



(11) **EP 3 584 345 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.12.2019 Bulletin 2019/52

(21) Application number: **18754731.0**

(22) Date of filing: **20.02.2018**

(51) Int Cl.:
C22C 38/00 ^(2006.01) **B21D 22/20** ^(2006.01)
C22C 38/60 ^(2006.01) **C21D 1/18** ^(2006.01)
C21D 9/00 ^(2006.01) **C21D 9/46** ^(2006.01)

(86) International application number:
PCT/JP2018/006086

(87) International publication number:
WO 2018/151332 (23.08.2018 Gazette 2018/34)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
MA MD TN

(30) Priority: **20.02.2017 JP 2017029318**

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(54) **HOT STAMP MOULDED BODY**

(57) The present invention, in consideration of the problems in the prior art, provides a hot stamped body simultaneously achieving the high bendability and high ductility for realizing impact resistance and also hydrogen embrittlement resistance and kept down in scattering in hardness. The hot stamped body according to the present invention is provided with a middle part in sheet thickness and a softened layer arranged at both sides or one side of the middle part in sheet thickness. The middle part in sheet thickness has a hardness of 500Hv to 800Hv and has metal structures from a depth of 20 μm below

the surface of the softened layer to a depth of 1/2 of the thickness of the softened layer with an area rate of a total of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° or more and 15° or less of 50% or more and less than 85%, when a region surrounded by grain boundaries having an orientation difference of 15° or more in a cross-section parallel to the sheet thickness direction is defined as a "crystal grain".

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Description

FIELD

5 **[0001]** The present invention relates to a hot stamped body used for structural members or reinforcing members of automobiles or structures where strength is required, in particular a hot stamped body excellent in strength, impact resistance, ductility, and hydrogen embrittlement resistance after hot stamping and small in scattering in hardness.

BACKGROUND

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[0002] In recent years, from the viewpoints of environmental protection and resource saving, lighter weight of automobile bodies is being sought. For this reason, application of high strength steel sheet to automobile members has been accelerating. However, along with the increase in strength of steel sheets, the formability deteriorates, and therefore in high strength steel sheets, formability into members with complicated shapes is a problem.

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[0003] To solve this problem, hot stamping, where the steel sheet is heated to a high temperature of the austenite region, then is press-formed, is increasingly being applied. Since hot stamping performs press-forming and simultaneously quenching in the die, it is possible to obtain a strength corresponding to the C amount of the steel sheet. This is being taken note of as a technique achieving both formation of a material into an automobile member and securing strength.

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[0004] However, since in conventional hot pressed parts which were produced by press hardening, the entire sheet thickness is formed by hard structures (mainly martensite), if bending deformation occurs at the time of collision of the automobile, the largest strain will be applied to the bent portion of the part, cracks will advance starting from the vicinity of the surface layer of the steel sheet, and finally fracture will easily be caused.

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[0005] For example, in a conventional hat-shaped member or other hot stamped body produced by press hardening, if bending deformation occurs at the time of collision of an automobile, the hat-shaped member will buckle and thereby deformation will become localized and the load resistance of the member will fall. That is, the maximum load of a member of a hot stamped body is affected not only by the strength of the member, but also the ease of buckling. If the ductility of the steel sheet is high, in the state of a member formed into a certain shape, it becomes harder for localization of the deformation region to occur. That is, the member becomes resistant to buckling.

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[0006] Further, in a hot stamped body, the way of contact with the die is not necessarily uniform. For example, at the vertical wall parts of a hat-shaped member etc., the cooling rate easily falls. For this reason, steel sheet is sometimes locally formed with regions with low hardnesses. Deformation concentrates in a local soft part at the time of collision and becomes a cause of cracking, so a small scattering in hardness of the body, that is, securing stable strength, is important in securing impact resistance.

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[0007] Therefore, in a hot stamped part as well, ductility is important, but in general the ductility of martensite is low. Further, the density of lattice defects of the surface layer of the steel sheet is high, so there is the problem that penetration by hydrogen is promoted and the part becomes poor in hydrogen embrittlement resistance. Due to such reasons, hot stamped parts produced by press hardening have been limited in locations of use in auto parts.

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[0008] To deal with this problem, art has been proposed for raising the deformability of hot pressed parts to suppress cracking. PTL 1 discloses making the hardness of the middle in sheet thickness of a hot pressed part 400Hv or more and forming a softened layer with a thickness of 20 μm to 200 μm and a hardness of 300Hv or less on a surface layer so as to secure a strength of a tensile strength of 1300 MPa or more while suppressing cracking at the time of automobile collision. PTL 2 discloses controlling the concentration of carbon at a surface layer in sheet thickness to 1/5 or less of the concentration of carbon of the middle part in sheet thickness so as to reduce the density of lattice defects of the surface layer and improve the hydrogen embrittlement resistance. PTL 3 discloses to make the middle part in sheet thickness a dual phase structure of ferrite and martensite and raise the structural fraction of ferrite of a surface layer portion so as to ease the stress even if the surface layer part receives severe bending deformation.

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[0009] However, in the members described in PTL 1 and PTL 2, by making a surface layer portion in sheet thickness by soft structures and making a middle part in sheet thickness by hard structures, a sharp gradient in hardness ends up being formed in the sheet thickness direction. For this reason, when subjected to bending deformation, there is the issue that cracking easily occurs near the boundary between the soft structures and hard structures where this sharp gradient of hardness occurs. Further, in PTL 3, a surface layer portion in sheet thickness is made by soft structures and the middle part in sheet thickness is made by a dual phase structure of hard structures and soft structures so as to reduce the sharp gradient in hardness in the sheet thickness direction. However, since making the middle part in sheet thickness a dual phase structure, the upper limit of tensile strength ends up becoming 1300 MPa or so. It is difficult to secure the tensile strength of 1500 MPa or more sought for hot pressed parts.

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[CITATION LIST]

[PATENT LITERATURE]

5 **[0010]**

[PTL 1] Japanese Unexamined Patent Publication No. 2015-30890

[PTL 2] Japanese Unexamined Patent Publication No. 2006-104546

[PTL 3] WO 2015/097882

10 SUMMARY

[TECHNICAL PROBLEM]

15 **[0011]** The present invention, in consideration of the technical issues in the prior art, has as its object to provide a hot stamped body achieving both a high bendability and high ductility for realizing impact resistance and hydrogen embrittlement resistance and keeping down the scattering in hardness.

[SOLUTION TO PROBLEM]

20 **[0012]** The inventors engaged in an in-depth study of a method for solving the above technical issues. As a result, to improve the hydrogen embrittlement resistance, it is effective to reduce the density of lattice defects at the surface layer in sheet thickness. For this reason, it is necessary to form soft structures at the surface layer. On the other hand, to secure a 1500 MPa or more tensile strength, it is necessary to form the middle part in sheet thickness by only hard structures. In this way, the inventors thought that if forming the surface layer in sheet thickness by soft structures and forming the middle part in sheet thickness by hard structures, if it were possible to reduce the sharp gradient of hardness in the sheet thickness direction occurring near the boundary of the hard structures and soft structures, a strength of a tensile strength of 1500 MPa or more and excellent hydrogen embrittlement resistance could be secured while excellent bendability could be obtained.

30 **[0013]** Therefore, the inventors investigated and engaged in intensive studies on metal structures of steel sheets where good bendability was obtained by controlling the structures of a surface layer of soft structures. As a result, it was discovered that the metal structures forming the surface layer should be comprised of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° to 15° when a region surrounded by grain boundaries having an orientation difference of 15° or more in the sheet thickness cross-section is defined as a "crystal grain". These measurements were performed in the region from a position of a depth of 20 μm below the surface of the surface layer to a position of a depth of 1/2 of the thickness of the surface layer (center of surface layer). It was discovered that the effects of the surface properties of the hot stamped body and the effects of the transitional part from the middle part in sheet thickness to the surface layer can be eliminated by such metal structures.

40 **[0014]** Further, by controlling the amounts of addition of Mn and Si at the middle part in sheet thickness, the inventors raised the ductility and raised the hardenability to stably secure high strength. As a result, it is possible to keep down the occurrence of cracking at the time of bending deformation. The inventors succeeded in securing a 1500 MPa or more tensile strength and good hydrogen embrittlement resistance while realizing excellent bendability, ductility, and stability of strength and were able to obtain a hot stamped body excellent in impact resistance and hydrogen embrittlement resistance.

45 **[0015]** The present invention was completed based on the above discovery and has as its gist the following:

(1) A hot stamped body comprising a middle part in sheet thickness and a softened layer arranged at both sides or one side of the middle part in sheet thickness, wherein

50 the middle part in sheet thickness comprises, by mass%,

C: 0.20% or more and less than 0.70%,

Si: less than 3.00%,

Mn: 0.20% or more and less than 3.00%,

P: 0.10% or less,

55 S: 0.10% or less,

sol. Al: 0.0002% or more and 3.0000% or less,

N: 0.01% or less, and

a balance of Fe and unavoidable impurities, and has a hardness of 500Hv or more and 800Hv or less,

in the metal structures from a depth of 20 μm below the surface of the softened layer to a depth of 1/2 of the thickness of the softened layer, when defining a region surrounded by grain boundaries having a 15° or higher orientation difference in a cross-section parallel to the sheet thickness direction as a "crystal grain", the area rate of the total of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° or more and 15° or less is 50% or more and less than 85%.

(2) The hot stamped body according to (1), wherein the Si content is 0.50% or less and the Mn content is 0.20% or more and less than 1.50%.

(3) The hot stamped body according to (1), wherein the Si content is 0.50% or less and the Mn content is 1.50% or more and less than 3.00%.

(4) The hot stamped body according to (1), wherein the Si content is more than 0.50% and less than 3.00%, the Mn content is 0.20% or more and less than 1.50%, and the middle part in sheet thickness comprises, by area percent, 1.0% or more and less than 5.0% of residual austenite.

(5) The hot stamped body according to (1), wherein the Si content is more than 0.50% and less than 3.00%, the Mn content is 1.50% or more and less than 3.00%, and the middle part in sheet thickness comprises, by area percent, 1.0% or more and less than 5.0% of residual austenite.

(6) The hot stamped body according to any one of (1) to (5), where the middle part in sheet thickness further comprises, by mass%, Ni: 0.01% or more and 3.00% or less.

(7) The hot stamped body according to any one of (1) to (6), where the middle part in sheet thickness further comprises, by mass%, one or more of Nb: 0.010% or more and 0.150% or less, Ti: 0.010% or more and 0.150% or less, Mo: 0.005% or more and 1.000% or less, and B: 0.0005% or more and 0.0100% or less.

(8) The hot stamped body according to any one of (1) to (7), where a plated layer is formed on the softened layer.

[ADVANTAGEOUS EFFECTS OF INVENTION]

[0016] According to the present invention, it is possible to provide a hot stamped body excellent in bendability, ductility, impact resistance, and hydrogen embrittlement resistance and with small scattering in hardness.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

FIG. 1 is a schematic view for explaining the diffusion of C atoms when producing a hot stamped body of the present invention.

FIG. 2 is a graph showing the change in dislocation density after a rolling pass relating to rough rolling used in the method for producing the hot stamped body of the present invention.

DESCRIPTION OF EMBODIMENTS

(Structure of Hot Stamped Body According to Present Invention)

[0018] The hot stamped body according to the present invention is a structure with a softened layer arranged on the surface at both sides or one side. The softened layer has a region having a hardness 10Hv or more lower than the hardness of the middle part in sheet thickness.

(Middle Part in Sheet Thickness)

[0019] The middle part in sheet thickness of the hot stamped body according to the present invention must have a hardness of 500Hv to 800Hv. The reasons for limiting the composition of constituents at the middle part in sheet thickness to make the hardness of the middle part in sheet thickness the above-mentioned range are explained below. Below, the % relating to the component of constituents means mass%.

(C: 0.20% or more and less than 0.70%)

[0020] C is an important element for obtaining a 500Hv to 800Hv hardness at the middle part in sheet thickness. With less than 0.20%, it is difficult to secure 500Hv or more at the middle part in sheet thickness, and therefore C is 0.20% or more. Preferably it is 0.30% or more. On the other hand, with more than 0.70%, the hardness of the middle part in sheet thickness exceeds 800Hv and the bendability falls, and therefore C is 0.70% or less. Preferably, it is 0.50% or less.

(Si: less than 3.00%)

[0021] Si is an element contributing to improvement of strength by solution strengthening. The amount of addition of Si for obtaining the effect of improvement of strength of the steel sheet by formation of a solid solution of Si in the metal structures is preferably 0.30% or more, but even if adding more than 0.5% of Si, the effect becomes saturated.

[0022] Si also has the effect of causing the formation of residual austenite and raising the ductility. To obtain this effect, addition of more than 0.50% is at least necessary. On the other hand, even if adding more than 3.00%, the effect becomes saturated, and therefore the amount of addition of Si is one with an upper limit of less than 3.00%. Preferably, the amount is less than 2.0%.

(Mn: 0.20% or more and less than 3.00%)

[0023] Mn is an element contributing to improvement of strength by solution strengthening. The effect of improving the strength of the steel sheet by solid solution of Mn in the metal structures cannot be obtained with an amount of addition of less than 0.20%, so 0.20% or more is added. Preferably the content is 0.70% or more. On the other hand, even if adding 1.50% or more, the effect becomes saturated.

[0024] Mn, further, has the effect of raising the hardenability. By adding 1.50% or more, it is possible to raise the hardenability and stably obtain high strength. The preferable amount of addition for obtaining the effect of raising the hardenability is 1.70% or more. Even if adding 3.00% or more, the effect becomes saturated, and therefore the upper limit of the amount of addition of Mn is 3.00%. Preferably, the content is less than 2.00%.

(P: 0.10% or less)

[0025] P is an element segregating at the grain boundaries and impairing the strength of the grain boundaries. If more than 0.10%, the strength of the grain boundaries remarkably falls and the hydrogen embrittlement resistance and bendability fall, and therefore P is 0.10% or less. Preferably, it is 0.05% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0001%, the dephosphorizing cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

(S: 0.10% or less)

[0026] S is an element forming inclusions. If more than 0.10%, inclusions are formed and the hydrogen embrittlement resistance and bendability fall, and therefore S is 0.10% or less. Preferably, it is 0.0025% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0015%, the desulfurizing cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

(sol. Al: 0.0002% or more and 3.0000% or less)

[0027] Al is an element acting to deoxidize the molten steel and make the steel sounder. In the present invention, to obtain the deoxidizing action, the range of content of not all of the Al contained in the steel, but the content of so-called "acid soluble aluminum" (sol. Al) is prescribed. With a sol. Al content of less than 0.0002%, the deoxidizing is insufficient, and therefore sol. Al is 0.0002% or more. Preferably the content is 0.0010% or more. On the other hand, even if adding more than 3.0%, the effect becomes saturated, and therefore the content is 3.0000% or less.

(N: 0.01% or less)

[0028] N is an impurity element and is an element which forms nitrides and impairs bendability. If more than 0.01%, coarse nitrides are formed and the bendability remarkably falls, and therefore N is 0.01% or less. Preferably the content is 0.0075% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0001%, the denitrizing cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

(Ni: 0.01% or more and 3.00% or less)

[0029] Ni is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.010%, the effect is not obtained, so 0.010% or more is added. Preferably, the content is 0.5% or more. On the other hand, even if added in more than 3.00%, the effect becomes saturated, and therefore the content is 3.00% or less. Preferably, the content is 2.50% or less.

(Nb: 0.010% or more and 0.150% or less)

[0030] Nb is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.010%, the effect is not obtained, so 0.010% or more is added. Preferably, the content is 0.035% or more. On the other hand, even if added in more than 0.150%, the effect becomes saturated, and therefore the content is 0.150% or less. Preferably, the content is 0.120% or less.

(Ti: 0.010% or more and 0.150% or less)

[0031] Ti is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.010%, the effect is not obtained, and therefore the content is 0.010% or more. Preferably, the content is 0.020%. On the other hand, even if added in more than 0.150%, the effect becomes saturated, and therefore the content is 0.150% or less. Preferably, the content is 0.120% or less.

(Mo: 0.005% or more and 1.0% or less)

[0032] Mo is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.005%, the effect is not obtained, and therefore the content is 0.005% or more. Preferably, the content is 0.0100% or more. On the other hand, even if added in more than 1.000%, the effect becomes saturated, and therefore the content is 1.000% or less. Preferably, the content is 0.800% or less.

(B: 0.0005% or more and 0.0100% or less)

[0033] B is an element segregating at the grain boundaries and improving the strength of the grain boundaries, so may be added as needed. With less than 0.0005%, the effect of addition is not sufficiently obtained, so 0.0005% or more is added. Preferably, the content is 0.0010% or more. On the other hand, even if added in more than 0.0100%, the effect becomes saturated, and therefore the content is 0.0100% or less. Preferably, the content is 0.0075% or less.

[0034] The balance of the composition of constituents of the middle part in sheet thickness consists of Fe and unavoidable impurities. The unavoidable impurities are elements which unavoidably enter from the steel raw materials and/or in the steelmaking process and are allowed in ranges not impairing the characteristics of the hot stamped body of the present invention.

(Hardness of Middle Part in Sheet Thickness is 500Hv or more and 800Hv or less)

[0035] If the hardness of the middle part in sheet thickness is 500Hv or more, as the tensile strength of the hot stamped body of the present invention, 1500 MPa or more can be secured. Preferably, it is 600Hv or more. On the other hand, if the hardness of the middle part in sheet thickness is more than 800Hv, since the difference in hardness with the softened layer becomes too large and deterioration of the bendability is invited, 800Hv is the upper limit. Preferably the hardness is 720Hv or less.

[0036] The method of measurement of the hardness of the middle part in sheet thickness is as follows: A cross-section vertical to the sheet surface of the hot stamped body is taken to prepare a sample of the measurement surface. This is supplied to a hardness test. The method of preparing the measurement surface may be based on JIS Z 2244. For example, #600 to #1500 silicon carbide paper may be used to polish the measurement surface, then a solution of particle size 1 μm to 6 μm diamond powder dispersed in alcohol or another diluent or pure water may be used to finish the sample to a mirror surface. The hardness test may be performed by the method described in JIS Z 2244. A micro-Vickers hardness tester is used to measure 10 points at the 1/2 position of thickness of the hot stamped body by a load of 1 kgf and intervals of 3 times or more of the dents. The average value was defined as the hardness of the middle part in sheet thickness.

(Metal Structures at Middle Part in Sheet Thickness)

[0037] The middle part in sheet thickness can be improved in ductility by including residual austenite in an area percent of 1% or more. The area percent of residual austenite at the middle part in sheet thickness is preferably 2% or more. However, if making the area percent of the residual austenite 5% or more, since deterioration of the bendability is invited, the upper limit is less than 5.0%. Preferably, the fraction is less than 4.5%.

[0038] The area percent of the residual austenite can be measured by the following method. A sample is taken from a hot stamped member and ground down at its surface to a depth of 1/2 of the sheet thickness from the normal direction of the rolling surface. The ground down surface is used for X-ray diffraction measurement. From the image obtained by the X-ray diffraction method using $K\alpha$ rays of Mo, the area rate V_γ of residual austenite can be determined using the following formula:

$$V_\gamma = (2/3) \{ 100 / (0.7 \times \alpha(211) / \gamma(220) + 1) \} + (1/3) \{ 100 / (0.78 \times \alpha(211) / \gamma(311) + 1) \}$$

Here, $\alpha(211)$ is the X-ray diffraction intensity at the (211) face of ferrite, $\gamma(220)$ is the X-ray diffraction intensity at the (220) face of austenite, and $\gamma(311)$ is the X-ray diffraction intensity at the (311) face of austenite.

(Softened Layer)

[0039] As explained above, in the present invention, the "softened layer" is the region in the sheet thickness direction of the cross-section of sheet thickness of the hot stamped body from the position where the hardness falls by 10Hv or more from hardness of the middle part in sheet thickness (hardness at position of 1/2 of sheet thickness) to the surface of the stamped body.

(Metal Structures of Softened Layer)

[0040] The inventors investigated the metal structures of steel sheets where good bendability was obtained and as a result discovered that the metal structures forming the softened layer should be comprised of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° to 15° when defining a region surrounded by grain boundaries having a 15° or higher orientation difference in a cross-section of sheet thickness as a "crystal grain". These measurements were performed in the region from a position of a depth of 20 μm below the surface of the softened layer to a position of a depth of 1/2 of the thickness of the softened layer (center of softened layer). The inventors engaged in intensive studies and as a result discovered that from the viewpoint of the bendability and other effects, the fractions of structures from a position of 20 μm from the surface of the softened layer to a position of a depth of 1/2 of the thickness of the softened layer are important. The effects of the surface properties of the hot stamped body and the effects of the transitional part from the middle part in sheet thickness to the softened layer can be eliminated by such metal structures.

[0041] In the above-mentioned metal structures of the softened layer, the area rate of the total of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° to 15° should be 50% or more, more preferably 55% or more. On the other hand, with an area rate of the total of the metal structures of the softened layer of 85% or more, the difference in hardness of the softened layer and the middle part in sheet thickness becomes too great and the effect of reduction of the sharp gradient of hardness in the sheet thickness direction occurring at the time of bending deformation cannot be obtained, and therefore the area rate is less than 85%. More preferably, it is 80% or less.

[0042] Between the position of a depth of 1/2 of the thickness of the softened layer (center of softened layer) to the middle part in sheet thickness, if the hardness at the sheet thickness middle part side of the softened layer (boundary with middle part in sheet thickness) is HvA and the hardness of the center of the softened layer is HvB, they are in the relationship of $HvA - HvB \geq 10Hv$.

[0043] The method of determining the region from 20 μm below the surface of the softened layer to a position of 1/2 of the thickness of the softened layer will be explained below. A cross-section vertical to the surface of the hot stamped body being measured (cross-section of sheet thickness) is taken to prepare a sample of the measurement surface. This is used for a hardness test. The method of preparing the measurement surface may be based on JIS Z 2244. For example, #600 to #1500 silicon carbide paper may be used to polish the measurement surface, then a solution of particle size 1 μm to 6 μm diamond powder dispersed in alcohol or another diluent or pure water may be used to finish the sample to a mirror surface. The sample with the prepared measurement surface is measured two times based on the method described in JIS Z 2244 using a micro Vickers hardness tester. The first time measures the hardness from the region within 20 μm from the surface of the hot stamped body in the sheet thickness direction to the middle part in sheet

thickness (position of 1/2 of sheet thickness) in the direction vertical to the surface (sheet thickness direction) by a load of 0.3 kgf at intervals of 3 times or more the dents. However, if there is a plated layer, this is measured from the region within 20 μm right under the plating or coating or the alloy layer of the plating or coating and material of the softened layer. The position where the hardness starts to drop by 10Hv or more from the hardness of the middle part in sheet thickness (hardness at position of 1/2 of sheet thickness) is determined and the layer from that sheet thickness position to the surface of the hot stamped body is defined as the "softened layer". If the softened layer is present at both surfaces, the second measurement is performed at the surface at the opposite side to the first one (back surface) by a similar method to determine the position where the hardness starts to drop by 10Hv or more from the hardness of the middle part in sheet thickness.

[0044] Next, the method of calculating the area rates of metal structures of the softened layer will be explained. A sample is cut out from a hot stamped body to enable examination of a cross-section vertical to its surface (sheet thickness direction). The length of the sample depends on the measuring device, but may be about 50 μm . The region in the sheet thickness direction of the sample from the surface of the softened layer to the position of 1/2 of the thickness of the softened layer (center of softened layer) is analyzed at 0.2 μm measurement intervals by EBSD to obtain information on the crystal orientation. Here, this EBSD analysis is performed using an apparatus comprised of a thermal field emission type scan electron microscope (JSM-7001F made by JEOL) and EBSD detector (DVC5 type detector made by TSL) at an analysis speed of 200 to 300 points/second.

[0045] Next, based on the obtained crystal orientation information, a region surrounded by grain boundaries having an orientation difference of 15° or more is defined as one crystal grain and a crystal orientation map in the sheet surface direction is prepared. The obtained crystal orientation map is used to find the crossing points of the long axis of one crystal grain and the crystal grain boundaries. Among the two crossing points, one is designated as the starting point and the other is designated as the end point and the difference in orientation among all measurement points contained on the long axis of the crystal grain is calculated. The maximum value of the orientation difference obtained was defined as the maximum crystal orientation difference at that crystal grain. The above analysis was performed for all crystal grains included in the measurement region, then the average of these values was defined as the maximum crystal orientation difference inside a region surrounded by grain boundaries of 15° or more.

[0046] The above-defined maximum crystal orientation difference can be simply calculated, for example, if using the "Inverse Pole Figure Map" and "Profile Vector" functions included in the software (OIM Analysis®) attached to the EBSD analysis system. With the "Inverse Pole Figure Map" function, it is possible to draw grain boundaries having slants of 15° or more as large angle grain boundaries and further possible to prepare a crystal orientation map in the sheet surface direction. With the "Profile Vector" function, it is possible to calculate the misorientation angle (difference in crystal orientations) between all measurement points included on any line. All crystal grains contained in the measurement region (crystal grains at end parts of measurement region not included) are analyzed as explained above and the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° is calculated. If the softened layer is formed on both surfaces, the above procedure is performed at the back surface side of the hot stamped body as well and the average value of the area rates obtained from the front surface side and the back surface side is employed.

(Composition of Softened Layer)

[0047] The composition of the softened layer is not particularly limited other than regarding the unavoidable impurity elements of P, S, and N impairing the strength and/or bendability, but the layer is preferably the following composition so as to secure the strength of the hot stamped body and steel exhibiting excellent bendability.

[0048] In the composition of the softened layer, one or more of the C content, Si content, and Mn content are preferably respectively 0.6 time the corresponding contents of elements of the middle part in sheet thickness. The preferable ranges of the constituents in this case are as follows:

(C: 0.05% or more and less than 0.42%)

[0049] C may be added in 0.05% or more so as to raise the strength. From the viewpoint of raising the load resistance as a member and improving the impact characteristics, preferably the content is 0.10% or more. To make the hardness of the softened layer lower than the hardness of the middle part in sheet thickness, it is preferable to make the content smaller than the middle part in sheet thickness. For this reason, the preferable C content of the softened layer is less than 0.42%. Preferably the content is 0.35% or less.

(Si: less than 2.00%)

[0050] Si is an element contributing to improvement of strength by solution strengthening, so is added for raising the strength. However, to make the hardness of the softened layer lower than the hardness of the middle part in sheet thickness, it is preferable to make this smaller in content than the middle part in sheet thickness.

[0051] If the Si content of the middle part in sheet thickness is 0.50% or less, the preferable Si content of the softened layer is 0.30% or less, more preferably 0.20% or less. Further, if the Si content of the middle part in sheet thickness is more than 0.50% and less than 3.00%, the preferable Si content of the softened layer is less than 2.00%, more preferably 1.50% or less.

(Mn: 0.12% or more and less than 1.80%)

[0052] Mn is an element contributing to improvement of strength by solution strengthening, so may be added in 0.12% or more for raising the strength. However, to make the hardness of the softened layer lower than the hardness of the middle part in sheet thickness, it is preferably smaller in content than the middle part in sheet thickness.

[0053] If the Mn content at the middle part in sheet thickness is 0.20% to less than 1.50%, the preferable Mn content of the softened layer is less than 0.90%, more preferably is 0.70% or less. Further, if the Mn content of the middle part in sheet thickness is 1.50% to less than 3.00%, the preferable Mn content of the softened layer is less than 1.80%, preferably 1.40% or less.

(P: 0.10% or less)

[0054] P is an element segregating at the grain boundaries and impairing the strength of the grain boundaries. If more than 0.10%, the strength of the grain boundaries remarkably falls and the hydrogen embrittlement resistance and bendability fall, and therefore P is 0.1% or less. Preferably, it is 0.05% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0001%, the dephosphorizing cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

(S: 0.10% or less)

[0055] S is an element forming inclusions. If more than 0.10%, inclusions are formed and the hydrogen embrittlement resistance and bendability fall, and therefore S is 0.10% or less. Preferably, it is 0.0025% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0015%, the desulfurizing cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

(sol. Al: 0.0002% or more and 3.0000% or less)

[0056] Al is an element acting to deoxidize the molten steel and make the steel sounder. In the present invention, to obtain this deoxidizing action, the range of content of not all of the Al contained in the steel, but the so-called "acid soluble aluminum" (sol. Al) is prescribed. With a sol. Al content of less than 0.0002%, the deoxidizing is insufficient, and therefore the sol. Al is preferably 0.0002% or more. More preferably the content is 0.0010% or more. On the other hand, even if adding more than 3.0000%, the effect becomes saturated, and therefore the content is 3.0000% or less.

(N: 0.01% or less)

[0057] N is an impurity element and is an element which forms nitrides and impairs bendability. If more than 0.01%, coarse nitrides are formed and the bendability remarkably falls, and therefore N is 0.01% or less. Preferably the content is 0.0075% or less. The lower limit is not particularly prescribed, but if reducing this to less than 0.0001%, the denitriding cost greatly rises and the result becomes economically disadvantageous, so in practical steel sheet, 0.0001% is the substantive lower limit.

[0058] Regarding the constituents of the softened layer, one or more of the C content, Si content, and Mn content are preferably respectively 0.6 time or less the C content, Si content, and Mn content of the middle part in sheet thickness. Other than the upper limits of the unavoidable impurity elements of P, S, and N impairing the strength and/or bendability being prescribed, the other constituents are not particularly limited. In general, the softened layer may optionally and selectively include one or more of the following constituents besides C, Si, and Mn.

(Ni: 0.01% or more and 3.00% or less)

[0059] Ni is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.01%, the effect is not obtained, and therefore preferably 0.01% or more is added. More preferably, the content is 0.50% or more. On the other hand, even if added in more than 3.00%, the effect becomes saturated, and therefore the content is 3.00% or less. Preferably, the content is 2.50% or less.

(Nb: 0.010% or more and 0.150% or less)

[0060] Nb is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.010%, the effect is not obtained, so preferably 0.010% or more is added. More preferably, the content is 0.035% or more. On the other hand, even if added in more than 0.150%, the effect becomes saturated, and therefore the content is 0.150% or less. Preferably, the content is 0.120% or less.

(Ti: 0.010% or more and 0.150% or less)

[0061] Ti is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.010%, the effect is not obtained, and therefore preferably the content is 0.010% or more. More preferably, the content is 0.020%. On the other hand, even if added in more than 0.150%, the effect becomes saturated, and therefore the content is 0.150% or less. Preferably, the content is 0.120% or less.

(Mo: 0.005% or more and 1.000% or less)

[0062] Mo is an element contributing to improvement of strength by solution strengthening, so may be added as needed. With less than 0.005%, the effect is not obtained, and therefore preferably the content is 0.005% or more. More preferably, the content is 0.010% or more. On the other hand, even if added in more than 1.000%, the effect becomes saturated, and therefore the content is 1.000% or less. Preferably, the content is 0.800% or less.

(B: 0.0005% or more and 0.0100% or less)

[0063] B is an element segregating at the grain boundaries and improving the strength of the grain boundaries, so may be added as needed. With less than 0.0005%, the effect of addition is not sufficiently obtained, and therefore preferably 0.0005% or more is added. More preferably, the content is 0.0010% or more. On the other hand, even if added in more than 0.0100%, since the effect becomes saturated, the content is 0.0100% or less. Preferably, the content is 0.0075% or less.

(Cross-Sectional Distribution of Hardness of Hot Stamped Body)

[0064] At the cross-section vertical to the surface of the hot stamped body, the distribution of hardness at the middle part in sheet thickness is preferably uniform with no scattering. In a hat-shaped structure, at the vertical wall parts, contact with the die is difficult and the cooling rate becomes low, so sometimes the hardness falls. If there is a region where the hardness falls by 100Hv or more from the average hardness of the cross-section vertical to the longitudinal direction of the hat-shaped member, at the time of impact, the deformation will concentrate at the softened part and the part will fracture early, so a high impact resistance cannot be obtained. For this reason, there must not be a point with a hardness more than 100HV below the average value of the distribution of hardness in the cross-section vertical to the surface of the hot stamped body (below, referred to as the "average hardness of cross-section"). The distribution of hardness at the cross-section and the average hardness of the cross-section are obtained by obtaining a cross-section vertical to the longitudinal direction of a long hot stamped body at any position in the longitudinal direction and measuring the Vickers hardness between the end parts of the cross-section at equal intervals of 1 mm pitch or less at the middle position of sheet thickness of the entire cross-sectional region including the vertical walls using a Vickers hardness tester (load of 1 kgf).

(Formation of Plated Layer)

[0065] The surface of the softened layer may be formed with a plated layer for the purpose of improving the corrosion resistance. The plated layer may be either an electroplated layer or a hot dip coated layer. An electroplated layer includes, for example, an electrogalvanized layer, electro Zn-Ni alloy plated layer, etc. As a hot dip coated layer, a hot dip galvanized layer, a hot dip galvanized layer, a hot dip aluminum coated layer, a hot dip Zn-Al alloy coated layer, a hot dip Zn-Al-

Mg alloy coated layer, a hot dip Zn-Al-Mg-Si alloy coated layer, etc., may be mentioned. The amount of deposition of the layer is not particularly limited and may be a general amount of deposition.

(Method of Production of Hot Stamped Body According to Present Invention)

[0066] Next, the method of production for obtaining the hot stamped body according to the present invention will be explained, but the present invention is not limited to the form of the double layer steel sheet explained below.

[0067] As one embodiment of the method of production of the present invention, first, a steel sheet satisfying the requirements of the composition of constituents of the middle part in sheet thickness explained above is ground down at its front surface and/or back surface to remove surface oxides, then a steel sheet for softened layer formation use (below, referred to as a "steel sheet for surface layer") is superposed on each ground down surface side. The method of joining the steel sheet for surface layer and the steel sheet for sheet thickness middle part is not particularly limited, but they may be joined by arc welding. A steel sheet for surface layer wherein one or more of the C content, Si content, and Mn content are 0.6 time or less the content of the corresponding element of the steel sheet for sheet thickness middle part is preferably superposed.

[0068] Further, by controlling the casting rate to ton/min or more in the continuous casting process of the steel sheet for surface layer, it is possible to keep down microsegregation of Mn in the steel sheet for surface layer and possible to make the distribution of concentration of Mn at the steel sheet for surface layer uniform. Mn raises the yield strength of austenite to thereby affect the behavior in formation of grain boundaries in the transformed structures, so when defining a region surrounded with grain boundaries having orientation differences of 15° or more as a "crystal grain", it has the effect of promoting the formation of crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° to 15°. For this reason, it is also possible to control the casting rate to 6 ton/min or more in the continuous casting process of steel sheet for surface layer for the purpose of promoting the formation of the above micro structures.

[0069] Further, a double layer steel sheet fabricated by the above method is preferably held at 1100°C or more and 1350°C or less in temperature for 20 minutes to less than 60 minutes. The held sheet is preferably used as the steel sheet for hot stamped body according to the present invention. The inventors studied this and as a result learned that by performing heat treatment holding the steel sheet at 1100°C or more and 1350°C or less for 20 minutes to less than 60 minutes, in the metal structures in the region from a position of a depth of 20 μm below the surface of the softened layer to the center of the softened layer, the area rate of the total of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° to 15° becomes 50% to less than 85% when a region surrounded by grain boundaries having an orientation difference of 15° or more is defined as a "crystal grain" and that excellent bendability and hydrogen embrittlement resistance can be obtained.

[0070] The multilayer member produced by the above method of production (double layer steel sheet) can be treated by hot rolling, cold rolling, hot stamping, continuous hot dip coating, etc., to obtain the hot stamped body according to the present invention.

[0071] The hot rolling may be hot rolling performed under usual conditions. For example, the finishing temperature may also be in the temperature range of 810°C or more. The subsequent following cooling conditions also do not have to be particularly prescribed. The steel sheet is coiled in the temperature region of 750°C or less. Further, it may be reheated for the purpose of softening the double layer steel sheet after hot rolling.

[0072] Further, to promote more the formation of the middle part in sheet thickness, the hot rolling after the above heat treatment of the double layer steel sheet preferably includes rough rolling and finish rolling with the rough rolling being performed twice under conditions of a temperature of 1100°C or more, a sheet thickness reduction rate per pass of 5% or more and less than 50%, and a time between passes of 3 seconds or more.

[0073] Specifically, to promote more the formation of the middle part in sheet thickness in the present invention, the concentrations of alloy elements, in particular C atoms, have to be controlled to become more moderately distributed. The distribution of concentration of C is obtained by diffusion of C atoms. The diffusion frequency of C atoms increases the higher the temperature. Therefore, to control the C concentration, control in the rough rolling from the hot rolling heating becomes important. In hot rolling heating, to promote the diffusion of C atoms, the heating temperature has to be high. Preferably, it is 1100°C or more and 1350°C or less, more preferably more than 1150°C and 1350°C or less. With hot rolled heating, the changes of (i) and (ii) shown in FIG. 1 occur. (i) shows the diffusion of C atoms from the middle part in sheet thickness to the surface layer, while (ii) shows the decarburization reaction of C being desorbed from the surface layer to the outside. A distribution occurs in the concentration of C due to the balance between this diffusion of C atoms and the desorption reaction of (i) and (ii). With less than 1100°C, the reaction of (i) is insufficient, so the preferable distribution of the concentration of C cannot be obtained. On the other hand, with more than 1350°C, the reaction of (ii) excessively occurs, so similarly a preferable distribution of concentration cannot be obtained.

[0074] After adjusting the hot rolling heating temperature to obtain the preferable distribution of concentration of C, to obtain a further optimum distribution of concentration of C, pass control in rough rolling becomes extremely important.

Rough rolling is performed two times or more under conditions of a rough rolling temperature of 1100°C or more, a sheet thickness reduction rate per pass of 5% or more and less than 50%, and a time between passes of 3 seconds or more. This is so as to promote the diffusion of C atoms of (i) in FIG. 1 by the strain introduced in the rough rolling. Even if using an ordinary method to rough roll and finish roll a slab controlled in concentration of C to a preferable state by hot rolling heating, the sheet thickness will be reduced without the C atoms sufficiently diffusing in the surface layer. Therefore, if manufacturing hot rolled steel sheet of a thickness of several mm from a slab having a thickness more than 200 mm through a general hot rolling process, the result will be a steel sheet changing rapidly in concentration of C at the surface layer. A moderate hardness change will no longer be able to be obtained. The method discovered to solve this is the above pass control of the rough rolling. The diffusion of C atoms is greatly affected by not only the temperature, but also the strain (dislocation density). In particular, compared with lattice diffusion, with dislocation diffusion, the diffusion frequency becomes 10 times or more higher, so steps have to be taken to leave the dislocation density while rolling to reduce the sheet thickness. Curve 1 of FIG. 2 shows the change in the dislocation density after a rolling pass in the case where the sheet thickness reduction rate per pass in the rough rolling is small. It will be understood that strain remains over a long time period. By causing strain to remain at the surface layer over a long time period in this way, C atoms sufficiently diffuse in the surface layer and the optimum distribution of concentration of C can be obtained. On the other hand, curve 2 shows the change in dislocation density in the case where the sheet thickness reduction rate is large. If the amount of strain introduced by the rolling rises, recovery is easily promoted and the dislocation density rapidly falls. For this reason, to obtain the optimal distribution of concentration of C, it is necessary to prevent the occurrence of a change in dislocation density like the curve 2. From such a viewpoint, the upper limit of the sheet thickness reduction rate per pass becomes less than 50%. To promote the diffusion of C atoms at the surface layer, certain amounts of dislocation density and holding time have to be secured, so the lower limit of the sheet thickness reduction rate becomes 5%. As the time between passes, 3 seconds or more has to be secured.

[0075] The cold rolling may be cold rolling performed by a usual rolling reduction, for example, 30 to 90%. The hot rolled steel sheet and the cold rolled steel sheet include steel sheets as hot rolled and cold rolled and also steel sheets obtained by recrystallization annealing hot rolled steel sheet or cold rolled steel sheet under usual conditions and steel sheets obtained by skin pass rolling under usual conditions.

[0076] The heating, shaping, and cooling steps at the time of hot stamping may also be performed under usual conditions. For example, hot rolled steel sheet obtained by uncoiling hot rolled steel sheet coiled in the hot rolling step, cold rolled steel sheet obtained by uncoiling and cold rolling coiled hot rolled steel sheet, or steel sheet obtained by plating or coating cold rolled steel sheet, heating this by a 0.1°C/s to 200°C/s heating rate up to 810°C or more and 1000°C or less in temperature, and holding it at this temperature is formed into the required shape by the usual hot stamping.

[0077] The holding time may be set according to the mode of forming, so is not particularly limited. For example, if 30 seconds or more and 600 seconds or less, a good hot stamped body is cooled to room temperature.

[0078] The cooling rate may also be set to a usual condition. For example, the average cooling rate in the temperature region from the heating temperature to more than 400°C may be 50°C/s or more. In the case of steel sheet with an Si content at the middle part in sheet thickness of more than 0.50% and less than 3.00% and an Mn content at the middle part in sheet thickness of 0.20% or more and less than 1.50% and steel sheet with an Si content at the middle part in sheet thickness of more than 0.50% and less than 3.00% and an Mn content at the middle part in sheet thickness of 1.50% or more and less than 3.00%, for the purpose of increasing the amount of formation of residual austenite to improve the ductility, it is preferable to control the average cooling rate at the cooling after heating and holding at the 200°C to 400°C temperature region to less than 50°C/s.

[0079] Further, for the purpose of adjusting the strength etc., it is possible to temper the body cooled down to room temperature in the range of 150°C to 600°C.

[0080] In the method of production of the hot stamped body of the above-mentioned embodiment, the middle part in sheet thickness and the softened layer were configured by separate steel sheets. However, the hot stamped body of the present invention is not limited to double layer steel sheet comprised of two of the above-mentioned steel sheets superposed. The middle part in sheet thickness and the softened layer may be formed inside a single material steel sheet. For example, it is possible to treat a single layer steel sheet to decarburize it and soften the surface layer part to thereby produce high strength steel sheet comprised of a softened layer and a middle part in sheet thickness.

EXAMPLES

[0081] Next, examples of the present invention will be explained, but the conditions in the examples are just illustrations of conditions employed for confirming the workability and advantageous effects of the present invention. The present invention is not limited to the illustration of conditions. The present invention can employ various conditions so long as not departing from the gist of the present invention and achieving the object of the present invention.

[Manufacturing Example A]

[0082] The Nos. 1 to 18 steel sheets for sheet thickness middle part having the chemical compositions shown in Table A-1-1 (in the table, "Steel Nos. 1 to 18") were ground down at their surfaces to remove the surface oxides. After that, the respective steel sheets for sheet thickness middle part were welded with steel sheets for surface layer having the chemical compositions shown in Table A-1-2 at both surfaces or single surfaces by arc welding to fabricate the Nos. 1 to 43 multilayer steel sheets for hot stamped body. The total of the sheet thicknesses of the steel sheet for surface layer and the steel sheet for sheet thickness middle part after arc welding is 200 mm to 300 mm and the thickness of the steel sheet for surface layer is 1/3 or so of the thickness of the steel sheet for sheet thickness middle part (1/4 or so in case of single side). The No. 37 multilayer steel sheet is steel with the steel sheet for surface layer welded to only one surface. In the Nos. 1 to 43 multilayer steel sheets of Table A-1-1 to Table A-1-2, ones with a steel sheet for sheet thickness middle part not satisfying the requirement for composition of the middle part in sheet thickness of the hot stamped body according to the present invention are indicated as "comparative steel" in the remarks column.

[0083] The Nos. 1 to 43 multilayer steel sheets were respectively treated under the conditions of the Nos. 1 to 43 manufacturing conditions shown in Table A-2-1 to Table A-2-2 by heat treatment before hot rolling, rough rolling, hot rolling, and cold rolling to obtain steel sheets. Next, the steel sheets were heat treated as shown in Table A-2-1 and Table A-2-2 (in the tables, "heat treatment of hot stamped body") for hot stamping to manufacture the Nos. 1A to 43A hot stamped bodies ("stamped bodies" of Table A-3). Further, the Nos. 35A and 36A hot stamped bodies were coated on a hot dip coating line at the surfaces with 120 to 160 g/m² amounts of aluminum.

[0084] In the tables, the item "sheet thickness reduction rate" of the "rough rolling" means the sheet thickness reduction rate per pass of the rough rolling. The item "number of rolling operations" means the number of rolling operations under the conditions of a time between passes of 3 seconds or more. Further, the item in the tables of "heating rate (°C/s)" means the rate of temperature rise until reaching the heating temperature of the "heat treatment at the time of hot stamping" after the cold rolling process. Further, in the tables, the item "heating temperature (°C)" of the "heat treatment at the time of hot stamping" is the temperature at the time of hot stamping, the "average cooling rate (°C/s) (more than 400°C)" means the average cooling rate (°C/s) in the temperature region from the heating temperature to more than 400°C, and the "average cooling rate (°C/s) (400°C or less)" means the average cooling rate (°C/s) in the temperature region from 200°C to 400°C. Further, in the tables, the fields with the notations "-" indicate no corresponding treatment performed.

[0085] Table A-3 shows the metal structures and characteristics of the Nos. 1A to 43A hot stamped bodies. The constituents obtained by analyzing the positions of 1/2 of the sheet thicknesses of the samples taken from the hot stamped bodies and positions of 20 μm from the surfaces of the softened layers were equivalent to the constituents of the steel sheets for sheet thickness middle part and steel sheets for surface layer of the Nos. 1 to 43 multilayer steel sheets of Table A-1-1 to Table A-1-2.

[0086] The metal structures of the hot stamped steel sheets were measured by the above-mentioned method. The hardness of the steel sheet for sheet thickness middle part forming the middle part in sheet thickness and the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer forming the softened layer to 1/2 of the thickness were calculated. The calculated values of the area rate are shown in the item "area rate (%)" of total of crystal grains with maximum crystal orientation difference inside large angle grain boundaries of 1° or less and crystal grains with maximum crystal orientation difference of 8° to 15° of Table A-3.

[0087] Further, a tensile test of the hot stamped body was performed. The results are shown in Table A-3. The tensile test was performed by preparing a No. 5 test piece described in JIS Z 2201 and following the test method described in JIS Z 2241.

[0088] The hydrogen embrittlement resistance of the hot stamped body was evaluated using a test piece cut out from the stamped body. In general, a hot stamped body is joined with other parts using spot welding or another joining method. Depending upon the precision of the shape of the part, the hot stamped body will be subjected to twisting and stress will be applied. The stress differs depending on the position of the part. Accurately calculating this is difficult, but if there is no delayed fracture at the yield stress, it is believed there is no problem in practical use. Therefore, a sheet thickness 1.2 mm×width 6 mm×length 68 mm test piece was cut out from the stamped body, a strain corresponding to the yield stress was imparted in a four-point bending test, then the body was immersed in pH3 hydrochloric acid for 100 hours. The presence of any cracking was used to evaluate the hydrogen embrittlement resistance. A case of no cracking was indicated as passing ("good") and a case with cracking was indicated as failing ("poor").

[0089] For the purpose of evaluating the impact resistance of the hot stamped body, the body was evaluated based on the VDA standard (VDA238-100) prescribed by the German Association of the Automotive Industry under the following measurement conditions. In the present invention, the displacement at the time of maximum load obtained in the bending test was converted to angle by the VDA standard to find maximum bending angle and thereby evaluate the impact

resistance of the hot stamped body.

[0090] Test piece dimensions: 60 mm (rolling direction)×60 mm (direction vertical to rolling) or 30 mm (rolling direction)×60 mm (direction vertical to rolling)

Bending ridgeline: direction perpendicular to rolling

Test method: roll support, punch pressing

Roll diameter: $\phi 30$ mm

Punch shape: tip R=0.4 mm

Distance between rolls: $2.0 \times \text{sheet thickness (mm)} + 0.5 \text{ mm}$

Indentation rate: 20 mm/min

Tester: SHIMAZU AUTOGRAPH 20kN

[0091] If the tensile strength is 1500 MPa or more, the maximum bending angle ($^{\circ}$) was $70(^{\circ})$ or more, and the hydrogen embrittlement resistance was a passing level, it was judged that the impact resistance and hydrogen embrittlement resistance were excellent and the case was indicated as an "invention example". If even one of the three aspects of performance is not satisfied, the case was indicated as a "comparative example".

[0092] In each hot stamped body of the invention examples, the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to $1/2$ of the thickness was 50% to less than 85%. Further, each hot stamped body of the invention examples was excellent in tensile strength, bendability, and hydrogen embrittlement resistance.

[0093] As opposed to this, the No. 5A hot stamped body was low in carbon content of the steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness became insufficient and the tensile strength became insufficient. The No. 9A hot stamped body was excessive in carbon content of the steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness became excessive and the targeted bendability could not be obtained. Further, the No. 11A hot stamped body was low in Mn content at the steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness became insufficient and the tensile strength became insufficient.

[0094] The Nos. 30A to 32A hot stamped bodies are comparative examples produced using the multilayer steel sheets for hot stamped body to which the desirable heat treatment had not been applied before the hot stamping process. The No. 30A hot stamped body was low in heat treatment temperature before the hot stamping process, while the No. 31A hot stamped body was short in heat treatment time before the hot stamping process, so in the metal structures from the surface of the softened layer to $1/2$ of the thickness, the soft structures and metal structures with intermediate hardnesses insufficiently grew and the target bendability could not be obtained. Further, the No. 32A hot stamped body was excessively high in heat treatment temperature before the hot stamping process, so the effect of reduction of the sharp gradient in hardness in the sheet thickness direction occurring at the time of bending deformation could not be obtained.

[0095] The No. 41A hot stamped body was low in rolling temperature of the rough rolling. Further, the No. 42A hot stamped body was low in sheet thickness reduction rate of the rough rolling. Further, the No. 43A hot stamped body was low in number of rolling operations under conditions of a time between passes of 3 seconds or more. These hot stamped bodies were not manufactured under the suitable rough rolling conditions, so the soft structures and metal structures with intermediate hardnesses insufficiently grew, it was not possible to ease the strain occurring due to bending deformation, and the targeted bendability could not be obtained.

[0096] The No. 44 hot stamped body is a steel sheet controlled in casting rate to 6 ton/min or more in the continuous casting process of steel sheet for surface layer. It can raise the area rate (%) of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to $1/2$ of the thickness and is excellent in bendability.

[Table A-1-1]

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet thickness middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	1	0.25	0.24	1.22	0.016	0.0025	0.047	0.0037	0	0	0	0	0	
2	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
3	3	0.38	0.13	1.31	0.011	0.0010	0.045	0.0033	0	0	0	0	0	
4	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
5	5	0.12	0.17	1.31	0.016	0.0011	0.037	0.0039	0	0	0	0	0	Comp. steel
6	6	0.23	0.17	1.28	0.015	0.0012	0.043	0.0037	0	0	0	0	0	
7	7	0.33	0.12	1.27	0.006	0.0014	0.037	0.0032	0	0	0	0	0	
8	8	0.32	0.11	1.34	0.007	0.0016	0.049	0.0033	0	0	0	0	0	
9	9	0.82	0.14	1.26	0.015	0.0007	0.043	0.0027	0	0	0	0	0	Comp. steel
10	10	0.35	0.43	1.29	0.010	0.0020	0.049	0.0028	0	0	0	0	0	
11	11	0.30	0.22	0.07	0.016	0.0016	0.042	0.0041	0	0	0	0	0	Comp. steel
12	12	0.29	0.22	0.76	0.015	0.0011	0.044	0.0027	0	0	0	0	0	
13	13	0.27	0.24	1.29	0.005	0.0014	0.045	0.0028	0.37	0	0	0	0	
14	14	0.35	0.18	1.29	0.018	0.0003	0.044	0.0034	0	0.042	0	0	0	
15	15	0.29	0.14	1.23	0.014	0.0013	0.050	0.0031	0	0	0.018	0	0	
16	16	0.32	0.12	1.40	0.010	0.0011	0.049	0.0032	0	0	0	0.06	0	
17	17	0.34	0.20	1.38	0.013	0.0018	0.047	0.0033	0	0	0	0	0.0021	
18	1	0.25	0.24	1.22	0.016	0.0025	0.047	0.0037	0	0	0	0	0	
19	1	0.25	0.24	1.22	0.016	0.0025	0.047	0.0037	0	0	0	0	0	
20	1	0.25	0.24	1.22	0.016	0.0025	0.047	0.0037	0	0	0	0	0	
21	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
22	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
23	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
24	3	0.38	0.13	1.31	0.011	0.0010	0.045	0.0033	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet thickness middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
25	3	0.38	0.13	1.31	0.011	0.0010	0.045	0.0033	0	0	0	0	0	
26	3	0.38	0.13	1.31	0.011	0.0010	0.045	0.0033	0	0	0	0	0	
27	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
28	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
29	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
30	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
31	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
32	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
33	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
34	18	0.69	0.22	1.34	0.005	0.0004	0.051	0.0027	0	0	0	0	0	
35	18	0.69	0.22	1.34	0.005	0.0004	0.051	0.0027	0	0	0	0	0	
36	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
37	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
38	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
39	4	0.45	0.17	1.35	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
40	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
41	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
42	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
43	2	0.30	0.23	1.25	0.015	0.0007	0.039	0.0036	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.														

[Table A-1-2]

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	0.095	0.098	0.476	0.017	0.0034	0.049	0.0036	0	0	0	0	0	
2	0.141	0.104	0.613	0.014	0.0012	0.037	0.0034	0	0	0	0	0	
3	0.175	0.069	0.655	0.011	0.0014	0.046	0.0033	0	0	0	0	0	
4	0.230	0.090	0.702	0.009	0.0001	0.040	0.0028	0	0	0	0	0	
5	0.043	0.071	0.655	0.015	0.0017	0.039	0.0041	0	0	0	0	0	Comp. steel
6	0.104	0.082	0.563	0.015	0.0018	0.044	0.0035	0	0	0	0	0	
7	0.162	0.052	0.584	0.004	0.0019	0.039	0.0032	0	0	0	0	0	
8	0.176	0.056	0.509	0.007	0.0024	0.051	0.0033	0	0	0	0	0	
9	0.328	0.064	0.517	0.016	0.0017	0.042	0.0028	0	0	0	0	0	Comp. steel
10	0.158	0.224	0.697	0.008	0.0029	0.051	0.0027	0	0	0	0	0	
11	0.147	0.119	0.029	0.014	0.0026	0.040	0.0042	0	0	0	0	0	Comp. steel
12	0.145	0.119	0.365	0.015	0.0016	0.045	0.0025	0	0	0	0	0	
13	0.124	0.127	0.684	0.003	0.002	0.045	0.0027	0.34	0	0	0	0	
14	0.172	0.085	0.555	0.018	0.0006	0.044	0.0033	0	0.0038	0	0	0	
15	0.136	0.064	0.492	0.016	0.0022	0.05	0.0032	0	0	0.0025	0	0	
16	0.166	0.061	0.63	0.008	0.0015	0.048	0.0031	0	0	0	0.05	0	
17	0.153	0.102	0.607	0.012	0.0021	0.047	0.0031	0	0	0	0	0.0018	
18	0.110	0.211	1.183	0.016	0.0029	0.045	0.0036	0	0	0	0	0	
19	0.105	0.214	0.622	0.016	0.0031	0.049	0.0038	0	0	0	0	0	
20	0.143	0.11	1.049	0.016	0.0031	0.048	0.0036	0	0	0	0	0	
21	0.273	0.101	0.638	0.014	0.0013	0.038	0.0038	0	0	0	0	0	
22	0.270	0.124	1.088	0.013	0.0014	0.041	0.0038	0	0	0	0	0	
23	0.264	0.205	0.575	0.015	0.0014	0.038	0.0038	0	0	0	0	0	
24	0.296	0.057	0.616	0.009	0.0018	0.044	0.0033	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
25	0.190	0.124	0.655	0.009	0.0018	0.047	0.0034	0	0	0	0	0	
26	0.175	0.061	1.009	0.010	0.0017	0.044	0.0032	0	0	0	0	0	
27	0.401	0.092	0.689	0.011	0.0004	0.038	0.0027	0	0	0	0	0	
28	0.207	0.153	0.594	0.007	0.0007	0.041	0.0028	0	0	0	0	0	
29	0.203	0.075	1.175	0.009	0.0007	0.040	0.0027	0	0	0	0	0	
30	0.144	0.127	0.550	0.014	0.0014	0.039	0.0036	0	0	0	0	0	
31	0.144	0.113	0.588	0.013	0.0009	0.038	0.0037	0	0	0	0	0	
32	0.135	0.113	0.563	0.017	0.0012	0.039	0.0036	0	0	0	0	0	
33	0.156	0.110	0.513	0.015	0.0016	0.039	0.0036	0	0	0	0	0	
34	0.290	0.125	0.63	0.004	0.0009	0.052	0.0025	0	0	0	0	0	
35	0.352	0.112	0.63	0.006	0.0004	0.053	0.0028	0	0	0	0	0	
36	0.132	0.12	0.575	0.017	0.0015	0.039	0.0036	0	0	0	0	0	
37	0.150	0.124	0.563	0.013	0.0010	0.038	0.0035	0	0	0	0	0	
38	0.221	0.092	0.689	0.011	0.0004	0.038	0.0027	0	0	0	0	0	
39	0.410	0.148	1.094	0.007	0.0007	0.041	0.0028	0	0	0	0	0	
40	0.141	0.104	0.613	0.014	0.0012	0.037	0.0034	0	0	0	0	0	
41	0.141	0.104	0.613	0.014	0.0012	0.037	0.0034	0	0	0	0	0	
42	0.141	0.104	0.613	0.014	0.0012	0.037	0.0034	0	0	0	0	0	
43	0.141	0.104	0.613	0.014	0.0012	0.037	0.0034	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.													

[Table A-2-1]

Multilayer steel sheet no.	Manufactur- ing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping						Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of re- duction of sheet thickness (%)	No. of roll- ing opera- tions (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
1	1	1320	35	1149	34	3	838	586	53	32	903	70	53	-	None	1.3	
2	2	1293	31	1171	32	3	840	538	58	34	872	97	94	-	None	1.2	
3	3	1257	41	1138	20	3	917	604	53	51	859	73	66	-	None	1.3	
4	4	1285	36	1157	42	3	840	567	48	61	885	100	86	-	None	1.5	
5	5	1318	36	1133	38	3	856	712	60	54	884	96	84	-	None	1.1	
6	6	1275	35	1165	30	3	865	578	57	74	822	70	62	-	None	1.2	
7	7	1275	32	1184	47	3	872	685	49	61	909	82	77	-	None	1.4	
8	8	1268	41	1130	42	3	847	680	37	51	817	81	79	-	None	1.8	
9	9	1338	50	1167	29	3	865	693	58	29	843	69	60	-	None	1.2	
10	10	1270	39	1132	37	3	838	602	51	40	913	77	69	-	None	1.4	
11	11	1272	45	1130	34	3	900	620	62	57	831	99	98	-	None	1.1	
12	12	1301	49	1174	37	3	844	536	61	59	880	75	77	-	None	1.1	
13	13	1297	52	1176	28	3	860	744	38	26	823	100	93	-	None	1.7	
14	14	1287	42	1143	42	3	927	536	53	42	905	73	63	-	None	1.3	
15	15	1341	58	1154	43	3	915	545	40	28	912	89	77	-	None	1.7	
16	16	1268	54	1142	35	3	845	722	50	34	887	104	95	-	None	1.4	
17	17	1321	43	1141	43	3	865	569	34	63	849	113	109	-	None	1.8	
18	18	1315	55	1146	34	3	868	570	49	49	902	96	83	-	None	1.4	
19	19	1306	47	1157	42	3	862	624	63	20	844	73	63	-	None	1	

(continued)

Multilayer steel sheet no.	Manufactur- ing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of re- duction of sheet thickness (%)	No. of roll- ing opera- tions (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)	None	Sheet thickness (mm)
20	20	1322	34	1126	42	3	867	652	40	22	887	106	86	-	None	1.7
21	21	1316	58	1159	48	3	847	589	57	19	845	102	93	-	None	1.2
22	22	1287	56	1171	34	3	856	562	44	29	812	99	92	-	None	1.6
23	23	1333	58	1132	40	3	856	707	47	61	834	97	80	-	None	1.5
24	24	1306	47	1167	34	3	861	574	42	70	940	79	67	-	None	1.6
25	25	1339	54	1143	40	3	882	697	48	63	899	91	83	-	None	1.5

[Table A-2-2]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
26	26	1267	58	1131	24	3	884	587	40	21	869	91	84	-	None	1.7
27	27	1251	46	1176	22	3	861	659	47	70	893	97	93	-	None	1.5
28	28	1267	53	1183	22	3	893	699	59	28	877	105	100	-	None	1.1
29	29	1270	49	1140	35	3	896	634	61	44	877	87	69	-	None	1.1
30	30	981	58	970	30	3	841	612	44	52	933	83	82	-	None	1.6
31	31	1320	7	1141	47	3	906	713	42	73	893	71	62	-	None	1.6
32	32	1387	48	1135	29	3	858	578	50	69	843	85	69	-	None	1.4
33	33	1298	42	1127	20	3	899	604	0	69	839	84	67	-	None	2.8
34	34	1281	55	1122	22	3	835	667	56	50	903	70	71	267	None	1.2
35	35	1289	49	1132	46	3	831	641	51	58	927	95	87	274	Yes	1.4
36	36	1318	49	1171	38	3	844	745	53	53	864	101	88	-	Yes	1.3
37	37	1239	48	1138	42	3	829	551	51	24	879	80	67	None	None	1.3
38	38	1250	44	1127	39	3	885	661	47	30	856	103	90	-	None	1.5
39	39	1251	49	1170	39	3	891	700	59	68	871	85	72	-	None	1.1
40	40	1322	52	1008	44	3	882	697	40	69	917	104	103	-	None	1.6
41	41	1333	43	1152	3	2	893	634	59	31	934	74	76	-	None	1.4
42	42	1267	58	1141	40	1	906	713	50	65	903	83	78	-	None	1.2
43	43	1339	22	1111	38	3	899	667	51	63	892	102	93	-	None	1.3

[Table A-3]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties			Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Max. bending angle (°)	Hydrogen embrittlement resistance	
1A	1	1	564	80	1674	87.5	Good	Inv. ex.
2A	2	2	632	72	1884	79.1	Good	Inv. ex.
3A	3	3	751	65	2259	72.6	Good	Inv. ex.
4A	4	4	771	57	2309	75.8	Good	Inv. ex.
5A	5	5	<u>377</u>	82	<u>1119</u>	89.9	Good	<u>Comp.</u> <u>ex.</u>
6A	6	6	528	76	1586	86.8	Good	Inv. ex.
7A	7	7	678	73	2034	79.4	Good	Inv. ex.
8A	8	8	663	68	1994	75.7	Good	Inv. ex.
9A	9	9	<u>973</u>	52	2915	<u>63.4</u>	Good	<u>Comp.</u> <u>ex.</u>
10A	10	10	700	69	2100	80.8	Good	Inv. ex.
11A	11	11	<u>490</u>	83	<u>1467</u>	81.7	Good	<u>Comp.</u> <u>ex.</u>
12A	12	12	630	71	1883	89.5	Good	Inv. ex.
13A	13	13	640	70	1927	88.4	Good	Inv. ex.
14A	14	14	653	68	1940	84.4	Good	Inv. ex.
15A	15	15	640	69	1918	89.3	Good	Inv. ex.
16A	16	16	642	69	1905	85.5	Good	Inv. ex.
17A	17	17	657	68	1963	83.7	Good	Inv. ex.
18A	18	18	505	80	1511	86.9	Good	Inv. ex.
19A	19	19	504	80	1502	87.4	Good	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties			Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Max. bending angle (°)	Hydrogen embrittlement resistance	
20A	20	20	500	80	1532	89.1	Good	Inv. ex.
21A	21	21	634	72	1909	78.9	Good	Inv. ex.
22A	22	22	631	72	1900	79	Good	Inv. ex.
23A	23	23	633	72	1905	77.1	Good	Inv. ex.
24A	24	24	710	65	2132	72.4	Good	Inv. ex.
25A	25	25	702	65	2084	71.9	Good	Inv. ex.
26A	26	26	703	65	2110	70.9	Good	Inv. ex.
27A	27	27	768	57	2290	74.3	Good	Inv. ex.
28A	28	28	767	57	2297	76.8	Good	Inv. ex.
29A	29	29	770	57	2308	76.2	Good	Inv. ex.
30A	30	30	631	16	1895	68.1	Poor	Comp. ex.
31A	31	31	630	18	1880	61.7	Poor	Comp. ex.
32A	32	32	632	95	1885	68.8	Good	Comp. ex.
33A	33	33	628	70	1878	83.1	Good	Inv. ex.
34A	34	34	721	63	2168	73	Good	Inv. ex.
35A	35	35	715	63	2145	78.3	Good	Inv. ex.
36A	36	36	631	70	1892	84	Good	Inv. ex.
37A	37	37	641	72	2153	72.6	Good	Inv. ex.
38A	38	38	776	56	2297	73.9	Good	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties			Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Max. bending angle (°)	Hydrogen embrittlement resistance	
39A	39	39	781	55	2381	70.2	Good	Inv. ex.
41A	41	41	627	10	2069	60.2	Poor	Comp. ex.
42A	42	42	635	11	2096	60.1	Poor	Comp. ex.
43A	43	43	625	13	2063	59.2	Poor	Comp. ex.
44A	44	44	634	46	2092	109.5	Good	Inv. ex.

[Manufacturing Example B]

[0097] The Nos. 1 to 18 steel sheets for sheet thickness middle part having the chemical compositions shown in Table B-1-1 ("Steel Nos. 1 to 18" in Table B-1-1) were ground down at their surfaces to remove the surface oxides. After that, the respective steel sheets for sheet thickness middle part were welded with steel sheets for surface layer having the chemical compositions shown in Table B-1-2 at both surfaces or single surfaces by arc welding to fabricate the Nos. 1 to 41 multilayer steel sheets for hot stamped body. The sheet thickness of the total of the steel sheet for surface layer and the steel sheet for sheet thickness middle part after arc welding was 200 mm to 300 mm and the thickness of the steel sheet for surface layer was 1/3 or so of the thickness of the steel sheet for sheet thickness middle part (in case of single side, 1/4 or so). The No. 37 multilayer steel sheet was steel with steel sheet for surface layer welded to only one side. The multilayer steel sheets other than No. 37 respectively had steel sheets for surface layer welded to both sides of the steel sheet for sheet thickness middle part. Among the Nos. 1 to 41 multilayer steel sheets of Table B-1-3, ones where the steel sheet for sheet thickness middle part did not satisfy the requirements of composition of the middle part in sheet thickness of the hot stamped body according to the present invention are indicated as "comparative steels" in the remarks columns.

[0098] The Nos. 1 to 41 multilayer steel sheets were respectively treated under the conditions of the Nos. 1 to 41 manufacturing conditions shown in Table B-2-1 to Table B-2-2 by heat treatment before hot rolling, rough rolling, hot rolling, and cold rolling to obtain steel sheets. Next, the steel sheets were heat treated as shown in Table B-2-1 and Table B-2-2 (in the tables, "heat treatment of hot stamped body") for hot stamping to manufacture the Nos. 1B to 41B hot stamped bodies ("stamped bodies" of Table B-3-1 and Table B-3-2). Further, the Nos. 35B and 36B hot stamped bodies were coated on a hot dip coating line at their surfaces with 120 to 160 g/m² amounts of aluminum. Further, the items in Table B-2-1 to Table B-2-2 correspond to the items in Table A-2-1 to Table A-2-2. Further, in the tables, the fields with the notations "-" indicate no corresponding treatment performed.

[0099] Table B-3-1 and Table B-3-2 show the metal structures and characteristics of the Nos. 1B to 41B hot stamped bodies. The constituents obtained by analyzing the positions of 1/2 of the sheet thicknesses of the samples taken from the hot stamped bodies (middle parts in sheet thickness) and positions of 20 μ m from the surfaces of the softened layers were equivalent to the constituents of the steel sheets for sheet thickness middle part and steel sheets for surface layer of the Nos. 1 to 41 multilayer steel sheets of Table B-1-1 to Table B-1-3.

[0100] The metal structures of the hot stamped steel sheets were measured by the above-mentioned method. The hardness of the steel sheet for sheet thickness middle part forming the middle part in sheet thickness and the area rate (%) of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer forming the softened layer to 1/2 of the thickness of that softened layer were calculated. The calculated values of the area rate are shown in the items "area rate (%) of total of crystal grains with maximum crystal orientation difference inside large angle grain boundaries of 1° or less and crystal grains with maximum crystal orientation difference of 8° to 15°" of Tables B-3-1 to Table B-3-2.

[0101] Further, the Nos. 1B to 41B hot stamped bodies were respectively measured for average hardness (HV) and minimum hardness (HV) at the middle part in sheet thickness (position of 1/2 of sheet thickness) by the above method. The measurement results are shown in Table B-3-1 to Table B-3-2. The Nos. 1B to 41B hot stamped bodies had differences of the average hardness (HV) and minimum hardness (HV) shown in the "scattering in cross-sectional hardness" of Table B-3-1 to Table B-3-2. Further, cases with a scattering in cross-sectional hardness of 100HV or more were indicated as failing.

[0102] The hot stamped bodies were subjected to tensile tests. The results are shown in Table B-3-1 to Table B-3-2. The tensile tests were performed by fabricating No. 5 test pieces described in JIS Z 2201 and testing them by the method described in JIS Z 2241.

[0103] The hydrogen embrittlement resistance of the hot stamped body, in the same way as Manufacturing Example A, was evaluated using a test piece cut out from the stamped body. That is, a test piece of a sheet thickness of 1.2 mm×width 6 mm×length 68 mm was cut out from the stamped body, given a strain corresponding to the yield stress in a four-point bending test, then immersed in pH3 hydrochloric acid for 100 hours and evaluated for hydrogen embrittlement resistance by the presence of any cracks. The case of no cracks was indicated as passing ("Good") and the case of cracks was evaluated as failing ("Poor").

[0104] For the purpose of evaluating the impact resistance of the hot stamped body, the body was evaluated based on the VDA standard (VDA238-100) prescribed by the German Association of the Automotive Industry under the same measurement conditions as Manufacturing Example A. In the present invention, the displacement at the time of maximum load obtained in the bending test was converted to angle by the VDA standard to find maximum bending angle and thereby evaluate the impact resistance of the hot stamped body.

[0105] If the tensile strength is 1500 MPa or more, the maximum bending angle (°) was 70(°) or more, and the hydrogen embrittlement resistance was a passing level, it was judged that the impact resistance and hydrogen embrittlement

resistance were excellent and the case was indicated as an "invention example". If even one of the three aspects of performance is not satisfied, the case was indicated as a "comparative example".

[0106] In each hot stamped body of the invention examples, the area rate (%) of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness was 50% to less than 85%. Further, each hot stamped body of the invention examples was excellent in tensile strength, bendability, and hydrogen embrittlement resistance.

[0107] As opposed to this, the No. 5B hot stamped body was low in carbon content at the steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness became insufficient and the tensile strength became insufficient. The No. 9B hot stamped body was excessive in carbon content of steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness also became excessive and the targeted bendability could not be obtained. Further, the No. 11B hot stamped body was sparse in Mn content at the steel sheet for sheet thickness middle part, so the hardness of the middle part in sheet thickness became insufficient and the tensile strength became insufficient.

[0108] The Nos. 30B to 32B hot stamped bodies are comparative examples produced using the multilayer steel sheets for hot stamped body to which the desirable heat treatment had not been applied before the hot stamping process. The No. 30B hot stamped body was low in heat treatment temperature before the hot stamping process, while the No. 31B hot stamped body was short in heat treatment time before the hot stamping process, so in the metal structures of the softened layer from the surface of the softened layer to 1/2 of the thickness, the soft structures and metal structures with intermediate hardnesses insufficiently grew and the target bendability could not be obtained. Further, the No. 32B hot stamped body was excessively high in heat treatment temperature before the hot stamping process, so the effect of reduction of the sharp gradient in hardness in the sheet thickness direction occurring at the time of bending deformation could not be obtained.

[0109] The No. 38B hot stamped body was low in rolling temperature of the rough rolling. Further, the No. 39B hot stamped body was low in sheet thickness reduction rate of the rough rolling. Further, the No. 40B hot stamped body was low in number of rolling operations under conditions of a time between passes of 3 seconds or more. These hot stamped bodies were not manufactured under the suitable rough rolling conditions, so the soft structures and metal structures with intermediate hardnesses insufficiently grew, it was not possible to ease the strain occurring due to bending deformation, and the targeted bendability could not be obtained.

[0110] The No. 41B hot stamped body is a steel sheet controlled in casting rate to 6 ton/min or more in the continuous casting process of steel sheet for surface layer. It can raise the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness and is excellent in bendability.

[Table B-1-1]

Multilayer steel sheet no.	Composition of constituents of steel sheet for sheet thickness middle part (mass%)												
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B
1	1	0.24	0.25	1.57	0.012	0.0005	0.042	0.0037					
2	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
3	3	0.38	0.13	1.79	0.006	0.0018	0.045	0.004					
4	4	0.45	0.21	1.69	0.009	0.0015	0.025	0.0044					
5	5	0.17	0.17	1.51	0.006	0.0018	0.025	0.0035					
6	6	0.24	0.20	1.64	0.014	0.0014	0.043	0.0027					
7	7	0.33	0.15	1.75	0.016	0.0014	0.031	0.0027					
8	8	0.32	0.11	1.57	0.012	0.0020	0.045	0.0031					
9	9	0.81	0.14	1.96	0.013	0.0016	0.034	0.003					
10	10	0.35	0.27	1.75	0.008	0.0013	0.033	0.003					
11	11	0.3	0.22	1.05	0.014	0.0013	0.026	0.003					
12	12	0.29	0.22	1.74	0.016	0.0007	0.032	0.004					
13	13	0.27	0.24	1.63	0.01	0.0007	0.045	0.0043	0.20				
14	14	0.35	0.20	1.55	0.012	0.0014	0.043	0.004		0.050			
15	15	0.29	0.15	2.05	0.006	0.0015	0.033	0.0039			0.015		
16	16	0.32	0.12	1.84	0.012	0.0007	0.032	0.0044				0.050	
17	17	0.34	0.20	1.79	0.009	0.0007	0.033	0.0043					0.0019
18	1	0.24	0.25	1.57	0.012	0.0005	0.042	0.0037					
19	1	0.24	0.25	1.57	0.012	0.0005	0.042	0.0037					
20	1	0.24	0.25	1.57	0.012	0.0005	0.042	0.0037					
21	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
22	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
23	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
24	3	0.38	0.13	1.79	0.006	0.0018	0.045	0.0040					

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for sheet thickness middle part (mass%)												
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B
25	3	0.38	0.13	1.79	0.006	0.0018	0.045	0.0040					
26	3	0.38	0.13	1.79	0.006	0.0018	0.045	0.0040					
27	4	0.45	0.21	1.69	0.009	0.0015	0.025	0.0044					
28	4	0.45	0.21	1.69	0.009	0.0015	0.025	0.0044					
29	4	0.45	0.21	1.69	0.009	0.0015	0.025	0.0044					
30	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
31	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
32	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
33	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
34	18	0.68	0.23	1.81	0.008	0.0019	0.041	0.0036					
35	18	0.68	0.23	1.81	0.008	0.0019	0.041	0.0036					
36	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
37	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
38	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
39	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
40	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
41	2	0.31	0.25	1.78	0.015	0.0009	0.032	0.0031					
In the table, blanks indicate corresponding constituents not intentionally added.													

[Table B-1-2]

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)											
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B
1	0.10	0.10	0.48	0.005	0.0018	0.030	0.0036					
2	0.13	0.10	0.60	0.016	0.0008	0.033	0.0030					
3	0.11	0.07	0.75	0.015	0.0010	0.041	0.0029					
4	0.22	0.09	0.70	0.006	0.0020	0.029	0.0031					
5	0.10	0.07	0.66	0.006	0.0019	0.028	0.0041					
6	0.14	0.08	0.56	0.014	0.0019	0.033	0.0028					
7	0.11	0.05	0.58	0.008	0.0016	0.030	0.0040					
8	0.12	0.06	0.51	0.006	0.0012	0.033	0.0027					
9	0.36	0.06	0.52	0.018	0.0017	0.036	0.0032					
10	0.15	0.22	0.70	0.018	0.0005	0.033	0.0042					
11	0.15	0.12	0.03	0.013	0.0008	0.027	0.0044					
12	0.11	0.12	0.36	0.008	0.0017	0.038	0.0041					
13	0.12	0.13	0.68	0.010	0.0013	0.032	0.0027	0.15				
14	0.14	0.08	0.55	0.018	0.0009	0.038	0.0040		0.010			
15	0.11	0.06	0.49	0.013	0.0008	0.034	0.0032			0.010		
16	0.10	0.06	0.63	0.018	0.0008	0.028	0.0039				0.050	
17	0.25	0.10	0.61	0.017	0.0010	0.035	0.0039					0.0018
18	0.12	0.21	1.18	0.012	0.0008	0.029	0.0030					
19	0.10	0.21	0.62	0.012	0.0007	0.037	0.0042					
20	0.10	0.11	1.05	0.016	0.0011	0.033	0.0039					
21	0.20	0.10	1.25	0.007	0.0007	0.029	0.0030					
22	0.13	0.16	1.09	0.009	0.0014	0.033	0.0036					
23	0.15	0.20	0.58	0.018	0.0019	0.027	0.0033					
24	0.11	0.06	0.62	0.007	0.0005	0.041	0.0032					

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)											
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B
25	0.10	0.12	0.66	0.011	0.0017	0.030	0.0042					
26	0.14	0.06	1.01	0.008	0.0016	0.027	0.0040					
27	0.30	0.09	0.69	0.014	0.0011	0.041	0.0029					
28	0.23	0.15	0.59	0.005	0.0013	0.040	0.0033					
29	0.23	0.07	1.17	0.007	0.0010	0.030	0.0031					
30	0.26	0.20	0.55	0.018	0.0020	0.043	0.0044					
31	0.17	0.11	0.59	0.017	0.0011	0.035	0.0029					
32	0.17	0.11	0.56	0.008	0.0014	0.032	0.0039					
33	0.17	0.11	0.51	0.008	0.0018	0.036	0.0027					
34	0.36	0.13	0.63	0.007	0.0005	0.042	0.0035					
35	0.37	0.11	0.63	0.007	0.0011	0.029	0.0031					
36	0.16	0.12	0.58	0.015	0.0005	0.033	0.0032					
37	0.17	0.12	0.56	0.008	0.0009	0.030	0.0044					
38	0.13	0.10	0.60	0.016	0.0008	0.033	0.0030					
39	0.13	0.10	0.60	0.016	0.0008	0.033	0.0030					
40	0.13	0.10	0.60	0.016	0.0008	0.033	0.0030					
41	0.13	0.10	0.60	0.016	0.0008	0.033	0.0030					
In the table, blanks indicate corresponding constituents not intentionally added.												

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[Table B-1-3]

5	Multilayer steel sheet no.	Steel sheet for sheet thickness middle part	Sheet thickness of steel sheet for surface layer (mm)	Remarks
		Steel no.		
	1	1	85	
	2	2	83	
10	3	3	84	
	4	4	97	
	5	5	94	<u>Comp. steel</u>
15	6	6	82	
	7	7	88	
	8	8	94	
	9	9	83	<u>Comp. steel</u>
20	10	10	88	
	11	11	83	<u>Comp. steel</u>
	12	12	92	
25	13	13	82	
	14	14	86	
	15	15	95	
	16	16	96	
30	17	17	96	
	18	1	95	
	19	1	99	
35	20	1	98	
	21	2	88	
	22	2	84	
	23	2	85	
40	24	3	83	
	25	3	91	
	26	3	88	
45	27	4	96	
	28	4	82	
	29	4	91	
	30	2	93	
50	31	2	92	
	32	2	94	
	33	2	84	
55	34	18	92	
	35	18	92	
	36	2	84	

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(continued)

Multilayer steel sheet no.	Steel sheet for sheet thickness middle part	Sheet thickness of steel sheet for surface layer (mm)	Remarks
	Steel no.		
37	2	93	
38	2	95	
39	2	98	
40	2	85	
41	2	88	

[Table B-2-1]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
1	1	1290	35	1151	33	3	917	565	50	35	858	72	49	None	None	1.4
2	2	1280	50	1167	31	3	911	688	44	35	849	96	89	None	None	1.6
3	3	1255	40	1141	22	3	915	515	57	46	861	77	65	None	None	1.2
4	4	1285	40	1153	39	3	887	661	40	64	896	96	86	None	None	1.7
5	5	1318	35	1129	40	3	895	513	55	57	916	101	81	None	None	1.3
6	6	1275	35	1162	33	3	885	527	57	70	880	72	61	None	None	1.2
7	7	1275	35	1180	51	3	896	591	49	56	912	82	78	None	None	1.4
8	8	1250	40	1135	47	3	895	628	35	47	902	76	76	None	None	1.8
9	9	1350	55	1168	30	3	920	701	35	25	863	65	60	None	None	1.8
10	10	1290	35	1136	35	3	899	611	51	35	854	73	71	None	None	1.4
11	11	1250	40	1125	38	3	894	688	50	52	871	100	102	None	None	1.4
12	12	1300	40	1171	41	3	907	652	50	63	884	78	77	None	None	1.4
13	13	1250	50	1175	26	3	896	687	38	30	895	101	93	None	None	1.7
14	14	1300	55	1142	41	3	900	714	53	43	910	68	67	None	None	1.3
15	15	1330	50	1157	46	3	906	559	40	27	909	87	78	None	None	1.7
16	16	1270	60	1146	34	3	895	710	50	31	891	107	97	None	None	1.4
17	17	1310	45	1137	45	3	899	672	34	65	901	111	114	None	None	1.8
18	18	1300	55	1151	34	3	888	664	50	50	855	95	83	None	None	1.4
19	19	1300	40	1156	40	3	917	564	50	15	915	75	66	None	None	1.4

(continued)

Multilayer steel sheet no.	Manufactur- ing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of re- duction of sheet thickness (%)	No. of roll- ing opera- tions (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)	None	Sheet thickness (mm)
20	20	1290	50	1122	44	3	903	666	50	23	871	108	88	None	None	1.4
21	21	1280	55	1163	46	3	907	614	57	22	868	101	89	None	None	1.2
22	22	1280	40	1171	30	3	914	514	44	34	855	96	93	None	None	1.6
23	23	1300	40	1136	42	3	888	562	47	66	878	93	79	None	None	1.5
24	24	1255	40	1164	32	3	893	524	57	70	857	75	71	None	None	1.2
25	25	1255	55	1143	39	3	910	520	57	67	899	91	83	None	None	1.2

[Table B-2-2]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
26	26	1300	35	1127	20	3	893	527	57	23	901	88	81	None	None	1.2
27	27	1285	40	1174	27	3	901	533	40	71	869	92	90	None	None	1.7
28	28	1285	40	1178	24	3	913	522	40	31	879	102	100	None	None	1.7
29	29	1350	55	1142	33	3	905	551	40	40	912	92	66	None	None	1.7
30	30	1070	50	1010	32	3	908	638	44	55	847	88	83	None	None	1.6
31	31	1300	10	1137	48	3	892	587	44	74	862	76	66	None	None	1.6
32	32	1400	50	1140	26	3	911	642	44	68	871	82	71	None	None	1.6
33	33	1300	40	1123	16	3	916	534	0	66	891	80	63	None	None	2.8
34	34	1280	55	1124	18	3	881	665	56	45	900	67	76	267	None	1.2
35	35	1300	40	1127	41	3	883	650	51	63	874	91	85	274	Yes	1.4
36	36	1290	50	1166	43	3	909	541	44	52	891	101	86	None	Yes	1.6
37	37	1280	50	1143	47	3	910	704	44	29	863	80	72	None	None	1.6
38	38	1330	40	1005	48	3	882	697	40	67	917	103	108	-	None	1.2
39	39	1310	45	1157	3	2	893	634	59	26	934	69	74	-	None	1.2
40	40	1290	40	1137	41	1	906	713	50	62	903	84	82	-	None	1.6
41	41	1280	23	1112	41	3	899	667	51	65	892	100	90	-	None	1.6

[Table B-3-1]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties						Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Average cross- sectional hardness (Hv)	Minimum hardness (Hv)	Scattering in cross- sectional hardness (Hv)	
1B	1	1	546	75	1621	89	Good	519	480	39	Inv. ex.
2B	2	2	647	64	1836	78.6	Good	607	575	32	Inv. ex.
3B	3	3	748	65	2187	72.4	Good	714	705	9	Inv. ex.
4B	4	4	785	57	2328	70.7	Good	742	724	18	Inv. ex.
5B	5	5	446	80	1210	89.7	Good	450	357	93	Comp. ex.
6B	6	6	528	66	1579	88.1	Good	499	469	30	Inv. ex.
7B	7	7	678	53	2027	79.6	Good	643	628	15	Inv. ex.
8B	8	8	663	71	1982	77.3	Good	615	581	34	Inv. ex.
9B	9	9	973	56	2746	57.8	Good	915	899	16	Comp. ex.
10B	10	10	700	65	2093	75.1	Good	668	655	13	Inv. ex.
11B	11	11	490	57	1362	88.5	Good	458	327	131	Comp. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties						Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Average cross- sectional hardness (Hv)	Minimum hardness (Hv)	Scattering in cross- sectional hardness (Hv)	
12B	12	12	618	54	1847	81.3	Good	588	562	26	Inv. ex.
13B	13	13	590	65	1760	82.5	Good	568	540	28	Inv. ex.
14B	14	14	705	77	2085	73.5	Good	655	631	24	Inv. ex.
15B	15	15	618	60	1832	80.2	Good	591	580	11	Inv. ex.
16B	16	16	662	65	1975	81.7	Good	625	618	7	Inv. ex.
17B	17	17	683	71	2034	74.3	Good	649	638	11	Inv. ex.
18B	18	18	534	80	1564	86.1	Good	504	461	43	Inv. ex.
19B	19	19	537	78	1596	89.2	Good	522	473	49	Inv. ex.
20B	20	20	541	60	1621	89.5	Good	518	497	21	Inv. ex.
21B	21	21	639	82	1901	77.4	Good	598	588	10	Inv. ex.
22B	22	22	630	75	1874	79.2	Good	581	567	14	Inv. ex.
23B	23	23	625	68	1850	80.8	Good	578	559	19	Inv. ex.
24B	24	24	740	60	2105	73.5	Good	691	681	10	Inv. ex.

(continued)

	Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties						Remarks
				Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Average cross- sectional hardness (Hv)	Minimum hardness (Hv)	Scattering in cross- sectional hardness (Hv)	
25B		25	25	735	76	2195	71.1	Good	667	656	11	Inv. ex.

[Table B-3-2]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties						Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal 1 grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Average cross- sectional hardness (Hv)	Minimum hardness (Hv)	Scattering in cross- sectional hardness (Hv)	
26B	26	26	731	78	2187	70.8	Good	671	654	17	Inv. ex.
27B	27	27	791	70	2387	72.5	Good	754	737	17	Inv. ex.
28B	28	28	775	63	2317	73	Good	739	717	22	Inv. ex.
29B	29	29	780	78	2271	74.5	Good	734	721	13	Inv. ex.
30B	30	30	657	15	1975	61.6	Poor	627	605	22	Comp. ex.
31B	31	31	647	18	1931	62.4	Poor	620	600	20	Comp. ex.
32B	32	32	644	90	1957	65.1	Good	611	599	12	Comp. ex.
33B	33	33	645	84	1930	75.8	Good	605	551	54	Inv. ex.
34B	34	34	745	64	2180	78.5	Good	717	702	15	Inv. ex.
35B	35	35	740	75	2260	79.3	Good	726	707	19	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties						Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal 1 grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Average cross- sectional hardness (Hv)	Minimum hardness (Hv)	Scattering in cross- sectional hardness (Hv)	
36B	36	36	647	71	1941	77.7	Good	611	581	30	Inv. ex.
37B	37	37	647	65	1920	78.1	Good	614	587	27	Inv. ex.
38B	38	38	643	9	2122	59.9	Poor	643	614	29	Comp. ex.
39B	39	39	637	10	2102	59.8	Poor	637	608	29	Comp. ex.
40B	40	40	645	12	2129	60.1	Poor	645	615	30	Comp. ex.
41B	41	41	641	45	2115	111.2	Good	641	611	30	Inv. ex.

[Manufacturing Example C]

[0111] Steel sheets for sheet thickness middle part having the chemical compositions shown in Table C-1-1 to Table C-1-2 were ground down at their surfaces to remove the surface oxides. After that, the respective steel sheets for sheet thickness middle part were welded with steel sheets for surface layer having the chemical compositions shown in Table C-1-3 to Table C-1-4 at both surfaces or single surfaces by arc welding to fabricate the Nos. 1 to 49 multilayer steel sheets for hot stamped body. The sheet thickness of the total of the steel sheet for surface layer and the steel sheet for sheet thickness middle part after arc welding was 200 mm to 300 mm and the thickness of the steel sheet for surface layer was 1/3 or so of the thickness of the steel sheet for sheet thickness middle part (in case of single side, 1/4 or so). The No. 31 multilayer steel sheet was steel with steel sheet for surface layer welded to only one side. Among the Nos. 1 to 53 multilayer steel sheets of Table C-1-1 to Table C-1-4, ones where the steel sheet for sheet thickness middle part did not satisfy the requirements of composition of the middle part in sheet thickness of the hot stamped body according to the present invention are indicated as "comparative steels" in the remarks columns.

[0112] The "ratio of C, Si, and Mn contents of steel sheet for surface layer to steel sheet for sheet thickness middle part" of Table C-1-3 to Table C-1-4 show the ratios of C, Si, and Mn contents of steel sheet for surface layer to the C, Si, and Mn contents of steel sheet for sheet thickness middle part in the Nos. 1 to 53 multilayer steel sheets for hot stamped body.

[0113] The Nos. 1 to 53 multilayer steel sheets were respectively treated under the conditions of the Nos. 1 to 53 manufacturing conditions shown in Table C-2-1 to Table C-2-2 by heat treatment before hot rolling, rough rolling, hot rolling, and cold rolling to obtain steel sheets. Next, the steel sheets were heat treated as shown in Table C-2-1 to Table C-2-2 (in the tables, "heat treatment of hot stamped body") for hot stamping to manufacture the Nos. 1C to 53C hot stamped bodies ("stamped bodies" of Table C-3-1 to Table C-3-2). Further, the No. 30C hot stamped body was coated on a hot dip coating line at the surface with a 120 to 160 g/m² amount of aluminum. Further, the items in Table C-2-1 to Table C-2-2 correspond to the items in Table A-2-1 to Table A-2-2. Further, in the tables, the fields with the notations "-" indicate no corresponding treatment performed.

[0114] Table C-3-1 to Table C-3-2 show the metal structures and characteristics of the Nos. 1C to 53C hot stamped bodies. The constituents obtained by analyzing the positions of 1/2 of the sheet thicknesses of the samples taken from the hot stamped bodies (middle parts in sheet thickness) and positions of 20 μ m from the surfaces of the softened layers were equivalent to the constituents of the steel sheets for sheet thickness middle part and the steel sheets for surface layer of the Nos. 1 to 53 multilayer steel sheets of Table C-1-1 to Table C-1-4.

[0115] The metal structures of the hot stamped steel sheets were measured by the above-mentioned method. The hardness of the steel sheet for sheet thickness middle part forming the middle part in sheet thickness and the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer forming the softened layer to 1/2 of the thickness of that softened layer were calculated. The calculated values of the area rate are shown in the items "area rate (%)" of total of crystal grains with maximum crystal orientation difference inside large angle grain boundaries of 1° or less and crystal grains with maximum crystal orientation difference of 8° to 15°" of Tables C-3-1 to C-3-2.

[0116] The hot stamped bodies were subjected to tensile tests. The results are shown in Table C-3-1 to Table C-3-2. The tensile tests were performed by fabricating No. 5 test pieces described in JIS Z 2201 and testing them by the method described in JIS Z 2241.

[0117] The hydrogen embrittlement resistance of the hot stamped body, in the same way as Manufacturing Example A, was evaluated using a test piece cut out from the stamped body. That is, a test piece of a sheet thickness of 1.2 mm×width 6 mm×length 68 mm was cut out from the stamped body, given a strain corresponding to the yield stress in a four-point bending test, then immersed in pH3 hydrochloric acid for 100 hours and evaluated for hydrogen embrittlement resistance by the presence of any cracks. The case of no cracks was indicated as passing ("Good") and the case of cracks was evaluated as failing ("Poor").

[0118] For the purpose of evaluating the impact resistance of the hot stamped body, the body was evaluated based on the VDA standard (VDA238-100) prescribed by the German Association of the Automotive Industry under the same measurement conditions as Manufacturing Example A. In the present invention, the displacement at the time of maximum load obtained in the bending test was converted to angle by the VDA standard to find maximum bending angle and thereby evaluate the impact resistance of the hot stamped body.

[0119] If the tensile strength is 1500 MPa or more, the maximum bending angle (°) was 70(°) or more, the uniform elongation was 5% or more, and the hydrogen embrittlement resistance was a passing level, it was judged that the impact resistance, hydrogen embrittlement resistance, and ductility were excellent and the case was indicated as an "invention example". If even one of the three aspects of performance is not satisfied, the case was indicated as a "comparative example".

[0120] In each hot stamped body of the invention examples, the area rate of the total of the crystal grains with a

maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness of the steel sheet for surface layer was 50% to less than 85%. Further, each hot stamped body of the invention examples was excellent in tensile strength, bendability, and hydrogen embrittlement resistance.

[0121] As opposed to this, the No. 5C hot stamped body was low in carbon content of the steel sheet for sheet thickness middle part, so became insufficient in hardness of the middle part in sheet thickness and became insufficient in tensile strength. The No. 9C hot stamped body was excessive in carbon content of the steel sheet for sheet thickness middle part, so also became excessive in hardness of the middle part in sheet thickness and could not be given the targeted bendability. Further, the No. 11C hot stamped body was low in Si content of the steel sheet for sheet thickness middle part, so the area percent of the residual austenite of the metal structures at the middle part in sheet thickness was less than 1.0% and the uniform elongation was low.

[0122] The Nos. 25C to 27C and 49C hot stamped bodies are comparative examples manufactured using the multilayer steel sheets for hot stamped body to which the preferable heat treatment is not applied before the hot stamping process. The No. 25C hot stamped body is too low in heat treatment temperature before the hot stamping process, so the soft structures and metal structures with intermediate hardnesses insufficiently grew, the effect of surface properties of the hot stamped body and effect of the transitional part from the middle part in sheet thickness to the softened layer could not be eliminated, and excellent bendability could not be obtained.

[0123] Further, the No. 26C hot stamped body was excessively high in heat treatment time before the hot stamping process, so the soft structures and metal structures with intermediate hardnesses excessively grew, the difference in hardness between the softened layer and the middle part in sheet thickness became too large, and the effect of reducing the sharp gradient of hardness in the sheet thickness direction occurring at the time of bending deformation could not be obtained. For this reason, the No. 26C hot stamped body could not be given the targeted bendability.

[0124] Further, the Nos. 27C and 49C hot stamped bodies were too long in heat treatment time before the hot stamping process, the difference in hardness between the softened layer and the middle part in sheet thickness become too great. Further, the heat treatment temperature was excessively high, so the effect of reducing the sharp gradient of hardness in the sheet thickness direction occurring at the time of bending deformation could not be obtained. For this reason, the Nos. 27C and 49C hot stamped bodies could not be given excellent bendability.

[0125] The No. 50C hot stamped body was low in rolling temperature of the rough rolling. Further, the No. 51C hot stamped body was low in sheet thickness reduction rate of the rough rolling. Further, the No. 52C hot stamped body was low in number of rolling operations under conditions of a time between passes of 3 seconds or more. These hot stamped bodies were not manufactured under the suitable rough rolling conditions, so the soft structures and metal structures with intermediate hardnesses insufficiently grew, it was not possible to ease the strain occurring due to bending deformation, and the targeted bendability could not be obtained.

[0126] The No. 53C hot stamped body is a steel sheet controlled in casting rate to 6 ton/min or more in the continuous casting process of steel sheet for surface layer. It can raise the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness and is excellent in bendability.

[Table C-1-1]

Multilayer steel sheet no.	Composition of constituents of steel sheet for sheet thickness middle part (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	0.22	1.67	1.23	0.007	0.0025	0.036	0.0041	0	0	0	0	0	
2	0.36	1.84	0.68	0.011	0.0028	0.027	0.0053	0	0	0	0	0	
3	0.28	2.29	1.33	0.012	0.0015	0.056	0.0030	0	0	0	0	0	
4	0.50	1.33	1.15	0.006	0.0043	0.032	0.0068	0	0	0	0	0	
5	0.19	2.23	1.48	0.006	0.0033	0.059	0.0044	0	0	0	0	0	Comp. steel
6	0.20	0.71	1.21	0.005	0.0029	0.025	0.0053	0	0	0	0	0	
7	0.22	2.70	1.21	0.010	0.0045	0.046	0.0055	0	0	0	0	0	
8	0.24	1.14	0.65	0.009	0.0049	0.036	0.0032	0	0	0	0	0	
9	0.72	1.45	0.68	0.007	0.0007	0.038	0.0060	0	0	0	0	0	Comp. steel
10	0.22	1.50	0.58	0.006	0.0059	0.052	0.0036	0	0	0	0	0	
11	0.34	0.42	1.18	0.010	0.0020	0.030	0.0038	0	0	0	0	0	Comp. steel
12	0.36	1.29	1.25	0.010	0.0016	0.041	0.0019	0	0	0	0	0	
13	0.25	0.85	0.80	0.006	0.0004	0.034	0.0023	0.10	0	0	0	0	
14	0.27	1.12	1.49	0.005	0.0007	0.031	0.0011	0	0	0	0	0.0015	
15	0.26	1.71	1.34	0.010	0.0051	0.034	0.0047	0	0.045	0.025	0	0.0020	
16	0.22	0.72	1.42	0.010	0.0041	0.047	0.0066	0	0	0	0	0	
17	0.23	0.58	1.13	0.012	0.0001	0.041	0.0062	0	0	0	0	0	
18	0.37	2.64	0.58	0.004	0.006	0.035	0.0044	0	0	0	0	0	
19	0.32	1.03	1.21	0.008	0.0038	0.030	0.0021	0	0	0	0	0	
20	0.37	2.35	0.56	0.007	0.0036	0.059	0.0053	0	0	0	0	0	
21	0.30	0.95	0.89	0.011	0.0035	0.054	0.0031	0	0	0	0	0	
22	0.55	1.03	1.00	0.004	0.0004	0.028	0.0055	0	0.020	0.025	0	0.0015	
23	0.56	1.80	1.04	0.009	0.0060	0.023	0.0053	0	0	0	0	0	
24	0.51	0.65	0.76	0.008	0.0028	0.036	0.0028	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for sheet thickness middle part (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
25	0.36	2.06	1.42	0.005	0.0020	0.041	0.0013	0	0	0	0	0	
26	0.33	1.01	1.27	0.011	0.0027	0.049	0.0041	0	0	0	0	0	
28	0.33	2.27	0.96	0.005	0.0006	0.038	0.0030	0	0	0	0	0	
29	0.61	2.88	0.60	0.011	0.0047	0.058	0.0047	0	0	0	0	0	
30	0.64	2.41	1.34	0.004	0.0006	0.038	0.0064	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.													

[Table C-1-2]

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet thickness middle part (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
31	0.32	1.13	0.84	0.006	0.0032	0.043	0.0014	0	0	0	0	0	
32	0.31	2.44	0.81	0.100	0.0060	2.600	0.0520	0	0	0	0	0	
33	0.28	2.08	0.67	0.083	0.0040	0.057	0.0300	2.50	0	0	0	0	
34	0.25	1.81	0.82	0.108	0.0030	0.053	0.0530	0.05	0	0	0	0	
35	0.34	2.48	1.08	0.072	0.0020	0.042	0.0330	0	0.120	0	0	0	
36	0.40	2.78	1.33	0.112	0.0030	0.059	0.0340	0	0	0.130	0	0	
37	0.28	1.89	0.80	0.088	0.0020	0.046	0.0340	0	0	0	0.600	0	
38	0.36	2.04	0.96	0.066	0.0050	0.059	0.0310	0	0	0	0.100	0	
39	0.38	2.48	1.05	0.084	0.0060	0.054	0.0570	0	0	0	0	0.0070	
40	0.31	2.43	1.11	0.100	0.0020	0.039	0.0360	0	0	0	0	0	
41	0.36	2.37	1.36	0.066	0.0040	0.035	0.0340	0	0	0	0	0	
42	0.32	1.93	1.08	0.119	0.0060	0.055	0.0550	0	0	0	0	0	1
43	0.31	1.93	0.63	0.082	0.0040	0.053	0.0380	0	0	0	0	0	
44	0.27	2.13	1.09	0.103	0.0040	0.049	0.0340	0	0	0	0	0	
45	0.37	1.96	0.64	0.074	0.0050	0.055	0.0440	0	0	0	0	0	
46	0.25	2.80	0.60	0.080	0.0030	0.053	0.0370	0	0	0	0	0	
47	0.34	2.00	1.38	0.095	0.0040	0.034	0.0540	0	0	0	0	0	
48	0.33	2.41	1.26	0.071	0.0060	0.055	0.0320	0	0	0	0	0	
49	0.35	2.55	1.32	0.066	0.0050	0.037	0.0380	0	0	0	0	0	
50	0.36	1.84	0.68	0.011	0.0028	0.027	0.0053	0	0	0	0	0	
51	0.36	1.84	0.68	0.011	0.0028	0.027	0.0053	0	0	0	0	0	
52	0.36	1.84	0.68	0.011	0.0028	0.027	0.0053	0	0	0	0	0	
53	0.36	1.84	0.68	0.011	0.0028	0.0271	0.0053	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.													

[Table C-1-3]

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)											Thickness of steel sheet for surface layer (mm)	Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	0.106	0.735	0.517	0.006	0.0024	0.048	0.0046	0	0	0	0	0	
2	0.173	1.030	0.360	0.006	0.0065	0.036	0.0016	0	0	0	0	0	
3	0.099	0.847	0.399	0.006	0.0032	0.036	0.0035	0	0	0	0	0	
4	0.294	0.479	0.414	0.006	0.0056	0.039	0.0070	0	0	0	0	0	
5	0.082	1.115	0.592	0.003	0.0070	0.034	0.0020	0	0	0	0	0	Comp. steel
6	0.075	0.355	0.520	0.006	0.0018	0.034	0.0031	0	0	0	0	0	
7	0.100	1.485	0.387	0.009	0.0025	0.034	0.0068	0	0	0	0	0	
8	0.143	0.684	0.390	0.009	0.0038	0.027	0.0027	0	0	0	0	0	
9	0.310	0.827	0.252	0.009	0.0078	0.035	0.0059	0	0	0	0	0	Comp. steel
10	0.106	0.795	0.313	0.006	0.0080	0.029	0.0058	0	0	0	0	0	
11	0.174	0.151	0.578	0.004	0.0062	0.049	0.0048	0	0	0	0	0	Comp. steel
12	0.182	0.606	0.713	0.011	0.0039	0.032	0.0031	0	0	0	0	0	
13	0.095	0.357	0.408	0.005	0.0019	0.043	0.0010	0	0	0	0	0	
14	0.155	0.437	0.760	0.006	0.0023	0.031	0.0024	0	0	0	0	0.0017	
15	0.153	1.163	0.965	0.012	0.0071	0.040	0.0035	0	0.045	0.025	0	0.0015	
16	0.096	0.518	0.809	0.009	0.0025	0.050	0.0034	0	0	0	0	0	
17	0.086	0.197	0.848	0.005	0.0071	0.032	0.0017	0	0	0	0	0	
18	0.260	1.320	0.209	0.003	0.0027	0.032	0.0070	0	0	0	0	0	
19	0.287	0.453	1.041	0.006	0.0062	0.035	0.0020	0	0	0	0	0	
20	0.296	2.021	0.235	0.008	0.0056	0.026	0.0054	0	0	0	0	0	
21	0.189	0.352	0.472	0.004	0.0045	0.040	0.0036	0	0	0	0	0	
22	0.456	0.474	0.570	0.004	0.0069	0.034	0.0054	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)												Thickness of steel sheet for surface layer (mm)	Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B		
23	0.373	1.278	0.530	0.004	0.0051	0.043	0.0051	0	0	0	0	0	102	
24	0.224	0.371	0.631	0.010	0.0028	0.029	0.0038	0.10	0	0	0	0	88	
25	0.155	1.030	0.667	0.011	0.0049	0.021	0.0061	0	0	0	0	0	84	
26	0.184	0.313	0.762	0.011	0.0075	0.031	0.0044	0	0	0	0	0	89	
28	0.109	1.339	0.490	0.010	0.0013	0.047	0.0069	0	0	0	0	0	101	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.														

[Table C-1-4]

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)											Thickness of steel sheet for surface layer (mm)	Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
29	0.262	1.699	0.180	0.009	0.0045	0.038	0.0027	0	0	0	0	0	86
30	0.230	0.940	0.590	0.007	0.0076	0.034	0.0046	0	0	0	0	0	81
31	0.188	0.350	0.454	0.007	0.0048	0.049	0.0064	0	0	0	0	0	162
32	0.146	0.625	1.127	0.006	0.0040	0.040	0.0045	0	0	0	0	0	103
33	0.118	0.545	1.120	0.007	0.0050	0.039	0.0088	0	0	0	0	0	88
34	0.130	0.484	1.128	0.010	0.0030	0.033	0.0077	0	0	0	0	0	107
35	0.136	0.588	0.893	0.012	0.0020	0.021	0.0073	0	0	0	0	0	81
36	0.200	0.673	0.680	0.012	0.0060	0.043	0.0051	0	0	0	0	0	102
37	0.120	0.530	0.966	0.012	0.0050	0.023	0.0056	0	0	0	0	0	96
38	0.180	0.650	1.680	0.007	0.0020	0.050	0.0099	0	0	0	0	0	100
39	0.163	0.383	1.250	0.007	0.0030	0.036	0.0053	0	0	0	0	0	92
40	0.177	0.519	0.800	0.009	0.0030	0.047	0.0097	2.20	0	0	0	0	91
41	0.209	0.573	1.081	0.009	0.0060	0.042	0.0041	0.05	0	0	0	0	86
42	0.157	0.522	1.368	0.011	0.0040	0.023	0.0067	0	0.110	0	0	0	103
43	0.183	0.447	1.566	0.012	0.0040	0.046	0.0064	0	0	0.110	0	0	89
44	0.130	0.423	1.260	0.010	0.0020	0.048	0.0065	0	0	0	0.600	0	92
45	0.215	0.567	1.120	0.013	0.0050	0.045	0.0052	0	0	0	0.100	0	109
46	0.130	0.672	1.653	0.009	0.0050	0.036	0.0059	0	0	0	0	0.010	82
47	0.160	0.452	1.276	0.007	0.0050	0.028	0.0049	0	0	0	0	0.001	88
48	0.211	0.595	1.612	0.011	0.0030	0.020	0.0070	0	0	0	0	0	97
49	0.172	0.656	0.846	0.010	0.0030	0.029	0.0094	0	0	0	0	0	91
50	0.173	1.030	0.360	0.006	0.0065	0.036	0.0016	0	0	0	0	0	91
51	0.173	1.030	0.360	0.006	0.0065	0.036	0.0016	0	0	0	0	0	91
52	0.173	1.030	0.360	0.006	0.0065	0.036	0.0016	0	0	0	0	0	91

(continued)

Multilayer steel sheet no.	Composition of constituents of steel sheet for surface layer (mass%)											Thickness of steel sheet for surface layer (mm)	Remarks	
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo			B
53	0.173	1.030	0.360	0.006 0.0065		0.036	0.0016	0	0	0	0	0	91	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.														

[Table C-2-1]

Manufacturing condition	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
	Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
1	1275	45	1144	36	3	948	609	69	39	847	70	44	-	None	1.6
2	1274	21	1166	31	3	872	510	66	39	848	98	42	-	None	1.4
3	1300	23	1145	26	3	924	665	63	41	882	79	29	-	None	1.4
4	1278	31	1162	39	3	869	741	50	68	916	94	30	-	None	1.2
5	1333	26	1129	45	3	925	635	41	61	849	100	29	-	None	1.0
6	1315	55	1161	32	3	915	581	50	68	891	75	25	-	None	1.2
7	1193	40	1180	52	3	920	678	51	55	822	87	28	-	None	1.2
8	1239	27	1137	52	3	919	606	61	48	838	80	37	-	None	1.4
9	1329	53	1169	28	3	905	550	52	23	872	63	30	-	None	1.1
10	1191	52	1145	39	3	909	686	45	32	836	76	27	-	None	1.0
11	1143	56	1135	43	3	921	747	66	50	903	96	30	-	None	1.4
12	1171	50	1150	36	3	942	546	49	62	873	74	38	-	None	1.1
13	1108	33	1102	23	3	883	619	45	35	898	101	33	-	None	1.0
14	1323	44	1149	37	3	886	633	46	41	869	69	25	-	None	1.0
15	1169	35	1150	46	3	856	500	50	24	925	88	27	-	None	1.0
16	1127	43	1112	31	3	863	500	69	36	904	104	25	-	None	1.6
17	1135	38	1128	49	3	881	590	60	64	850	113	44	-	None	1.4
18	1111	50	1103	38	3	948	541	60	49	826	100	32	-	None	1.4
19	1194	39	1159	43	3	939	606	55	15	900	71	28	-	None	1.2

(continued)

Manufacturing condition	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
	Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)	None	Sheet thickness (mm)
20	1277	23	1131	40	3	920	563	49	25	917	104	32	-	None	1.0
21	1131	31	1121	48	3	867	693	42	25	889	97	41	-	None	1.0
22	1204	32	1167	33	3	938	514	57	35	886	98	44	-	None	1.2
23	1231	22	1129	44	3	876	668	60	71	896	90	32	-	None	1.4
24	1160	23	1142	32	3	936	657	53	75	855	74	26	-	None	1.2
25	1070	20	1020	40	3	943	523	53	65	892	96	27	-	None	1.2
26	1370	43	1123	16	3	912	666	49	20	907	86	43	-	None	1.1
28	1196	22	1173	26	3	883	749	42	35	914	105	29	-	None	1
In the table, fields with notations "-" indicate corresponding treatment not performed.															

[Table C-2-2]

Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
	Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)		
29	1192	21	1145	35	3	941	659	57	35	919	89	33	322	None	1.2
30	1336	54	1136	37	3	864	649	60	55	926	92	27	395	Yes	1.4
31	1178	25	1135	50	3	861	708	44	74	852	72	38	-	None	1
32	1258	37	1137	23	3	900	630	45	65	947	80	34	-	None	1.7
33	1246	47	1128	13	3	868	576	45	62	841	85	44	-	None	1.2
34	1226	32	1121	22	3	868	576	56	41	891	67	27	-	None	1.1
35	1208	23	1123	38	3	895	588	47	62	937	88	41	-	None	1.5
36	1256	46	1160	46	3	879	616	52	53	906	100	29	-	None	1.1
37	1196	50	1152	52	3	881	621	56	33	895	81	43	-	None	1.3
38	1191	58	1152	44	3	894	563	53	33	856	104	38	-	None	1.1
39	1245	34	1121	22	3	893	618	52	69	848	72	37	-	None	1.6
40	1236	51	1166	22	3	937	622	45	67	873	83	30	-	None	1.6
41	1217	32	1170	29	3	945	628	45	70	913	98	30	-	None	1.7
42	1248	23	1143	35	3	864	554	46	28	861	70	35	-	None	1.7
43	1237	24	1150	35	3	918	620	57	67	842	93	42	-	None	1.2
44	1188	33	1132	51	3	924	621	55	28	925	97	35	-	None	1.7
45	1183	23	1131	21	3	909	621	48	39	835	82	36	-	None	1
46	1236	24	1126	14	3	910	590	52	56	846	102	39	-	None	1.1
47	1239	42	1125	22	3	917	595	50	67	838	72	37	-	None	1.4

(continued)

Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
	Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
48	1195	56	1124	39	3	896	642	57	67	893	88	39	-	None	1.8
49	1214	15	1182	22	3	853	583	51	66	910	99	33	-	None	1.1
50	1208	32	1013	48	3	882	697	40	71	917	107	26	-	None	1.7
51	1191	50	1161	4	2	893	634	59	28	934	71	36	-	None	1
52	1236	34	1137	46	1	906	713	50	63	903	84	32	-	None	1
53	1248	22	1103	46	3	899	667	51	60	892	96	34	-	None	1.4
In the table, fields with notations "-" indicate corresponding treatment not performed.															

[Table C-3-1]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Uniform elongation (%)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Residual γ area rate(%)	
1C	1	1	576	70	1547	5.2	87.5	Good	4.5	Inv. ex.
2C	2	2	738	50	2083	7.5	95.6	Good	2.6	Inv. ex.
3C	3	3	639	58	2156	5.6	95.6	Good	3	Inv. ex.
4C	4	4	785	68	2212	6	71.1	Good	1.7	Inv. ex.
5C	5	5	<u>402</u>	55	<u>1116</u>	6.5	91.9	Good	4	Comp. ex.
6C	6	6	554	54	1770	6.2	88.5	Good	3.8	Inv. ex.
7C	7	7	567	65	1644	7.2	85.5	Good	2.9	Inv. ex.
8C	8	8	592	79	1963	6.6	82.2	Good	4.4	Inv. ex.
9C	9	9	<u>823</u>	64	2442	5.6	<u>39.4</u>	Good	1	Comp. ex.
10C	10	10	694	71	1805	7.5	80.4	Good	2.5	Inv. ex.
11C	11	11	664	55	2145	<u>4.2</u>	97.7	Good	<u>0.8</u>	Comp. ex.
12C	12	12	727	82	2062	6.3	88.2	Good	3.1	Inv. ex.
13C	13	13	622	84	1901	5.7	89.8	Good	2	Inv. ex.
14C	14	14	667	85	1969	7.4	84.7	Good	4.8	Inv. ex.
15C	15	15	542	54	1545	5.2	81	Good	2	Inv. ex.
16C	16	16	590	80	1536	7.5	83.9	Good	2.6	Inv. ex.
17C	17	17	513	80	1549	6.8	92.8	Good	2.6	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Uniform elongation (%)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Residual γ area rate(%)	
18C	18	18	759	59	2024	6.1	88	Good	2.3	Inv. ex.
19C	19	19	603	77	2006	6.4	87	Good	2.9	Inv. ex.
20C	20	20	578	81	1895	6.3	92.3	Good	4.6	Inv. ex.
21C	21	21	713	79	2035	5.8	87.6	Good	4.9	Inv. ex.
22C	22	22	683	74	2690	7.2	75.6	Good	3.6	Inv. ex.
23C	23	23	726	69	2475	6.4	78.1	Good	4.3	Inv. ex.
24C	24	24	771	55	2450	5.5	73.2	Good	1.9	Inv. ex.
25C	25	25	700	15	1964	7.5	54.3	Poor	1	Comp. ex.
26C	26	26	728	92	1832	7.1	54.2	Good	3	Comp. ex.
28C	28	28	639	78	2044	6.9	68.6	Good	3.4	Inv. ex.

[Table C-3-2]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Uniform elongation (%)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Residual γ area rate(%)	
29C	29	29	792	51	2102	5.8	89.1	Good	4.7	Inv. ex.
30C	30	30	698	70	2317	5.1	81.8	Good	3.5	Inv. ex.
31C	31	31	695	56	2139	6.6	82	Good	3	Inv. ex.
32C	32	32	633	72	2018	5.5	74	Good	3.7	Inv. ex.
33C	33	33	671	62	2261	6.9	90	Good	2.6	Inv. ex.
34C	34	34	612	64	2240	6.2	73	Good	3.3	Inv. ex.
35C	35	35	682	71	2055	7.5	82	Good	4.3	Inv. ex.
36C	36	36	622	61	2118	5.8	86	Good	2.5	Inv. ex.
37C	37	37	659	50	2003	5.7	75	Good	2.4	Inv. ex.
38C	38	38	647	72	2253	6.5	87	Good	2.9	Inv. ex.
39C	39	39	614	73	2072	7.4	75	Good	3.4	Inv. ex.
40C	40	40	649	56	2115	5.8	83	Good	2.6	Inv. ex.
41C	41	41	606	62	2167	6.6	90	Good	2.9	Inv. ex.
42C	42	42	639	61	2032	6.4	83	Good	4.5	Inv. ex.
43C	43	43	670	53	2140	8	75	Good	4.1	Inv. ex.
44C	44	44	669	67	2055	7	88	Good	2.9	Inv. ex.
45C	45	45	692	53	2246	6.5	78	Good	4.4	Inv. ex.
46C	46	46	673	62	2222	6.5	90	Good	2.1	Inv. ex.
47C	47	47	659	56	2156	6.5	90	Good	2.7	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Tensile strength (MPa)	Uniform elongation (%)	Maximum bending angle (°)	Hydrogen embrittlement resistance	Residual γ area rate(%)	
48C	48	48	625	52	2177	7.8	85	Good	2.3	Inv. ex.
49C	49	49	656	13	2222	6.5	62	Poor	2.8	Comp. ex.
50C	50	50	630	9	2079	6.7	59.1	Poor	3.1	Comp. ex.
51C	51	51	644	10	2125	6.2	59.8	Poor	3.1	Comp. ex.
52C	52	52	635	13	2096	6.3	60.4	Poor	3.2	Comp. ex.
53C	53	53	638	47	2105	6.3	112.5	Good	3.1	Inv. ex.

[Manufacturing Example D]

[0127] Steel sheets for sheet thickness middle part having the Nos. 1 to 37 chemical compositions shown in Table D-1-1 to Table D-1-2 (in the tables, "Steel Nos. 1 to 37") were ground down at their surfaces to remove the surface oxides. After that, the respective steel sheets for sheet thickness middle part were welded with steel sheets for surface layer having the chemical compositions shown in Table D-1-3 to Table D-1-4 at both surfaces or single surfaces by arc welding to fabricate the Nos. 1 to 60 multilayer steel sheets for hot stamped body. The sheet thickness of the total of the steel sheet for surface layer and the steel sheet for sheet thickness middle part after arc welding was 200 mm to 300 mm and the thickness of the steel sheet for surface layer was 1/3 or so of the thickness of the steel sheet for sheet thickness middle part (in case of single side, 1/4 or so). The No. 37 multilayer steel sheet is steel with the steel sheet for surface layer welded to only one surface. The multilayer steel sheets other than No. 37 have steel sheets for surface layer welded to both surfaces of the steel sheet for sheet thickness middle part. In the Nos. 1 to 60 multilayer steel sheets of Table D-1-1 to Table D-1-4, cases where the steel sheet for sheet thickness middle part does not satisfy the requirement of the composition of the middle part in sheet thickness of the hot stamped body according to the present invention are indicated as "comparative steels" in the remarks column.

[0128] The Nos. 1 to 60 multilayer steel sheets were treated under the conditions of the Nos. 1 to 60 manufacturing conditions shown in Table D-2-1 to Table D-2-3 by heat treatment before hot rolling, rough rolling, hot rolling, and cold rolling to obtain steel sheets. Next, the steel sheets were heat treated as shown in Table D-2-1 to Table D-2-3 (in the tables, "heat treatment of hot stamped bodies") for hot stamping to produce the Nos. 1D to 60D hot stamped bodies ("stamped bodies" of Tables D-3-1 to D-3-3). Further, the Nos. 38D and 39D hot stamped bodies were coated on a hot dip coating line at the surfaces with 120 to 160 g/m² amounts of aluminum. Further, the items of Table D-2-1 to Table D-2-3 correspond to the items of Table A-2-1 to Table A-2-2. Further, in the tables, the fields with the notations "-" indicate no corresponding treatment performed.

[0129] Tables D-3-1 to D-3-3 show the metal structures and characteristics of the Nos. 1D to 60D hot stamped bodies. The constituents obtained by analyzing the positions of 1/2 of the sheet thicknesses of the samples taken from hot stamped bodies (middle parts in sheet thickness) and positions of 20 μ m from the surfaces of the softened layers were equivalent to the constituents of the steel sheets for sheet thickness middle part and the steel sheets for surface layer of the Nos. 1 to 60 multilayer steel sheets of Table D-1-1 to Table D-1-3.

[0130] The metal structures of the hot stamped steel sheets were measured by the above-mentioned method. The hardness of the steel sheet for sheet thickness middle part forming the middle part in sheet thickness and the area rate of the total of the crystal grains with a maximum crystal orientation difference inside the regions surrounded by grain boundaries of 15° or more of 1° or less and the crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer forming the softened layer to 1/2 of the thickness of that softened layer were calculated. The calculated values of the area rate are shown in the items "area rate (%) of total of crystal grains with maximum crystal orientation difference inside large angle grain boundaries of 1° or less and crystal grains with maximum crystal orientation difference of 8° to 15°" of Tables D-3-1 to D-3-3.

[0131] The Nos. 1D to 60D hot stamped bodies were subjected to tensile tests. The results are shown in Tables D-3-1 to D-3-3. The tensile tests were performed by fabricating No. 5 test pieces described in JIS Z 2201 and testing them by the method described in JIS Z 2241.

[0132] The hot stamped bodies were evaluated for hydrogen embrittlement resistance in the same way as Manufacturing Example A using test pieces cut out from the stamped bodies. That is, test pieces of a sheet thickness of 1.2 mm×width 6 mm×length 68 mm were cut out from the stamped bodies, given strain corresponding to the yield stress in four-point bending tests, then immersed in pH3 hydrochloric acid for 100 hours and evaluated for hydrogen embrittlement resistance by the presence of any cracks. Cases of no fracture were evaluated as passing ("good") and cases of fracture were evaluated as failing ("Poor").

[0133] For the purpose of evaluating the impact resistance of the hot stamped body, the body was evaluated based on the VDA standard (VDA238-100) prescribed by the German Association of the Automotive Industry under the same measurement conditions as Manufacturing Example A. In the present invention, the displacement at the time of maximum load obtained in the bending test was converted to angle by the VDA standard to find maximum bending angle and thereby evaluate the impact resistance of the hot stamped body.

[0134] The hot stamped bodies were also evaluated for impact resistance from the viewpoint of ductility. Specifically, the hot stamped steel sheets were subjected to tensile tests to find the uniform elongations of the steel sheet to evaluate the impact resistance. The tensile tests were performed by fabricating No. 5 test pieces described in JIS Z 2201 and testing them by the method described in JIS Z 2241. The elongations where the maximum tensile loads were obtained were defined as the uniform elongations.

[0135] Deformation concentrates at a local softened part at the time of collision and becomes a cause of cracking, so a small scattering in hardness at the stamped body, that is, securing stable strength, is important in securing impact resistance. Therefore, the impact resistance of a hot stamped body was also evaluated from the viewpoint of the scattering

in hardness. A cross-section vertical to the longitudinal direction of a long hot stamped body was taken at any position in that longitudinal direction and measured for hardness at the middle position in sheet thickness at the entire cross-sectional region including the vertical walls. For the measurement, use was made of a Vickers hardness tester. The measurement load was 1 kgf, 10 points were measured, and the measurement interval was 1 mm. The difference between the average cross-sectional hardness and the minimum hardness is shown in Table D-3-1 to Table D-3-3. Cases with no measurement points of below 100Hv from the average value of all measurement points were evaluated as being small in scattering in hardness, that is, excellent in stability of strength and, as a result, were evaluated as excellent in impact resistance and therefore passing, while cases with measurement points below 100Hv were evaluated as failing.

[0136] Cases where the tensile strength was 1500 MPa or more, the uniform elongation was 5% or more, the scattering in hardness was a passing level, the maximum bending angle (°) was 70.0 (°) or more, and the hydrogen embrittlement resistance was passing were evaluated as hot stamped bodies excellent in impact resistance and hydrogen embrittlement resistance ("invention examples" in Table D-3-1 to Table D-3-3). On the other hand, cases where even one of the above five aspects of performance was not satisfied are indicated as "comparative examples".

[0137] In each of the hot stamped bodies of the invention examples, the area rate of the total of crystal grains with a maximum crystal orientation difference inside regions surrounded by grain boundaries of 15° or higher of 1° or less and crystal grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness was 50% to less than 85%. Further, in each of the hot stamped bodies of the invention examples, the tensile strength, bendability, and hydrogen embrittlement resistance were excellent.

[0138] As opposed to this, the No. 5D hot stamped body was low in carbon content of the steel sheet for sheet thickness middle part, so became insufficient in hardness of the middle part in sheet thickness and became insufficient in tensile strength. The No. 9D hot stamped body was excessive in carbon content of the steel sheet for sheet thickness middle part, so became excessive in hardness of the middle part in sheet thickness as well and could not be given the targeted bendability. Further, the Nos. 10D and 11D hot stamped bodies were sparse in Si content of the steel sheet for sheet thickness middle part, so were insufficient in uniform elongation. Further, the No. 12D hot stamped body was insufficient in Mn content, so became insufficient in hardness of the middle part in sheet thickness and were insufficient in tensile strength. The No. 14D and the No. 15D hot stamped bodies were sparse in Si content and Mn content, so had an area percent of residual austenite of less than 1.0% and an insufficient uniform elongation. Further, the No. 12D to No. 15D hot stamped bodies were large in scattering in hardness and deemed failing.

[0139] The Nos. 33D to 35D hot stamped bodies are comparative examples produced using multilayer steel sheets for hot stamped body which were not subjected to the desirable heat treatment before the hot stamping process. The No. 33D hot stamped body was low in heat treatment temperature before the hot stamping process, so became insufficient in growth of soft structures and metal structures of intermediate hardnesses in the metal structures of the softened layer from the surface of the softened layer to 1/2 of the thickness and was not able to be given the targeted bendability. The No. 34D hot stamped body was excessively high in heat treatment temperature before the hot stamping process, so the fraction of structures from a position of 20 μm from the surface of the softened layer to a position of a depth of 1/2 of the thickness of the softened layer exceeded 85%. For this reason, in the No. 34D hot stamped body, the difference in hardness between the softened layer and the middle part in sheet thickness became too large, and the effect of reduction of the sharp gradient in hardness in the sheet thickness direction occurring at the time of bending deformation could not be obtained. Further, the No. 35D hot stamped body was short in heat treatment time before the hot stamping process, so in the metal structures from the surface of the softened layer to 1/2 of the thickness, the soft structures and metal structures with intermediate hardnesses insufficiently grew and the target bendability could not be obtained.

[0140] The No. 40D hot stamped body was excessive in Si content, so residual austenite was excessively produced exceeding an area percent of 5%. For this reason, the No. 40D hot stamped body was inferior in bendability. The No. 41D hot stamped body was excessive in Mn content, so became the greatest in tensile strength among the Nos. 1D to 56D hot stamped bodies and was inferior in bendability. The No. 42D hot stamped body was poor in content of acid soluble aluminum, so inclusions containing oxygen were excessively produced and bendability was inferior. Further, the No. 45D hot stamped body included excessive aluminum, so oxides mainly comprised of aluminum were excessively produced and bendability was inferior.

[0141] The No. 57D hot stamped body was low in rolling temperature of the rough rolling. Further, the No. 58D hot stamped body was low in sheet thickness reduction rate of the rough rolling. Further, the No. 59D hot stamped body was low in number of rolling operations under conditions of a time between passes of 3 seconds or more. These hot stamped bodies were not produced under optimal rough rolling conditions, so were insufficient in growth of soft structures and metal structures of intermediate hardnesses, were not able to be eased in strain caused by bending deformation, and were not able to be given the targeted bendability.

[0142] The No. 60D hot stamped body is steel sheet with a casting rate controlled to 6 ton/min or more in a continuous casting process of steel sheet for surface layer. It can raise the area rate of the total of crystal grains with a maximum crystal orientation difference inside regions surrounded by grain boundaries of 15° or higher of 1° or less and crystal

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grains with a crystal orientation difference of 8° to 15° in the metal structures from the surface of the steel sheet for surface layer to 1/2 of the thickness and is excellent in bendability.

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[Table D-1-1]

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	1	0.26	1.32	1.82	0.013	0.0028	0.049	0.0036	0	0	0	0	0	
2	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
3	3	0.35	1.54	1.68	0.013	0.0011	0.043	0.0036	0	0	0	0	0	
4	4	0.48	1.5	2.08	0.005	0.0002	0.035	0.0026	0	0	0	0	0	
5	5	0.08	1.25	1.77	0.016	0.0010	0.029	0.0036	0	0	0	0	0	Comp. steel
6	6	0.23	1.45	1.98	0.016	0.0014	0.035	0.0037	0	0	0	0	0	
7	7	0.36	1.81	1.89	0.010	0.0018	0.044	0.0032	0	0	0	0	0	
8	8	0.28	1.75	1.90	0.011	0.0017	0.054	0.0029	0	0	0	0	0	
9	9	0.83	1.65	1.84	0.017	0.0008	0.034	0.0027	0	0	0	0	0	Comp. steel
10	10	0.38	0.13	1.87	0.009	0.0022	0.058	0.003	0	0	0	0	0	Comp. steel
11	11	0.32	0.41	1.90	0.020	0.0016	0.048	0.0038	0	0	0	0	0	Comp. steel
12	12	0.25	1.21	0.19	0.012	0.0009	0.046	0.0023	0	0	0	0	0	Comp. steel
13	13	0.31	1.27	0.90	0.006	0.0021	0.052	0.0028	0	0	0	0	0	Comp. steel
14	14	0.34	0.48	1.34	0.018	0.0016	0.051	0.0041	0	0	0	0	0	Comp. steel
15	15	0.27	0.27	1.18	0.016	0.0008	0.053	0.0031	0	0	0	0	0	Comp. steel
16	16	0.30	1.59	1.75	0.004	0.0012	0.052	0.0030	0.33	0	0	0	0	
17	17	0.36	1.00	1.78	0.022	0.0007	0.045	0.0032	0	0.078	0	0	0	
18	18	0.27	1.63	1.97	0.016	0.0012	0.051	0.0029	0	0	0.032	0	0	
19	19	0.29	1.27	2.01	0.013	0.0013	0.057	0.0030	0	0	0	0.040	0	
20	20	0.30	1.45	1.72	0.014	0.0016	0.043	0.0032	0	0	0	0	0.0020	
21	1	0.26	1.32	1.82	0.013	0.0028	0.049	0.0036	0	0	0	0	0	
22	1	0.26	1.32	1.82	0.013	0.0028	0.049	0.0036	0	0	0	0	0	
23	1	0.26	1.32	1.82	0.013	0.0028	0.049	0.0036	0	0	0	0	0	
24	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
25	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
26	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
27	3	0.35	1.54	1.68	0.013	0.0011	0.043	0.0036	0	0	0	0	0	
28	3	0.35	1.54	1.68	0.013	0.0011	0.043	0.0036	0	0	0	0	0	
29	3	0.35	1.54	1.68	0.013	0.0011	0.043	0.0036	0	0	0	0	0	
30	4	0.48	1.5	2.08	0.005	0.0002	0.035	0.0026	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.														

[Table D-1-2]

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet thickness middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
31	4	0.48	1.50	2.08	0.005	0.0002	0.035	0.0026	0	0	0	0	0	
32	4	0.48	1.50	2.08	0.005	0.0002	0.035	0.0026	0	0	0	0	0	
33	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
34	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
35	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
36	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
37	21	0.65	1.29	1.84	0.008	0.0005	0.058	0.003	0	0	0	0	0	
38	21	0.65	1.29	1.84	0.008	0.0005	0.058	0.003	0	0	0	0	0	
39	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
40	22	0.38	5.30	1.87	0.009	0.0022	0.058	0.003	0	0	0	0	0	Comp. steel
41	23	0.25	1.21	4.90	0.012	0.0009	0.046	0.0023	0	0	0	0	0	Comp. steel
42	24	0.26	1.32	1.82	0.013	0.0028	0.0001	0.0036	0	0	0	0	0	Comp. steel
43	25	0.26	1.32	1.82	0.013	0.0028	0.001	0.0036	0	0	0	0	0	
44	26	0.26	1.32	1.82	0.013	0.0028	2.600	0.0036	0	0	0	0	0	
45	27	0.26	1.32	1.82	0.013	0.0028	4.200	0.0036	0	0	0	0	0	Comp. steel
46	28	0.30	1.59	1.75	0.004	0.0012	0.052	0.0030	0.03	0	0	0	0	
47	29	0.30	1.59	1.75	0.004	0.0012	0.052	0.0030	2.70	0	0	0	0	
48	30	0.36	1.00	1.78	0.022	0.0007	0.045	0.0032	0	0.020	0	0	0	
49	31	0.36	1.00	1.78	0.022	0.0007	0.045	0.0032	0	0.130	0	0	0	
50	32	0.27	1.63	1.97	0.016	0.0012	0.051	0.0029	0	0	0.040	0	0	
51	33	0.27	1.63	1.97	0.016	0.0012	0.051	0.0029	0	0	0.120	0	0	
52	34	0.29	1.27	2.01	0.013	0.0013	0.057	0.003	0	0	0	0.009	0	
53	35	0.29	1.27	2.01	0.013	0.0013	0.057	0.003	0	0	0	0.900	0	
54	36	0.30	1.45	1.72	0.014	0.0016	0.043	0.0032	0	0	0	0	0.0009	

(continued)

Multilayer steel sheet no.	Chemical constituents of steel sheet for sheet thickness middle part (mass%)													Remarks
	Steel no.	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
55	37	0.30	1.45	1.72	0.014	0.0016	0.043	0.0032	0	0	0	0	0.0070	
56	4	0.48	1.50	2.08	0.005	0.0002	0.035	0.0026	0	0	0	0	0	
57	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
58	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
59	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
60	2	0.27	1.29	1.84	0.012	0.0011	0.045	0.0035	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.														

[Table D-1-3]

Multilayer steel sheet no.	Chemical constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
1	0.15	0.66	0.91	0.011	0.0026	0.045	0.0031	0	0	0	0	0	
2	0.12	0.72	0.94	0.01	0.0008	0.041	0.003	0	0	0	0	0	
3	0.19	0.88	0.96	0.009	0.0008	0.038	0.0031	0	0	0	0	0	
4	0.28	0.78	1.14	0.004	0.0001	0.029	0.0021	0	0	0	0	0	
5	0.05	0.60	0.90	0.014	0.0006	0.024	0.0034	0	0	0	0	0	Comp. steel
6	0.11	0.80	1.09	0.013	0.0011	0.029	0.0035	0	0	0	0	0	
7	0.17	0.81	0.91	0.009	0.0015	0.041	0.0029	0	0	0	0	0	
8	0.15	0.86	0.86	0.007	0.0014	0.050	0.0027	0	0	0	0	0	
9	0.39	0.79	0.92	0.015	0.0005	0.029	0.0024	0	0	0	0	0	Comp. steel
10	0.21	0.06	0.94	0.004	0.0021	0.053	0.0027	0	0	0	0	0	Comp. steel
11	0.16	0.24	0.93	0.019	0.0015	0.042	0.0035	0	0	0	0	0	Comp. steel
12	0.14	0.64	0.11	0.009	0.0005	0.041	0.0021	0	0	0	0	0	Comp. steel
13	0.17	0.64	0.41	0.002	0.0017	0.046	0.0024	0	0	0	0	0	Comp. steel
14	0.16	0.24	0.72	0.014	0.0015	0.046	0.0036	0	0	0	0	0	Comp. steel
15	0.14	0.15	0.58	0.013	0.0006	0.047	0.0029	0	0	0	0	0	Comp. steel
16	0.15	0.78	0.95	0.003	0.0008	0.046	0.0028	0.21	0	0	0	0	
17	0.17	0.55	0.91	0.020	0.0003	0.040	0.0027	0	0.036	0	0	0	
18	0.15	0.85	1.04	0.013	0.0009	0.046	0.0026	0	0	0.028	0	0	
19	0.15	0.74	1.13	0.008	0.0012	0.054	0.0027	0	0	0	0.030	0	
20	0.17	0.78	0.81	0.013	0.0012	0.039	0.0027	0	0	0	0	0.0020	
21	0.21	0.59	0.87	0.009	0.0027	0.044	0.0031	0	0	0	0	0	
22	0.12	0.91	0.82	0.009	0.0027	0.043	0.0032	0	0	0	0	0	
23	0.14	0.73	1.55	0.010	0.0025	0.044	0.0032	0	0	0	0	0	
24	0.21	0.59	1.03	0.009	0.0009	0.041	0.0033	0	0	0	0	0	

(continued)

Multilayer steel sheet no.	Chemical constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
25	0.14	0.95	0.83	0.009	0.0007	0.039	0.0031	0	0	0	0	0	
26	0.15	0.66	1.69	0.011	0.0008	0.041	0.0032	0	0	0	0	0	
27	0.28	0.75	0.81	0.010	0.001	0.039	0.0032	0	0	0	0	0	
28	0.20	1.40	0.96	0.008	0.0009	0.037	0.0032	0	0	0	0	0	
29	0.17	0.89	1.46	0.009	0.0009	0.037	0.0031	0	0	0	0	0	
30	0.41	0.75	1.1	0.002	0.0009	0.032	0.0021	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.													

[Table D-1-4]

Multilayer steel sheet no.	Chemical constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
31	0.24	1.26	1.02	0.003	0.0009	0.029	0.0021	0	0	0	0	0	
32	0.27	0.84	1.68	0.003	0.0009	0.030	0.0024	0	0	0	0	0	
33	0.13	0.62	1.01	0.010	0.0009	0.039	0.0032	0	0	0	0	0	
34	0.16	0.62	0.83	0.007	0.0010	0.041	0.0031	0	0	0	0		
35	0.12	0.63	0.96	0.007	0.0010	0.040	0.0033	0	0	0	0	0	
36	0.15	0.66	0.85	0.011	0.0009	0.040	0.0031	0	0	0	0	0	
37	0.3	0.59	1.03	0.006	0.0003	0.053	0.0027	0	0	0	0	0	
38	0.32	0.74	0.98	0.007	0.0003	0.054	0.0028	0	0	0	0	0	
39	0.14	0.58	0.86	0.008	0.0008	0.042	0.0033	0	0	0	0	0	
40	0.21	0.06	0.94	0.007	0.002	0.054	0.0026	0	0	0	0	0	Comp. steel
41	0.14	0.64	0.11	0.011	0.0006	0.043	0.0018	0	0	0	0	0	Comp. steel
42	0.15	0.66	0.91	0.01	0.0026	0.042	0.0032	0	0	0	0	0	Comp. steel
43	0.15	0.66	0.91	0.01	0.0026	0.043	0.0032	0	0	0	0	0	
44	0.15	0.66	0.91	0.011	0.0026	2.595	0.0032	0	0	0	0	0	
45	0.15	0.66	0.91	0.009	0.0026	2.819	0.0031	0	0	0	0	0	Comp. steel
46	0.15	0.78	0.95	0.002	0.001	0.047	0.0027	0.04	0	0	0	0	
47	0.15	0.78	0.95	0.002	0.0008	0.049	0.0025	2.60	0	0	0	0	
48	0.17	0.55	0.91	0.021	0.0004	0.041	0.0028	0	0.030	0	0	0	
49	0.17	0.55	0.91	0.019	0.0006	0.042	0.0030	0	0.120	0	0	0	
50	0.15	0.85	1.04	0.011	0.0010	0.046	0.0027	0	0	0.060	0	0	
51	0.15	0.85	1.04	0.012	0.0009	0.046	0.0025	0	0	0.110	0	0	
52	0.15	0.74	1.13	0.009	0.0011	0.052	0.0025	0	0	0	0.010	0	
53	0.15	0.74	1.13	0.008	0.0011	0.054	0.0027	0	0	0	0.800	0	
54	0.17	0.78	0.81	0.009	0.0015	0.037	0.0027	0	0	0	0	0.001	

(continued)

Multilayer steel sheet no.	Chemical constituents of steel sheet for surface layer (mass%)												Remarks
	C	Si	Mn	P	S	sol.Al	N	Ni	Nb	Ti	Mo	B	
55	0.17	0.78	0.81	0.009	0.0014	0.037	0.0029	0	0	0	0	0.006	
56	0.2	0.98	1.44	0.003	0.0009	0.030	0.0024	0	0	0	0	0	
57	0.12	0.72	0.94	0.01	0.0008	0.041	0.003	0	0	0	0	0	
58	0.12	0.72	0.94	0.01	0.0008	0.041	0.003	0	0	0	0	0	
59	0.12	0.72	0.94	0.01	0.0008	0.041	0.003	0	0	0	0	0	
60	0.12	0.72	0.94	0.01	0.0008	0.041	0.003	0	0	0	0	0	
In the table, fields with compositions of constituents of 0 indicate corresponding constituents not intentionally added.													

[Table D-2-1]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
1	1	1220	47	1147	33	3	854	556	45	39	895	69	41	None	None	1.5
2	2	1205	43	1156	26	3	855	674	54	35	899	94	42	None	None	1.3
3	3	1218	43	1141	24	3	840	602	48	37	910	78	28	None	None	1.5
4	4	1254	38	1164	35	3	834	601	50	69	898	99	33	None	None	1.4
5	5	1268	23	1123	44	3	831	675	53	61	886	97	27	None	None	1.3
6	6	1260	23	1153	31	3	856	614	42	70	904	76	21	None	None	1.6
7	7	1264	46	1170	47	3	862	553	54	57	891	88	32	None	None	1.3
8	8	1224	32	1141	52	3	870	680	49	52	908	83	37	None	None	1.4
9	9	1153	38	1123	23	3	843	600	46	28	893	68	31	None	None	1.5
10	10	1263	23	1140	36	3	845	564	50	37	891	72	22	None	None	1.4
11	11	1239	38	1132	42	3	865	627	54	55	910	101	30	None	None	1.3
12	12	1249	45	1180	31	3	831	582	48	58	883	69	41	None	None	1.5
13	13	1177	57	1155	18	3	840	684	54	30	910	100	38	None	None	1.3
14	14	1223	36	1150	36	3	856	578	43	39	898	65	22	None	None	1.6
15	15	1240	34	1149	45	3	853	714	49	20	884	90	31	None	None	1.4
16	16	1229	25	1154	27	3	849	637	52	36	897	101	22	None	None	1.3
17	17	1151	39	1127	46	3	868	582	54	64	883	111	41	None	None	1.3
18	18	1192	28	1162	36	3	857	643	49	52	884	95	35	None	None	1.4
19	19	1316	32	1159	43	3	832	677	47	14	892	66	26	None	None	1.5
20	20	1264	44	1140	39	3	859	628	45	29	904	107	37	None	None	1.5

[Table D-2-2]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
21	21	1217	23	1170	46	3	858	601	47	21	890	99	38	None	None	1.5
22	22	1165	40	1158	31	3	840	621	48	36	895	95	40	None	None	1.5
23	23	1259	39	1127	44	3	854	552	51	66	881	85	33	None	None	1.4
24	24	1176	32	1171	28	3	849	643	42	78	909	77	25	None	None	1.6
25	25	1153	29	1137	40	3	834	597	51	62	883	92	30	None	None	1.4
26	26	1193	39	1128	11	3	856	608	45	20	898	83	47	None	None	1.5
27	27	1250	54	1181	23	3	861	651	42	72	909	95	41	None	None	1.6
28	28	1304	32	1169	23	3	842	707	43	40	910	108	26	None	None	1.6
29	29	1226	27	1153	31	3	864	633	43	33	894	89	29	None	None	1.6
30	30	1188	38	1141	33	3	861	566	49	50	897	91	28	None	None	1.4
31	31	1267	36	1144	47	3	853	597	44	77	893	69	40	None	None	1.6
32	32	1262	36	1128	20	3	859	687	51	64	885	83	37	None	None	1.4
33	33	1084	37	1052	12	3	836	647	43	59	892	87	43	None	None	1.6
34	34	1372	50	1118	17	3	861	623	52	40	899	63	31	None	None	1.3
35	35	1204	14	1127	34	3	850	555	49	57	910	84	43	None	None	1.4
36	36	1274	29	1153	44	3	865	713	0	53	892	105	26	None	None	2.8
37	37	1294	51	1145	52	3	868	671	54	35	897	78	43	258	None	1.3
38	38	1211	43	1160	43	3	855	562	48	34	890	99	33	271	Yes	1.5
39	39	1305	51	1111	17	3	840	679	46	72	901	71	37	None	Yes	1.5

(continued)

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)	None	1.4
40	40	1229	47	1159	21	3	847	555	50	62	892	85	26	None	None	1.4

[Table D-2-3]

Multilayer steel sheet no.	Manufacturing condition no.	Heat treatment before hot rolling		Rough rolling			Hot rolling		Cold rolling	Heat treatment at hot stamping					Plating	Sheet thickness (mm)
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of reduction of sheet thickness (%)	No. of rolling operations (times)	Finish rolling temp. (°C)	Coiling temp. (°C)		Heating rate (°C/s)	Heating temp. (°C)	Average cooling rate (°C/s) (more than 400°C)	Average cooling rate (°C/s) (400°C or less)	Tempering temp. (°C)		
41	41	1270	30	1161	29	3	848	596	48	70	897	100	29	None	None	1.5
42	42	1233	56	1145	33	3	839	608	45	32	879	66	34	None	None	1.5
43	43	1247	40	1158	35	3	850	576	45	69	888	88	40	None	None	1.5
44	44	1237	36	1141	47	3	841	583	45	31	885	98	40	None	None	1.5
45	45	1246	54	1134	17	3	851	591	45	36	894	80	38	None	None	1.5
46	46	1257	51	1136	9	3	838	636	52	59	887	105	36	None	None	1.3
47	47	1239	33	1126	21	3	847	565	52	72	875	70	35	None	None	1.3
48	48	1265	57	1130	37	3	852	565	54	65	876	83	42	None	None	1.3
49	49	1235	56	1183	19	3	849	638	54	66	877	98	34	None	None	1.3
50	50	1276	45	1155	31	3	842	624	49	72	883	107	27	None	None	1.4
51	51	1232	38	1138	50	3	846	565	49	25	889	69	37	None	None	1.4
52	52	1257	26	1128	18	3	848	564	47	66	890	89	36	None	None	1.5
53	53	1220	31	1132	12	3	845	628	47	64	893	94	31	None	None	1.5
54	54	1215	38	1130	17	3	842	555	45	29	877	81	31	None	None	1.5
55	55	1264	33	1132	39	3	843	644	45	68	890	93	29	None	None	1.5
56	56	1261	37	1192	18	3	856	681	51	59	855	91	35	None	None	1.4
57	57	1246	40	1019	47	3	841	596	48	69	885	106	28	None	None	1.5
58	58	1265	54	1163	1	2	852	591	45	32	875	75	39	None	None	1.5
59	59	1232	56	1143	41	1	842	565	54	61	877	88	36	None	None	1.3

Multilayer steel sheet no.	Manufactur- ing condition no.	Heat treatment before hot rolling		Rough rolling		Hot rolling		Cold rolling	Heat treatment at hot stamping				Plating	Sheet thickness (mm)	
		Heating temp. (°C)	Holding time (min)	Rolling temp. (°C)	Rate of re- duction of sheet thickness (%)	No. of roll- ing opera- tions (times)	Finish rolling temp. (°C)		Coiling temp. (°C)	Rolling rate (%)	Heating rate (°C/s)	Heating temp. (°C)			Average cooling rate (°C/s) (more than 400°C)
60	60	1215	21	1102	43	3	848	638	49	57	893	96	32	None	1.5

[Table D-3-1]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks	
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundanes of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Tensile strength (MPa)	Uniform elongation (%)	Average cross- sectional hardness- minimum hardness	Maximum bending angle (°)		Hydrogen embrittlement resistance
1D	1	1	600	82	2.5	1740	5.2	43	84.8	Good	Inv. ex.
2D	2	2	671	78	2.2	1945	5.1	26	75.6	Good	Inv. ex.
3D	3	3	768	71	3.3	2227	6.3	44	73.4	Good	Inv. ex.
4D	4	4	793	63	4.7	2300	6.8	68	74.9	Good	Inv. ex.
5D	5	5	420	84	3.2	1218	6.1	53	88.9	Good	Comp. ex.
6D	6	6	570	66	4.4	1653	6.8	44	86.6	Good	Inv. ex.
7D	7	7	720	83	4	2088	6.4	60	76.2	Good	Inv. ex.
8D	8	8	699	78	2.3	2026	5.8	61	76.2	Good	Inv. ex.
9D	9	9	1014	52	2.8	2941	5.8	58	61.2	Good	Comp. ex.
10D	10	10	741	71	0.2	2148	2.6	35	80	Good	Comp. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures			Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Tensile strength (MPa)	Uniform elongation (%)	Average cross- sectional hardness- minimum hardness	Maximum bending angle (°)	Hydrogen embrittlement resistance	
11D	11	11	751	81	0.5	2478	4.3	43	83.6	Good	Comp. ex.
12D	12	12	443	84	3.5	1285	6.4	167	89.2	Good	Comp. ex.
13D	13	13	492	53	4.6	1427	6.8	155	86.8	Good	Comp. ex.
14D	14	14	632	63	0.7	1832	4.8	115	76.8	Good	Comp. ex.
15D	15	15	629	83	0.3	1824	3.7	127	74.1	Good	Comp. ex.
16D	16	16	681	78	4.3	1975	6.9	41	89.6	Good	Inv. ex.
17D	17	17	688	65	2.6	1995	5	49	88.3	Good	Inv. ex.
18D	18	18	685	63	3.2	1987	6.1	72	86.2	Good	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures			Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Tensile strength (MPa)	Uniform elongation (%)	Average cross- sectional hardness- minimum hardness	Maximum bending angle (°)	Hydrogen embrittlement resistance	
19D	19	19	678	79	3.8	1966	6.9	38	82.9	Good	Inv. ex.
20D	20	20	697	67	2.7	2021	5.4	64	84.5	Good	Inv. ex.

[Table D-3-2]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks	
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with h maximum difference of crystal orientation inside large angle grain boundaries of 1° or and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ (%) area rate	Tensile strength (MPa)	Uniform elongation (%)	Average cross- sectional hardness- minimum hardness	Maximum bending angle (°)		Hydrogen embrittlement resistance
21D	21	21	542	72	2.5	1573	5.6	57	79.5	Good	Inv. ex.
22D	22	22	546	80	4.5	1584	6.8	56	78.6	Good	Inv. ex.
23D	23	23	540	64	4.5	1567	6.9	27	87.6	Good	Inv. ex.
24D	24	24	669	68	3.1	1940	6.1	32	75.3	Good	Inv. ex.
25D	25	25	671	73	3	1945	5.9	69	80.5	Good	Inv. ex.
26D	26	26	676	82	3	1960	5.3	39	74.6	Good	Inv. ex.
27D	27	27	749	66	4.3	2171	6.6	32	82.3	Good	Inv. ex.
28D	28	28	747	80	3.6	2166	5.7	36	81.2	Good	Inv.ex.
29D	29	29	742	72	2.4	2151	5.7	56	76.7	Good	Inv. ex.
30D	30	30	781	67	3.9	2265	5.4	27	83.7	Good	Inv. ex.
31D	31	31	792	79	2.8	2297	5.5	69	75.7	Good	Inv. ex.
32D	32	32	788	77	4.1	2285	6.7	64	84.9	Good	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures			Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ (%) area rate	Tensile strength (MPa)	Uniform elongation (%)	Average cross- sectional hardness- minimum hardness	Maximum bending angle (°)	Hydrogen embrittlement resistance	
33D	33	33	668	14	4.6	1937	6.9	44	66.8	Poor	Comp. ex.
34D	34	34	667	95	4.6	1934	6.9	52	67.4	Good	Comp. ex.
35D	35	35	673	17	4.2	1951	6.8	26	61.9	Poor	Comp. ex.
36D	36	36	671	61	3.1	1945	6.1	28	82.4	Good	Inv. ex.
37D	37	37	763	69	4.4	2213	6.6	44	71.2	Good	Inv. ex.
38D	38	38	753	71	4.2	2184	5.9	26	78.5	Good	Inv. ex.
39D	39	39	669	77	2.9	1940	5.8	54	82.5	Good	Inv. ex.
40D	40	40	743	71	12.5	2148	8	67	61.8	Good	Comp. steel

[Table D-3-3]

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures		Mechanical properties					Remarks	
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Tensile strength (MPa)	Uniform elongation (%)	Average cross-secti onal hardness- minimum hardness	Maximum bending angle (°)		Hydrogen embrittlement resistance
41D	41	41	792	84	3.5	2610	6.3	26	51.2	Good	Comp. steel
42D	42	42	605	83	2.1	1997	52	42	61.4	Good	comp. Steel
43D	43	43	612	75	2.5	2020	5.4	71	84.5	Good	Inv. ex.
44D	44	44	608	76	2.2	2006	5.5	65	84.4	Good	Inv. ex.
45D	45	45	605	84	2.3	1997	5.3	40	56.1	Good	Comp. steel
46D	46	46	651	76	4.3	2148	6.8	39	88.7	Good	Inv. ex.
47D	47	47	701	79	4.4	2313	6.9	60	89.8	Good	Inv. ex.
48D	48	48	661	63	2.5	2181	5.1	57	88.1	Good	Inv. ex.
49D	49	49	703	65	2.6	2320	5.3	41	88.7	Good	Inv. ex.
50D	50	50	658	61	3	2171	5.9	34	86.7	Good	Inv. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures			Mechanical properties					Remarks
			Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Tensile strength (MPa)	Uniform elongation (%)	Average cross-secti onal hardness- minimum hardness	Maximum bending angle (°)	Hydrogen embrittlement resistance	
51D	51	51	709	64	3.3	2340	6.2	60	85.1	Good	Inv. ex.
52D	52	52	661	77	3.7	2181	6.7	65	81.6	Good	Inv. ex.
53D	53	53	682	80	3.8	2251	7	61	82.5	Good	Inv. ex.
54D	54	54	683	65	2.4	2254	5.3	25	81.8	Good	Inv. ex.
55D	55	55	705	67	2.8	2327	5.5	68	84.4	Good	Inv. ex.
56D	56	56	781	76	4	2577	6.6	61	85.3	Good	Inv. ex.
57D	57	57	642	10	2.9	2119	6.3	30	59.2	Poor	Comp. ex.
58D	58	58	634	11	3.0	2092	6.7	26	61.4	Poor	Comp. ex.
59D	59	59	637	12	3.0	2102	6.6	22	61.9	Poor	Comp. ex.

(continued)

Stamped body no.	Multilayer steel sheet no.	Manufacturing condition no.	Metal structures	Hardness of middle part in sheet thickness (Hv)	Area rate (%) of total of crystal grains with maximum difference of crystal orientation inside large angle grain boundaries of 1° or less and crystal grains with maximum difference of crystal orientation of 8° to 15°	Residual γ area rate(%)	Mechanical properties	Tensile strength (MPa)	Uniform elongation (%)	Average cross-secti onal hardness- minimum hardness	Maximum bending angle (°)	Hydrogen embrittlement resistance	Remarks
60D	60	60		636	46	3.0		2099	6.7	27	111.8	Good	Inv. ex.

INDUSTRIAL APPLICABILITY

[0143] The hot stamped body of the present invention is excellent in strength, ductility, bendability, impact resistance, and hydrogen embrittlement resistance and is small in scattering in hardness, so can be suitably used for structural members or reinforcing members for automobiles or structures requiring strength.

Claims

1. A hot stamped body comprising a middle part in sheet thickness and a softened layer arranged at both sides or one side of the middle part in sheet thickness, wherein the middle part in sheet thickness comprises, by mass%,
C: 0.20% or more and less than 0.70%,
Si: less than 3.00%,
Mn: 0.20% or more and less than 3.00%,
P: 0.10% or less,
S: 0.10% or less,
sol. Al: 0.0002% or more and 3.0000% or less,
N: 0.01% or less, and
a balance of Fe and unavoidable impurities, and has a hardness of 500Hv or more and 800Hv or less, in the metal structures from a depth of 20 μm below the surface of the softened layer to a depth of 1/2 of the thickness of the softened layer, when defining a region surrounded by grain boundaries having a 15° or higher orientation difference in a cross-section parallel to the sheet thickness direction as a "crystal grain", the area rate of the total of crystal grains with a maximum crystal orientation difference inside the crystal grains of 1° or less and crystal grains with a maximum crystal orientation difference inside the crystal grains of 8° or more and 15° or less is 50% or more and less than 85%.
2. The hot stamped body according to claim 1, wherein the Si content is 0.50% or less and the Mn content is 0.20% or more and less than 1.50%.
3. The hot stamped body according to claim 1, wherein the Si content is 0.50% or less and the Mn content is 1.50% or more and less than 3.00%.
4. The hot stamped body according to claim 1, wherein the Si content is more than 0.50% and less than 3.00%, the Mn content is 0.20% or more and less than 1.50%, and the middle part in sheet thickness comprises, by area percent, 1.0% or more and less than 5.0% of residual austenite.
5. The hot stamped body according to claim 1, wherein the Si content is more than 0.50% and less than 3.00%, the Mn content is 1.50% or more and less than 3.00%, and the middle part in sheet thickness comprises, by area percent, 1.0% or more and less than 5.0% of residual austenite.
6. The hot stamped body according to any one of claims 1 to 5, where the middle part in sheet thickness further comprises, by mass%, Ni: 0.01% or more and 3.00% or less.
7. The hot stamped body according to any one of claims 1 to 6, where the middle part in sheet thickness further comprises, by mass%, one or more of Nb: 0.010% or more and 0.150% or less, Ti: 0.010% or more and 0.150% or less, Mo: 0.005% or more and 1.000% or less, and B: 0.0005% or more and 0.0100% or less.
8. The hot stamped body according to any one of claims 1 to 7, where a plated layer is formed on the softened layer.

FIG. 1

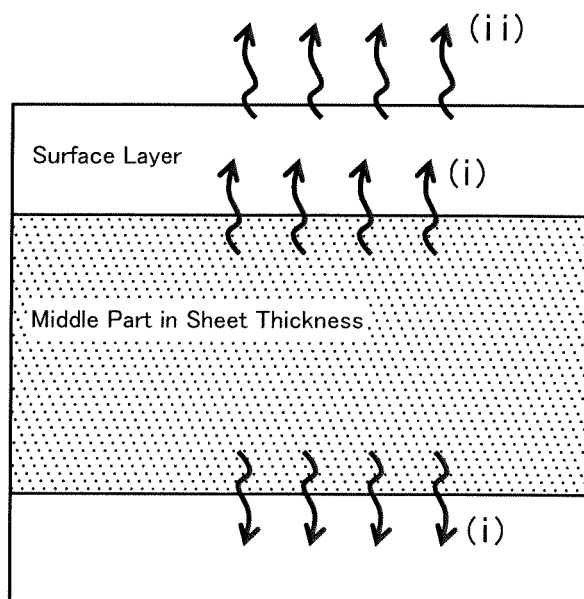
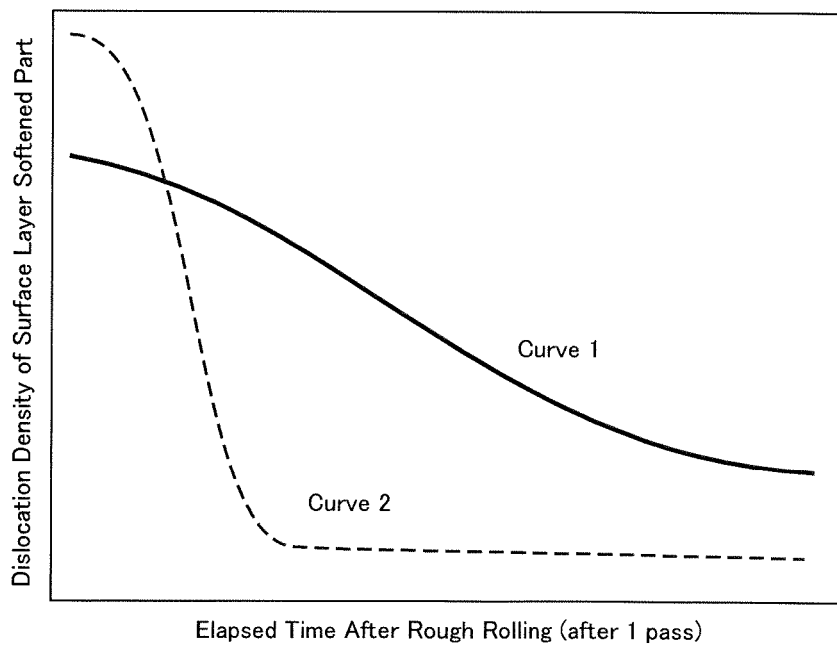


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/006086

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. C22C38/00(2006.01)i, B21D22/20(2006.01)i, C22C38/60(2006.01)i,
C21D1/18(2006.01)n, C21D9/00(2006.01)n, C21D9/46(2006.01)n

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)

Int.Cl. C22C38/00-38/60, B21D22/20, C21D1/18, C21D9/00, C21D9/46

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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 2015-30890 A (JFE STEEL CORPORATION) 16 February 2015 (Family: none)	1-8
A	WO 2015/194571 A1 (KOBE STEEL, LTD.) 23 December 2015 & JP 2016-3389 A	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&"

document member of the same patent family

Date of the actual completion of the international search

10 May 2018 (10.05.2018)

Date of mailing of the international search report

22 May 2018 (22.05.2018)

Name and mailing address of the ISA/

Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/006086

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2014/024831 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 13 February 2014 & US 2015/0225830 A1 & EP 2881484 A1 & CA 2879540 A1 & CN 104520460 A & KR 10-2015-0029731 A & MX 2015001583 A & RU 2015103482 A & TW 201410883 A	1-8
A	WO 2015/099382 A1 (POSCO) 02 July 2015 & JP 2017-508069 A & US 2016/0312331 A1 & EP 3088552 A1 & KR 10-2015-0075329 A & CN 105849298 A & MX 2016008267 A	1-8

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2015030890 A [0010]
- JP 2006104546 A [0010]
- WO 2015097882 A [0010]