 to 0.100%,
Ti: 0.010 to 0.200%,
B: 0.0005 to 0.0200%,
Cr: 0.010 to 0.80%,
Mo: 0.0010 to 1.000%,
Co: 0 to 2.00%,
Ni: 0 to 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
balance: Fe and impurities, and
a metallographic structure comprising, by area ratio,
ferrite: 10% or more and
pearlite: 10% or more, wherein
a total of ferrite and pearlite is 80% or more, and
a dispersion index of pearlite is 0.50 or more.

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

Co: 0.001 to 2.00%,
Ni: 0.001 to 3.00%,
Cu: 0.001 to 1.00%,
V: 0.001 to 1.00%,
W: 0.001 to 1.000%,
Ca: 0.0001 to 0.010%,
Mg: 0.0001 to 1.000%,
REM: 0.0001 to 1.000%,
Sb: 0.001 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 stamped part having a chemical composition comprising, by mass%,

C: 0.40 to 0.70%,
Si: 0.010 to 1.300%,
Mn: 0.60 to 3.00%,
P: 0.100% or less,
S: 0.0100% or less,
N: 0.0200% or less,
O: 0.0200% or less,
Al: 0.0010 to 0.5000%,
Nb: 0.0010 to 0.100%,
Ti: 0.010 to 0.200%,
B: 0.0005 to 0.0200%,
Cr: 0.010 to 0.80%,
Mo: 0.0010 to 1.000%,

Co: 0 to 2.00%,
 Ni: 0 to 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
 balance: Fe and impurities, and
 a metallographic structure comprising, by area ratio, at least one of martensite, bainite, and tempered martensite
 in a total of 90% or more, wherein
 a standard deviation in a hardness distribution of prior austenite grains at a sheet thickness 1/4 position is 150 Hv
 or less.

4. The hot stamped part according to claim 3, wherein the chemical composition contains, by mass%, one or more
 selected from the group consisting of

Co: 0.001 to 2.00%,
 Ni: 0.001 to 3.00%,
 Cu: 0.001 to 1.00%,
 V: 0.001 to 1.00%,
 W: 0.001 to 1.000%,
 Ca: 0.0001 to 0.010%,
 Mg: 0.0001 to 1.000%,
 REM: 0.0001 to 1.000%,
 Sb: 0.001 to 1.000%,
 Zr: 0.001 to 1.000%,
 Sn: 0.001 to 1.000%, and
 As: 0.001 to 0.100%.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/007831

A. CLASSIFICATION OF SUBJECT MATTER

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

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2021-155793 A (NIPPON STEEL CORP.) 07 October 2021 (2021-10-07) entire text	1-4
A	WO 2020/162509 A1 (NIPPON STEEL CORP.) 13 August 2020 (2020-08-13) entire text, all drawings	1-4
P, A	WO 2022/239731 A1 (NIPPON STEEL CORP.) 17 November 2022 (2022-11-17) entire text	1-4

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

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Date of the actual completion of the international search

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Name and mailing address of the ISA/JP

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/007831

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2021-155793	A	07 October 2021	(Family: none)	
WO	2020/162509	A1	13 August 2020	US 2021/0395870 A1 entire text, all drawings EP 3854900 A1 CN 111801436 A KR 10-2021-0050539 A	
WO	2022/239731	A1	17 November 2022	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2016136810 A [0004]

Non-patent literature cited in the description

- *Acta Materialia*, 2010, vol. 58, 6393-6403 [0086]