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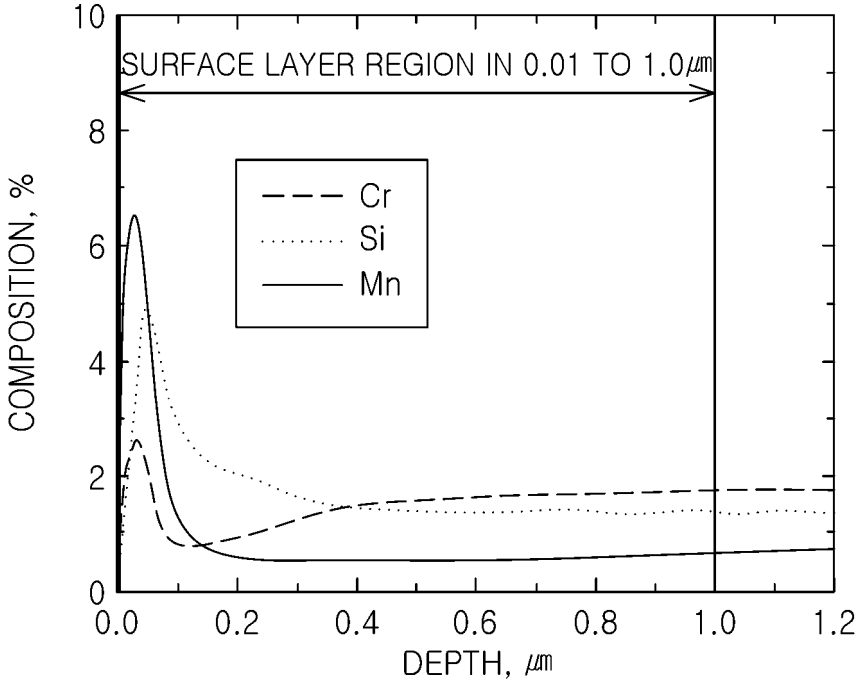
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(54) **STEEL SHEET FOR HOT FORMING, HOT FORMED MEMBER, HOT (PRESS) FORMED PART, AND MANUFACTURING METHODS THEREFOR, AND FORMING DEVICE, FORMING METHOD, BRACKET FOR BATTERY CASE, AND BATTERY PACK MODULE**

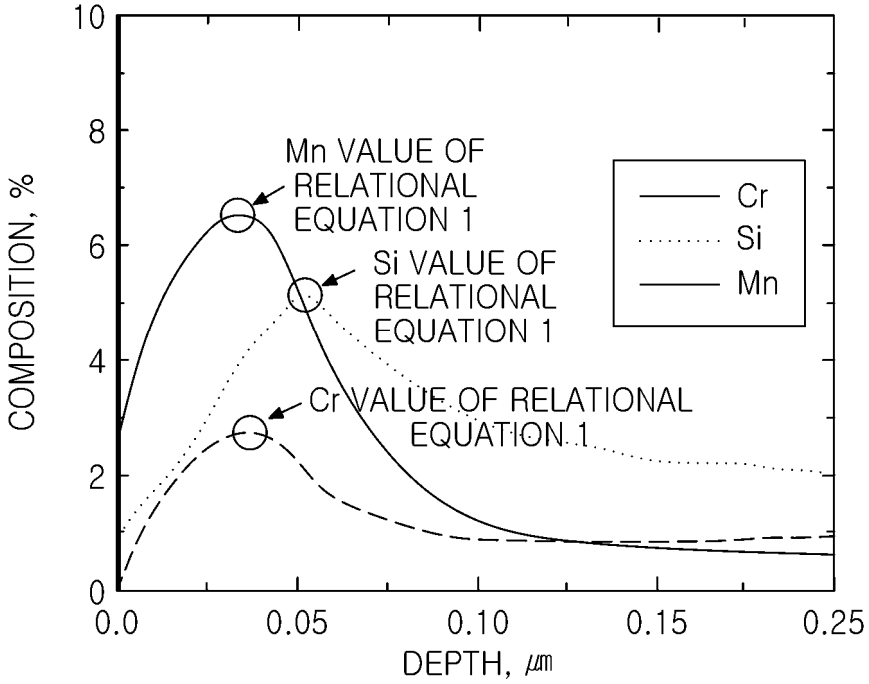
(57) An aspect of the present invention is to provide a steel sheet for hot forming. The steel sheet for hot forming may comprise, in weight%, carbon (C): 0.1-0.45%, silicon (Si): 0.8-3.0%, manganese (Mn): 0.5-4.0%, phosphorus (P): 0.001-0.05%, sulfur (S): 0.0001-0.02%, aluminum (Al): 0.001-0.1%, chromium (Cr): 1.0-5.0%, nitrogen (N): 0.001-0.02%, and the balance being Fe and inevitable impurities, and may have an R value of 2.8 or more.

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[FIG. 1]


SURFACE LAYER REGION IN 0.01 TO 1.0㎛
Cr
Si
Mn
COMPOSITION, %
DEPTH, ㎛
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0
1.2

(a)


Mn VALUE OF RELATIONAL EQUATION 1
Si VALUE OF RELATIONAL EQUATION 1
Cr VALUE OF RELATIONAL EQUATION 1
Cr
Si
Mn
COMPOSITION, %
DEPTH, ㎛
0
2
4
6
8
10
0.0
0.05
0.10
0.15
0.25

(b)

Description

Technical Field

[0001] The present disclosure relates to a steel sheet for hot forming, a hot formed member, a hot (press) formed part, and a manufacturing method therefor.

[0002] In addition, another aspect of the present disclosure relates to a forming device for forming high-strength steel, a forming method, a bracket for a battery case formed thereby, and furthermore, a battery pack module.

Background Art

[0003] Recently, the application of high-strength steel has been actively promoted in response to demands for weight reduction and improved vehicle safety standards.

[0004] In particular, efforts are being made to improve fuel efficiency through weight reductions of vehicles and to enhance crash resistance, etc., by adopting ultra-high-strength steel in a vehicle. Accordingly, a large number of members manufactured using a hot forming method as structural components (structural parts) of vehicles are currently being applied, and research thereinto continues to progress.

[0005] The hot press forming method is a processing method in which a blank is heated, the heated blank is formed to have a desired shape through press forming, and then cooled while the die is kept closed, thereby manufacturing high-strength formed components.

[0006] As such a hot press forming method, when a hot press forming method performing forming at high temperature is employed, the hot press forming method may form even parts with a small radius of curvature without cracks due to excellent elongation of over 50% at high temperatures thereof where the forming is performed, thereby making it possible to secure the shape of formed parts that may not be achieved with cold ultra-high strength.

[0007] Furthermore, hot press formed parts, manufactured using hot-working (hot stamping) the blank, may be formed at high temperatures with excellent general formability, thereby manufacturing parts with a wider variety of shapes than conventional giga-grade cold-formed materials.

[0008] As an example of technologies related to hot forming, Patent Document 1 discloses a technique in which an Al-Si-plated steel sheet is heated to 850°C or higher, subjected to hot forming using a press, and then rapidly quenched to form the structure in the member into a martensitic microstructure, thereby securing ultra-high strength.

[0009] Furthermore, Patent Document 1 discloses a technology that secures corrosion resistance and spot weldability without the need for processes such as shot blasting by diffusing Fe from a base metal into a plating layer through a heat treatment process to form an alloy layer and a diffusion layer.

[0010] However, Patent Document 1 requires the formation of an Al-Si plating layer, thereby necessitating an additional plating process, which is disadvantageous in terms of economic efficiency and productivity.

[0011] Meanwhile, for uncoated materials, a Fe-based oxide layer generated during hot forming limits the improvement of surface quality. Furthermore, for the uncoated materials, a shot blasting process is essential to remove the Fe-based oxide layer, which may increase manufacturing costs of parts.

[0012] Therefore, there is a growing need to develop technologies that may improve surface quality without performing the processes such as plating or shot blasting. Furthermore, there is a growing need to develop technologies capable of enhancing not only the strength of the hot-formed member but also its surface quality.

[0013] Meanwhile, the shape, material, and thickness of automotive structural parts are determined by their intended purpose, such as functional structural parts, high-strength structural parts, compression-mode impact parts, and bending-mode impact parts. In particular, parts that support multi-directional collision loads and are connected to a plurality of surrounding parts should have ultra-high strength of 1300 MPa or higher for thinning and weight reduction, while a wrinkle height of a flange portion joined to the surrounding parts should be equal to or less than an allowable limit of a product assembly line. For example, the center pillar part should withstand a collision transfer load to prevent the deformed structure from injuring passengers during a side collision, and may allow sufficient application of spot welding so as to have robust connectivity with surrounding parts such as internal reinforcement material/roof side rail/side outer/side sill. Additionally, when the corresponding part has a complex shape or deep forming depth, the material inflow into the flange portion should be appropriately controlled to prevent cracking during forming. The center pillar part described above as an example also has a deep forming depth of approximately 100 to 150 mm, requiring a complex arrangement of pressure pads, gap holders, etc., in a die to control the material inflow during forming.

[0014] FIG. 3 illustrates an example of changes in temperature, microstructure, and tensile strength during the conventional hot press forming. As illustrated in FIG. 3, the conventional method for imparting a tensile strength of 1300 MPa or higher to a hot press formed part includes austenizing a material, forming the austenized material at a high temperature, and then cooling the austenized material faster than a critical cooling rate through heat transfer with a die surface, which is maintained at a low temperature, thereby forming a hard martensite structure. The conventional 22MnB5

material for hot press forming is typically produced using a temperature cycle in which the 22MnB5 material austenized at 850-1000°C, hot formed at 650-850°C, and then cooled to a martensitic transformation end temperature of 150°C or lower at a critical cooling rate of 28°C/s or higher. The material should be a single-phase austenite without any soft phases within the material at a hot forming end time, and the alloy composition is designed to ensure that the entire austenite is transformed to martensite during subsequent rapid cooling.

[0015] FIG. 4 illustrates an example of the temperature, microstructure, and tensile strength of a part manufactured using the conventional hot press forming process. As illustrated in FIG. 4, when the conventional 22MnB5 material uses a blank holding force during high-temperature draw forming, a part of the material contacts the die surface, which is maintained at a low temperature of 150°C or lower, resulting in rapid local cooling. As a result, the corresponding region hardens before the surrounding area and the ductility is reduced, which may lead to tearing at the boundary with the surrounding region during forming. Therefore, in the hot draw forming process, it is difficult to use the blank holding force or draw beads that are effective in controlling material inflow and suppressing wrinkles, which complicates the die structure and limits the maximum forming depth. For this reason, describing automotive body parts as an example, the hot press forming process is mainly applied to members and channels that are shallow or have relatively simple shapes, and is selectively applied to parts where flange wrinkles are a concern/parts with deep depth/large-area parts that require material inflow control/parts with complex shapes, etc.

[0016] To apply the hot press forming process to difficult-to-form parts, many manufacturers are utilizing complex die structures utilizing a plurality of pads and shaped beads, or have developed and utilized either a divided process in which product shape is controlled through cold press forming in advance and material properties are subsequently secured by post-heat treatment, or alternative forming processes that employ materials insensitive to temperature cycles. However, forming processes utilizing the blank holding force, widely used in the cold press forming, are not yet actively utilized due to the difficulty in managing conditions to prevent cracking.

[0017] FIG. 5 illustrates an example of changes in temperature, microstructure, and tensile strength during hot press forming for 22MnB5 material and low-temperature heating materials. Recently, steel manufacturers have been developing materials that may be hot stamped with a temperature cycle different from the conventional one to overcome the limitations of the conventional 22MnB5. For example, there are "low-temperature heating" hot forming materials for alleviating heat resistance standards for the materials illustrated in FIG. 3, and "hardenability-improved" hot forming materials for alleviating critical cooling rate standards for securing material properties, etc.

[0018] FIG. 6 illustrates an example of the changes in temperature, microstructure, and tensile strength during the hot press forming for the 22MnB5 material and hardenability-improved material. As illustrated in FIG. 6, the "hardenability-improved" material has the advantage of achieving the target ultra-high strength even at a relatively slow cooling rate condition compared to 22MnB5 by changing metallurgical compositions to suppress the development of soft phases in a continuous cooling phase transformation diagram. However, in general, when forming a sheet metal into a part, thickness reduction occurs in a shoulder-R portion of a part, which is curved by a wall surface of the part or by a die. When the degree of thickness reduction is large, a gap may occur between the die surface and the material, resulting in both a relatively slower cooling rate and the failure to achieve the target material properties.

[0019] Accordingly, even using the hot press forming, there is a need for a method that may manufacture automotive filler parts with relatively deep forming depths or large panel parts requiring material inflow control. Furthermore, there is a need for a method that may secure ultra-high strength while eliminating forming defects such as cracks and sufficiently suppressing wrinkles formed in the flange portion for assembly with surrounding parts.

[0020] Meanwhile, a battery system used in electric vehicles uses battery cases to protect battery cells therein. These battery cases should secure crashworthiness performance and watertightness.

[0021] While battery cases for electric vehicles are typically made of an expensive aluminum extrusions or sheet metals, attempts are being made to use steel due to its competitive price and ease of recycling. However, the high-strength steel suffers from poor formability, making it difficult to form into desired shapes.

[0022] The high-strength steel is often limited only to simple, linear-shaped parts formed through roll forming. When manufacturing the battery cases using these straight parts, alignment issues arise due to the thin steel sheet and a springback of a part, making butt welding difficult at a corner where the two straight parts meet.

[0023] To overcome this problem, a separate part (bracket) may be used to support the two straight parts by wrapping around the corner. The corresponding part has a longitudinal curved portion reflecting the required corner angle and also has a flange shape that is connected to upper and lower plates of the battery pack, making forming difficult.

[0024] FIG. 10 schematically illustrates a side frame of the battery case, and FIG. 11 illustrates a cross-sectional view taken along line A-A' of FIG. 10. As illustrated in FIGS. 10 and 11, a side frame B-1 of the battery case requires flanges formed at the top and bottom to be connected to the upper and lower plates. This also applies to a bracket B-20. That is, the bracket B-20 also includes a main body B-23 and flanges B-21 and B-22 formed by bending from the main body B-23. Forming the bracket B-20 is difficult because it includes a curved portion having a radius of curvature R1 while also requiring a curved surface with a radius of curvature R2 for forming upper and lower flanges.

[0025] When a part includes a curve or dimensional transition, a stretch flange or shrink flange is formed on the surfaces

of the flanges B-21 and B-22 depending on the geometric characteristics of the corresponding area. Furthermore, both types of flanges may be formed simultaneously, with one type being dominant. In a stretch flange region accompanied by the thickness reduction, excessive forming strain or insufficient formability of the material relative to the required part geometry may cause necking, which is a localized reduction in cross-sectional area due to plastic instability, followed by fracture. Meanwhile, in the shrink flange region, increased in-plane compressive load may lead to increased thickness, buckling, and wrinkles. When such wrinkling or folding occurs, non-uniform gaps occur in the battery pack, thereby impairing the watertightness of the battery pack.

[0026] Meanwhile, the bracket B-20 should be formed from the same material as the frame B-10, which is the straight part, to secure the uniform strength and crashworthiness performance. When forming with high-strength steel, there is a significant difficulty in forming flanges that include a curved portion.

[0027] In the case of the conventional cold-forming steel sheets, ultra-high-strength steel with a tensile strength of 980 MPa or higher increases the risk of wrinkling and fracture due to the high strength and low ductility of a material, thereby making it difficult to manufacture the flange with the curved portion. As a result, press-hardened steel is increasingly being used as an alternative.

[0028] Since the press-hardened steel is formed at high temperature, the press-hardened steel has low strength and high ductility at the time of forming. As a result, the press-hardened steel may be formed into complex shapes. However, since the press-hardened steel needs to be formed in one operation while maintaining the high temperature, it is difficult to apply a blank holder or a drawbead which is a fracture and wrinkling control means, which imposes limitations on the degree of freedom in the forming process.

[0029] Furthermore, the high-strength steel suffers from poor bending formability, which makes it difficult to form parts with a small radius of curvature. However, in recent years, in electric vehicles, etc., there is a growing need for formed parts that may achieve significant weight reduction and improved safety of vehicles. These formed parts are required to maintain high strength while having a much smaller curvature radius compared to conventional parts, thereby greatly improving space utilization.

[0030] Meanwhile, in the hot press forming method, high-temperature materials heated in a heating furnace need to be formed before they cool in the air, and thus, unlike cold forming, may not be sequentially formed through dies of multiple stages. Due to these drawbacks, there is also the problem that it is difficult to form a plurality of parts with a hat shape using the hot press forming method. Since it may not be formed in a single operation, the parts may be formed separately and then joined together during the subsequent assembly stage. However, this approach has the drawback of increased process costs due to the separate forming of each part, along with potential performance limitations.

(Patent Document 1) U.S. Patent Publication No. 6296805
(Patent Document 2) US Patent Laid-Open Publication No. 2014-0056754
(Patent Document 3) Korean Patent Laid-Open Publication No. 10-2020-006635
(Patent Document 4) Korean Patent Publication No. 10-2023-0092430

Summary of Invention

Technical Problem

[0031] An aspect of the present disclosure is to provide a steel sheet for hot forming having high strength and excellent surface quality, a hot formed member manufactured using hot forming therefor and having high strength, and a manufacturing method therefor.

[0032] An aspect of the present disclosure is to provide a hot press formed part capable of ensuring high strength while reducing wrinkles in a flange portion, and a manufacturing method therefor.

[0033] An aspect of the present disclosure is to provide a forming device capable of forming a bracket having a flange and a curved portion, a forming method, and a bracket manufactured thereby.

[0034] An aspect of the present disclosure is to provide a formed part having a higher tensile strength and a smaller radius of curvature than conventional parts, or a battery pack module including the same.

[0035] An aspect of the present disclosure is to provide a press formed part that minimizes damage, such as cracks, during hot press forming to manufacture a plurality of hat-shaped parts, and a manufacturing method therefor.

[0036] The object of the present disclosure is not limited to the matters described above. Additional objects of the present disclosure are described throughout the specification, and a person skilled in the art to which the present disclosure pertains will have no difficulty in understanding the additional objects of the present disclosure from the contents described in the specification of the present disclosure.

Solution to Problem

[0037] Hereinafter, the technical solutions of the present disclosure are described. While not essential, it should be noted that the technical solutions for each aspect of the present disclosure can also be usefully applied to other aspects of the present disclosure. For example, the steel sheet for hot forming and/or the manufacturing method therefor according to the first aspect of the present disclosure may be usefully used in the hot formed member, various parts obtained therefrom, and manufacturing methods therefor according to the second to fifth aspects. In addition, the method of manufacturing a part according to the second aspect of the present disclosure, heat treatment conditions used therefor, etc., may be usefully used in the process of manufacturing a bracket for a battery case, a formed part, etc., according to the third to fifth aspects. In addition, the composition and various useful parameters according to each aspect of the present disclosure may be appropriately combined with other aspects to obtain advantageous effects.

[0038] An aspect of the present disclosure is to provide a steel sheet for hot forming. The steel sheet for hot forming may include, in weight%, carbon (C): 0.1-0.45%, silicon (Si): 0.8-3.0%, manganese (Mn): 0.5-4.0%, phosphorus (P): 0.001-0.05%, sulfur (S): 0.0001-0.02%, aluminum (Al): 0.001-0.1%, chromium (Cr): 1.0-5.0%, nitrogen (N): 0.001-0.02%, with a balance of Fe and inevitable impurities, and may have an R value of 2.8 or greater, defined by [Relational Equation 1] below.

[Relational Equation 1]

$$R = ([Cr] + [Mn] + [Si]) / ([Cr^*] + [Mn^*] + [Si^*])$$

[0039] (In the above [Relational Equation 1], [Cr], [Mn], and [Si] represent a maximum content (wt%) of each element within a range of 0.01 to 1.0 μm in a thickness direction from a surface of the steel sheet in a GDS profile, and [Cr*], [Mn*], and [Si*] represent an average content (wt%) of each element in the steel sheet.)

[0040] In addition, the steel sheet for hot forming described above may further include at least one selected from the following a) to f).

a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
b) boron (B): 0.01 wt% or less (excluding 0%),
c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,
e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
f) rare earth elements (REM): 0.0001 to 0.02 wt%

[0041] In addition, in one of the above-described steel sheets for hot forming, a microstructure of the steel sheet for hot forming may include ferrite and cementite.

[0042] In addition, in one of the above-described steel sheets for hot forming, a sum of area fractions of the ferrite and the cementite may be 5% or more.

[0043] In addition, in one of the above-described steel sheets for hot forming, the steel sheet for hot forming may have a tensile strength of 500 MPa or higher.

[0044] Another aspect of the present disclosure is to provide a method of manufacturing a steel sheet for hot forming. The method may include heating a slab containing, in weight%, carbon (C): 0.1 to 0.45%, silicon (Si): 0.8 to 3.0%, manganese (Mn): 0.5 to 4.0%, phosphorus (P): 0.001 to 0.05%, sulfur (S): 0.0001 to 0.02%, aluminum (Al): 0.001 to 0.1%, chromium (Cr): 1.0 to 5.0%, nitrogen (N): 0.001 to 0.02%, with a balance of Fe and inevitable impurities; obtaining a hot-rolled steel sheet by finish hot rolling the heated slab; cooling the hot-rolled steel sheet; coiling the cooled hot-rolled steel sheet; obtaining a cold-rolled steel sheet by cold rolling the coiled hot-rolled steel sheet; annealing the cold-rolled steel sheet from 700 to 1,000°C to a dew point temperature of -30 to 0°C; and pickling the annealed cold-rolled steel sheet for 1 to 10 seconds.

[0045] In addition, in the above-described method, in the annealing, a temperature increases at a first rate of 3.0 to 20.0°C/s in a first temperature range of room temperature to 700°C, and then increases at a second rate of 0.015 to 10.0°C/s in a second temperature range of 700 to 1,000°C.

[0046] In addition, in one of the above-described methods, the slab may further include at least one selected from the following a) to f).

a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
b) boron (B): 0.01 wt% or less (excluding 0%),
c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,

e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
f) rare earth elements (REM): 0.0001 to 0.02 wt%

[0047] In addition, in one of the above-described methods, the heating may be performed at 1000 to 1300°C, and in the obtaining of the hot-rolled steel sheet, the finish hot rolling of the slab may be performed at Ar3 to 1000°C.

[0048] In addition, in one of the above-described methods, the cooling may be performed at a cooling rate of 20 to 100°C/s, and the coiling may be performed at a temperature exceeding Ms and lower than or equal to 750°C.

[0049] Another aspect of the present disclosure provides a hot formed member. The hot formed member may include, in weight%, carbon (C): 0.1 to 0.45%, silicon (Si): 0.8 to 3.0%, manganese (Mn): 0.5 to 4.0%, phosphorus (P): 0.001 to 0.05%, sulfur (S): 0.0001 to 0.02%, aluminum (Al): 0.001 to 0.1%, chromium (Cr): 1.0 to 5.0%, nitrogen (N): 0.001 to 0.02%, with a balance of Fe and inevitable impurities, and may satisfy [Relational Equation 2] below.

[Relational Equation 2]

$$Fe_{40\sim80\%} \text{ slope} \geq 200 \ (wt\%/\mu m)$$

[0050] (In the above [Relational Equation 2], the $Fe_{40\sim80\%}$ slope may represent a slope of a straight line in a section where the Fe content (wt%) may be 40 to 80% within a range of 5μm or less in a thickness direction from a surface of the member in a GDS profile. In addition, the slope of the straight line here may represent a slope derived after performing a simple linear regression on a graph of a section where the Fe content (wt%) may be 40 to 80% in the GDS profile.)

[0051] In addition, in the above-described hot formed member, the hot formed member may further include at least one selected from the following a) to f).

a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
b) boron (B): 0.01 wt% or less (excluding 0%),
c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,
e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
f) rare earth elements (REM): 0.0001 to 0.02 wt%

[0052] In addition, in one of the above-described hot formed members, a microstructure of the hot-formed member may contain martensite or bainite as a main phase.

[0053] In addition, in one of the above-described hot formed members, an area fraction of the main phase may be 10% or more.

[0054] In addition, in one of the above-described hot formed members, the hot formed member may have a tensile strength of 1000 MPa or higher.

[0055] Another aspect of the present disclosure provides a method for manufacturing a hot formed member. The method may include preparing a blank using the above-described steel sheet for hot forming; heat-treating the blank at a heat treatment temperature of 700 to 1000°C for 180 to 600 seconds; and hot-forming the heat-treated blank and then cooling the heat-treated blank.

[0056] In addition, in the above-described method, in the heat-treating, the heat-treated blank may be heated to the heat treatment temperature at a temperature increase rate of 1 to 1000°C/s.

[0057] In addition, in one of the above-described methods, in the cooling, the heat-treated blank may be cooled to a cooling end temperature of Mf or lower.

[0058] In addition, in one of the above-described methods, in the cooling, the heat-treated blank may be cooled to the cooling end temperature at a cooling rate of 5 to 1000°C/s.

[0059] Although not essential, the steel sheet for hot forming or the hot formed member according to the first aspect of the present disclosure may secure improved performance when combined with the advantageous features of other aspects described below.

[0060] A second aspect of the present disclosure provides a hot formed member. The hot-formed member may have, at a point of t/4 in the thickness direction (where *t* may represent the thickness (mm) of the member), a number of cementite particles having a Cr content of 1.20% or more and a short-axis length of 100 nm or greater of 10.00/μm^2 or less.

[0061] According to an example embodiment of the present disclosure, a hot press formed part having ultra-high strength and reduced wrinkles in a flange portion may be provided.

[0062] In an example embodiment of the present disclosure, the hot press formed part may be obtained from the steel sheet for hot forming described above.

[0063] Another aspect of the present disclosure provides a method of manufacturing a hot press formed part using a die

including an upper die, a lower punch provided on a central lower portion of the upper die, and a lower holder provided on a lower portion of the upper die and a side portion of the lower punch, the method including: austenizing a steel; providing the austenized steel on the lower punch and the lower holder; supporting and heating the steel between the lower holder and the upper die by applying a blank holding force (F) and heat through the lower holder; and forming and cooling the steel by applying pressure through the lower punch, in which the steel may have a martensite transformation critical cooling rate of 15 to 25°C/s in a temperature range of 800 to 400°C.

[0064] In an example embodiment of the present disclosure, the blank holding force (F) may satisfy the following [Relational Equation 3], and the following P may be 1 to 10 MPa.

$$[\text{Relational Equation 3}] \quad F = P \times A$$

(Wherein, in [Relational Equation 3], P may represent blank holding pressure, and A may represent a contact area between the lower holder and the steel.)

[0065] In an example embodiment of the present disclosure, a minimum temperature value T_{min} of the lower holder may be 300°C.

[0066] In an example embodiment of the present disclosure, a maximum temperature value T_{max} of the lower holder may satisfy the following [Relational Equation 4] and [Relational Equation 5].

$$[\text{Relational Equation 4}] \quad T_{max} = T_{blank} - [(CR_{min} \cdot w \cdot \rho \cdot C)/h]$$

$$[\text{Relational Equation 5}] \quad h = A \cdot P^{N}$$

[0067] (Wherein, in [Relational Equations 4] and [Relational Equation 5], h may represent a heat transfer coefficient between the steel and the lower holder, T_{blank} may represent a forming temperature of the steel, T_{max} may represent a maximum temperature value of the lower holder, w may represent a thickness of the steel, ρ may represent a density of the steel, C may represent the specific heat of the steel, CR_{min} may represent the martensite transformation critical cooling rate, a may represent a heat transfer pressure coefficient of the steel, P may represent the blank holding pressure, and b may represent a heat transfer pressure index of the steel.)

[0068] In an example embodiment of the present disclosure, a temperature of the remaining dies, excluding the lower holder, may be 300°C or lower.

[0069] Although not essential, the hot press formed part according to the second aspect of the present disclosure may secure improved performance when combined with the advantageous features of the other aspects described below.

[0070] A third aspect of the present disclosure provides a forming device. The forming device may include: a pad; a die disposed outside the pad in a first direction; and a punch including a main body disposed at a lower portion of the pad and having a punch forming portion formed thereon, in which the punch forming portion may include a linear first punch forming portion, a curved second punch forming portion having a radius of curvature Rp of a curved forming portion, and a linear third punch forming portion when viewed in the first direction, the first to third punch forming portions may be continuously disposed along a second direction perpendicular to the first direction on a horizontal plane, and the first to third punch forming portions include first to third extended surface forming portions of a surface perpendicular to the first direction on both sides of the first direction, first to third main body forming portions of a directional surface facing the pad, and first to third curved surface forming portions having a bending radius of curvature r between the extended surface forming portion and the main body forming portion, the pad may include a pressing surface corresponding to the first to third main body forming portions, the die may include a linear first die forming portion, a curved second die forming portion having a radius of curvature Rd of the curved die, and a linear third die forming portion when viewed in the first direction, the first to third die forming portions may be disposed continuously along the second direction, and when upper positions of the third main body forming portion and the third die forming portion may be disposed on the same plane, the first main body forming portion may be disposed above the upper position of the first die forming portion when viewed in the first direction.

[0071] According to an example embodiment of the present disclosure, there is an effect of enabling forming of steel (e.g., high-strength steel) having insufficient formability.

[0072] In an example embodiment of the present disclosure, the punch may further include fourth and fifth punch forming portions symmetrical to the second and first punch forming portions with respect to the third punch forming portion, the die may further include fourth and fifth die forming portions symmetrical to the second and first die forming portions with respect to the third die forming portion, and the pressing surface of the pad may also include a surface corresponding to the main body forming portions of the fourth and fifth punch forming portions.

[0073] In an example embodiment of the present disclosure, the punch may include a support portion that supports preforming material outside the first and fifth forming portions with respect to the third punch forming portion.

[0074] In an example embodiment of the present disclosure, the radius of curvature Rp of the curved forming portion

may be smaller than the radius of curvature Rd of the curved die.

[0075] In an example embodiment of the present disclosure, a second direction length lp of the third main body forming portion may be longer than a second direction length ld of the third die forming portion.

[0076] In an example embodiment of the present disclosure, when viewed in the first direction, a center of the radius of curvature Rd of curved die in the second direction may coincide with a center of the third main body forming portion, and when viewed in the first direction, in the second and fourth punch forming portions, an angle θ at which extension lines of virtual tangents at both end portions of the second and fourth punch forming portions intersect may be between 95 and 135°.

[0077] In an example embodiment of the present disclosure, the first to fifth die forming portions may include first to fifth die curved surface forming portions formed as curved surfaces at positions relatively close to the punch in the first direction, and first to fifth flat forming portions at positions relatively far from the punch, the curved surfaces of the first to fifth die curved surface forming portions may increase in height as they get closer to the punch, and when the upper positions of the third main body forming portion and the third die forming portion may be disposed on the same plane, at least a portion of the second main body forming portion may be disposed below the upper position of the second die forming portion when viewed in the first direction.

[0078] In an example embodiment of the present disclosure, at least one of the punch and the die may include a cooling channel therein, and the radius of curvature Rp of the curved forming portion and the bending radius of curvature r may satisfy 25 mm $\leq$ Rp (mm) + r (mm) $\leq$ 30 mm.

[0079] Another aspect of the present disclosure provides a material forming method, including: a material mounting operation of mounting, on a punch, a material longer in a first direction than the punch having a forming portion; a primary forming operation of forming the material into a shape of a main body forming portion of the punch through the pad disposed on an upper portion of the punch; and a secondary forming operation of forming the material to follow the shape of the forming portion of the punch through a die disposed outside the pad in the first direction, in which, in the secondary forming operation, the die may form the material in the order of an edge portion, a center portion, and an intermediate portion between the center and the edge portion of the material in that order in a second direction perpendicular to the first direction and a vertical direction.

[0080] In an example embodiment of the present disclosure, the forming portion may include, when viewed in the first direction, a linear first forming portion, a second forming portion having a radius of curvature Rp of the curved forming portion, a linear third forming portion, a curved fourth forming portion having the radius of curvature Rp of the curved forming portion, and a linear fifth forming portion, the intermediate portion of the die may be formed as a curved surface having the radius of curvature Rd of the curved die, and the radius of curvature Rd of the curved die may be greater than the radius of curvature Rp of the curved forming portion.

[0081] In an example embodiment of the present disclosure, the material may be a steel sheet, and the material mounting operation may be performed while the material may be heated to an AC3 temperature or higher of the material, and the material forming method may further include a cooling operation in which the material may be cooled to have a martensite structure by at least one of the punch and the die.

[0082] In an example embodiment of the present disclosure, the material may be the above-described steel sheet for hot forming, or a hot-formed member obtained by performing hot forming on the steel sheet for hot forming. As one example, the steel sheet for hot forming and the hot formed member may have the above-described alloy composition and may be manufactured using the above-described manufacturing method.

[0083] In an example embodiment of the present disclosure, in the material mounting operation, the material may include a notch formed toward the center of the material in the first direction in a position corresponding to the intermediate portion of the die.

[0084] In an example embodiment of the present disclosure, the first to fifth forming portions may include first to fifth extended surface forming portions formed on a surface perpendicular to the first direction on both sides in the first direction, first to fifth main body forming portions on a directional surface facing the pad, and first to fifth curved surface forming portions having a bending radius of curvature r between the extended surface forming portion and the main body forming portion, and the radius of curvature Rp of the curved forming portion and the bending radius of curvature r may satisfy 25 mm $\leq$ Rp (mm) + r (mm) < 30 mm, 3 mm $\leq$ r (mm) $\leq$ 10 mm.

[0085] Another aspect of the present disclosure provides a bracket for a battery case, including a forming surface having a radius of curvature Rp of a curved forming portion, in which the forming surface may include: a main body; a flange extending by being bent from an end portion of the main body; and a curved surface connected between the main body and the flange with a bending radius of curvature r, the bracket may be formed of steel containing boron with a tensile strength of 1200 MPa or higher and may have a martensitic structure, and the radius of curvature Rp of the curved forming portion and the bending radius of curvature r satisfy 25 mm $\leq$ Rp (mm) + r (mm) $\leq$ 30 mm, 3 mm $\leq$ r (mm) $\leq$ 10 mm.

[0086] In an example embodiment of the present disclosure, a minimum thickness tmin and an initial thickness tini before forming in the flange may satisfy (tini - tmin)/tini $\leq$ 0.2, and a maximum thickness tmax and the initial thickness tini before forming in the curved surface may satisfy (tini - tmax)/tini $\geq$ -0.4.

[0087] In an example embodiment of the present disclosure, the bracket may have an angle θ between 95° and 135° at which extension lines of a virtual tangent at both end portions of the forming surface intersects.

[0088] A bracket for a battery case according to an example embodiment of the present disclosure may be manufactured using the forming method described above.

[0089] According to an example embodiment of the present disclosure, the bracket manufactured using the forming method described above may secure weight reduction, watertightness, and crashworthiness performance of the battery pack.

[0090] Although not essential, the product according to the third aspect of the invention may secure further enhanced performance when combined with the advantageous features of the other aspects described below.

[0091] A fourth aspect of the present disclosure provides a high-strength steel hot press formed part. The high-strength steel hot press formed part may include a first wall extending in a first direction, a second wall extending in a direction intersecting the first wall, and a third wall extending in the first direction and extending in a direction intersecting the second wall, a curved portion may be formed between the first wall and the second wall, and the first wall, the second wall, and the curved portion may be integrally formed, and the high-strength steel hot press formed part may satisfy the following [Relational Equation 6].

[Relational Equation 6]

$$\text{Wall height } (hw) \leq 13.4 * \text{wall angle } (\theta w) + 182.4$$

[0092] (Here, the wall height hw may represent a length from the first wall to the third wall in the direction perpendicular to the first direction and the unit may be mm, the wall angle θw may represent an angle between an arbitrary line perpendicular to the first direction and the second wall and the unit may be degree, and left and the right sides may be dimensionless and calculated.)

[0093] In an example embodiment of the present disclosure, the high-strength steel may be the above-described steel sheet for hot forming.

[0094] According to an example embodiment of the present disclosure, a formed part with high tensile strength and a small curvature may be provided.

[0095] In an example embodiment of the present disclosure, the first wall, the second wall, and the curved portion may be formed integrally by processing sheet metal. In addition, the first wall, the second wall, and the curved portion may be formed integrally by processing the sheet metal, and the radius of curvature r of the curved portion may be greater than or equal to 0.5 mm, and a ratio r/t of a radius of curvature r to a thickness t of the sheet metal may be less than 2.5.

[0096] In an example embodiment of the present disclosure, the formed part may have a tensile strength of 1300 to 2100 MPa.

[0097] In an example embodiment of the present disclosure, the formed part may include a third wall and a fourth wall parallel to the first direction, and a fifth wall connected to the third wall and the fourth wall, the third wall may extend from the second wall, and the first to fifth walls may be formed integrally.

[0098] In an example embodiment of the present disclosure, an angle between an arbitrary line perpendicular to the first direction and the second wall may be 5° or less.

[0099] In an example embodiment of the present disclosure, the microstructure of the formed part may be formed of martensite having an area fraction of 98% or more.

[0100] Another aspect of the present disclosure provides a battery pack module, including: a battery case formed to surround a battery pack; a base disposed on a lower portion of the battery case and connected to the battery case to form a space in which the battery pack may be disposed; and a hot press forming part disposed across an inside of the battery case and connected to the battery case and the base.

[0101] According to an example embodiment of the present disclosure, a part with high space utilization may be manufactured when manufacturing a module such as a battery pack.

[0102] In an example embodiment of the present disclosure, the plurality of hot press forming parts may be disposed at regular intervals within the battery case.

[0103] Although not essential, the part according to the fourth aspect of the invention may secure further enhanced performance when combined with the advantageous features of the other aspects described below.

[0104] A fifth aspect of the present disclosure provides a press formed part. The press formed part may have a hat shape including a top plate portion, a longitudinal wall portion continuous with the top plate portion, and a boundary portion continuous with the vertical wall portion, and include a plurality of deformation portions having a preset height, and a flat plate portion disposed between the plurality of deformation portions, connecting two adjacent boundary portions, and having a preset length.

[0105] In an example embodiment of the present disclosure, the relationship between the preset length and the preset height may be determined based on the number of deformation portions.

[0106] In an example embodiment of the present disclosure, three deformation portions may be provided, and the relationship between the preset length and the preset height may be defined by the following [Relational Equation 7], where

$$w \leq 114.85e^{0.0455h} \ldots \quad [\text{Relational Equation 7}],$$

and in the [Relational Equation 7], w may denote the preset length, and h may denote the preset height.

[0107] In an example embodiment of the present disclosure, the deformation portion may be provided in four or more, and the relationship between the preset length and the preset height may be defined by [Relational Equation 8] below, where

$$w \leq 46.309e^{0.105h} \ldots \quad [\text{Relational Equation 8}],$$

and in the above [Relational Equation 8], w may denote the preset length and h may denote the preset height.

[0108] In an example embodiment of the present disclosure, the preset length (w) may be 20 mm or more.

[0109] In an example embodiment of the present disclosure, the press formed part may be manufactured using the hot press forming method.

[0110] In an example embodiment of the present disclosure, the hot press forming method may be the method described above.

[0111] Another aspect of the present disclosure provides a method for manufacturing a press formed part, including: a operation of supplying a metal sheet to a processing position; a operation of performing primary press forming on the metal sheet using a first die provided with a plurality of first pressing units and an intermediate pressing unit; and, after the primary press forming on the metal sheet, performing secondary press forming on the metal sheet using the first die and the second die provided with a plurality of second pressing units.

[0112] In an example embodiment of the present disclosure, the metal sheet may be the above-described steel sheet for hot forming.

[0113] In an example embodiment of the present disclosure, the press forming operation may use the above-described forming device.

[0114] In an example embodiment of the present disclosure, in the operation of supplying the metal sheet to the processing position, the metal sheet may be supplied between the first die and the intermediate pressing unit, and a central region of the metal sheet may be disposed in a position facing the intermediate pressing unit.

[0115] In an example embodiment of the present disclosure, in the operation of supplying the metal sheet to the processing position, the intermediate pressing unit may be disposed above the second die at the processing position.

[0116] In an example embodiment of the present disclosure, in the operation of supplying the metal sheet to the processing position, the intermediate pressing unit may be disposed in a position where the height difference between the intermediate pressing unit and the second die may be 65% or more of the height of the press formed part.

[0117] In an example embodiment of the present disclosure, in the operation of performing the primary press forming on the metal sheet, the intermediate pressing unit may be introduced into a first pressing unit disposed centrally among the plurality of first pressing units to press a central region of the metal sheet.

[0118] In an example embodiment of the present disclosure, in the operation of performing the secondary press forming on the metal sheet, the second pressing unit may be introduced into the first pressing unit disposed externally among the plurality of first pressing units to press an outer region of the metal sheet.

[0119] In an example embodiment of the present disclosure, in the operation of performing the primary press forming on the metal sheet and the operation of performing the secondary press forming on the metal sheet, the metal sheet may be formed using the hot press forming method.

[0120] In an example embodiment of the present disclosure, the method for manufacturing a press formed part may further include, between the operation of performing the primary press forming on the metal sheet and the operation of performing the secondary press forming on the metal sheet, a operation of performing the press forming on the metal sheet using an additional intermediate pressing unit disposed outside the intermediate pressing unit and the first die.

Advantageous Effects of Invention

[0121] According to an aspect of the present disclosure, it is possible to provide a steel sheet for hot forming and a hot formed member having high strength and excellent surface quality after hot forming, and a method of manufacturing the same. Furthermore, the hot formed member may be suitable for use in an automotive structural member, beam steel, etc. In addition, it is possible to manufacture the steel sheet for hot forming and the hot formed member having excellent surface quality and strength without processes such as plating or shot blasting.

[0122] According to another aspect of the present disclosure, it is possible to provide a hot press formed part capable of ensuring ultra-high strength while reducing wrinkles in the flange portion and a manufacturing method therefor.

[0123] According to another aspect of the present disclosure, it is possible to provide a forming device capable of forming a bracket formed with a flange and a curved portion, a forming method, and a bracket manufactured thereby, and to secure weight reduction, watertightness, and crashworthiness performance of a battery pack through the bracket.

[0124] According to another aspect of the present disclosure, it is possible to provide a formed part that has high tensile strength, has a small radius of curvature, and is manufactured at once, thereby facilitating processing, and manufacture a part having high space utilization when manufacturing a module such as a battery pack.

[0125] According to another aspect of the present disclosure, it is possible to dispose an intermediate pressing unit having a height difference between upper/lower dies, and to perform press forming on a metal sheet using three pressing units. In this case, by performing a stepwise forming process that first presses a central region of the metal sheet and then presses an outer region, it is possible to prevent deformation force from concentrating at a specific location of the metal sheet during press forming. Accordingly, it is possible to prevent damage to the press formed part during the manufacturing and improve the quality of the part.

[0126] Various and beneficial advantages and effects in the present disclosure are not limited to the above description, and may be more easily understood in the course of describing the specific example embodiments in the present disclosure.

Brief Description of Drawings

[0127] In order to more fully understand the drawings cited in the detailed description of the present disclosure, a brief description of each drawing is provided:

FIG. 1 is a graph of Cr, Mn, and Si GDS profiles of a steel sheet for hot forming according to an example embodiment of the present disclosure;

FIG. 2 is a graph showing GDS profiles of Fe after hot forming for Inventive Example A-1 and Comparative Example A-11;

FIG. 3 is a view illustrating changes in temperature, microstructure, and tensile strength during the conventional hot press forming;

FIG. 4 is a diagram illustrating an example of the temperature, microstructure, and ductility of a part manufactured using the conventional hot press forming process;

FIG. 5 is a diagram illustrating an example of changes in temperature, microstructure, and tensile strength during hot press forming for 22MnB5 material and low-temperature heating materials;

FIG. 6 is a diagram illustrating an example of the changes in temperature, microstructure, and tensile strength during the hot press forming for the 22MnB5 material and hardenability-improved material;

FIG. 7 is a diagram illustrating an example of changes in temperature, microstructure, and tensile strength during hot press forming of a hardenability-improved material;

FIG. 8 is a schematic diagram illustrating hot press forming equipment applicable to the present disclosure;

FIG. 9 is a schematic diagram illustrating hot press forming equipment applicable to the conventional 22MnB5 material.

FIG. 10 is a schematic diagram of a side frame of a battery case;

FIG. 11 is a cross-sectional view taken along line A-A' of FIG. 10;

FIG. 12 is an exploded perspective view of a forming device according to an example embodiment of the present disclosure;

FIG. 13 is a side view of a forming device according to an example embodiment of the present disclosure;

FIG. 14 is a flowchart of a forming method according to an example embodiment of the present disclosure;

FIG. 15 is a plan view of a material immersed into a forming device according to an example embodiment of the present disclosure;

FIG. 16 is a schematic perspective view illustrating a primary forming operation in a forming method according to an example embodiment of the present disclosure;

FIG. 17 is a schematic perspective view illustrating a secondary forming operation in the forming method according to an example embodiment of the present disclosure;

FIG. 18a is a perspective view illustrating the secondary forming operation in the forming method according to an example embodiment of the present disclosure, viewed from another direction, and FIG. 18b is a front view illustrating the secondary forming operation in the forming method according to an example embodiment of the present disclosure;

FIG. 19 is a front view illustrating a cooling operation in the forming method according to an example embodiment of the present disclosure;

FIG. 20 is a perspective view illustrating a trimming operation in the forming method according to an example embodiment of the present disclosure;

FIG. 21 is a perspective view of a bracket manufactured using the forming method according to an example embodiment of the present disclosure;

FIG. 22 is a distribution diagram of a thickness reduction ratio of a formed product manufactured using the forming method according to an example embodiment of the present disclosure;

FIG. 23 is the distribution diagram of the thickness reduction ratio of the formed product manufactured using the forming method of Comparative Example 1-1;

FIG. 24 is a distribution graph of the thickness reduction ratio in cross-sections of the formed products of FIGS. 22 and 23;

FIG. 25 is a side view illustrating the forming method of Comparative Example 1-2;

FIG. 26 is a perspective view of a formed product manufactured using the forming method of Comparative Example 1-2;

FIG. 27 is a perspective view of a formed part according to an example embodiment of the present disclosure;

FIG. 28 is a front view of the formed part according to an example embodiment of the present disclosure;

FIGS. 29a, 29b, 30a, and 30b are diagrams illustrating interpretations of an example embodiment and Comparative Example of the present disclosure, in which, referring to Table 1, FIG. 29a illustrates Inventive Example 2-1, FIG. 29b illustrates Comparative Example 2-1, FIG. 30a illustrates Inventive Example 2-3, and FIG. 30b illustrates Comparative Example 2-3;

FIG. 31 is a perspective view of a battery pack module according to an example embodiment of the present disclosure;

FIG. 32 is a cross-sectional view of a portion of the battery pack module according to an example embodiment of the present disclosure, and illustrates space utilization when the battery pack is disposed, in which FIG. 32(a) illustrates a case in which the radius of curvature is small, and FIG. 32(b) illustrates a case in which the radius of curvature is larger than FIG. 32(a);

FIG. 33 is a perspective view illustrating a press formed part according to an example embodiment of the present disclosure;

FIG. 34 is a perspective view illustrating a press formed part according to another example embodiment of the present disclosure;

FIG. 35(a) is a graph illustrating the relationship between a preset length and a preset height of the press formed part according to an example embodiment of the present disclosure, and FIG. 35(b) is a graph illustrating the relationship between a preset length and a preset height of the press formed part according to another example embodiment of the present disclosure;

FIG. 36(a) is an example illustrating deformation force applied to a press formed part manufactured using the conventional manufacturing method, and FIG. 36(b) is an example illustrating deformation force applied to a press formed part manufactured using a manufacturing method according to example embodiments of the present disclosure;

FIG. 37 is a flowchart illustrating a method of manufacturing a press formed part according to an example embodiment of the present disclosure;

FIG. 38 is a diagram schematically illustrating a first operation of manufacturing the press formed part of FIG. 33;

FIG. 39 is a diagram schematically illustrating a second operation of manufacturing the press formed part of FIG. 33;

FIG. 40 is a diagram schematically illustrating a third operation of manufacturing the press formed part of FIG. 33;

FIG. 41 is a diagram schematically illustrating a fourth operation of manufacturing the press formed part of FIG. 33;

FIG. 42 is a diagram schematically illustrating a first operation of manufacturing the press formed part of FIG. 34;

FIG. 43 is a diagram schematically illustrating a second of manufacturing the press formed part of FIG. 34;

FIG. 44 is a diagram schematically illustrating a third operation of manufacturing the press formed part of FIG. 34; and

FIG. 45 is a diagram schematically illustrating a fourth operation of manufacturing the press formed part of FIG. 34.

Best Mode for Invention

[0128] Hereinafter, example embodiments of the present disclosure will be described. However, example embodiments of the present disclosure may be modified in various different forms, and the terminology used herein is for the purpose of describing the present disclosure and is not intended to limit the present disclosure. In addition, singular forms used herein include the plural forms unless the relevant definition clearly dictates the contrary.

[0129] In this specification, the term "including" is used to indicate the inclusion of other components, rather than excluding other components, unless specifically stated otherwise.

[0130] Furthermore, unless otherwise specified in the specification of the present disclosure, the unit "%" means wt%, and 1 ppm is 0.0001 wt%.

[0131] Unless defined otherwise, all terms including technical terms and scientific terms used herein have the same

meaning as commonly understood by a person of ordinary skill in the art to which the present invention belongs. The terms defined in the dictionary are interpreted to have a meaning consistent with the related technical literature and the currently disclosed content.

[0132] The inventors of the present disclosure recognized the problem that, in the case of an uncoated steel sheet for hot forming, an Fe oxide layer forms during the heat treatment process performed during manufacturing of a hot-formed member, making it difficult to secure excellent surface quality of the member, and a shot blast process is necessarily performed to remove the Fe oxide layer. Therefore, the inventors studied a steel sheet for hot forming that may address this issue and secure excellent surface quality.

[0133] As a result, the inventors confirmed that, by precisely controlling the alloy composition and manufacturing conditions, particularly the content of Cr, Si, and Mn, as well as the temperature and temperature increase rate during an annealing process, Cr, Si, and Mn could be concentrated in a surface layer of the steel sheet to a desired composition. Furthermore, the inventors confirmed that, by controlling the temperature and time conditions during the hot forming process, the excellent surface quality of the member may be secured without the shot blast process, leading to the completion of the present disclosure.

[0134] First, the alloy composition of the steel sheet for hot forming according to a first aspect of the present disclosure will be described. The content of the alloy composition refers to wt% unless otherwise specified.

Carbon (C): 0.1 to 0.45%

[0135] Carbon (C) may improve the strength of members manufactured through hot forming. When the C content is less than 0.1%, it may be difficult to sufficiently secure strength. When the C content exceeds 0.45%, the strength of the hot-rolled steel sheet may be excessively high during cold rolling, resulting in poor cold-rollability or reduced spot weldability. That is, the C content may range from 0.1 to 0.45%, specifically, from 0.10 to 0.45%, more specifically from 0.11 to 0.40%, and even more specifically from 0.12 to 0.38%.

Silicon (Si): 0.8 to 3.0%

[0136] Silicon (Si) not only plays a role in forming a silicon-based oxide layer by concentrating on the surface during the annealing process of the cold-rolled steel sheet in a continuous annealing line, but also suppressing the formation of an Fe iron oxide layer during the hot forming process, thereby securing the surface quality and/or spot weldability of the component. When the Si content is less than 0.8%, it may be difficult to sufficiently secure above-described effects. Furthermore, when the Si content exceeds 3.0%, as silicon-based amorphous oxide layer may be excessively formed on the surface of the steel sheet, there may be a problem in that surface quality and/or spot weldability are rather degraded. That is, the Si content may range from 0.8 to 3.0%, more specifically from 0.9 to 2.9%, and even more specifically from 1.0 to 2.8%.

Manganese (Mn): 0.5 to 4.0%

[0137] Manganese (Mn) may play a role in securing a solid solution strengthening effect and, in a member manufactured through hot forming, lowering a critical cooling rate required to secure martensite. When the Mn content is less than 0.5%, it may be difficult to sufficiently secure above-described effects. When the Mn content exceeds 4.0%, the strength of the steel sheet for hot forming increases excessively, making blanking difficult. Furthermore, the excessive addition of alloy iron may increase manufacturing costs and reduce spot weldability. Furthermore, if the Mn content exceeds 4.0%, segregation zones may form on the exterior and/or interior of the steel sheet, leading to crack initiation and propagation, which may degrade mechanical properties (especially, bendability). That is, the Mn content may be 0.5 to 4.0%, more specifically 0.6 to 3.9%, and even more specifically 0.8 to 3.8%.

Phosphorus (P): 0.001 to 0.05%

[0138] Phosphorus (P) is an element contained as an impurity in steel. When the P content is less than 0.001%, manufacturing costs may increase excessively for controlling the P content. Furthermore, if the P content exceeds 0.05%, the weldability of the hot-formed member may be degraded due to P segregation. That is, the P content may range from 0.001 to 0.05%, specifically, from 0.001 to 0.050%, more specifically from 0.001 to 0.04%, and even more specifically from 0.001 to 0.03%.

Sulfur (S): 0.0001 to 0.02%

[0139] Sulfur (S) is an element contained as an impurity in steel. When the S content is less than 0.0001%,

manufacturing costs may increase excessively for controlling the S content. Furthermore, when the S content exceeds 0.02%, the ductility, impact properties, or weldability of the steel sheet and/or hot-formed member may be degraded. That is, the S content may range from 0.0001 to 0.02%, specifically, from 0.0001 to 0.0200%, more specifically from 0.0001 to 0.015%, and even more specifically from 0.0001 to 0.010%.

Aluminum (Al): 0.001 to 0.1%

[0140] Aluminum (Al) acts as a deoxidizer during steelmaking, improving the cleanliness of the steel. When the Al content is less than 0.001%, it may be difficult to sufficiently secure above-described effects. Furthermore, when the Al content exceeds 0.1%, the Ac3 temperature may increase excessively, there may be a problem of having to increase the heating temperature during annealing. That is, the Al content may range from 0.001 to 0.1%, specifically, from 0.001 to 0.100%, more specifically from 0.003 to 0.09%, and even more specifically from 0.005 to 0.08%.

Chromium (Cr): 1.0 to 5.0%

[0141] Chromium (Cr) may play a role in improving the hardenability of steel sheets and, through appropriate reactions with silicon (Si), stably assisting in the formation of a Si-based amorphous oxide layer on the surface of the steel sheet. When the Cr content is less than 1.0%, it may be difficult to sufficiently secure above-described effects. When the Cr content exceeds 5.0%, as the effect becomes saturated and a Cr-based amorphous oxide layer is excessively formed, there may be a problem in that the surface quality and/or spot weldability may rather be degraded. Furthermore, when the Cr content exceeds 5.0%, there may be a problem in that manufacturing costs may increase excessively. That is, the Cr content may be 1.0 to 5.0%, more specifically 1.2 to 4.8%, and even more specifically 1.5 to 4.5%.

Nitrogen (N): 0.001 to 0.02%

[0142] Phosphorus (P) is an element contained as an impurity in steel. When the N content is less than 0.001%, manufacturing costs may increase excessively for controlling the N content. Furthermore, when the N content exceeds 0.02%, the steel becomes susceptible to cracking during slab casting and impact properties may be degraded. That is, the N content may range from 0.001 to 0.02%, specifically, from 0.001 to 0.020%, more specifically from 0.001 to 0.015%, and even more specifically from 0.001 to 0.010%.

[0143] A steel sheet for hot forming according to an example embodiment of the present disclosure may include the above components and iron (Fe) as the remaining component. In addition, since the unintended impurities from raw materials or the surrounding environment may inevitably be mixed in a normal manufacturing process, the unintended impurities may not be excluded. For example, the steel sheet may further contain elements that can be included in the steel in a total amount of 1.0% or less. Since these impurities are known to those skilled in the ordinary manufacturing process, not all of them are specifically mentioned in this specification.

[0144] For example, the steel sheet for hot forming according to an example embodiment of the present disclosure may further include at least one selected from the following a) to f).

a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
Titanium (Ti), niobium (Nb), zirconium (Zr), and/or vanadium (V) may form fine precipitates to enhance the strength of the hot-formed member, and stabilize retained austenite and improve impact toughness through grain refinement. When the content of Ti, Nb, Zr, and/or V (meaning the sum of their contents when two or more are added) is less than 0.001%, it may be difficult to sufficiently secure the above-described effects. Furthermore, when the content of Ti, Nb, Zr, and/or V exceeds 0.4%, the above-described effects may be saturated, or manufacturing costs may increase due to the excessive addition of alloy iron. That is, the content of Ti, Nb, Zr and/or V may be 0.001 to 0.4%, specifically 0.001 to 0.400%, more specifically 0.001 to 0.3%, and even more specifically 0.0015 to 0.27%.
b) Boron (B): 0.01 wt% or less (excluding 0%)

[0145] Even a small amount of boron B may improve hardenability and, by segregating boron to the prior austenite grain boundaries, suppress embrittlement of hot formed members due to grain boundary segregation of P and/or S. When the boron content exceeds 0.01%, the above-described effect may be saturated or hot embrittlement may occur during the hot rolling process. That is, the B content may be 0.01% or less, more specifically 0.008% or less, and even more specifically 0.005% or less.

c) At least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%

[0146] Molybdenum (Mo) and/or tungsten W enhance hardenability and precipitation strengthening, thereby enhancing

strength and refining grains. If the Mo and/or W content is less than 0.001%, it may be difficult to sufficiently secure the above-described effects. Furthermore, when the Mo and/or W content exceeds 1.0%, the above-described effects may be saturated or manufacturing costs may excessively increase. That is, the Mo and/or W content may range from 0.001 to 1.0%, specifically from 0.001 to 1.000%, more specifically from 0.0015 to 0.9%, and even more specifically from 0.002 to 0.8%.

d) At least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%

[0147] Copper (Cu) may form fine precipitates and improve strength. Since Cu may cause hot brittleness when added alone, nickel (Ni) may be additionally added as needed. When the Cu and/or Ni content is less than 0.005%, it may be difficult to sufficiently secure the above-described effects. In addition, when the Cu and/or Ni content exceeds 2.0%, the manufacturing cost may increase excessively. That is, the Cu and/or Ni content may be 0.005 to 2.0%, specifically 0.005 to 2.000%, more specifically 0.01 to 1.8%, and even more specifically 0.02 to 1.7%.

e) At least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%

[0148] Antimony (Sb) and/or tin (Sn) suppress the formation of oxides that may form at the surface grain boundaries of a hot-rolled steel sheet containing Si, thereby minimizing dent defects caused by surface grain boundary decohesion during the annealing process of a cold-rolled steel sheet. When the Sb and/or Sn content is less than 0.001%, it may be difficult to sufficiently secure the above-described effects. Furthermore, when the Sb and/or Sn content exceeds 1.0%, manufacturing costs may increase excessively, or when the Sb and/or Sn content is dissolved in the slab grain boundaries, edge cracks may occur in the coil during the hot rolling process. That is, the Sb and/or Sn content may range from 0.001 to 1.0%, specifically from 0.001 to 1.000%, more specifically from 0.0015 to 0.9%, and even more specifically from 0.002 to 0.8%.

f) Rare earth element (REM): 0.0001 to 0.02 wt%

[0149] A rare earth element (REM) control the activity of Fe in steel, thereby controlling the thickness of the Fe scale formed on the surface during the hot forming process. When the REM content is less than 0.0001%, it may be difficult to sufficiently secure above-described effects. Furthermore, when the REM content exceeds 0.02%, the ability to control the activity of Fe is lost, which may degrade the surface quality. That is, the REM content may range from 0.0001 to 0.02%, specifically, from 0.0001 to 0.0200%, more specifically from 0.0001 to 0.015%, and even more specifically from 0.0001 to 0.01%.

[0150] The steel sheet for hot forming according to an example embodiment of the present disclosure may have a value of R defined by the following [Relational Equation 1] of 2.8 or greater, and more specifically 2.80 or greater.

[Relational Equation 1]

$$R = ([Cr] + [Mn] + [Si]) / ([Cr^*] + [Mn^*] + [Si^*])$$

[0151] In the above [Relational Equation 1], [Cr], [Mn], and [Si] represent a maximum content (wt%) of each element within a range of 0.01 to 1.0 μm in a thickness direction from a surface of the steel sheet in a GDS profile, and [Cr*], [Mn*], and [Si*] represent an average content (wt%) of each element in the steel sheet.

[0152] The above [Relational Equation 1] is an equation that quantitatively expresses how the contents of Cr, Si, and Mn may contribute to the surface quality of the hot formed member. Specifically, by precisely controlling the contents of Cr, Si, and Mn to enrich Cr, Si, and Mn in the surface layer of the steel sheet, the surface quality of the hot formed member may be secured.

[0153] FIG. 1 is a graph showing Cr, Mn, and Si GDS profiles of a steel sheet for hot forming according to an example embodiment of the present disclosure. Specifically, FIG. 1A is a graph illustrating GDS profiles of Cr, Mn, and Si within a region extending from the surface of the steel sheet to 1.2 μm in a thickness direction. In addition, FIG. 1B is a graph that enlarges the region where the maximum contents of Cr, Mn, and Si appear in the GDS profile of FIG. 1A to calculate the value of R defined by [Relational Equation 1].

[0154] Referring to FIG. 1, glow discharge emission spectrometry (GDS) analysis may be performed from the surface of the steel sheet in a depth direction to measure the value of R, defined by [Relational Equation 1]. For example, based on the GDS profile, the maximum contents (in wt%) of Cr, Mn, and Si within a region ranging from 0.01 to 1.0 μm in the thickness direction of the steel sheet may be expressed as [Cr], [Mn], and [Si] in [Relational Equation 1]. Furthermore, for example, the contents (in wt%) of Cr, Mn, and Si contained in a steel slab during the manufacture of each steel sheet may be

expressed as [Cr*], [Mn*], and [Si*].

[0155] When the value of R, defined by [Relational Equation 1], is less than 2.8, a sufficient protective film may not be formed on the surface of the steel sheet, resulting in excessive formation of Fe oxide on the surface of the member during the hot forming process. As a result, the surface quality of the member may be degraded. That is, the value of R may be 2.8 or greater, and more specifically, 2.80 or greater.

[0156] Hereinafter, the microstructure of a steel sheet for hot forming according to an example embodiment of the present disclosure will be described. The microstructure fraction refers to area % unless otherwise specified. Furthermore, the microstructure fraction may be measured by analyzing the matrix at a point 1/4 the thickness of the steel sheet, and specifically, the microstructure fraction may be measured using FE-SEM and optical microscopy.

[0157] For example, the microstructure of the steel sheet for hot forming may include ferrite and cementite. Ferrite is a soft structure that may reduce the load of the steel sheet blanking process when manufacturing the blank for the hot formed member.

[0158] The sum of the area fractions of ferrite and cementite may be 5% or more. When the combined area fraction of ferrite and cementite is less than 5%, as the strength of the steel sheet may increase excessively, there may be a problem in that die wear occurs during manufacturing of the blank. That is, the sum of the area fraction of ferrite and cementite may be 5% or more, more specifically 10% or more, or even 20% or more.

[0159] The steel sheet for hot forming according to an example embodiment of the present disclosure may include the above-described microstructure and pearlite as the remaining microstructure. However, the present disclosure is not limited thereto, and the steel sheet for hot forming may include bainite, martensite, etc. In this case, the fraction of each phase is not particularly limited.

[0160] The steel sheet for hot forming according to an example embodiment of the present disclosure may secure the strength of the steel sheet by controlling the value of R, defined by [Relational Equation 1], to an appropriate value by adjusting the content of the alloy components. For example, the steel sheet for hot forming may have a tensile strength of 500 MPa or higher.

[0161] Hereinafter, a method of manufacturing a steel sheet for hot forming according to an example embodiment of the present disclosure will be described in detail. However, the manufacturing method described below is only an example embodiment among all possible example embodiments, and does not necessarily imply that the steel sheet for hot forming must be manufactured using the manufacturing method described below.

[Slab Heating Operation]

[0162] A slab having the above-described composition may be heated. Heating the slab facilitates the subsequent rolling process and secures sufficient physical properties of the steel sheet. In this case, the composition of the slab is identical to that of the above-described steel sheet, and the reasons for adding and limiting the content of each component in the slab are the same as those described for the above-described steel sheet.

[0163] For example, the heating operation may be performed at 1000 to 1300°C. When the heating temperature is below 1000°C, it may be difficult to homogenize the slab structure. Furthermore, when the heating temperature exceeds 1300°C, oxide may be formed excessively or manufacturing costs may increase. That is, the heating temperature may be 1000 to 1300°C, more specifically 1050 to 1280°C, and even more specifically 1080 to 1270°C.

[Hot-Rolled Steel Sheet Obtaining Operation]

[0164] The slab heated in the above operation may be hot-rolled at a conventional hot rolling temperature to obtain a hot-rolled steel sheet.

[0165] For example, in the operation of obtaining the hot-rolled steel sheet, finish hot rolling of the slab may be performed at a temperature of Ar3 to 1000°C. When the finish rolling temperature is below Ar3, two-phase rolling tends to occur, which may result in the formation of mixed grain structures on the surface and make the shape control of the hot-rolled steel sheet difficult. Furthermore, when the finish rolling temperature exceeds 1000°C, the grains may become coarser. That is, the finish rolling temperature may be Ar3 to 1000°C, more specifically 850 to 980°C, and even more specifically 870 to 960°C.

[Cooling Operation]

[0166] The hot-rolled steel sheet obtained through the above-described process may be cooled. The cooling operation may appropriately secure the microstructure of the steel sheet. For example, the cooling operation may be performed at a cooling rate of 20 to 100°C/s. When the cooling rate is less than 20°C/s, excessive Fe scale may form on the surface of the steel sheet, and the scale may not be sufficiently removed during cold rolling, resulting in poor surface quality of the cold-rolled steel sheet. Furthermore, when the cooling rate exceeds 100°C/s, the strength of the steel sheet may increase excessively, significantly increasing the cold rolling load and degrading cold rollability.

[0167] For example, the cooling operation may cool the hot-rolled steel sheet to the temperature required for the subsequent coiling process. Additionally/alternatively, the cooling method is not specifically limited, but various methods known in the art, such as air cooling or water cooling, may be applied.

[Coiling Operation]

[0168] The hot-rolled steel sheet cooled in the above-described operation may be coiled. For example, the coiling temperature may be between Ms (the onset temperature of martensitic transformation) and 750°C. When the coiling temperature is less than or equal to Ms, the strength of the hot-rolled steel sheet may increase excessively, reducing cold rollability. When the coiling temperature exceeds 750°C, the oxide layer thickness may increase or grain boundary oxidation may occur in the surface layer, resulting in poor pickling properties, in the continuous annealing process, a problem may occur in which grain boundary decohesion is induced at the surface layer.

[Cold-Rolled Steel Sheet Obtaining Operation]

[0169] The hot-rolled steel sheet coiled in the above-described operation may be cold rolled to obtain a cold-rolled steel sheet. While the reduction ratio during cold rolling is not specifically limited, for example, the operation of obtaining the cold-rolled steel sheet may be performed at a reduction ratio of 30 to 80%. When the reduction ratio is less than 30%, it may be difficult to secure the desired thickness. Furthermore, when the reduction ratio exceeds 80%, the risk of cracks occurring at the steel sheet edges increases, or problems associated with rolling loads may arise during the cold rolling process.

[0170] For example, prior to performing the cold rolling, a pickling operation may be additionally included to treat the coiled hot-rolled steel sheet. This pickling process removes the oxide layer formed on the surface of the steel sheet. The method of the pickling process is not particularly limited, and methods commonly used in the art (e.g., immersing the steel sheet into a hydrochloric acid bath, etc.) may be applied.

[Annealing Operation]

[0171] The cold-rolled steel sheet obtained in the above-described operation may be annealed. During the annealing process, steam is supplied to the steel sheet, allowing the alloy components of the steel sheet to react with the steam under a constant dew point and steel sheet temperature. Specifically, the steam in the furnace and the Cr, Mn, and Si of the base metal may form oxides that concentrate on the surface of the steel sheet. For example, by controlling the temperature, dew point temperature, and/or temperature increase rate during the annealing process, the concentration of Cr, Mn, and Si may be precisely controlled, improving the surface quality of members manufactured by hot forming.

[0172] The annealing process may be performed at temperatures ranging from 700°C to 1000°C. When the annealing temperature is below 700°C, the rolled structure generated during the cold rolling process may be difficult to recover and recrystallize. Furthermore, when the annealing temperature exceeds 1000°C, manufacturing costs may increase due to factors such as the degradation in the annealing equipment. That is, the annealing temperature may be 700 to 1000°C, more specifically 710 to 980°C, and even more specifically 720 to 970°C.

[0173] The annealing operation may be performed at a dew point temperature of -30 to 0°C at 700 to 1000°C. By controlling the dew point temperature within the above range, the degree of enrichment of Cr, Mn, and Si in the surface layer may be more precisely controlled. When the dew point temperature is below -30°C, the enrichment of Cr, Mn, and Si is not sufficient, making it difficult to ensure the surface quality of the member manufactured by the hot forming process. Furthermore, when the dew point temperature exceeds 0°C, Fe oxides are formed on the surface of the cold-rolled steel sheet, degrading the surface quality of the steel sheet. As a result, it may be difficult to also ensure the surface quality of the hot-formed member. That is, the dew point temperature at 700 to 1000°C may be -30 to 0°C, more specifically -27 to -5°C, and even more specifically -25 to -7°C.

[0174] For example, in the annealing operation, the temperature may be increased at a first rate of 3.0 to 20.0°C/s in a first temperature range of room temperature to 700°C, and then increased at a second rate of 0.015 to 10.0°C/s in a second temperature range of 700 to 1000°C. Here, room temperature may refer to a temperature region of 15 to 25°C. By differently controlling the temperature increase rates in the first temperature range and the second temperature range, the degree of enrichment of Cr, Mn, and Si in the surface layer may be more precisely controlled.

[0175] When the first rate in the first temperature range is less than 3.0°C/s, the time for the steam in the furnace to come into contact with the base metal becomes longer, which may make it difficult to secure sufficient surface enrichment due to excessive internal oxide formation. In addition, when the first rate exceeds 20.0°C/s, a problem may arise in that sufficient Cr, Mn, and/or Si enrichment in the surface layer is not secured. That is, the first rate may be 3.0 to 20.0°C/s.

[0176] When the second rate in the second temperature range is less than 0.015°C/s, excessive decarburization may occur due to internal oxidation of the surface layer, resulting in unsatisfactory mechanical properties and poor fatigue characteristics. In addition, when the second rate exceeds 10.0°C/s, a problem may arise in that sufficient Cr, Mn, and/or Si

enrichment in the surface layer is not secured. That is, the second rate may be 0.015 to 10.0°C/s.

[0177] For example, the annealing operation may be performed for 1 to 1,000 seconds. When the annealing time is less than 1 second, it may be difficult to sufficiently secure the effects of the annealing process. Furthermore, when the annealing time exceeds 1,000 seconds, productivity may be reduced.

[Pickling Operation]

[0178] The cold-rolled steel sheet annealed in the above-described operation may be pickled. The method of the pickling process is not particularly limited, and methods commonly used in the art (e.g., immersing the steel sheet into a hydrochloric acid bath, etc.) may be applied.

[0179] The pickling operation may be performed for 1 to 10 seconds. When the pickling time exceeds 10 seconds, the Cr, Mn, and/or Si concentrated layer, which is densely concentrated on the surface of the steel sheet after annealing, may be excessively pickled, resulting in poor surface quality during hot forming.

[0180] Hereinafter, the hot formed member according to an example embodiment of the present disclosure will be described in detail. The hot formed member is manufactured by performing hot pressing on one of the above-described steel sheets for hot forming. The alloy composition of the hot formed member may be identical to that of the above-described steel sheet for hot forming. Therefore, the reasons for adding each component of the hot formed member and the reasons for limiting the content thereof are the same as those described for the steel sheet described above.

[0181] The hot formed member according to an example embodiment of the present disclosure may satisfy [Relational Equation 2] below.

$$[\text{Relational Equation 2}]$$

$$Fe_{40\sim80\%} \text{ slope} \geq 200 \ (wt\%/\mu m)$$

[0182] In the above [Relational Equation 2], the $Fe_{40\sim80\%}$ slope represents the slope of the straight line in the region extending from the surface of the member to a thickness of 5μm or less in the GDS profile, where the Fe content (wt%) is 40 to 80%. Furthermore, the slope of the straight line represents a slope derived by performing simple linear regression on a portion of a graph in a GDS profile corresponding to a range in which the Fe content (wt%) is 40 to 80%.

[0183] [Relational Equation 2] is an equation that quantitatively expresses the correlation between the Fe content formed in the surface layer of the member and its surface quality. Specifically, as Fe oxides are excessively formed in the surface layer of a member, the surface quality of the member may be degraded.

[0184] When the $Fe_{40\sim80\%}$ slope is less than 200 wt%/μm, excessive Fe oxide formation on the surface may occur, which may degrade the surface quality of the member. That is, the $Fe_{40\sim80\%}$ slope may be 200 wt%/μm or greater, more specifically 220 wt%/μm or greater, and even more specifically 240 wt%/μm or greater. While there is no need to specifically limit the upper limit of the $Fe_{40\sim80\%}$ slope, as a non-limiting example, the upper limit of the $Fe_{40\sim80\%}$ slope may be 1000 wt%/μm, and more specifically 950 wt%/μm.

[0185] Hereinafter, the microstructure of the hot formed member according to an example embodiment of the present disclosure will be described. The microstructure fraction refers to area % unless otherwise specified. Furthermore, the microstructure fraction may be measured by analyzing the matrix at a point 1/4 the thickness of the steel sheet, and specifically, the microstructure fraction may be measured using the FE-SEM and optical microscopy.

[0186] For example, the microstructure of the hot formed member may include martensite or bainite as the main phase. Here, the main phase may refer to the phase with the largest area fraction among the various phases forming the microstructure. The martensite or bainite may enhance the strength of the member.

[0187] The area fraction of the main phase may be 10% or more. When the area fraction of the main phase is less than 10%, it may be difficult to secure an appropriate level of strength of the member. That is, the area fraction of the main phase may be 10% or more, more specifically 30% or more, or even 40% or more. While there is no need to specifically limit the upper limit of the area fraction of the main phase, as a non-limiting example, the upper limit of the area fraction of the main phase may be 95%, and more specifically 90%.

[0188] The hot formed member according to an example embodiment of the present disclosure may include the above structure and, as the remaining microstructure, ferrite or the like. In this case, the fraction of each phase is not particularly limited.

[0189] The hot formed member according to an example embodiment of the present disclosure may secure the strength of the member by controlling the alloy composition and microstructure fraction. For example, the hot formed member may have a tensile strength of 1000 MPa or higher. Thus, the hot formed member may achieve excellent strength and crash resistance.

[0190] Hereinafter, a method of manufacturing a hot formed member according to an example embodiment of the present disclosure will be described in detail. However, the manufacturing method described below is merely an example

embodiment among all possible example embodiments, and does not necessarily imply that the hot formed member should be manufactured using the manufacturing method described below.

[Blank Preparation Operation]

[0191] A blank may be prepared using the steel sheet for hot forming. Here, the steel sheet for hot forming may be the steel sheet for hot forming according to an example embodiment of the present disclosure, but is not limited thereto.

[0192] For example, the blank manufacturing process is not particularly limited. For example, a method commonly applied in the art, such as manufacturing a blank according to the final shape of the desired member, may be used.

[Heat Treatment Operation]

[0193] The blank prepared in the above-described operations may be heat treated. The heat treatment operation may secure the strength of the hot formed member. Furthermore, by utilizing the steel sheet for hot forming with Cr, Si, and Mn enriched on the surface, the formation of Fe oxide on the blank surface during the heat treatment process may be minimized, thereby securing the surface quality of the member.

[0194] By controlling the heat treatment conditions, such as temperature and duration, during the heat treatment operation, excellent surface quality of the member may be secured even without the shot blasting process. For example, the blank may be heat treated at 700 to 1000°C. When the heat treatment temperature is below 700°C, the presence of untransformed ferrite may make it difficult to secure strength. Furthermore, when the heat treatment temperature exceeds 1000°C, despite the Cr, Si, and Mn enriched on the surface, the Fe oxide may be formed excessively on the member surface, so the surface quality may be degraded. That is, the heat treatment temperature may be 700 to 1000°C, more specifically 800 to 990°C, and even more specifically 810 to 980°C.

[0195] In the heat treatment operation, the blank may be heat treated for 180 to 600 seconds. When the heat treatment time is less than 180 seconds, the blank may not be sufficiently heat treated, making it difficult to secure strength, which may result in degradation of physical properties. Furthermore, when the heat treatment time exceeds 600 seconds, it may be difficult to suppress the formation of Fe oxide on the surface of the member, even though Cr, Si, and Mn are concentrated in the surface layer, which may result in degradation of surface quality after hot forming. That is, the heat treatment time may be 180 to 600 seconds, more specifically 200 to 580 seconds, and even more specifically 240 to 540 seconds.

[0196] For example, in the heat treatment operation, the blank may be heated to the heat treatment temperature at a temperature increase rate of 1 to 1,000°C/s. Here, the temperature increase rate may refer to the temperature increase rate of the furnace atmosphere. When the temperature increase rate is less than 1°C/s, it may be difficult to sufficiently secure productivity. Furthermore, when the temperature increase rate exceeds 1,000°C/s, excessively expensive equipment is required, which may lead to increased manufacturing costs. That is, the temperature increase rate may range from 1 to 1,000°C/s, more specifically from 3 to 500°C/s, and even more specifically from 5 to 300°C/s.

[Hot Forming and Cooling Operation]

[0197] The blank heat-treated in the above operation may be hot formed and then cooled. For example, the hot forming process is not particularly limited, and any method commonly used in the art, such as forming into a desired shape using a die, may be used.

[0198] For example, the cooling operation may be performed to a cooling end temperature lower than or equal to Mf (martensite transformation end temperature). When the cooling end temperature exceeds Mf, it may be difficult to secure the strength of the hot formed member, as re-cooling to room temperature is required after the end of cooling.

[0199] For example, the cooling operation may be performed to the cooling end temperature at a cooling rate of 5 to 1,000°C/s. When the cooling rate is less than 5°C/s, undesirable ferrite and/or pearlite may form, making it difficult to secure the desired tensile strength. Furthermore, when the cooling rate exceeds 1,000°C/s, expensive cooling equipment is required to control the cooling rate, which may degrade productivity. That is, the cooling rate may range from 5 to 1,000°C/s, more specifically from 7 to 950°C/s, and even more specifically from 10 to 900°C/s.

[0200] For example, in the cooling operation, the first cooling may be performed to a temperature between Ms (martensite transformation start temperature) and Mf, followed by reheating to the primary cooling temperature or a temperature higher than or equal to Mf, so the heat treatment may be performed for 1 to 1,000 seconds and the final cooling may be performed to a temperature lower than or equal to Mf.

[0201] Hereinafter, a hot press formed part according to a second aspect of the present disclosure will be described.

[0202] FIG. 7 is a diagram illustrating an example of changes in temperature, microstructure, and tensile strength during hot press forming of a hardenability-improved type material. The hot press formed part according to an example embodiment of the present disclosure is characterized by using a hardenability-improved type material having changes

in temperature, microstructure, and tensile strength during hot press forming, as illustrated in FIG. 7. The hardenability-improved type material has the advantage of achieving an ultra-high strength of 1,300 MPa or higher, and more advantageously, 1,500 MPa or higher, even under relatively slow cooling conditions compared to the conventionally used 22MnB5. Furthermore, when the sheet metal is formed into a part, there is an advantage in that a target material property may be secured even in a thickness-reduced region at a shoulder radius portion having a curvature formed by a product side wall or a die, which is generally generated during the forming process.

[0203] Meanwhile, the hardenability-improved type material may have a martensite transformation critical cooling rate CR_{min} of 15 to 25°C/s in the temperature range of 800 to 400°C. The temperature range of 800 to 400°C is a temperature at which the martensite transformation occurs. The martensite transformation critical cooling rate refers to a cooling rate at which a martensite single-phase structure is obtained, and more specifically, it refers to a cooling rate at which no structures other than martensite are generated within the CCT curve. When the martensite transformation critical cooling rate is as low as described above in the temperature range of 800 to 400°C, it is easy to secure a martensite single-phase structure even at low cooling rates. When the martensite transformation critical cooling rate is less than 15°C/s, there may be disadvantage in that premature transformation may occur due to air cooling during the material transfer stage, making the forming difficult. When the martensite transformation critical cooling rate exceeds 25°C/s, it may be difficult to utilize the blank holding force, so wrinkles in the flange portion may increase.

[0204] Furthermore, the hot press formed part according to an example embodiment of the present disclosure may have a wrinkle depth of the flange portion of 1 mm or less. As such, by controlling the wrinkle depth of the flange portion to 1 mm or less, it is possible to facilitate assembly with other parts. Meanwhile, the flange portion refers to a region secured by the upper die and lower holder, and spot welding may be applied to the flange portion to secure a strong connection with other parts. Furthermore, the wrinkle depth refers to the difference between the lowest and highest points of the wrinkle.

[0205] As described above, the hot press formed part according to an example embodiment of the present disclosure may be applied to parts requiring deep forming depth or controlled material flow. In addition, it is possible to secure ultra-high strength without causing forming defects such as cracks, and since the wrinkle depth formed in the flange portion is also reduced, the improved weldability with other parts may be expected.

[0206] FIG. 8 is a schematic diagram illustrating hot press forming device applicable to the present disclosure. Hereinafter, a method of manufacturing a hot press formed part according to an aspect of the present disclosure will be described with reference to FIG. 8.

[0207] As illustrated in FIG. 8, hot press forming equipment applicable to the present disclosure, i.e., die A-100, may include an upper die A-10; a lower punch A-20 provided on the central lower portion of the upper die; and a lower holder A-30 provided on the lower portion of the upper die A-10 and the side portion of the lower punch A-20. Meanwhile, a cooling channel A-12 for cooling steel may be provided within the upper die A-10. A cooling channel A-22 for cooling steel may also be provided within the lower die A-20. Furthermore, a heating heater A-32 for heating the flange portion of the steel may be provided within the lower holder A-30.

[0208] First, the steel is austenitized. The austenitization is performed to transform the microstructure of the steel into austenite, thereby enabling the subsequent hot press forming process to produce a single-phase martensitic microstructure. In an example embodiment of the present disclosure, the austenizing process is not particularly limited, and any conventional method used in the art may be utilized. However, as an example, the austenizing process may include heating to 850 to 950°C and then maintaining the temperature for 30 to 180 seconds.

[0209] In an example embodiment of the present disclosure, the steel may be the above-described steel sheet for hot forming and may have the above-described alloy composition. Furthermore, the steel may be obtained by the above-described manufacturing method, for example, the above-described cold-rolled steel sheet manufacturing method.

[0210] Thereafter, the austenitized steel A-200 is provided on the lower punch A-20 and the lower holder A-30. The present disclosure does not specifically limit the method of preparing the steel, and any conventional method used in the art may be utilized. However, the steel is a hardenability-improved type material, and its martensite transformation critical cooling rate may be 15 to 25°C/s at a temperature range of 500 to 200°C.

[0211] Thereafter, blank holding force F and heat are applied through the lower holder A-30 to support and heat the steel A-100 between the lower holder A-30 and the upper die A-10. The blank holding force F and heat control the material flow to prevent cracking during forming of the steel into a part, and serve to reduce the wrinkle depth of the flange portion.

[0212] The blank holding force F satisfies [Relational Equation 3] below, and the blank holding pressure P may be 1 to 10 MPa. When the blank holding pressure is less than 1 MPa, the wrinkle suppression effect may not be sufficiently obtained. When the blank holding pressure exceeds 10 MPa, the supercooling by the upper die may occur, leading to cracks in the steel.

$$[\text{Relational Equation 3}]\quad F = P \times A$$

[0213] (Wherein, in [Relational Equation 3], P represents the blank holding pressure, and A represents the contact area between the lower holder and the steel.)

[0214] The heat may be supplied by a heater A-32 provided within the lower holder A-30. For this purpose, the minimum temperature value T_{min} of the lower holder A-30 may be 300°C. This may suppress cracks that may occur due to the temperature difference between the region in contact with the lower holder and the region not in contact. When the temperature of the lower holder A-30 is less than 300°C, cracks in the steel may occur. In addition, the maximum temperature value T_{max} of the lower holder may satisfy [Relational Equation 4] and [Relational Equation 5] below. When the temperature of the lower holder exceeds the maximum temperature value T_{max}, the cooling occurs slower than the critical cooling rate of the material, which may prevent the target material from being obtained.

$$[\text{Relational Equation 4}]\ T_{max} = T_{blank} - [(CR_{min} \cdot w \cdot \rho \cdot C)/h]$$

$$[\text{Relational Equation 5}]\ h = a \cdot P^{b}$$

[0215] (Wherein, in [Relational Equations 4] and [Relational Equation 5], h may represent a heat transfer coefficient between the steel and the lower holder, T_{blank} may represent a forming temperature of the steel, T_{max} may represent a maximum temperature value of the lower holder, w may represent a thickness of the steel, ρ may represent a density of the steel, C may represent the specific heat of the steel, CR_{min} may represent the martensite transformation critical cooling rate, a may represent a heat transfer pressure coefficient of the steel, P may represent the blank holding pressure, and b may represent a heat transfer pressure index of the steel.)

[0216] In this case, the T_{blank} may have a temperature range of 650 to 850°C, the w may have a range of 0.9 to 1.8 mm, the ρ may have a range of 7.5×10^{9} to 8.1×10^{9} ton/mm^3, C is the specific heat of the material and may have a range of 6.3×10^{8} to 8.3×10^{8} mJ/ton K, a may have a range of 2.0 to 2.5, and n may have a range of 0.16 to 0.28.

[0217] Thereafter, the steel is formed by applying pressure through the lower punch and cooled. The present disclosure does not specifically limit the pressure application method or cooling method through the lower punch, and all the conventional methods used in the relevant technical field may be used.

[0218] Meanwhile, the temperature of the remaining dies excluding the lower holder may be 300°C or lower. Through this, the region of the steel that does not come into contact with the lower holder may be cooled faster than the critical internal velocity after forming, thereby securing the ultra-high-strength material. Meanwhile, the present disclosure does not specifically limit the temperature control method of the dies other than the lower holder, and all the conventional methods used in the art may be used. However, for example, a fluid coolant may be continuously supplied to the cooling channel A-12 provided in the upper die A-10 and the cooling channel A-22 provided in the lower punch A-20, the fluid coolant may be continuously brought into direct contact with the steel, or a die with excellent heat transfer performance may be used so that a target cooling rate may be secured without a separate cooling device.

[0219] Hereinafter, a forming device according to a third aspect of the present disclosure and a forming method using the same will be described.

[0220] According to an example embodiment of the present disclosure, there are provided a device and method of forming a bracket having a curved portion and a flange using high-strength steel, and forming a bracket for a battery case formed thereby. This enables the forming of the bracket for a battery case that could not previously be formed using high-strength steel.

[0221] In an example embodiment of the present disclosure, the high-strength steel may be the above-described steel sheet for hot forming and may have the above-described alloy composition. Furthermore, the material may be manufactured using the above-described manufacturing methods.

[0222] FIGS. 12 and 13 illustrate a forming device according to an example embodiment of the present disclosure. Specifically, FIG. 12 illustrates an exploded perspective view of a forming device according to an example embodiment of the present disclosure, and FIG. 13 illustrates a side view of a forming device according to an example embodiment of the present disclosure. In this example embodiment, the forming device is illustrated with a focus on an appearance of a die.

[0223] As illustrated in FIG. 12, the forming device according to an example embodiment of the present disclosure includes: a pad B-200; a die B-300 disposed outside the first direction 2 of the pad B-200; and a punch B-100 disposed on the lower portion of the pad B-200 and including a main body in which first to fifth punch forming portions B-120, B-130, B-140, B-150, and B-160 are formed. Although not illustrated in FIGS. 12 and 13, the forming device according to an example embodiment of the present disclosure is a hot press forming device, in which cooling channels B-170 and B-370 (see FIG. 10) through which cooling water flows are disposed inside the punch B-100 and the die B-300, so that the material may be hardened through heat treatment during or after forming.

[0224] The pad B-200 and die B-300 are connected to the upper die of the press, and the punch B-100 is connected to the lower die of the press, such that the pad B-200 and the die B-300 move in a third direction 4, which is a vertical direction toward the punch B-100, thereby forming the material. Although not illustrated, the pad B-200 and the die B-300 may be configured to move independently or to allow relative movement in the vertical direction. For example, an elastic member is attached to the upper portion of the pad B-200, so that the pad B-200 and the die B-300 move together during the forming

process. After the forming of the pad B-200 is completed, only the die B-300 moves downward relative to the pad (B-200) by the elastic member.

[0225] The punch B-100 is configured to form two brackets simultaneously. Accordingly, the punch B-100 includes two forming portions corresponding to the curved portion of the bracket. Specifically, the punch B-100 includes, when viewed in a first direction 2, a linear first punch forming portion B-110, a curved second punch forming portion B-120 having a radius of curvature Rp of the forming portion, a linear third punch forming portion B-130, a curved fourth forming portion B-140 having the radius of curvature Rp of the forming portion, and a linear fifth punch forming portion B-150 continuously along a second direction 3 perpendicular to the first direction 2 on a horizontal plane, and a support portion B-160 for supporting the material before forming is disposed outside the first forming portion and the fifth forming portion B-150.

[0226] The first and fifth punch forming portions B-110 and B-150 have a structure that is entirely inclined toward the third punch forming portion B-130, the third punch forming portion B-130 has, at a central region thereof, a structure parallel to a horizontal plane, and the second and fourth punch forming portions B-120 and B-140 have a structure that is curved to connect the first and fifth punch forming portions B-110 and B-150 with the third punch forming portion B-130.

[0227] The first and second punch forming portions B-110 and B-120 and the fourth and fifth punch forming portions B-140 and B-150 have a symmetrical structure centered on the third punch forming portion B-130, so one bracket is formed centered on the second punch forming portion B-120, and another bracket is formed centered on the fourth punch forming portion B-140.

[0228] The first punch forming portion B-110 includes a first extended surface forming portion B-111 extending along the third direction 4 to form flanges B-21 and B-23 (see FIG. 11) of a bracket B-20 (see FIG. 10) on both sides of the first direction 2, a first main body forming portion B-113 configured to form a main body B-23 (see FIG. 11) of the bracket B-20 and disposed at a lower portion of the pad B-200, and a first curved surface forming portion B-112 having a bending radius of curvature r between the first extended surface forming portion B-111 and the first main body forming portion B-113.

[0229] The second punch forming portion B-120 and the third punch forming portion B-130 further include second and third extended surface forming portions B-121 and B-131 extending along the third direction 4 to form flanges B-21 and B-22 of the bracket B-20 on both sides in the first direction 2, second and third main body forming portions B-123 and B-133 forming the main body B-23 of the bracket B-20 and disposed at a lower portion of the pad B-200, and second and third curved surface forming portions B-122 and B-132 having the bending radius of curvature r, disposed between the second extended surface forming portion B-121 and the second main body forming portion B-113, and between the third extended surface forming portion B-131 and the third main body forming portion B-133. In this case, the third main body forming portion B-133 and the support portion B-160 may be parallel to the horizontal plane.

[0230] Since the fourth and fifth punch forming portions B-140 and B-150 have a structure symmetrical to the first and second punch forming portions B-110 and B-120, the fourth and fifth punch forming portions B-140 and B-150 also include the fourth and fifth extended surface forming portions B-141 and B-151, the fourth and fifth curved surface forming portions B-142 and B-152, and the fourth and fifth main body forming portions B-143.

[0231] Meanwhile, the pad B-200 includes first to fifth pressing surfaces B-210, B-220, B-230, B-240, and B-250 having shapes corresponding to the first to fifth main body forming portions B-113, B-123, B-133, and B-143 of the punch B-100. The pad B-200 presses the material toward the upper portion of the punch B-100 to primarily form the material to have an overall curved portion. The pad B-200 may have a length from a length corresponding to the third main body forming portion B-133 in the first direction 2 to the third extended surface forming portion B-131.

[0232] The die B-300 has a structure that is disposed on both sides of the first direction of the pad B-200 and forms flanges B-21 and B-22. In this example embodiment, the die B-300 is disposed on both sides to form the flanges B-21 and B-22 formed on both sides of the bracket B-20, but is not limited thereto and may be disposed on only one side. Since the shapes on both sides of the die B-300 are symmetrical with respect to the pad B-200, the description will be given focusing on one side of the die B-300.

[0233] The die B-300 includes, when viewed in the first direction 2, a linear first die forming portion B-310, a curved second die forming portion B-320 having a radius of curvature Rd of the curved die, a linear third die forming portion B-330, a curved fourth die forming portion B-340 having the radius of curvature Rd of the curved die, and a linear fifth die forming portion B-310, corresponding to first to fifth forming portions B-110, B-120, B-130, B-140, and B-150 of the punch B-100. The first to fifth die forming portions B-310, B-320, B-330, B-340, and B-350 are connected via a vertical plane B-360.

[0234] Similar to the punch B-100, the first and second die forming portions B-310 and B-320 and the fourth and fifth die forming portions B-340 and B-350 of the die B-300 have a structure that is symmetrical with respect to the third die forming portion B-330.

[0235] The first die forming portion B-310 is adjacent to the punch B-100 and includes a first die curved surface forming portion B-311 formed as a curved surface in a position relatively close to the punch B-100 in the first direction, and a first flat surface forming portion B-312 formed in a position relatively far from the punch B-100.

[0236] Similarly, the second to fifth die forming portions B-320, B-330, B-340, and B-350 include second to fifth die curved surface forming portions B-321, B-331, B-341, and B-351 and second to fifth flat surface forming portions B-322, B-332, B-342, and B-352. The curved surfaces of the first to fifth die curved surface forming portions B-311, B-321, B-331,

B-341, and B-351 increase in height as they get closer to the punch B-100.

[0237] In this example embodiment, the radius of curvature Rd of the second and fourth die forming portions B-320 and B-340 refers to the radius of curvature at the upper portion B-321a and B-341a closest to the punch B-100 of the second and fourth curved surface forming portions B-321 and B-341 when viewed in the first direction 2.

[0238] As illustrated in FIG. 13, in this example embodiment, when forming the flange, the die B-300 is configured such that the first and fifth die forming portions B-310 and B-350 first come into contact with the material, the third die forming portion B-330 comes into contact next, and the second and fourth die forming portions B-320 and B-340 contact the material last. By performing such sequential forming, stretching/contraction are carried out while the material between the second and fourth die forming portions B-320 and B-340 and the second and fourth punch forming portions B-120 and B-140 is secured, thereby preventing the occurrence of wrinkles or tearing during the forming process.

[0239] Specifically, when the third main body forming portion B-133 and an upper portion B-331a of the third die forming portion B-330 are disposed (a) on the same plane, when viewed in the first direction 2, the first main body forming portion B-113 is disposed (c) above an upper portion B-311a of the first die forming portion B-310, and the second main body forming portion B-123 is disposed (b) below an upper portion B-321a of the second die forming portion B-320. The relationship between the symmetrical fourth and fifth die forming portions B-340 and B-350 and the fourth and fifth main body forming portions B-143 and B-153 is also the same.

[0240] That is, when the third die forming portion B-330 starts forming a flange on the material, the first die forming portion B-310 is already performing flange forming, while the second die forming portion B-320, which is a curved portion, has not yet started forming.

[0241] In this example embodiment, a length lp of the third main body forming portion B-133 is longer than a length ld of the third die forming portion B-330, and the radius of curvature Rp of the curved forming portion of the second main body forming portion B-123 is configured to be smaller than the radius of curvature Rd of the curved die of the second die forming portion B-320, so that the above-described relationship may be achieved.

[0242] Since the radius of curvature Rd of the curved die is formed to be larger than the radius of curvature Rp of the curved forming portion, the center of the radius of curvature Rd of the curved die may be disposed at the center of the second direction 3 of the third die forming portion B-330. As a result, the centers of the radius of curvature Rd of the curved die of the second die forming portion B-320 and the fourth die forming portion B-340 may be disposed at the same position, but are not limited thereto.

[0243] In this case, when viewed in the first direction, the angle θ at which the extension lines of the virtual tangents of both end portions intersect in the fourth punch forming portion B-143 may be 90° or greater, and specifically, may be between 95° and 135°. This also applies to the second punch forming portion B-123.

[0244] Meanwhile, the forming device according to one example embodiment of the present disclosure achieves a structure that is difficult to realize by press forming with conventional high-strength steel of 1200 MPa or higher, by using hot press forming and the above-described structure. The radius of curvature Rp of the curved forming portion and the bending radius of curvature r may satisfy the conditions of $25\ mm \leq Rp\ (mm) + r\ (mm) \leq 30\ mm$.

[0245] As described above, the bracket produced by the forming device may be used in a battery case. However, when the radius of curvature in the battery case is large, a dead space will occur, so the bending radius of curvature r, which is practically permissible for forming a flange in the battery case, is 10 mm or less. Meanwhile, when the bending radius of curvature r is less than 3 mm, it is difficult to perform the forming even with hot press forming steel of 1200 MPa or higher. Even when the radius of curvature r is 3 mm, it is determined whether the forming is possible by the radius of curvature Rp of the curved forming portion. This will be described again while describing the bracket for a battery case.

[0246] FIGS. 14 to 20 illustrate a forming method according to an example embodiment of the present disclosure. FIG. 14 is a flowchart of a forming method according to an example embodiment of the present disclosure, FIG. 15 is a plan view of a material immersed into a forming device according to an example embodiment of the present disclosure, FIG. 16 is a schematic perspective view illustrating a primary forming operation in a forming method according to an example embodiment of the present disclosure, FIGS. 17, 18a, and 18b are schematic perspective view and another perspective view and front view illustrating a secondary forming operation in the forming method according to an example embodiment of the present disclosure, FIG. 19 is a front view illustrating a cooling operation in the forming method according to an example embodiment of the present disclosure, and FIG. 20 is a perspective view illustrating a trimming operation in the forming method according to an example embodiment of the present disclosure.

[0247] Since a forming method according to another aspect of the present disclosure may be performed by the above-described forming device, it will be described with reference to FIG. 12 as well.

[0248] The forming method according to an example embodiment of the present disclosure includes: a material mounting operation (S110) of mounting a heated material B-400 on a punch B-100 having a forming portion and having a length longer in a first direction 2 than the punch B-100; a primary forming operation (S120) of forming the material B-400 into the shapes of the main body forming portions B-113, B-123, B-133, and B-143 of the punch B-100 through the pad B-200 disposed above the punch B-100; a secondary forming operation (S130) of forming the material B-400 to follow the shape of the forming portion of the punch B-100 through the die B-300 disposed outside the pad B-200 in the first direction

2; a cooling operation (S140) of cooling the material to have a martensitic structure by at least one of the punch and the die; and a trimming operation (S150) of cutting the cooled formed product into a bracket shape.

[0249] The material mounting operation (S110) is a operation in which the material is immersed into a forming device and mounted on the punch B-100. In this case, the material is a steel sheet, and the material is mounted on the punch B-100 in an austenitic state, i.e., heated to a temperature higher than AC3, so that structural changes may occur during or after forming. The material may be a hot press forming steel, for example, 22MnB5.

[0250] In an example embodiment of the present disclosure, the material may be the above-described steel sheet for hot forming and may have the above-described alloy composition.

[0251] In addition, in order to form two brackets at once in the present disclosure, the material B-400 includes notches B-410 formed on both sides toward the center of the material in the second direction 3. The notches B-410 concentrate deformation during forming, thereby preventing cracks from occurring in regions other than the notches B-410.

[0252] As illustrated in FIG. 16, the primary forming operation (S120) is a operation in which the material B-400 is formed into a curved shape through a pad B-200 after the material B-400 is secured. The material B-400 is formed by pressing the pad B-200 against the material B-400 above the punch B-100.

[0253] As illustrated in FIGS. 17 to 18a and 18b, the secondary forming operation (S130) is a operation of forming a flange on a curved material through a die B-300, and is a operation of deforming the material by applying pressure to the die B-300 on a portion of the material B-400 that is not in contact with the pad B-200 that is first formed by the pad B-200. In this case, as described in FIG. 13, in the secondary forming operation (S130), the die B-300 sequentially forms the edge portion, the central portion, and the intermediate portion between the center and the edge of the material in the second direction 3, so that the curved portions of the first formed material B-400, that is, the second and fourth punch forming portions B-120 and B-140, are formed last, thereby forming the flange on the material B-400. In this case, the shape of the forming portion of the punch B-100 and die B-300 is described with reference to FIGS. 12 and 13.

[0254] The cooling operation (S140) is a operation of cooling the material B-400 during or after forming, and cools the material B-400 having an austenitic structure by circulating a cooling fluid through a cooling channel B-170 and B-370 formed in at least one of the punch and the die, thereby transforming the austenitic structure into the martensitic structure. As a result, the material B-400 is formed into a high-strength steel having a tensile strength of 1200 MPa or higher. In this example embodiment, the cooling channels B-170 and B-370 are formed in both the punch B-100 and the die B-300. When the austenitic structure may be transformed into a martensitic structure, the cooling channels B-170 and B-370 may be provided in only one of the punch B-100 and the die B-300. In addition, if necessary, the cooling channels B-170 and B-370 may also be provided in the pad B-200.

[0255] After the cooling operation (S140) is completed, the trimming operation (S150) is performed, cutting the formed material B-400 along a cutting line B-420 to leave only the portions corresponding to the two brackets. The two brackets are cut around the second and fourth punch forming portions B-120 and B-140 of the punch B-100.

[0256] The forming method according to an example embodiment of the present disclosure enables forming a bracket with a curved portion and a flange from high-strength steel. Furthermore, by applying the hot press forming process, springback occurring during forming of a high-strength steel may be prevented, and forming defects caused by the flange forming in the curved portion, such as wrinkles or thickness thinning, may be suppressed.

[0257] FIG. 21 is a perspective view of a bracket manufactured by the forming method according to an example embodiment of the present disclosure.

[0258] A bracket B-20 of FIG. 21 has a main body B-23 and flanges B-21 and B-22, and is curved overall with a radius of curvature Rp of the curved forming portion. In this case, flanges B-21 and B-22 are connected to the main body B-23 by a curved surface B-24 bent with the bending radius of curvature r. The surface formed with the radius of curvature Rp of the curved forming portion in the main body B-23, the flanges B-21 and B-22 of the bracket B-20, and the curved surface B-24 therebetween may be called a forming surface.

[0259] FIG. 22 illustrates a distribution diagram of a thickness reduction ratio of a formed product manufactured using the forming method according to an example embodiment of the present disclosure (Embodiment 1-1), FIG. 23 illustrates a distribution diagram of a thickness reduction ratio of Comparative Example 1-1 manufactured using a different forming method, and FIG. 24 illustrates a distribution graph of the thickness reduction ratio in cross-sections of the formed products of FIGS. 22 and 23.

[0260] The distribution diagram of the thickness reduction ratio illustrates how the thickness of the material B-400 (see FIG. 15) changes after forming. The thickness reduction ratio is a value obtained by subtracting the thickness of the corresponding position of the bracket B-20 from the initial thickness tini of the material B-400 and dividing the value by the initial thickness tini. A positive value indicates a reduced thickness, whereas a negative value indicates an increased thickness.

[0261] The example embodiment of FIG. 22 was manufactured using the forming device of FIG. 12. A material heated to have a martensitic structure from 22MnB5 steel was supplied, and a cooling rate was adjusted, such that the bracket had a tensile strength of 1500 MPa. In this case, the thickness of the material was 1.2 t, the bending radius of curvature r was 5 mm, and the radius of curvature Rp of the curved forming portion was 22 mm.

[0262] As illustrated in FIGS. 22 and 24, the thickness of the main body B-23 in the bracket B-20 is not different from the initial thickness tini, so the average thickness tav of the main body B-23 of bracket B-20 may be regarded as the initial thickness tini of the material B-400. The value obtained by subtracting the thickness of each position from the average thickness tav of the main body B-23 and dividing the value by the average thickness tav may be regarded as the thickness reduction ratio.

[0263] Comparative Example 1-1 was formed using the same forming device using a mat steel having a tensile strength of 1500MPa.

[0264] As illustrated in FIG. 24, when manufacturing the bracket using the forming device and the forming method according to an example embodiment of the present disclosure (Embodiment 1-1), it may be seen that the maximum thickness reduction ratio, i.e., the thickness reduction ratio at the portion with the minimum thickness value T_{min} does not exceed 0.2, but, in Comparative Example 1-1, the thickness reduction ratio at the thinnest portion exceeds 0.2. When the thickness reduction ratio exceeds 0.2, a height difference occurs between the flanges B-21 and B-22, which may degrade the sealing performance of the battery case when manufactured.

[0265] Furthermore, as illustrated in FIG. 24, even when the bracket is curved and elongation is dominant, shrinkage may occur in certain portions. When buckling occurs, this shrinkage may result in damage to the material. In the case of the bracket formed using the forming method according to an example embodiment of the present disclosure, even at a location of the maximum thickness T_{max} on the curved surface, a thickness reduction ratio of -0.3 or less did not occur, and thus it was confirmed that the stable forming was achieved even in the curved portion.

[0266] However, in the case of Comparative Example 1-1, a thickness reduction ratio of -0.8 occurred at the maximum thickness T_{max} position, and thus, it may be seen that buckling has occurred in that area. Such buckling may lead to cracking, thereby degrading the structural performance of the battery case and allowing water to infiltrate through the affected portion, such that the bracket such as that of Comparative Example 1-1 may not be applied to the battery case. To maintain sealing properties, it is advantageous to maintain a thickness reduction ratio of -0.4 or greater even in the curved portion.

[0267] Meanwhile, the forming was possible only when a sum of the radius of curvature Rp of the curved forming portion and the bending radius of curvature r was 25 mm or more. However, when the bending radius of curvature r was less than 3 mm, it was difficult to form a bracket applicable to a battery case even with the forming device and method according to an example embodiment of the present disclosure. Even when the flange forming was possible because the bending radius of curvature r was 3 mm, the forming was not properly performed at the curved portion flange when the radius of curvature Rp of the curved forming portion was less than 22 mm. Meanwhile, when the bending radius of curvature r and the radius of curvature Rp of the curved forming portion increased, forming itself was not difficult; however, the increased radius of curvature in the battery case resulted in dead space, making the battery case impractical. Therefore, it is preferable that the sum of the radius of curvature Rp of the curved forming portion and the bending radius of curvature r is 30 mm or less for the bracket applicable to the battery case.

[0268] In addition, in the bracket B-20, the angle θ at which the extension lines of the virtual contacts intersect at both end portions of the forming surface may be between 95 and 135°. When the angle θ is less than 95°, the forming is not performed properly even when the conditions of the radius of curvature Rp of the curved forming portion and the bending radius of curvature r are satisfied. When the angle θ exceeds 135°, the battery case should be configured to have an angle corresponding to a polygon with more than eight sides, resulting in dead space in which the generally rectangular battery cells may not be accommodated, thereby making the battery case impractical.

[0269] Meanwhile, FIG. 25 illustrates a side view illustrating the forming method of Comparative Example 1-2, and FIG. 26 illustrates a perspective view of the formed product manufactured using the forming method of Comparative Example 1-2.

[0270] The forming method of FIG. 25 follows the same sequence as the forming method of the present disclosure. However, in the secondary forming operation (S130), the flange forming is performed using the die B-300 configured such that the forming is performed in an order of a central portion-curved portion-edge in the second direction 3, rather than in an order of an edge-central portion-curved portion. In Comparative Example 1-2, the die B-300 is configured such that the center is at a lowest position B-301a, and the forming is sequentially performed outward.

[0271] Even when the hot press forming process is applied in the same manner, forming in this way results in the occurrence of a folded region B, as illustrated in FIG. 26, thereby producing a bracket that cannot be used as a battery case.

[0272] While the above description focuses on example embodiments of the present disclosure, it should be understood that the present disclosure is not limited thereto and may be implemented in various ways.

[0273] Hereinafter, a hot press formed part according to a fourth aspect of the present disclosure will be described.

[0274] FIG. 27 is a perspective view of a formed part according to an example embodiment of the present disclosure, and FIG. 28 is a front view of a formed part according to an example embodiment of the present disclosure.

[0275] The hot press formed part according to an example embodiment of the present disclosure includes a first wall C-110 extending in a first direction (Y direction) and a second wall C-120 extending in a direction intersecting the first wall C-110, a curved portion C-160 is formed between the first wall C-110 and the second wall C-120, and an angle between an

arbitrary line perpendicular to the first direction (a line parallel to the Z direction) and the second wall C-120 is 0° or more and 5° or less, and the first wall C-110, the second wall C-120, and the curved portion C-160 are formed integrally.

[0276] A hot press formed part according to an example embodiment of the present disclosure includes a first wall C-110, a second wall C-120, and a curved portion C-160 disposed between the first wall C-110 and the second wall C-120. The first wall C-110, the curved portion C-160, and the second wall C-120 are formed integrally and sequentially.

[0277] The hot press formed part is integrally formed to include the first wall C-110 formed parallel to the first direction, the curved portion C-160 bent from the first wall C-110, and the second wall C-120 connected to one end of the curved portion C-160.

[0278] Assuming an arbitrary line perpendicular to the first direction, the second wall C-120 may form an angle of 0° to 5° with the arbitrary line.

[0279] To meet the demands for the weight reduction and improved safety of the vehicle, many parts are being produced using high-strength steel. However, high-strength steel suffers from difficulties in producing parts having a small radius of curvature due to its poor bendability.

[0280] The hot press forming method is a processing method in which a blank is heated, the heated blank is formed into a desired shape through press forming, and then cooled while the die is kept closed, thereby manufacturing high-strength formed parts. As such a hot press forming method, when a hot press forming method performing forming at high temperature is employed, the hot press forming method may form even parts with a small radius of curvature without cracks due to excellent elongation of over 50% at high temperatures thereof where the forming is performed, thereby making it possible to secure the shape of formed parts that may not be achieved with cold ultra-high strength.

[0281] An example embodiment of the present disclosure relates to a formed part C-10 formed integrally, including the first wall C-110, the curved portion C-160, and the second wall C-120, through the hot press forming method, in which the second wall C-120 has a smaller angle with respect to the arbitrary line, that is, 0° to 5°, compared to a conventional one. Therefore, the first wall C-110 and the second wall C-120 have a shape close to a right angle, thereby securing the efficient use of the space enclosed by the first wall C-110 and the second wall C-120.

[0282] According to an example embodiment of the present disclosure, the first wall C-110, the second wall C-120, and the curved portion C-160 may be integrally formed by processing the sheet metal.

[0283] The first wall C-110, the curved portion C-160, and the second wall C-120 may be formed integrally using a hot press forming method using a single sheet metal or a sheet metal blank formed by joining a plurality of sheet metals in the thickness direction. By being integrally formed through hot press forming, processing is facilitated, and it is possible to manufacture the formed part C-10 having a relatively high tensile strength while preventing processing-related problems or damage due to stress concentration at joining portions such as welds.

[0284] In an example embodiment of the present disclosure, the steel metal may be the above-described steel sheet for hot forming and may have the above-described alloy composition.

[0285] According to an example embodiment of the present disclosure, the radius of curvature r of the curved portion C-160 may be greater than or equal to 0.5 mm, and the limit bending r/t, which is the ratio of the thickness t of the sheet metal to the radius of curvature r, may be formed to be less than 2.5.

[0286] The ratio r/t of the radius of curvature r to the thickness t of the sheet metal before processing is generally determined by the limit bending value of the raw material. The limit bending may be viewed as a numerical value representing the maximum radius of curvature without lag, expressed in terms of the material thickness. Since the thickness t of the sheet metal is typically set before processing, when the radius of curvature becomes smaller than a ratio (r/t) that may be formed in the sheet metal, cracks may occur in the formed part C-10.

[0287] According to an example embodiment of the present disclosure, the ratio r/t of the radius of curvature r to the thickness t of the sheet metal may be less than 2.5. In comparison, the limit bending value of the existing ultra-high-strength materials with a tensile strength of 1500 MPa is known to be 2.5 or greater. For example, this means that the minimum radius of curvature for a part that may be formed with a 1.0 mm thick material to a 1500 MPa ultra-high-strength material is 2.5 or greater. However, according to the present disclosure, even when forming with ultra-high strength, the ratio r/t may have a value less than 2.5, so that even with an ultra-high strength material having a tensile strength of 1500 MPa, a product having a ratio r/t of less than 2.5 may be formed. Therefore, the formed part according to an example embodiment of the present disclosure may be a part having excellent formability and high space utilization. According to an example embodiment of the present disclosure, the formed part includes a third wall C-130 and a fourth wall C-140 parallel to the first direction and a fifth wall C-150 connected to the third wall C-130 and the fourth wall C-140, and the third wall C-130 extends from the second wall C-120 and the first wall C-110 to the fifth wall C-150 may be formed integrally.

[0288] The hot press forming process allows the simultaneous formation of a hat-shaped, multi-walled shape, resulting in excellent formability.

[0289] For example, the third wall C-130 and the fourth wall C-140 parallel to the first direction may be formed. The first wall C-110 and the fourth wall C-140 may have the same height in a direction perpendicular to the first direction, but this is not limited thereto. Furthermore, the third wall C-130 may have different heights. The fifth wall may be disposed between the third wall C-130 and the fourth wall C-140, the second wall C-120 and the third wall C-130 may be connected by a first

connection portion C-170, the third wall C-130 and the fifth wall C-150 may be connected by a second connection portion C-180, and the fifth wall C-150 and the fourth wall C-140 may be connected by a third connection portion C-190. Accordingly, the first to fifth walls C-150 and the curved portion C-160 and the first connection portion C-170 to the third connection portion C-190 may be integrally formed by processing the sheet metal.

[0290] Here, the first connecting portion C-170 to the third connecting portion C-190 may be formed into a shape having a curvature radius, similar to the curved portion C-160. The curvature radius may have all the characteristics of the curved portion C-160 of the first wall C-110 and the second wall C-120. However, the present disclosure is not limited to this shape.

[0291] According to an example embodiment of the present disclosure, the formed part may have a tensile strength of 1300 to 2100 MPa.

[0292] Tensile strength, which is referred to as ultra-high strength, is typically around 1500 MPa. According to the present disclosure, the formed part having a tensile strength of 1300 to 2100 MPa, which may be considered the high strength or ultra-high strength, may be manufactured. Because the formability is enhanced by the hot press forming, the formed part according to an example embodiment of the present disclosure may be integrally manufactured and may be manufactured with a relatively small radius of curvature while still possessing the ultra-high tensile strength.

[0293] Furthermore, by utilizing the excellent formability at high temperatures for hot press forming at 1800 MPa and 2000 MPa, parts with a small radius of curvature may be formed. Therefore, according to the present disclosure, a formed part with a small radius of curvature may be manufactured with a tensile strength of 1700 to 1900 MPa, or even 1900 to 2100 MPa.

[0294] Furthermore, the microstructure of the formed part C-10 may contain martensite with an area fraction of 98% or more. The formed part C-10 according to the present disclosure is formed of martensite, a high-strength hard phase, which occupies the majority of the area fraction, thereby enabling the formation of the above-described ultra-high tensile strength.

[0295] For example, the formed part C-10 may be formed with an area fraction of 98% or more of martensite, and may also include trace amounts of phases such as ferrite or bainite.

[0296] According to an example embodiment of the present disclosure, the formed part C-10 further includes the third wall C-130 which is parallel to the first direction and connected to the second wall C-120. When the length from the first wall C-110 to the third wall C-130 in a direction perpendicular to the first direction is defined as a wall height hw, and the angle between an arbitrary line perpendicular to the first direction and the second wall C-120 is defined as a wall angle θw, the following [Relational Equation 6] may be satisfied.

[Relational Equation 6]

$$hw \leq 13.4 * \theta w + 182.4$$

[0297] Here, the unit of hw is mm, the unit of θw is degree, and the left and right sides are calculated as dimensionless.

[0298] The formed parts that satisfy [Relational Equation 6] above and are processed by hot press forming may be manufactured with excellent quality without defects such as cracks.

[0299] Referring to Table 1 below, it may be seen that, when the above equation is satisfied, formability is excellent.

[Table 1]

Division	θw (°)	hw(mm)	Calculate d value on right side	Whether to satisfy [Relation al Equation 6]	Formabili ty
Inventive Example 2-1	0	180	182.4	Satisfactory	Acceptable
Inventive Example 2-2	1	190	195.8	Satisfact ory	Acceptabl e
Inventive Example 2-3	3	220	222.6	Satisfact ory	Acceptabl e
Inventive Example 2-4	5	240	249.4	Satisfact ory	Acceptabl e
Comparati ve Example 2-1	0	190	182.4	Unsatisfa ctory	Unaccepta ble
Comparati ve Example 2-2	1	200	195.8	Unsatisfa ctory	Unaccepta ble
Comparati ve Example 2-3	3	230	222.6	Unsatisfa ctory	Unaccepta ble
Comparati ve Example 2-4	5	260	249.4	Unsatisfa ctory	Unaccepta ble

[0300] Comparative Examples 2-1 to 2-4 were formed identically to Inventive Examples 2-1 to 2-4, except for the wall heights indicated above. However, Comparative Examples exhibited problems with formability, such as cracks, as a result

of forming.

[0301] FIG. 29a is a diagram interpreted under the same conditions as Inventive Example 2-1, and FIG. 29b is a diagram interpreted under the conditions of Comparative Example 2-1. Comparing FIGS. 29a and 29b, it may be seen that in Comparative Example 2-1, cracks marked in red occurred in the upper portion of the second wall C-120 or the fifth wall C-150, and some areas were interpreted as being at risk of the occurrence of cracks, marked in yellow.

[0302] FIG. 30a is a diagram interpreted under the same conditions as Inventive Example 2-3, and FIG. 30b is a diagram interpreted under the conditions of Comparative Example 2-3. Comparing FIGS. 30a and 30b, it may be seen that in Comparative Example 2-3, cracks marked in red occurred in the lower portion of the second wall C-120 or the fifth wall C-150, and some areas were interpreted as being at risk of the occurrence of cracks, marked in yellow. In contrast, Inventive Example 2-3 has some areas at risk of the occurrence of cracks, marked in yellow, but no cracks occur.

[0303] Hereinafter, a battery pack module according to another aspect of the present disclosure will be described.

[0304] The following battery pack module includes the formed part described above, and the description of the formed part shall be incorporated by reference to the foregoing.

[0305] FIG. 31 is a diagram illustrating a battery pack module according to an example embodiment of the present disclosure, and FIG. 32 is a cross-sectional view of a portion of the battery pack module to illustrate space utilization when the battery pack is disposed, in which FIG. 32(a) illustrates a case in which the hot press forming part has a small radius of curvature, and FIG. 32(b) illustrates a case in which the radius of curvature is larger than that of FIG. 32(a).

[0306] The battery pack module C-1 according to an example embodiment of the present disclosure includes a battery case C-20 formed to surround a battery pack, a base C-30 disposed on the lower portion of the battery case C-20 and connected to the battery case C-20 to form a space where the battery pack is disposed, and a hot press forming part C-10 disposed across the interior of the battery case C-20 and connected to the battery case C-20 and the base C-30.

[0307] The battery case C-20 is formed to surround the side of the battery pack, and the base C-30 is formed of general sheet metal or, as necessary, has a curved or grooved structure in which the battery pack is mounted.

[0308] For example, a reinforcing member C-40 may be further included to prevent collisions and be coupled to the outer surface of the battery case C-20.

[0309] For example, the hot press formed part C-10 serves as a cross member to reinforce the rigidity of the battery frame and may be disposed inside the battery case C-20 to protect against impacts from collisions.

[0310] For example, a plurality of hot press formed parts C-10 may be disposed at regular intervals within the battery case C-20.

[0311] The battery pack is disposed in the space formed between the base C-30, the battery case C-20, and the cross member. The battery pack module C-1, including the battery pack, securely positions the battery within the vehicle body.

[0312] The battery pack is formed with a smaller radius of curvature than conventional parts and features a high tensile strength formed part, thereby increasing the rigidity of the battery pack module C-1. As a result, it is possible to prevent fires and other damage to the battery due to impact.

[0313] In addition, since a plurality of cross members are generally provided within the battery case C-20, the size of the battery pack may increase according to the benefit of increased space utilization, and therefore, when the battery pack module C-1 has the same volume, it is possible to increase the battery capacity.

[0314] As an example of use as a cross member, when a radius of curvature r2 of a lower end portion of a hot press formed part C-10b according to Embodiment 2-2 shown in FIG. 32(b) is formed to be larger than a radius of curvature r1 of a lower end portion of a hot press formed part C-10a according to Embodiment 2-1 shown in FIG. 32(a), it can be identified by comparing gaps corresponding to spaces remaining after a battery pack b is disposed. It may be seen that a gap g2 of FIG. 32(b) is formed to be larger than a gap g1 of FIG. 32(a), and as the radius of curvature r increases, the space that may not be used for mounting the battery pack (b) becomes larger.

[0315] As the radius of curvature r decreases, the space utilization increases, which may be seen to have greater utility when the plurality of cross members are mounted within the same battery pack module C-1.

[0316] Hereinafter, a hot press formed part according to a fifth aspect of the present disclosure will be described.

[0317] FIG. 33 is a perspective view illustrating a press formed part according to an example embodiment of the present disclosure; FIG. 34 is a perspective view illustrating a press formed part according to another example embodiment of the present disclosure; FIG. 35(a) is a graph illustrating the relationship between a preset length and a preset height of the press formed part according to an example embodiment of the present disclosure; and FIG. 35(b) is a graph illustrating the relationship between a preset length and a preset height of the press formed part according to another example embodiment of the present disclosure; FIG. 36(a) is an example illustrating deformation force applied to a press formed part manufactured using the conventional manufacturing method; and FIG. 36(b) is an example illustrating deformation force applied to a press formed part manufactured using a manufacturing method according to example embodiments of the present disclosure.

[0318] Referring to FIGS. 33 and 34, press formed parts D-10 and D-10' according to example embodiments of the present disclosure may be manufactured by performing the press forming on the metal sheet. In this case, the press formed parts D-10 and D-10' may be manufactured using the hot press forming method.

[0319] The press formed parts D-10 and D-10' may include a flat plate portion D-110, which is a portion that has not been press formed and thus has a flat shape, and a deformation portion D-120, which is a portion that has a shape that is convex in one direction due to the press forming. In this case, the deformation portion D-120 may be formed in multiple pieces. In this case, the flat plate portion D-110 may be disposed between a plurality of deformation portions D-120.

[0320] The deformation portion D-120 may have a shape that protrudes upward +Z based on the drawing. Here, the deformation portion D-120 may include a top plate portion D-121, a longitudinal wall portion D-122, and a boundary portion D-123.

[0321] The top plate portion D-121 may be an upper end portion of the deformation portion D-120 extending in a first direction. Here, the first direction may be, for example, a direction parallel to the longitudinal direction Y of press formed parts D-10 and D-10'.

[0322] The longitudinal wall portion D-122 may be a side wall portion of the deformation portion D-120 extending in a second direction. Here, the second direction may be a direction different from the first direction. For example, the second direction may be a direction inclined at a predetermined angle with respect to the first direction. As another example, the second direction may be a direction perpendicular to the first direction, that is, a direction parallel to the vertical direction Z in the drawing. Meanwhile, the vertical direction Z may be parallel to the height direction of deformation portion D-120.

[0323] The longitudinal wall portion D-122 may be continuous with the top plate portion D-121. More specifically, the upper end of the longitudinal wall portion D-122 may be disposed to be continuous with one side end of the top plate portion D-121. A pair of such longitudinal wall portions D-122 may be provided. The pair of longitudinal wall portions D-122 may be disposed to be continuous with both side ends of the top plate portion D-121, respectively, to form both side wall portions of the deformation portion D-120.

[0324] A portion (hereinafter, "shoulder portion") D-121a, where the side end of the top plate portion D-121 and the upper end of the longitudinal wall portion D-122 are connected, may have a rounded shape having a first radius of curvature. In this case, the shoulder portion D-121a may be convexly curved outward from the deformation portion D-120.

[0325] A boundary portion D-123 may be a boundary between the deformation portion D-120 and the flat plate portion D-110, which are continuous along the longitudinal direction Y of the press formed parts D-10 and D-10'. One end of the boundary portion D-123 may be continuous with the lower end of the longitudinal wall portion D-122, and the other end of the boundary portion D-123 may be continuous with one end of the flat plate portion D-110. In this case, the other end of the flat plate portion D-110 may be continuous with the boundary portion D-123 provided on another deformation portion D-120. A pair of such boundary portions D-123 may be provided and disposed to be continuous with the lower ends of the pair of longitudinal wall portions D-122, respectively.

[0326] The boundary portion D-123 may be rounded with a second radius of curvature. The boundary portion D-123 may be concavely curved inwardly of the deformation portion D-120. In this case, the second radius of curvature may be equal to or similar to the first radius of curvature.

[0327] As described above, the deformation portion D-120 may have a shape in which the boundary portion D-123, the longitudinal wall portion D-122, the top plate portion D-121, the longitudinal wall portion D-122, and the boundary portion D-123 are sequentially connected along the longitudinal direction Y. Accordingly, the deformation portion D-120 may have a hat shape or a similar shape.

[0328] As described above, the plurality of deformation portions D-120 may be provided. More specifically, at least three deformation portions D-120 may be provided. In this case, a flat plate portion D-110 may be disposed between two adjacent deformation portions D-120 among the plurality of deformation portions D-120. In this case, the two adjacent deformation portions D-120 may be connected by the flat plate portion D-110 disposed at their center.

[0329] Accordingly, the press formed parts D-10 and D-10' may have a form in which three or more deformation portions D-120 and a plurality of flat plate portions D-110 are alternately disposed in a row along the longitudinal direction Y. In this case, the flat plate portions D-110 may be disposed on both outer sides of the press formed parts D-10 and D-10' based on the longitudinal direction Y, but is not limited thereto.

[0330] The deformation portion D-120 may be formed to a preset height h. Here, the preset height h refers to the height of the deformation portion D-120, and may refer to the length from the lower surface of the flat plate portion D-110 to the upper surface of the top plate portion D-121.

[0331] Two adjacent deformation portions D-120 may be spaced apart by a preset length w along the longitudinal direction Y. Here, the preset length w may refer to the length of the flat plate portion D-110 measured relative to the longitudinal direction Y. Here, the preset length w may be measured relative to the flat plate portion D-110 disposed between two adjacent deformation portions D-120.

[0332] As illustrated in FIG. 33, a press formed part D-10 according to an example embodiment of the present disclosure (hereinafter, Embodiment 3-1) may include three deformation portions D-120. Accordingly, the press formed part D-10 of Embodiment 3-1 may include at least two flat plate portions D-110, which are disposed between three deformation portions D-120.

[0333] As illustrated in FIG. 34, the press formed part D-10' according to another example embodiment of the present disclosure (hereinafter, Embodiment 3-2) may include four or more deformation portions D-120. Accordingly, the press

formed part D-10 of Embodiment 1 may include at least three flat plate portions D-110, which are disposed between four or more deformation portions D-120.

[0334] Meanwhile, the drawing only illustrates a case in which the press formed part D-10' has four deformation portions D-120, but the present disclosure is not limited thereto. Although not illustrated in the drawing, as another example, five or more deformation portions D-120 may be formed in the press formed part D-10', and in this case, the upper limit of the number of deformation portions D-120 is not limited.

[0335] Referring to FIGS. 35 and 36, in the case of the conventional hot press forming method, the deformation portion D-120 is first formed, and then a separate flat metal sheet is bonded to the lower end of the formed deformation portion D-120. In this case, as the number of deformation portions D-120 to be formed increases, as exemplarily illustrated in FIG. 36 (a), the force (deformation force) (stress) is concentrated on the longitudinal wall portion D-122 and its surrounding area [A1 and B1 in FIG. 36(a)] to which the flat metal sheets are connected during the manufacturing process. This presents a disadvantage in that cracks, etc., may occur in the deformation portion D-120 of the press formed part, resulting in damage. To prevent this, the distance between the connected deformation portions D-120 should increase. However, since the sizes of the press formed parts D-10 and D-10' being manufactured are inevitably limited, there is a problem in that the number of deformation portions D-120 that may be included is also limited.

[0336] Therefore, an example embodiment of the present disclosure provides the press formed parts D-10 and D-10' that may prevent damage to the deformation portions D-120 due to the hot press forming by utilizing the relationship between the height (preset height) h of the deformation portion D-120 and the separation distance (preset length) w between two adjacent deformation portions D-120. In this case, the "relationship between the preset height h and the preset length w" may be determined based on the number of deformation portions D-120 formed in the press formed parts D-10 and D-10'.

[0337] In the case of the press formed part D-10 according to Embodiment 3-1 of the present disclosure, since three deformation portions D-120 are formed, the relationship between the "preset height h" of the deformation portion D-120 and the "preset length w" by which two adjacent deformation portions D-120 are spaced apart may be defined by [Relational Equation 7] below.

$$w_{min} \leq w \leq 114.85e^{0.0455h} \quad \text{... [Relational Equation 7]}$$

[0338] Here, w may refer to the preset length of Embodiment 3-1, and h may refer to the preset height of Embodiment 3-1. Furthermore, w_{min} may refer to the minimum value (i.e., minimum gap) of the preset length w of Embodiment 3-1.

[0339] As illustrated in the graph of FIGS. 35(a) and 36(b), when the distance (preset length) w between the three deformation portions D-120 included in the press formed part D-10 is designed to satisfy [Relational Equation 7], the occurrence of damage such as cracks in the deformation portion D-120 and its surroundings [A2 and B2 in FIG. 36 (b)] during the hot press forming process may be minimized. In this case, the method of manufacturing a press formed part D-10 according to Embodiment 3-1 will be described in detail below.

[0340] In addition, in the case of the press formed part D-10 according to Embodiment 3-2 of the present disclosure, since four or more deformation portions D-120 are formed, the relationship between the "preset height h" of the deformation portion D-120 and the "preset length w" by which two adjacent deformation portions D-120 are spaced apart may be defined by [Relational Equation 8] below.

$$w_{min} \leq w \leq 46.309e^{0.105h} \quad \text{... [Relational Equation 8]}$$

[0341] Here, w may refer to the preset length of Embodiment 3-2, and h may refer to the preset height of Embodiment 3-2. Furthermore, w_{min} may denote the minimum value of the preset length of Embodiment 3-2.

[0342] As illustrated in the graph of FIGS. 35(b) and 36(b), when the distance (preset length) w between the three deformation portions D-120 included in the press formed part D-10 is designed to satisfy [Relational Equation 8], the occurrence of damage such as cracks in the deformation portion D-120 and its surroundings [A2 and B2 in FIG. 36 (b)] during the hot press forming process may be minimized. In this case, the method of manufacturing a press formed part D-10 according to Embodiment 3-1 will be described in detail below.

[0343] Meanwhile, in the above-described Embodiments 3-1 and 3-2, the preset length w may be 20 mm or more. That is, the minimum gap w_{min} between two adjacent deformation portions D-120 may be 20 mm. This may be the minimum gap required to secure a space for disposing cooling holes (not illustrated) between the first pressing units D-210 provided in the dies D-200 and D-400 and/or between the second pressing unit D-410 and the intermediate pressing unit D-300 in the manufacturing devices D-20 and D-20' of the press formed parts D-10 and D-10' to be described later.

[0344] FIG. 37 is a flowchart illustrating a method of manufacturing a press formed part according to an example embodiment of the present disclosure; FIG. 38 schematically illustrates a first operation of manufacturing the press formed part of FIG. 33; FIG. 39 is a diagram schematically illustrating a second operation of manufacturing the press formed part of

FIG. 33; FIG. 40 is a diagram schematically illustrating a third operation of manufacturing the press formed part of FIG. 33; and FIG. 41 is a diagram schematically illustrating a fourth operation of manufacturing the press formed part of FIG. 33.

[0345] Referring to FIGS. 37 to 41, the manufacturing device D-20 for manufacturing the press formed part D-10 according to Embodiment 3-1 may include the first die D-200, the intermediate pressing unit D-300, and the second die D-400. In this case, one intermediate pressing unit D-300 may be provided. In this case, based on the vertical direction Z, the first die D-200 may be the upper die, and the second die D-400 may be the lower die.

[0346] The first die D-200 and the second die D-400 may be disposed to face each other along the pressing direction - Z. The first die D-200 may be disposed above the second die D-400. In this case, the first die D-200 may be installed on an upper support (not illustrated) that may be elevated. Accordingly, the first die D-200 may descend toward the second die D-400 or ascend away from the second die D-400. In addition, the second die D-400 may be disposed on a lower support (not illustrated) that is fixedly installed on the floor surface of a building where the manufacturing device D-20 is installed, for example.

[0347] The first die D-200 may be provided with a first pressing unit D-210. The first pressing unit D-210 may pressurize an upper surface portion of a metal sheet during press forming. Here, the metal sheet may be a material used to manufacture the press formed part D-10. Before the press forming, the metal sheet may have, for example, a flat upper surface portion and a flat lower surface portion. In this case, the first pressing unit D-210 may be configured to have a shape and size corresponding to the "upper surface of the deformation portion D-120 of the press formed part D-10" described above.

[0348] The manufacturing device D-20 is for manufacturing the press formed part D-10 of Embodiment 3-1, and may be provided with three first pressing units D-210. In this case, the three first pressing units D-210 may be spaced apart from each other by a first distance. The first distance may be the same distance as the preset length w described above. In addition, the first die D-200 may be provided with a first flat surface portion D-220. The first flat surface portion D-220 may be disposed between two adjacent first pressing units D-210. The first flat surface portion D-220 may extend parallel to the longitudinal direction Y between the two first pressing units D-210 to connect the first pressing units D-210. As described above, since three first pressing units D-210 are provided, at least two first flat surface portions D-220 may be provided.

[0349] Accordingly, the first die D-200 may have three first pressing units D-210 spaced apart from each other by a first distance (i.e., a preset length) W along the longitudinal direction Y, and a first flat surface portion D-220 disposed therebetween to connect the first pressing units D-210.

[0350] The second die D-400 may have a second pressing unit D-410 and a second flat surface portion D-420a. In this case, the second pressing unit D-410 may be formed in a shape and size corresponding to the lower surface of the press formed part D-10.

[0351] Unlike the first die D-200, the second die D-400 may be provided with only two second pressing units D-410. In this case, the two second pressing units D-410 may be disposed to be symmetrical with the two first pressing units D-210 disposed on both sides among the three first pressing units D-210 along the longitudinal direction Y. Accordingly, the second die D-400 may not have the second pressing unit D-410 in the region (hereinafter, "central region") facing the central first pressing unit D-210 among the three first pressing units D-210.

[0352] Accordingly, the second die D-400 may be a single structure having a form connected by two second pressing units D-410 and a second flat surface portion D-420a disposed therebetween. In this case, the flat surface portion D-420a may be provided with a penetration portion D-420aa. The intermediate pressing unit D-300 may be inserted into the penetration portion D-420aa during the press forming of the outer region of the metal sheet D-10A. The penetration portion D-420aa may be formed by penetrating a portion of the flat surface portion D-420a along the vertical direction Z. This penetration portion D-420aa may have a cross-sectional shape and area corresponding to the shape and size of the intermediate pressing unit D-300. In addition, a second-second flat surface portion D-420b may be further provided on each of the two sides of the first pressing units D-210.

[0353] The intermediate pressing unit D-300 may be disposed between the first die D-200 and the second die D-400. As illustrated in FIG. 38, a metal sheet D-10A, which is a press-forming object, may be placed below the first die D-200. In this case, the intermediate pressing unit D-300 is disposed between the metal sheet D-10A and the second die D-400, so that, when the first die D-200 descends, a portion of the lower surface of the metal sheet D-10A may be pressed. The intermediate pressing unit D-300 may be, for example, a pad for pressing and bending the lower surface of the metal sheet D-10A.

[0354] The intermediate pressing unit D-300 may be disposed directly above the above-described central region of the second die D-400. In this case, the intermediate pressing unit D-300 may have the same form as the second pressing unit D-410. That is, the intermediate pressing unit D-300 may have a shape and size corresponding to the lower surface of the press formed part D-10. Such an intermediate pressing unit D-300 may, together with the first pressing unit D-210 in the center of the three first pressing units D-210, press the metal sheet (D-10A) up and down during the press forming to form the deformation portion D-120 located in the center.

[0355] The intermediate pressing unit D-300 may be configured to be elevated. Accordingly, the intermediate pressing unit D-300 may descend along the pressing direction -Z during the press forming. Furthermore, after the press forming is

completed, the intermediate pressing unit D-300 may ascend in the opposite direction Z of the pressing direction. The elevation of the intermediate pressing unit D-300 may be achieved by an elastic member (not illustrated) installed in the intermediate pressing unit D-300.

[0356] The "method of manufacturing a press formed part D-10 according to Embodiment 3-1" using the above-described manufacturing device D-20 may be as follows.

[0357] First, the metal sheet D-10A may be supplied to the manufacturing device D-20 (S100). Before the press forming starts, as illustrated in FIG. 38, the metal sheet D-10A may be disposed between the first die D-200 and the intermediate pressing unit D-300 (hereinafter referred to as the "processing position"). Meanwhile, the metal sheet D-10A may be supplied to the manufacturing device D-20 while heated by a separate heating device (not illustrated).

[0358] For example, when the metal sheet D-10A is in a processing position, an upper surface of the metal sheet D-10A may be in contact with a lower surface of the first die D-200, or may be disposed such that only a minute clearance is present therebetween. In this case, the second die D-400 may be disposed to be symmetrical with the first die D-200, with the metal sheet D-10A and the intermediate pressing unit D-300 interposed therebetween.

[0359] Furthermore, when the metal sheet D-10A is disposed in the processing position (i.e., before press forming begins), the intermediate pressing unit D-300 may be disposed above the second die D-400. Accordingly, a height difference hi may exist between the intermediate pressing unit D-300 and the second pressing unit D-410. Here, the height difference hi described above may refer to the distance from the upper surface of the second pressing unit D-410 to the upper surface of the intermediate pressing unit D-300. In this case, the height difference hi between the intermediate pressing unit D-300 and the second pressing unit D-410 may be smaller than the "preset height h", which is the height of the press formed part D-10. In this case, the height difference hi may be 65% or more of the preset height h. When the manufacturing device D-20 is configured to have such a height difference hi, damage such as cracks in the deformation portion D-120 formed through press forming may be minimized.

[0360] Next, the metal sheet D-10A may be subjected to the primary press forming by the first die D-200 and the intermediate pressing unit D-300 (S200). As illustrated in FIG. 39, the first die D-200 may be lowered along the pressing direction -Z to pressurize the upper surface of the metal sheet D-10A. In this case, the first die D-200 may be lowered to a position where the lower surface of the metal sheet D-10A does not come into contact with the second die D-400. In this case, since the intermediate pressing unit D-300 is disposed higher than the second pressing unit D-410 by the height difference hi, only the intermediate pressing unit D-300 may be inserted into the first pressing unit D-210 and may press the central region of the metal sheet D-10A. Accordingly, only the central region of the metal sheet D-10A may be pressed vertically by the first pressing unit D-210 among the three first pressing units D-210 and the intermediate pressing unit D-300. Thus, only the central region of the metal sheet D-10A may be bent, thereby forming one deformation portion D-120.

[0361] Next, the metal sheet D-10A may be subjected to the secondary press forming by the first die D-200 and the second die D-400 (S300). After the primary press forming is performed in operation S200, as illustrated in FIG. 40, the first die D-200 may be further lowered along the pressing direction -Z. In this process, the intermediate pressing unit D-300 may descend together with the first die D-200 while being inserted into a central first pressing unit D-210 together with the central region of the metal sheet D-10A. Accordingly, the outer region of the metal sheet D-10A may come into contact with the upper surfaces of the two second pressing units D-410.

[0362] Thereafter, as the first die D-200 continues to descend, the second pressing unit D-410 may be inserted into the first pressing unit D-210 and press the outer regions of both sides of the metal sheet D-10A. In this process, the intermediate pressing unit D-300 may be accommodated within the penetration portion D-420aa of the second die D-400. The outer regions of both sides of the metal sheet D-10A may be simultaneously pressed vertically by two outer first pressing units D-210 and two outer second pressing units D-410. Thus, by bending both the outer regions of the metal sheet D-10A, two additional deformation portions D-120 may be formed.

[0363] Next, the first die D-200 and the intermediate pressing unit D-300 may be returned to their original positions (S400). After the "stepwise press forming" in operations S200 and S300, as illustrated in FIG. 9, the first die D-200 may be raised in the opposite direction +Z to the pressing direction -Z. During this process, the deformation portions D-120 may be separated from the first pressing units D-210. Additionally, the intermediate pressing unit D-300 may be separated from the central deformation portion D-120 and returned to its original position. As a result, the press formed part D-10 in which the three deformation portions D-120 each having the preset height h are spaced apart from each other by the preset length w may be manufactured.

[0364] Then, the manufactured press formed part D-10 may be discharged (S500). After being discharged from the manufacturing device D-20, the press formed part D-10 may be transported for the next processing or manufacturing process. Thereafter, the next metal sheet D-10A is supplied, allowing the above-described manufacturing method to be repeatedly performed.

[0365] FIG. 42 is a diagram schematically illustrating a first operation of manufacturing the press formed part of FIG. 34. FIG. 43 is a diagram schematically illustrating a second of manufacturing the press formed part of FIG. 34. FIG. 44 is a diagram schematically illustrating a third operation of manufacturing the press formed part of FIG. 34. FIG. 45

schematically illustrates a fourth operation of manufacturing the press formed part of FIG. 34.

[0366] Referring to FIG. 37 and FIGS. 42 to 45, the press formed part D-10 according to Embodiment 3-2 may be manufactured through the following manufacturing method. The manufacturing device D-20' for the press formed part may include the first die D-200, the intermediate pressing unit D-300, and the second die D-400. In this case, at least two intermediate pressing units D-300 may be provided. In this case, most of the features of the first die D-200, the intermediate pressing unit D-300, and the second die D-400 are the same or similar to those of the above-described Embodiment 3-1, and therefore, a duplicate description thereof will be omitted.

[0367] Since the press formed part D-10' according to Embodiment 3-2 is provided with four or more deformation portions D-120, the first die D-200 may be provided with four or more first pressing units D-210. Hereinafter, for convenience of description, a case in which four first pressing units D-210 are provided and are spaced apart from one another by a preset length (w) will be mainly described. In this case, two first pressing units D-210 may be disposed in the central region of the first die D-200, and one first pressing unit D-210 may be disposed on each side of the central region.

[0368] The second die D-400 may be provided with two second pressing units D-410. In this case, two second pressing units D-410 may be disposed to face two first pressing units D-210 disposed on each side of the first die D-200.

[0369] When four first pressing units D-210 are provided, two intermediate pressing units D-300 may be provided. In this case, the two intermediate pressing units D-300 may be disposed to face the two first pressing units D-210 disposed in the central region of the first die D-200. The intermediate pressing units D-300 are disposed between the first die D-200 and the second die D-400 in the same manner as described above.

[0370] In addition, in the case of Embodiment 3-2, the second flat surface portion D-420a of the second die D-400 may be provided with two penetration portions D-420aa. Accordingly, when the outer region of the metal sheet D-10A is press formed by the first die D-200 and the second die D-400, two intermediate pressing units D-300 may be accommodated in the penetration portions D-420aa, respectively.

[0371] In the "method of manufacturing a press formed part D-10' according to Embodiment 3-2" using the above-described manufacturing device D-20', operations S100, S200, S300, and S400 may be sequentially performed, similar to the method of manufacturing a press formed part D-10 of Embodiment 3-1. In this case, since the specific manufacturing methods performed in each operation are the same or similar to those of Embodiment 3-1, the differences will be primarily described.

[0372] First, in operation S100, as illustrated in FIG. 42, the metal sheet D-10' may be supplied to the above-described processing position. In this case, the metal sheet D-10A may be supplied to the manufacturing device D-20' while heated by a separate heating device (not illustrated). When supplied to the processing position, two intermediate pressing units D-300 may be disposed below the central region of the metal sheet D-10'. In this case, the two intermediate pressing units D-300 may be disposed at the same height. In this case, the height difference hi between the intermediate pressing units D-300 and the second pressing unit D-410 is the same as in Embodiment 3-1.

[0373] Next, in operation S200, as illustrated in FIG. 43, as the first die D-200 descends, the intermediate pressing units D-300 are each inserted into the two first pressing units D-210 in which the first die D-200 is disposed in the central region, thereby pressing the central region of the metal sheet D-10'. By this primary press forming operation, two deformation portions D-120 may be formed in the central region of the metal sheet D-10A.

[0374] Next, in operation S300, as illustrated in FIG. 44, the first die D-200 is lowered further, so the second pressing unit D-410 may be inserted into each of the two first pressing units D-210 disposed in the outer region of the first die D-200. As a result, the outer region of the metal sheet D-10' may be pressed vertically by the first pressing unit D-210 and the second pressing unit D-410. By this secondary press forming operation, two deformation portions D-120 may be additionally formed in the outer region of the metal sheet D-10A.

[0375] Next, in operation S400, as illustrated in FIG. 45, the first die D-200 may be raised in the opposite direction +Z to the pressing direction -Z. Accordingly, the press formed part D-10', which has undergone the press forming, may be separated from the first die D-200, the intermediate pressing unit D-300, and the second die D-400. During this process, the two intermediate pressing units D-300 may be raised and returned to their original positions in the processing position described above.

[0376] Then, after the completed press formed part D-10' is discharged from the manufacturing device D-20', a new metal sheet D-10' may be supplied, allowing the next press-forming process to start.

[0377] Meanwhile, when the number of deformation portions D-120 formed on the press formed part D-10' increases, the number of intermediate pressing units D-300 may also increase accordingly.

[0378] For example, although not illustrated in the drawing, when five deformation portions D-120 are formed in the press formed part D-10, the first die D-200 should be provided with five first pressing units D-210. Accordingly, the three intermediate pressing units D-300 may be provided and disposed to face the three first pressing units D-210 disposed in the central region of the first die D-200. In this case, the three intermediate pressing units D-300 may be disposed between the first die D-200 and the second die D-400.

[0379] Among the three intermediate pressing units D-300, one intermediate pressing unit (hereinafter, the first

intermediate pressing unit) D-300 disposed in the center may be disposed at the highest position. The remaining two intermediate pressing units (hereinafter, referred to as the second intermediate pressing units) D-300 may be disposed between the first intermediate pressing unit D-300 and the second die D-400. In this case, the two second intermediate pressing units D-300 may be disposed at the same height. The height difference between the first intermediate pressing unit D-300 and the second intermediate pressing unit D-300 may be the same as or similar to the height difference hi between the above-described intermediate pressing unit D-300 and the second pressing unit D-410.

[0380] With this arrangement, the primary press forming may be performed first by the first die D-200 and the first intermediate pressing unit D-300. When the primary press forming is completed or just before the primary press forming is completed, the first die D-200 is lowered further together with the first intermediate pressing unit D-300, so the secondary press forming may be performed by the first die D-200 and two second intermediate pressing units D-300. By performing the press forming twice, the forming of the central region of the metal sheet D-10A may be performed first. Then, after the secondary press forming is completed or just before the secondary press forming is completed, the first die D-200 is lowered further, so the third press forming of the outer region of the metal sheet D-10A may be performed by the first die D-200 and the second die D-400.

[0381] As another example, although not illustrated in the drawing, when six deformation portions D-120 are formed in the press formed part D-10', the first die D-200 should be provided with six first pressing units D-210. Accordingly, the four intermediate pressing units D-300 may be provided and disposed to face the four first pressing units D-210 disposed in the central region of the first die D-200. In this case, the three intermediate pressing units D-300 may be disposed between the first die D-200 and the second die D-400.

[0382] Among the four intermediate pressing units D-300, two intermediate pressing units (hereinafter, the first intermediate pressing unit) D-300 disposed in the center may be disposed at the highest position. The remaining two intermediate pressing units (hereinafter, referred to as the second intermediate pressing units) D-300 may be disposed between the first intermediate pressing unit D-300 and the second die D-400. In this case, the two first intermediate pressing units D-300 may be disposed at the same height. In this case, the two second intermediate pressing units D-300 may be disposed at the same height. The height difference between the first intermediate pressing unit D-300 and the second intermediate pressing unit D-300 may be the same as or similar to the height difference hi between the above-described intermediate pressing unit D-300 and the second pressing unit D-410.

[0383] With this arrangement, the primary press forming may be performed first by the first die D-200 and the two first intermediate pressing units D-300. When the primary press forming is completed or just before the primary press forming is completed, the first die D-200 is lowered further together with the first intermediate pressing units D-300, so the secondary press forming may be performed by the first die D-200 and two second intermediate pressing units D-300. By performing the press forming twice, the forming of the central region of the metal sheet D-10A may be performed first. Then, after the secondary press forming is completed or just before the secondary press forming is completed, the first die D-200 is lowered further, so the third press forming of the outer region of the metal sheet D-10A may be performed by the first die D-200 and the second die D-400.

[0384] In addition, when the deformation portion D-120 formed in the press formed part D-10' increases to 7 or more, the number of the first pressing unit D-210 and the intermediate pressing unit D-300 should be further increased similarly to the above. Accordingly, the number of penetration portions D-420aa in the second die D-400 may also increase. With the manufacturing device configured in this manner, by adding the press forming operation, the press forming may be performed first on the central region of the metal sheet D-10A, and then on the outer region of the metal sheet D-10A.

[0385] The press formed parts D-10 and D-10' and the manufacturing method (S10) thereof according to the example embodiments of the present disclosure as described above may perform the press forming on the metal sheets D-10 and D-10' by disposing the intermediate pressing unit D-300 having the height difference hi between the upper/lower dies D-200 and D-400 and using the three pressing units D-210, D-300, and D-410. In this case, through the stepwise forming process in which the central region of the metal sheets D-10 and D-10' is first pressed and then the outer region is sequentially pressed, it is possible to prevent the deformation force from being concentrated at a specific location of the metal sheets D-10 and D-10' during the press processing. As a result, the press formed parts D-10 and D-10' may be prevented from being damaged during the manufacturing process and the quality of the parts may be improved.

[0386] Although the example embodiments of the present disclosure has been described with reference to the accompanying drawings, those skilled in the art will appreciate that various modifications and alterations may be made without departing from the spirit or essential feature of the present disclosure. Therefore, it should be understood that the above-described example embodiments are not restrictive, but are exemplary in all aspects.

Description of Reference Characters

[0387]

A-10: Upper die

A-12: Cooling channel
A-20: Lower punch
A-22: Cooling channel
A-30: Lower holder
A-32: Heating Heater
A-34: Cooling channel
A-100: Die
A-200: Steel
A-300: 22MnB5 material
B-1: Side frame B-10: Frame
B-20: Bracket B-21, B-22: Flange
B-23: Main body B-24: Curved surface
B-100: Punch
B-110, B-120, B-130, B-140, B-150: First to fifth punch forming portions
B-111, B-121, B-131, B-141, B-151: First to fifth extended surface forming portions
B-112, B-122 B-132, B-142, B-152: First to fifth curved surface forming portions
B-113, B-123, B-133, B-143: First to fourth main body forming portions
B-200: Pad
B-300: Die
B-310, B-320, B-330, B-340, B-350: First to fifth die forming portions
B-311, B-321, B-331, B-341, B-351: First to fifth die curved surface forming portions
B-312, B-322, B-332, B-342, B-352: First to fifth die flat forming portions
B-360: Vertical plane
B-400: Material B-410: Notch
C-1: Battery pack module C-10: Hot press formed part
C-20: Battery case C-30: Base
C-40: Reinforcing member C-110: First wall
C-120: Second wall C-130: Third wall
C-140: Fourth wall C-150: Fifth wall
C-160: Curved portion C-170: First connection portion
C-180: Second connection portion C-190: Third connection portion
b: Battery pack r: Curvature radius
t: Sheet metal thickness θw: Wall angle
hw: Wall height
D-10, D-10': Press formed part
D-10A: Metal sheet
D-110: Flat plate portion
D-120: Deformation portion
D-20, D-20': Press forming device
D-200: First die
D-210: First protrusion
D-220: First Flat surface portion
D-300: Intermediate pressing unit
D-400: Second die
D-410: Second protrusion
D-420: Second flat surface portion

Mode for Invention

[0388] Hereinafter, the present disclosure will be described in more detail with reference to Examples. However, it should be noted that the following Examples are only for illustrating the present disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and the matters reasonably inferred therefrom.

(**Example 1)**

M**anufacturing of Steel Sheet for Hot Forming**

[0389] A steel slab (thickness: 100 mm) having the composition (remaining alloy components: Fe and unavoidable impurities) illustrated in Table 2 below was manufactured through vacuum melting. The steel slab was heated to 1250°C, finished hot rolled at 900°C, cooled at a cooling rate of 30°C/s, and coiled at 640°C to obtain a hot-rolled steel sheet (final thickness: 2.5 mm). Thereafter, the hot-rolled steel sheet was then pickled and cold-rolled at a reduction ratio of 45% to produce the cold-rolled steel sheet. Thereafter, the cold-rolled steel sheet was annealed at 780°C under the dew point temperature conditions listed in Table 3 in a 5% hydrogen-95% nitrogen atmosphere. The steel sheet was pickled under the conditions listed in Table 3 and cooled to room temperature to manufacture the hot formed steel sheet.

M**anufacturing of Hot Formed Members**

[0390] The blank was prepared using the steel sheet for hot forming, and then transferred to a heating furnace and heat-treated under the conditions listed in Table 3. Thereafter, the heat-treated blank was hot formed using the hot-forming die and then cooled to manufacture the hot formed member.

[Table 2]

Ste el typ e	Alloy composition (wt%)									
	C	Si	Mn	P	S	Al	Cr	Ti	B	N
A	0.25 5	1.55	0.83	0.01	0.00 2	0.03 97	1.53	0.03 07	0.00 28	0.00 35
B	0.3	1.53	0.67	0.00 7	0.00 08	0.03 5	1.0	0.01 4	0.00 25	0.00 4
C	0.25	1.48	0.79 3	0.01 01	0.00 25	0.02 7	4.5	0.02 8	0.00 28	0.00 56
D	0.12	0.96	1.6	0.00 8	0.00 3	0.05 1	1.93	0.01 5	0.00 2	0.00 1
E	0.3	1.53	0.39	0.00 7	0.00 08	0.03 5	1.0	0.01 4	0.00 25	0.00 4
F	0.29	1.49	0.73	0.00 92	0.00 07	0.05 2	0.9	0.01 5	0.00 26	0.00 37
G	0.29 1	0.5	1.21	0.00 8	0.00 2	0.05 3	2.0	0.01 6	0.00 18	0.00 1
H	0.12	2.89	3.84	0.00 8	0.00 3	0.00 34	2.3	0.01 5	0.00 2	0.00 1

[Table 3]

Division	Steel type	Manufacturing condition of steel sheet for hot forming		Manufacturing condition of hot formed member	
		Dew point temperatur e (°C)	Pickling time (second)	Heat treatment temperatur e (°C)	Heat treatment time (second)
Inventive Example A-1	A	-10	5	900	300
Comparati ve Example A-1	A	-10	14	900	300
Comparati ve Example A-2	A	5	5	900	300
Inventive Example A-2	B	-25	7	900	300
Comparati ve Example A-3	B	-10	5	900	820
Comparati ve Example A-4	B	-28	6	1120	192
Inventive Example A-3	C	-20	7	930	270
Comparati ve Example A-5	C	-40	5	930	270
Comparati ve Example A-6	C	-20	18	930	270
Inventive Example A-4	D	-25	8	930	360
Comparati ve Example A-7	D	-25	8	930	660
Comparati ve Example A-8	E	-20	5	900	420
Comparative Example A-9	F	-20	5	900	420

(continued)

Division	Steel type	Manufacturing condition of steel sheet for hot forming		Manufacturing condition of hot formed member	
		Dew point temperatur e (°C)	Pickling time (second)	Heat treatment temperatur e (°C)	Heat treatment time (second)
Comparati ve Example A-10	G	-20	5	900	420
Inventive Example A-5	H	-10	6	900	600
Comparati ve Example A-11	H	-10	6	1050	650

[0391] For each steel sheet for hot forming, the R value, defined by [Relational Equation 1] below, was calculated to evaluate the degree of surface-concentrated layer formation. The results were shown in Table 4.

[Relational Equation 1]

$$R = ([Cr] + [Mn] + [Si]) / ([Cr^*] + [Mn^*] + [Si^*])$$

[0392] Glow discharge emission spectrometry (GDS) analysis was performed on each steel sheet from the surface in the depth direction. Based on the GDS profile, the maximum Cr, Mn, and Si contents (wt%) within the range of 0.01 to 1.0 μm in the thickness region of the steel sheet were shown as [Cr], [Mn], and [Si] in [Relational Equation 1]. The Cr, Mn, and Si contents (wt%) contained in the steel slab during the manufacturing of each steel sheet were shown as [Cr*], [Mn*], and [Si*].

[0393] Furthermore, for each hot formed member, the physical properties (yield strength (YS), tensile strength (TS), yield ratio (YS), and elongation (EL)) and surface quality ($Fe_{40\text{-}80\%}$ slope, visual inspection, and standard gloss) were evaluated, and the results were shown in Table 4.

[0394] Specifically, to evaluate the physical properties, the room-temperature tensile test was conducted using JIS-5 specimen according to the ISO 6892 standard.

[0395] For the $Fe_{40\text{-}80\%}$ slope, the glow discharge emission spectrometry (GDS) analysis was performed from the surface of the member in the depth direction. Based on the GDS profile, the slope of the straight line in the region where the Fe content (wt%) was 40 to 80% within a thickness range of 5.0 μm or less was measured and shown as the $Fe_{40\text{-}80\%}$ slope. More specifically, the slope of the straight line represented a slope derived by performing simple linear regression on a portion of a graph in a GDS profile corresponding to a range in which the Fe content (wt%) is 40 to 80%.

[0396] For visual inspection, the surface quality was evaluated as good when light was reflected from the surface of each sample. When no light was reflected, the surface quality was evaluated as poor.

[0397] For standard gloss, the standard gloss (the angle between the incident angle and the normal vector to the surface: 60°) of each component surface was measured using the ISO 2813 standard. In this case, the criterion of the standard gloss is 25 GU, and when the standard gloss is 25 GU or greater, it is possible to secure good surface quality, and good surface quality could be secured even without necessarily undergoing the shot blasting process.

[Table 4]

Divisi on	Steel sheet for hot forming	Hot formed member						
	[Relatio nal Equation 1]	Physical property				Surface quality		
		YS (MPa)	TS (MPa)	YR	El (%)	$Fe_{40\sim80\%}$ slope	Visua l inspe ction	Gloss (GU)
Invent ive Ex-ampl e A-1	3.2	1198	1695	0.71	6.12	309.0	Accep ta-ble	59.2
Compar ative Exampl e A-1	2.1	1150	1660	0.69	6.84	95.3	Unacc ep-tab le	24.7
Compar ative Exampl e A-2	1.8	1054	1660	0.63	6.64	23.9	Unacc ep-tab le	11.9

(continued)

Division	Steel sheet for hot forming	Hot formed member						
	[Relational Equation 1]	Physical property				Surface quality		
		YS (MPa)	TS (MPa)	YR	El (%)	$Fe_{40\sim80\%}$ slope	Visual inspection	Gloss (GU)
Inventive Example A-2	6.5	1291	1905	0.68	6.1	287.8	Acceptable	66.0
Comparative Example A-3	5.2	1308	1896	0.69	6.2	61.4	Unacceptable	19.9
Comparative Example A-4	4.7	1355	1903	0.71	6.4	32.9	Unacceptable	14.7
Inventive Example A-3	3.6	1168	1899	0.62	5.9	216.6	Acceptable	62.1
Comparative Example A-5	1.6	1265	1900	0.67	6.2	39.0	Unacceptable	19.5
Comparative Example A-6	2.4	1125	1801	0.62	6.7	69.3	Unacceptable	24.5
Inventive Example A-4	3.2	853	1267	0.67	9.8	375.4	Acceptable	84.3
Comparative Example A-7	3.6	894	1253	0.71	9.27	68.2	Unacceptable	10.6
Comparative Example A-8	2.7	1223	1915	0.64	5.93	84.0	Unacceptable	6.5
Comparative Example A-9	2.2	1215	1897	0.64	6.01	39.0	Unacceptable	5.2
Comparative Example A-10	2.6	1210	1909	0.63	5.9	56.3	Unacceptable	4.7
Inventive Example A-5	4.8	950	1387	0.68	8.1	617.6	Acceptable	109.3
Comparative Example A-11	4.7	862	1359	0.63	8.3	13.5	Acceptable	3.8

[0398] As illustrated in Table 4, for Inventive Examples A-1 to A-5, which satisfied the alloy composition and manufacturing conditions of the present disclosure, Cr, Si, and Mn were appropriately concentrated on the surface of the steel sheet for hot forming. As a result, the excellent surface quality of the hot formed member was secured even without the shot blast process. Furthermore, it was confirmed that the physical properties of the hot formed member were also maintained at the target level.

[0399] Meanwhile, it was confirmed that, in the steel sheet for hot forming of Comparative Example A-1, since the pickling time exceeded the range of the Examples, the value of R was measured to be low, and thus Cr, Si, and Mn were not appropriately enriched in the surface layer. This was found to be because the pickling time was long, such that erosion occurred due to the pickling solution and the enrichment layer was removed. Accordingly, the hot formed member of Comparative Example A-1 exhibited excessive Fe scale formation on the surface, resulting in poor surface quality.

[0400] It was confirmed that, in the steel sheet for hot forming of Comparative Example A-2, since the dew point temperature exceeded the range of the Examples, the value of R defined by [Relational Equation 1] was measured to be low, such that Cr, Si, and Mn were not appropriately enriched in the surface layer, and Fe oxides were formed on the surface. Accordingly, in the hot formed member of Comparative Example A-2, the excessive Fe scale was formed on the surface layer, the surface gloss of 25 GU or greater was not secured, and the surface quality was inferior.

[0401] Although the steel sheets for hot forming of Comparative Examples A-3 and A-7 secured values of R within the range of the Examples, the hot formed members of Comparative Examples A-3 and A-7 exhibited excessive formation of Fe oxides in the surface layer because the heat treatment time exceeded the range of the Examples, and thus surface

quality was degraded.

[0402] The hot formed member of Comparative Example A-4 exhibited excessive Fe oxide formation on the surface, resulting in poor surface quality, due to the heat treatment temperature exceeding the range specified in the examples.

[0403] It was confirmed that, in the steel sheet for hot forming of Comparative Example A-5, since the dew point temperature was below the range of the Examples, the value of R defined by [Relational Equation 1] was measured to be low, and thus enrichment of Cr, Si, and Mn was not sufficiently achieved. Accordingly, in the hot formed member of Comparative Example A-5, the excessive Fe scale was formed on the surface layer, the surface gloss of 25 GU or greater was not secured, and the surface quality was inferior.

[0404] It was confirmed that, in the steel sheet for hot forming of Comparative Example A-6, since the pickling time exceeded the range of the Examples, the shape, color, etc., of the surface became non-uniform. Accordingly, the hot formed member of Comparative Example A-6 exhibited excessive Fe scale formation on the surface, resulting in poor surface quality.

[0405] It was confirmed that, in Comparative Examples A-8 to A-10, since the contents of Cr, Si, and Mn were below the range of the Examples, the value of R defined by [Relational Equation 1] was measured to be low, and thus enrichment of Cr, Si, and Mn was not sufficiently achieved. Accordingly, in the hot formed members of Comparative Examples A-8 to A-10, excessive Fe oxides were formed in the surface layer, a surface gloss of 25 GU or greater was not secured, and surface quality was poor.

[0406] In the hot formed member of Comparative Example A-11, since the heat treatment temperature and time exceeded the range of the Examples, the excessive Fe oxides were formed in the surface layer, the surface gloss of 25 GU or greater was not secured, and the surface quality was degraded.

[0407] Meanwhile, FIG. 2 is a graph showing GDS profiles of Fe after hot forming for Inventive Example A-1 and Comparative Example A-11. Specifically, FIG. 2A is a graph illustrating the GDS profile of the hot formed member of Inventive Example A-1, and FIG. 2B is a graph illustrating the GDS profile of the hot formed member of Comparative Example A-11.

[0408] Referring to FIG. 2A, it was confirmed that, in the case of Inventive Example A-1, Cr, Si, and Mn were sufficiently enriched in the surface layer of the steel sheet to minimize the formation of the Fe oxide on the surface of the member during the hot forming process, and thus the Fe 40-80% slope was 200 wt%/μm or greater.

[0409] Referring to FIG. 2B, it could be seen that, in the case of Comparative Example A-11, the excessive Fe oxides were formed in the surface layer during the hot forming process, and thus the Fe 40-80% slope was measured to be less than 200 wt%/μm.

(**Example 2)**

M**anufacturing of Inventive Example B**

[0410] A steel having a martensite transformation critical cooling rate of 18°C/s in a temperature range of 800 to 400°C was heated to 930°C and held for 60 seconds, and then air-cooled to 730°C at a cooling rate of 15°C/s. Thereafter, after the steel was provided in the hot press forming equipment as illustrated in FIG. 8, the blank holding force F and heat were applied through the lower holder to support the steel between the lower holder and the upper die while simultaneously heating the steel. In this case, the blank holding pressure P was 5 MPa, and the contact area A between the lower holder and the steel was 30,000 mm^2. In other words, the blank holding force F was 150 kN. The temperature of the lower holder was 600°C. The forming temperature T_{blank} of the steel was 730°C, the thickness w was 1.5 mm, the density (ρ) was 7.7×10^{-9} ton/mm^3, and the specific heat C was 6.7×10^8 mJ/ton K. The heat transfer pressure coefficient a of the steel was 2.3, and the heat transfer pressure index b was 0.18. Thereafter, the steel was formed and cooled at a cooling rate of 20°C/s. Meanwhile, the temperatures of all dies except the lower holder were set to 80°C. The wrinkle depth of the flange portion of the hot press formed part manufactured thereby was measured to be 0.5 mm. In this case, the wrinkle depth was calculated as the difference between the maximum and minimum wrinkle heights of the flange portion.

M**anufacturing of Comparative Example B**

[0411] FIG. 9 is a schematic diagram illustrating hot press forming equipment applied to 22MnB5 material. 22MnB5 material A-300 was heated to 930°C and maintained for 60 seconds, and then air-cooled to 730°C at a cooling rate of 15°C/s. Thereafter, after the 22MnB5 material (A-300) was provided in the hot press forming equipment as illustrated in FIG. 7, the steel was formed and cooled at a cooling rate of 50°C/s. In this case, the gap between the upper die and the lower holder was set to 3 mm, and the temperatures of all dies were set to 80°C. The wrinkle depth of the flange portion of the hot press formed part manufactured thereby was measured to be 3.0mm. In this case, the wrinkle depth was calculated as the difference between the maximum and minimum wrinkle heights of the flange portion.

[0412] The above example embodiments are exemplary and should not be construed as limiting the present disclosure.

Any configuration having substantially the same construction as the technical idea described in the claims of the present disclosure and achieving the same operational effects shall fall within the technical scope of the present disclosure.

Claims

1. A steel sheet for hot forming, comprising:

   in weight%, carbon (C): 0.1 to 0.45%, silicon (Si): 0.8 to 3.0%, manganese (Mn): 0.5 to 4.0%, phosphorus (P): 0.001 to 0.05%, sulfur (S): 0.0001 to 0.02%, aluminum (Al): 0.001 to 0.1%, chromium (Cr): 1.0 to 5.0%, nitrogen (N): 0.001 to 0.02%, with a balance of Fe and inevitable impurities,
   wherein an R value defined by [Relational Equation 1] below is 2.8 or greater.

   [Relational Equation 1]

   $$R = ([Cr] + [Mn] + [Si]) / ([Cr^*] + [Mn^*] + [Si^*])$$

   (In the above [Relational Equation 1], [Cr], [Mn], and [Si] represent a maximum content (wt%) of each element within a range of 0.01 to 1.0 μm in a thickness direction from a surface of the steel sheet in a GDS profile, and [Cr*], [Mn*], and [Si*] represent an average content (wt%) of each element in the steel sheet.)

2. The steel sheet for hot forming of claim 1, wherein the steel sheet for hot forming further includes at least one selected from the following a) to f),

   a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
   b) boron (B): 0.01 wt% or less (excluding 0%),
   c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
   d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,
   e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
   f) rare earth elements (REM): 0.0001 to 0.02 wt%.

3. The steel sheet for hot forming of claim 1, wherein a microstructure of the steel sheet for hot forming includes ferrite and cementite.

4. The steel sheet for hot forming of claim 3, wherein a sum of area fractions of the ferrite and the cementite is 5% or more.

5. The steel sheet for hot forming of claim 1, wherein the steel sheet for hot forming has a tensile strength of 500 MPa or higher.

6. A method of manufacturing a steel sheet for hot forming, comprising:

   heating a slab containing, in weight%, carbon (C): 0.1 to 0.45%, silicon (Si): 0.8 to 3.0%, manganese (Mn): 0.5 to 4.0%, phosphorus (P): 0.001 to 0.05%, sulfur (S): 0.0001 to 0.02%, aluminum (Al): 0.001 to 0.1%, chromium (Cr): 1.0 to 5.0%, nitrogen (N): 0.001 to 0.02%, with a balance of Fe and inevitable impurities;
   obtaining a hot-rolled steel sheet by finish hot rolling the heated slab;
   cooling the hot-rolled steel sheet;
   coiling the cooled hot-rolled steel sheet;
   obtaining a cold-rolled steel sheet by cold rolling the coiled hot-rolled steel sheet;
   annealing the cold-rolled steel sheet from 700 to 1,000°C to a dew point temperature of -30 to 0°C; and
   pickling the annealed cold-rolled steel sheet for 1 to 10 seconds.

7. The method of claim 6, wherein, in the annealing, a temperature increases at a first rate of 3.0 to 20.0°C/s in a first temperature range of room temperature to 700°C, and then increases at a second rate of 0.015 to 10.0°C/s in a second temperature range of 700 to 1,000°C.

8. The method of claim 6, wherein the slab further includes at least one selected from the following a) to f).

   a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,

b) boron (B): 0.01 wt% or less (excluding 0%),
c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,
e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
f) rare earth elements (REM): 0.0001 to 0.02 wt%

9. The method of claim 6, wherein the heating is performed at 1000 to 1300°C, and in the obtaining of the hot-rolled steel sheet, the finish hot rolling of the slab is performed at Ar3 to 1000°C.

10. The method of claim 6, wherein the cooling is performed at a cooling rate of 20 to 100°C/s, and the coiling is performed at a temperature exceeding Ms and lower than or equal to 750°C.

11. A hot formed member, comprising:

in weight%, carbon (C): 0.1 to 0.45%, silicon (Si): 0.8 to 3.0%, manganese (Mn): 0.5 to 4.0%, phosphorus (P): 0.001 to 0.05%, sulfur (S): 0.0001 to 0.02%, aluminum (Al): 0.001 to 0.1%, chromium (Cr): 1.0 to 5.0%, nitrogen (N): 0.001 to 0.02%, with a balance of Fe and inevitable impurities,
wherein the hot formed member satisfies [Relational Equation 2] below.

[Relational Equation 2]

$$Fe_{40\sim80\%} \text{ slope} \geq 200 \ (wt\%/\mu m)$$

(In the above [Relational Equation 2], the $Fe_{40\sim80\%}$ slope represents a slope of a straight line in a section where the Fe content (wt%) is 40 to 80% within a range of 5μm or less in a thickness direction from a surface of the member in a GDS profile. In addition, the slope of the straight line represents a slope derived after performing a simple linear regression on a graph of a section where the Fe content (wt%) is 40 to 80% in the GDS profile.)

12. The hot formed member of claim 11, wherein the hot formed member further includes at least one selected from the following a) to f).

a) at least one selected from titanium (Ti), niobium (Nb), zirconium (Zr), and vanadium (V): 0.001 to 0.4 wt%,
b) boron (B): 0.01 wt% or less (excluding 0%),
c) at least one selected from molybdenum (Mo) and tungsten (W): 0.001 to 1.0 wt%,
d) at least one selected from copper (Cu) and nickel (Ni): 0.005 to 2.0 wt%,
e) at least one selected from antimony (Sb) and tin (Sn): 0.001 to 1.0 wt%, and
f) rare earth elements (REM): 0.0001 to 0.02 wt%

13. The hot formed member of claim 11, wherein a microstructure of the hot-formed member contains martensite or bainite as a main phase.

14. The hot formed member of claim 13, wherein an area fraction of the main phase is 10% or more.

15. The hot formed member of claim 11, wherein the hot formed member has a tensile strength of 1000 MPa or higher.

16. A method for manufacturing a hot formed member, comprising:

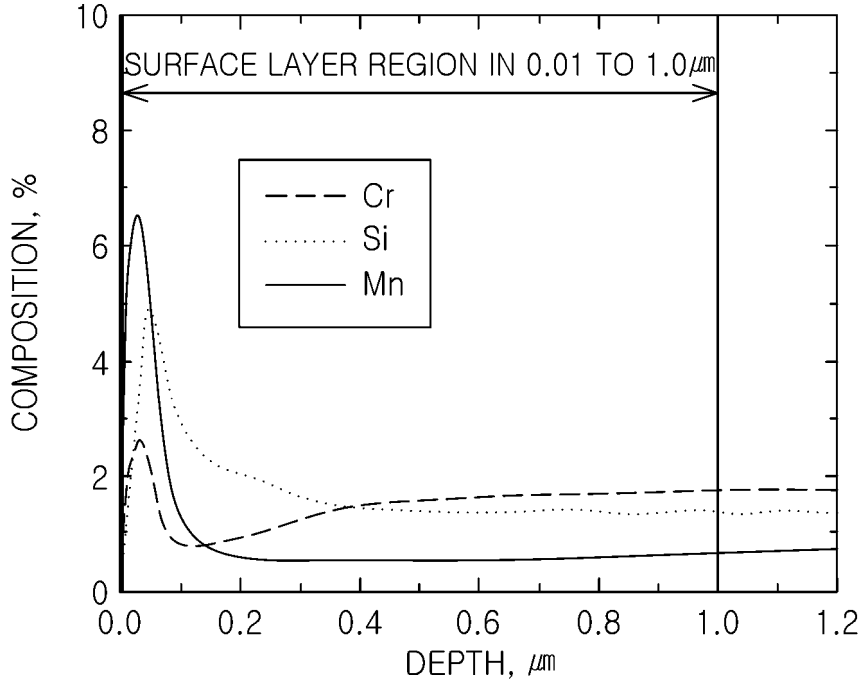
preparing a blank using the steel sheet for hot forming of any one of claims 1 to 5;
heat-treating the blank at a heat treatment temperature of 700 to 1000°C for 180 to 600 seconds; and
hot-forming the heat-treated blank and then cooling the heat-treated blank.

17. The method of claim 16, wherein, in the heat-treating, the heat-treated blank is heated to the heat treatment temperature at a temperature increase rate of 1 to 1000°C/s.

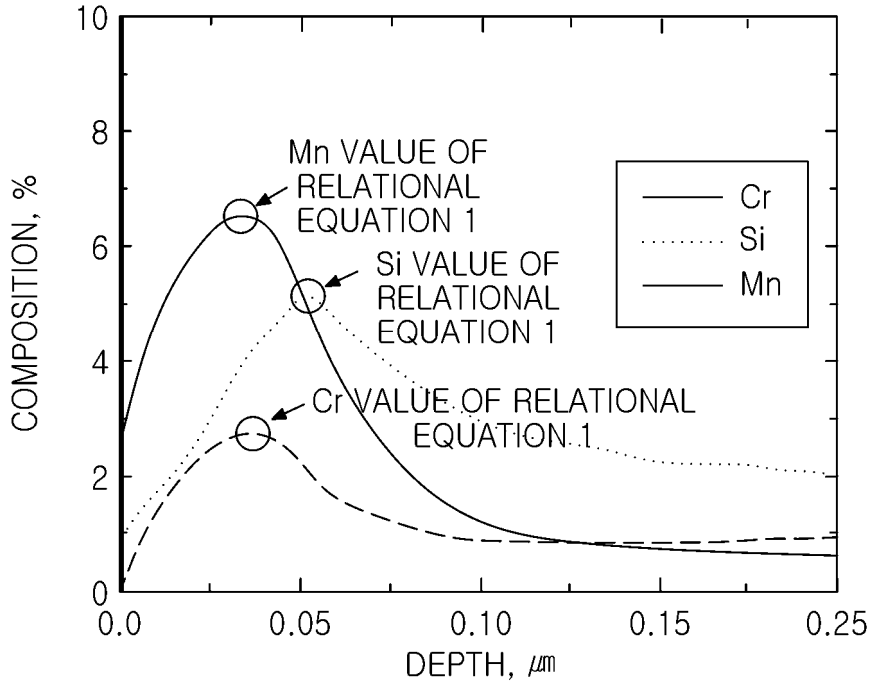
18. The method of claim 16, wherein, in the cooling, the heat-treated blank is cooled to a cooling end temperature of Mf or lower.

19. The method of claim 18, wherein, in the cooling, the heat-treated blank is cooled to the cooling end temperature at a cooling rate of 5 to 1000°C/s.

[FIG. 1]

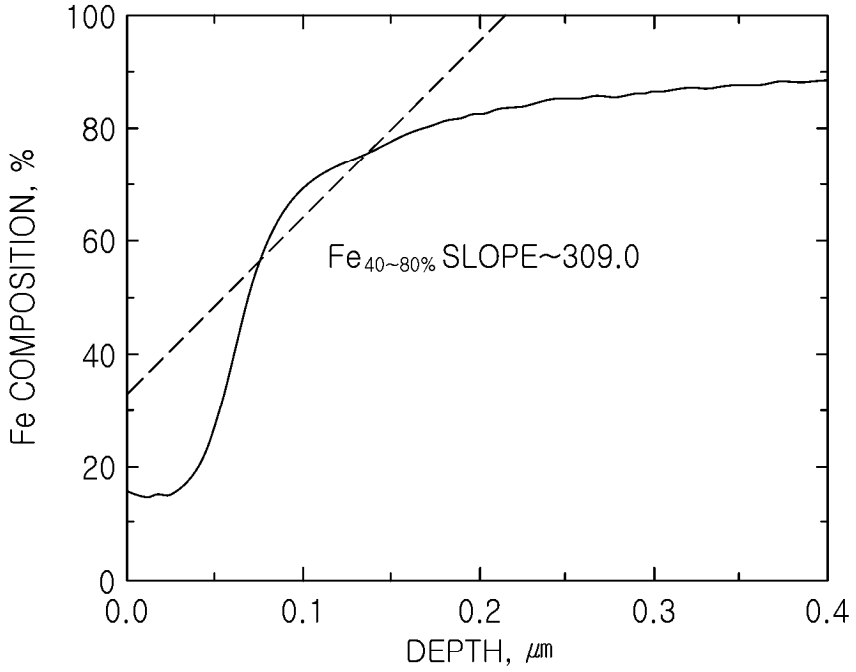

SURFACE LAYER REGION IN 0.01 TO 1.0㎛
Cr
Si
Mn
COMPOSITION, %
DEPTH, ㎛
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0
1.2

(a)

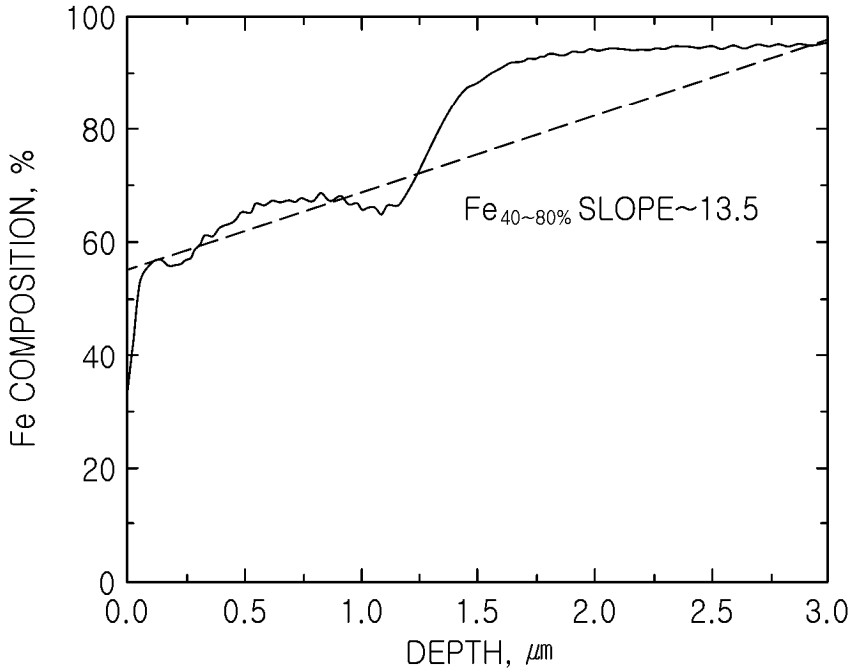

Mn VALUE OF RELATIONAL EQUATION 1
Si VALUE OF RELATIONAL EQUATION 1
Cr VALUE OF RELATIONAL EQUATION 1
Cr
Si
Mn
COMPOSITION, %
DEPTH, ㎛
0
2
4
6
8
10
0.0
0.05
0.10
0.15
0.25

(b)

[FIG. 2]

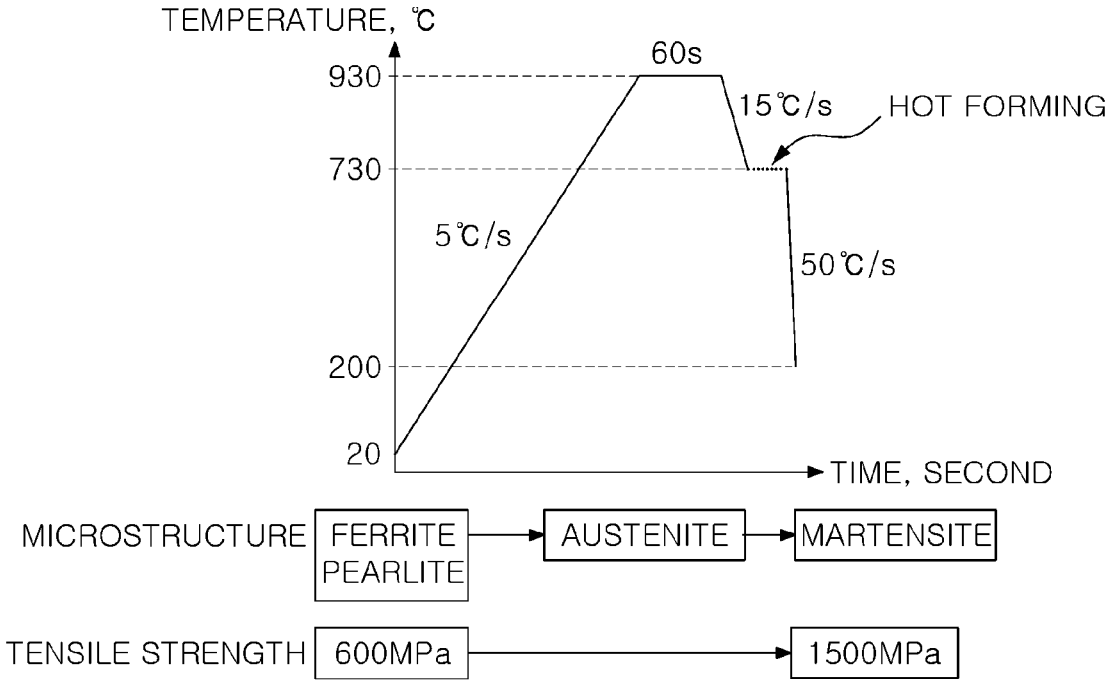

100
80
60
40
20
0
Fe COMPOSITION, %
Fe40~80% SLOPE~309.0
0.0
0.1
0.2
0.3
0.4
DEPTH, ㎛

(a)

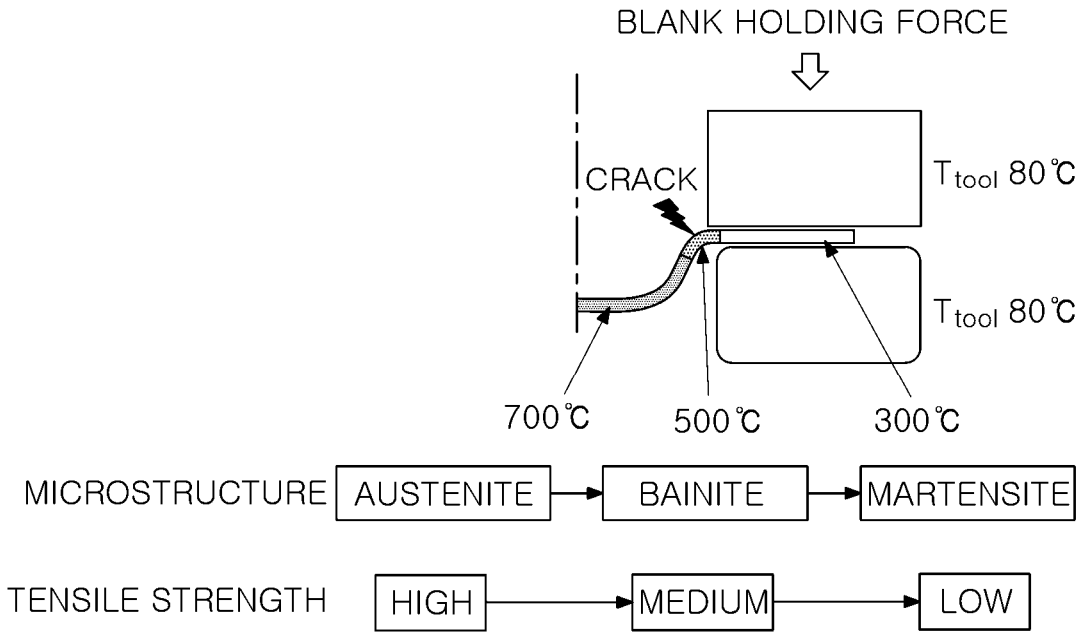

100
80
60
40
20
0
Fe COMPOSITION, %
Fe40~80% SLOPE~13.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
DEPTH, ㎛

(b)

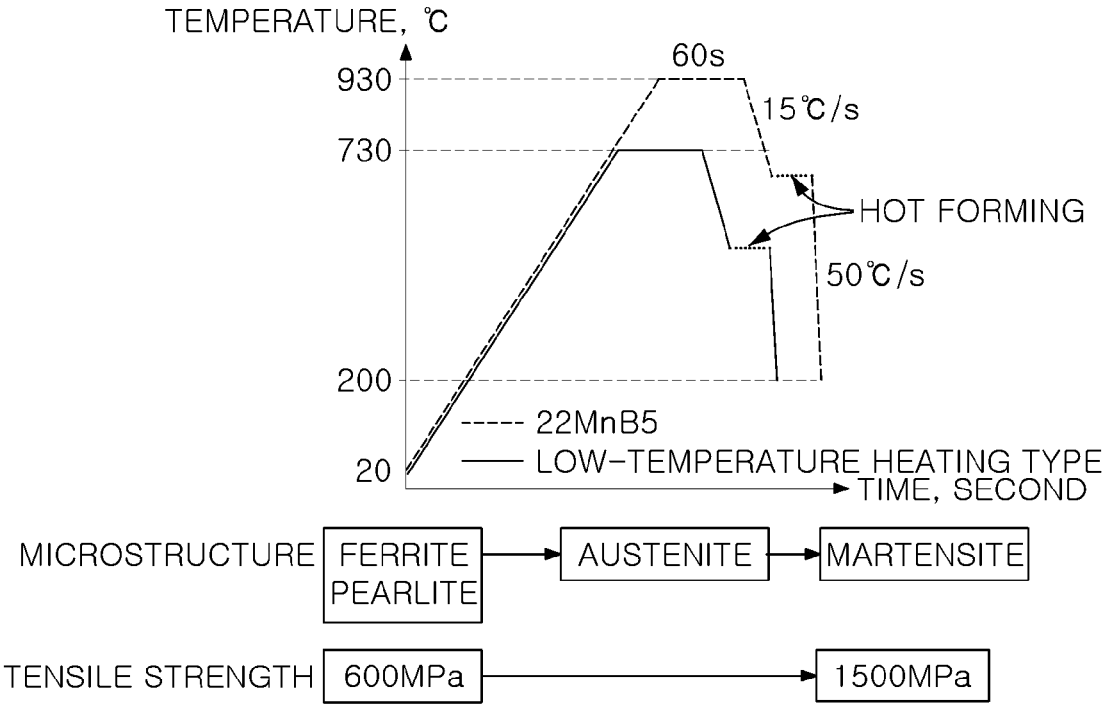
[FIG. 3]


TEMPERATURE, ℃
930
730
200
20
60s
15℃/s
HOT FORMING
5℃/s
50℃/s
TIME, SECOND
MICROSTRUCTURE
FERRITE
PEARLITE
AUSTENITE
MARTENSITE
TENSILE STRENGTH
600MPa
1500MPa

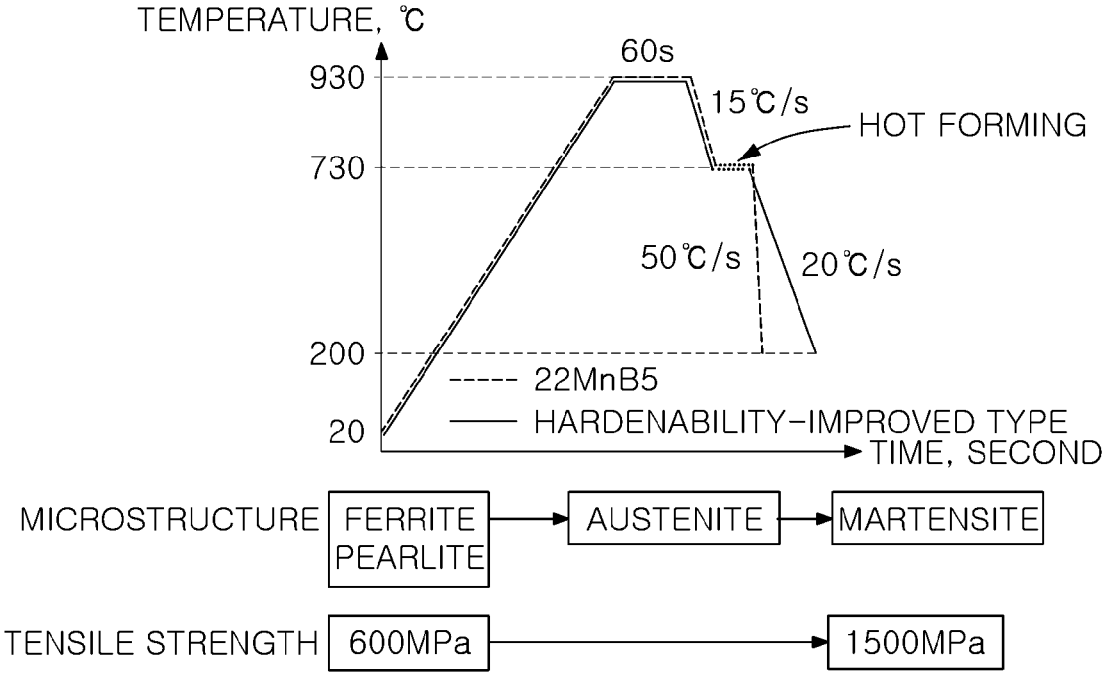
[FIG. 4]


BLANK HOLDING FORCE
CRACK
Ttool 80℃
Ttool 80℃
700℃
500℃
300℃
MICROSTRUCTURE
AUSTENITE
BAINITE
MARTENSITE
TENSILE STRENGTH
HIGH
MEDIUM
LOW

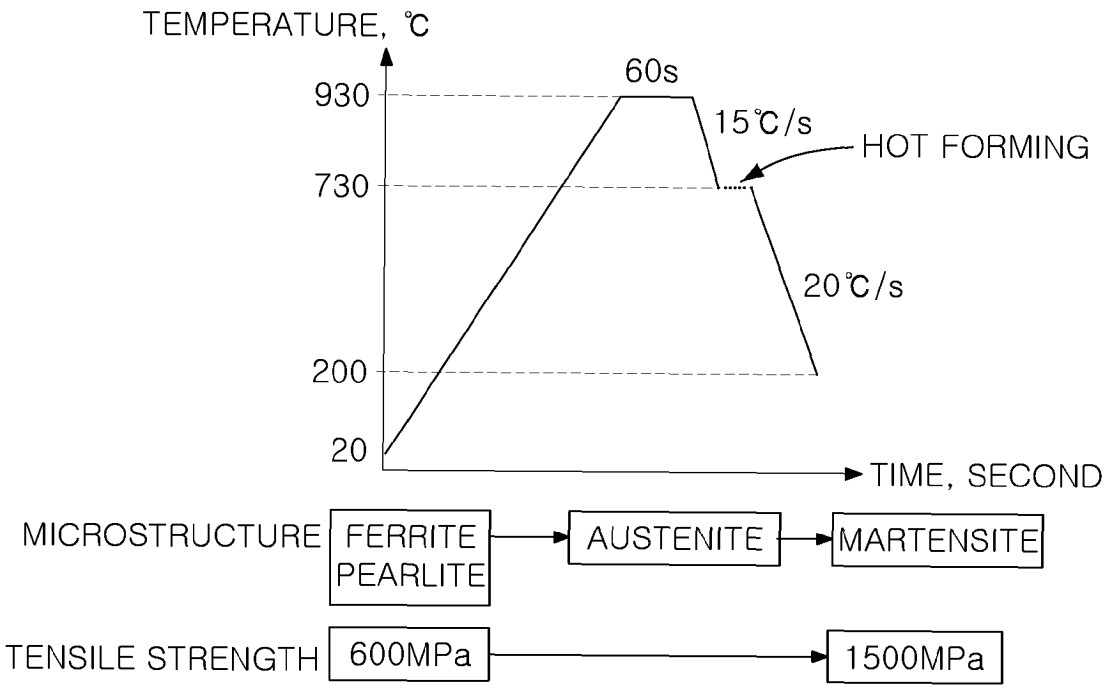
[FIG. 5]


TEMPERATURE, ℃
930
730
200
20
60s
15℃/s
HOT FORMING
50℃/s
----- 22MnB5
—— LOW-TEMPERATURE HEATING TYPE
TIME, SECOND
MICROSTRUCTURE
FERRITE PEARLITE
AUSTENITE
MARTENSITE
TENSILE STRENGTH
600MPa
1500MPa

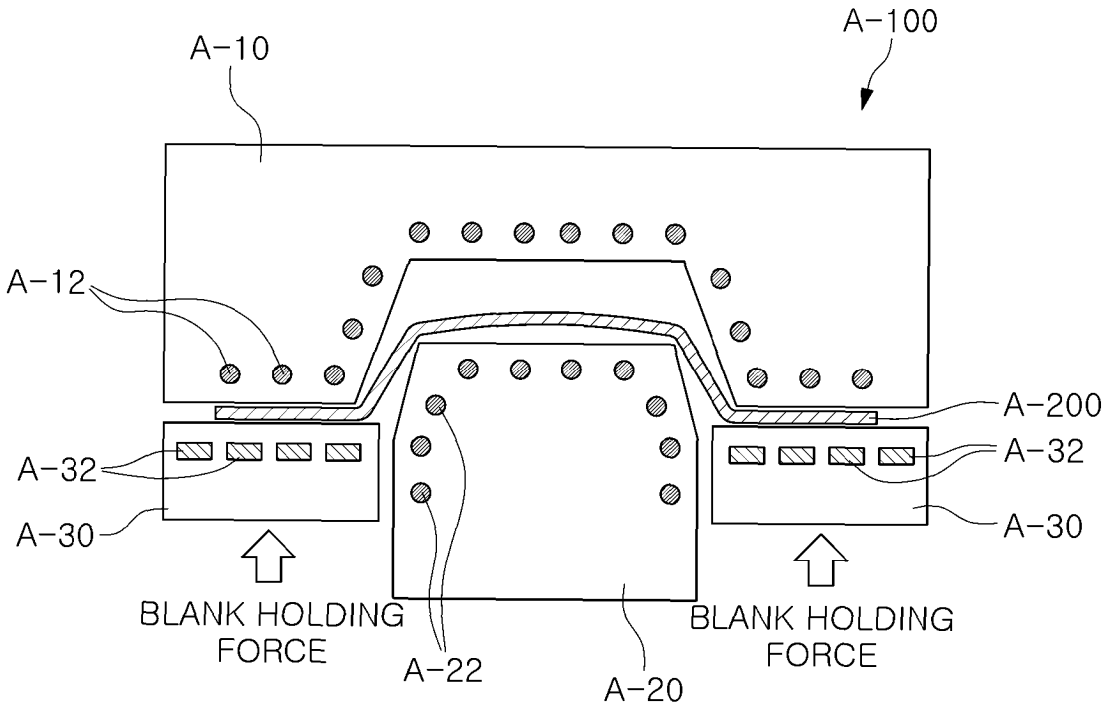
[FIG. 6]


TEMPERATURE, ℃
930
730
200
20
60s
15℃/s
HOT FORMING
50℃/s
20℃/s
----- 22MnB5
—— HARDENABILITY-IMPROVED TYPE
TIME, SECOND
MICROSTRUCTURE
FERRITE PEARLITE
AUSTENITE
MARTENSITE
TENSILE STRENGTH
600MPa
1500MPa

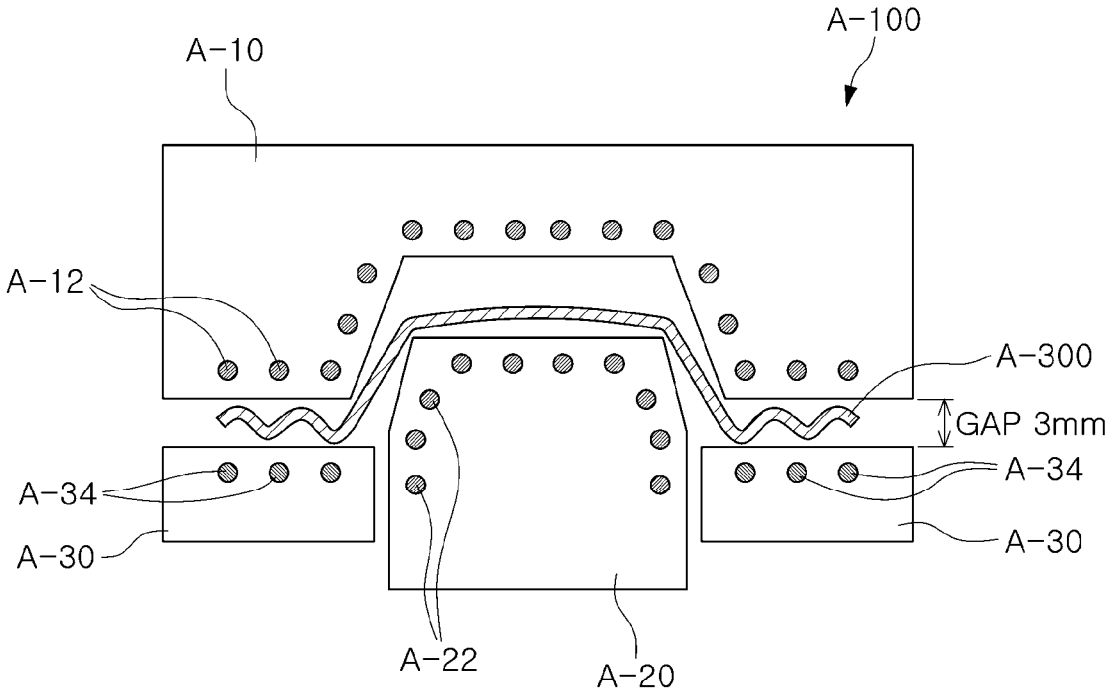
[FIG. 7]


TEMPERATURE, ℃
930
730
200
20
60s
15℃/s
HOT FORMING
20℃/s
TIME, SECOND
MICROSTRUCTURE
FERRITE
PEARLITE
AUSTENITE
MARTENSITE
TENSILE STRENGTH
600MPa
1500MPa

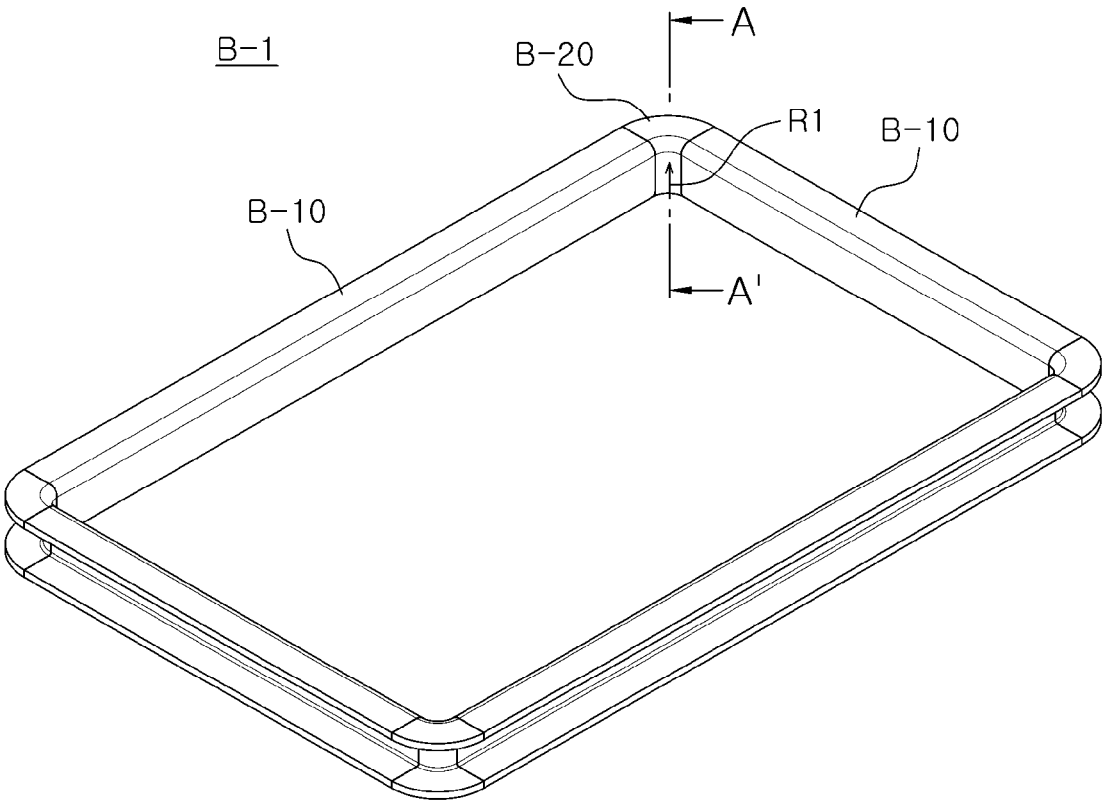
[FIG. 8]


A-100
A-10
A-12
A-200
A-32
A-30
A-32
A-30
BLANK HOLDING FORCE
BLANK HOLDING FORCE
A-22
A-20

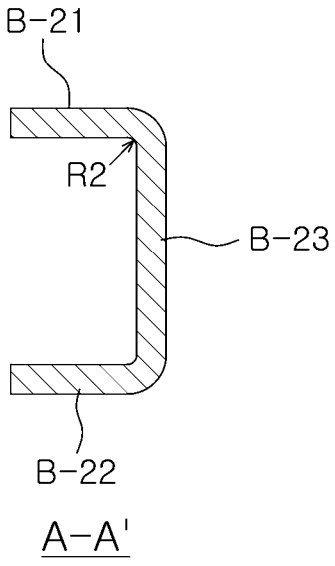
[FIG. 9]



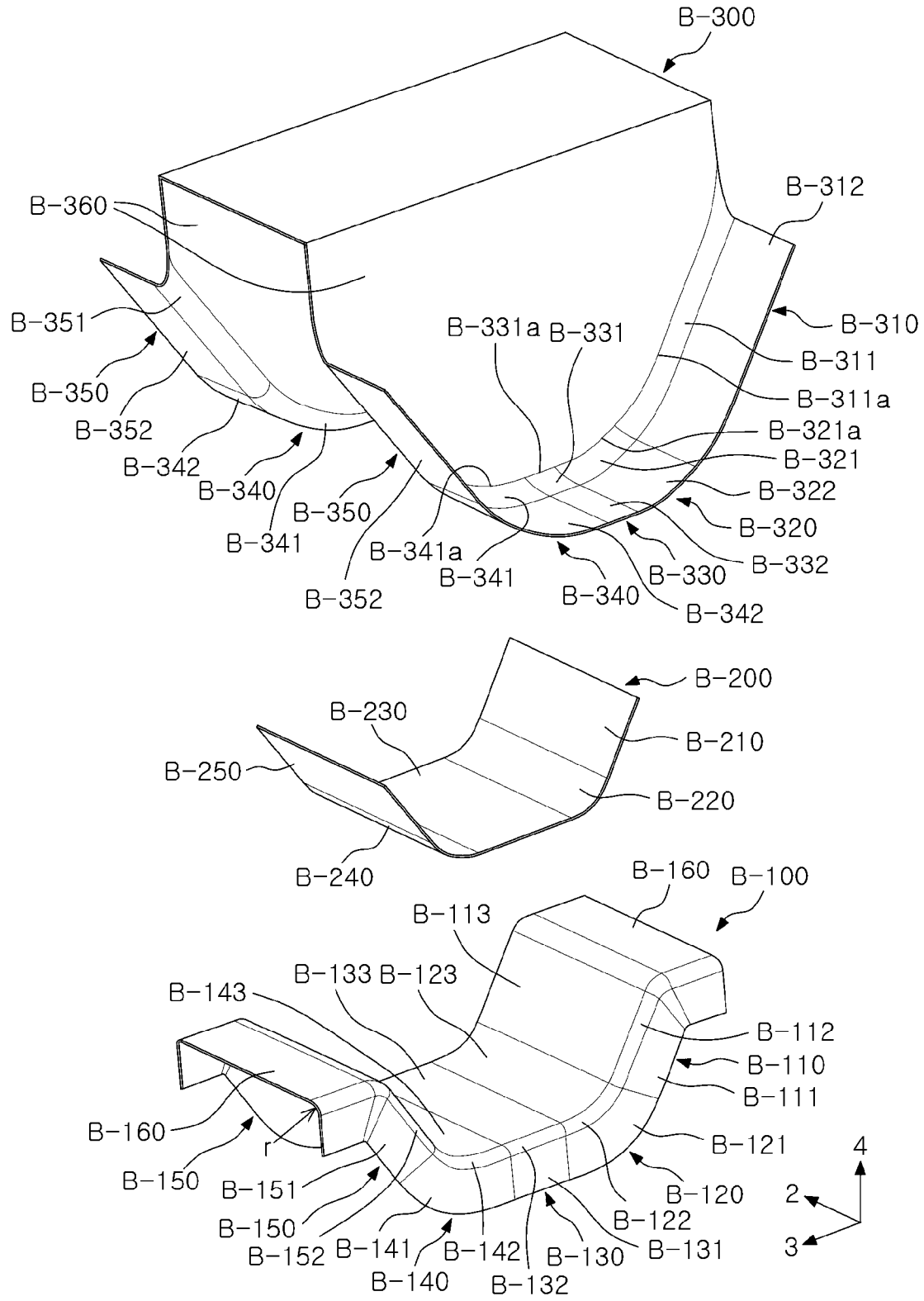
[FIG. 10]



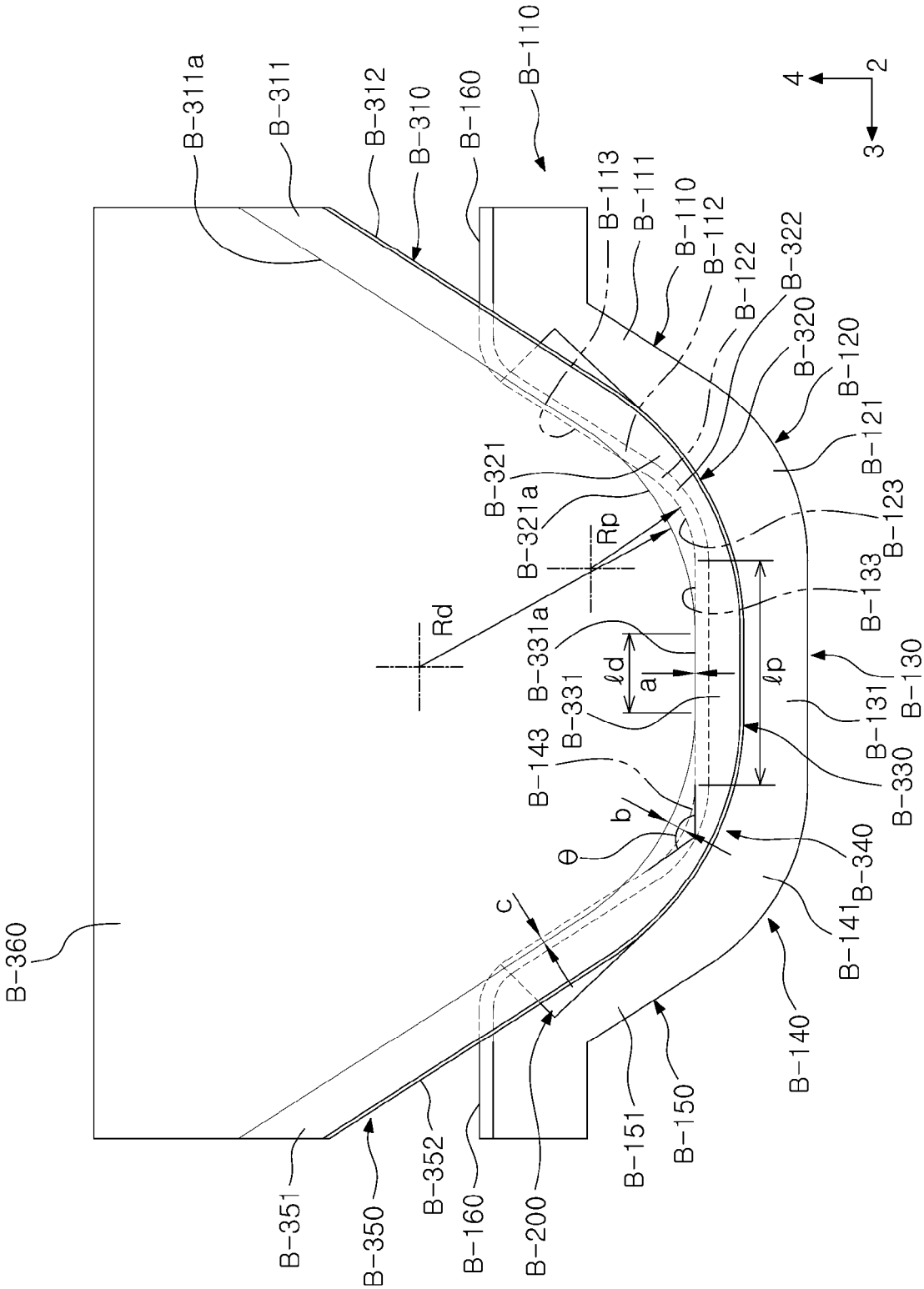
[FIG. 11]



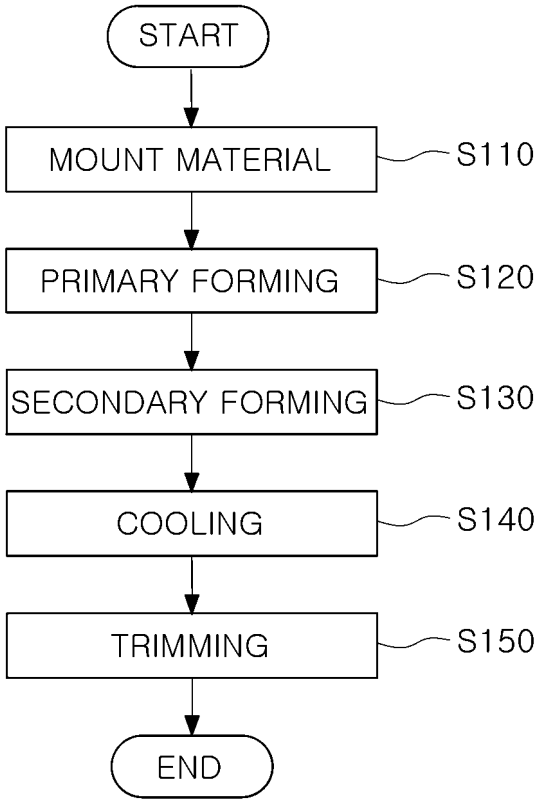
[FIG. 12]


B-300
B-360
B-312
B-351
B-331a
B-331
B-310
B-311
B-350
B-311a
B-352
B-321a
B-342
B-340
B-350
B-321
B-322
B-341
B-341a
B-320
B-332
B-352
B-341
B-330
B-340
B-342
B-200
B-230
B-210
B-250
B-220
B-240
B-160
B-100
B-113
B-133
B-123
B-143
B-112
B-110
B-111
B-160
B-121
B-150
B-151
B-120
B-150
B-122
B-152
B-141
B-142
B-130
B-131
B-140
B-132
4
2
3

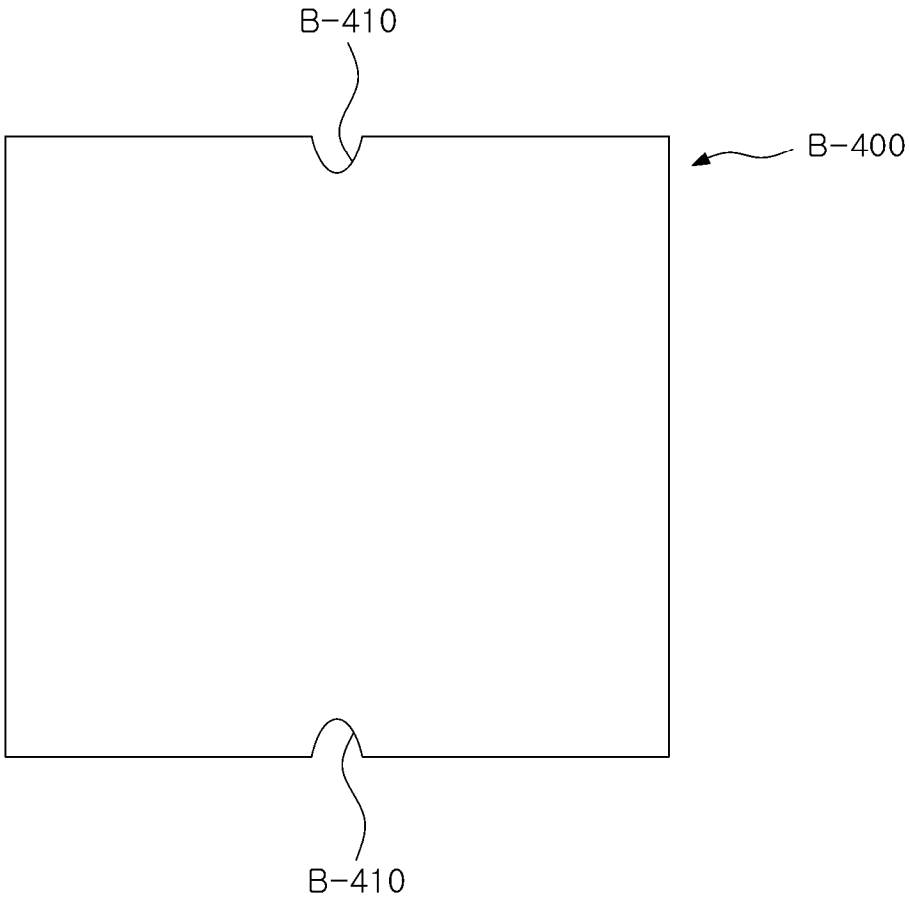
[FIG. 13]


B-311a
B-311
B-312
B-310
B-160
B-110
B-113
B-111
B-110
B-112
B-122
B-322
B-320
B-120
B-121
B-123
B-133
B-130
B-131
B-330
B-340
B-141
B-140
B-150
B-151
B-200
B-160
B-352
B-350
B-351
B-360
B-321
B-321a
B-331a
B-331
B-143
Rp
Rd
ℓd
a
ℓp
b
θ
c
4
2
3

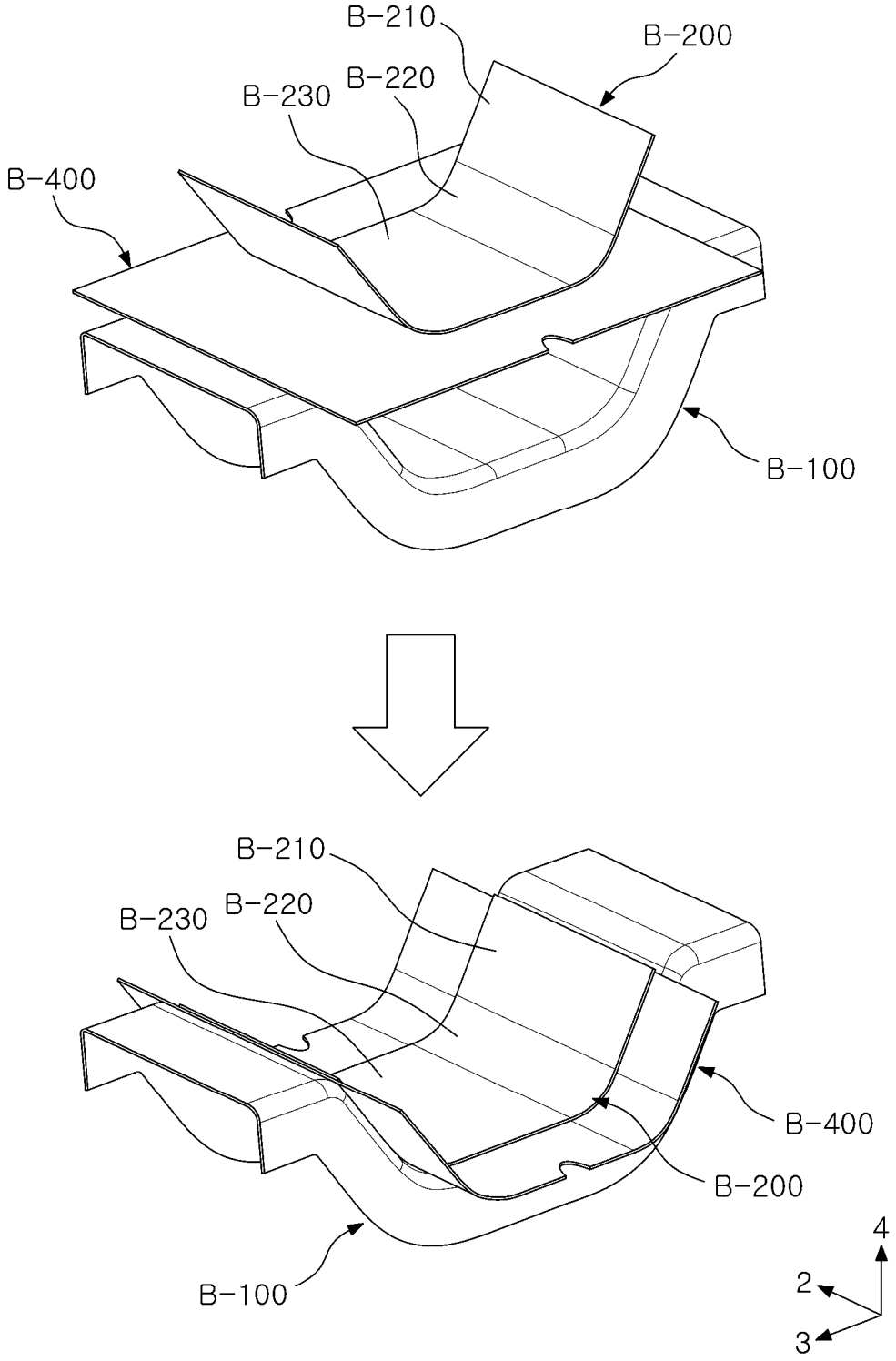
[FIG. 14]


START
MOUNT MATERIAL
S110
PRIMARY FORMING
S120
SECONDARY FORMING
S130
COOLING
S140
TRIMMING
S150
END

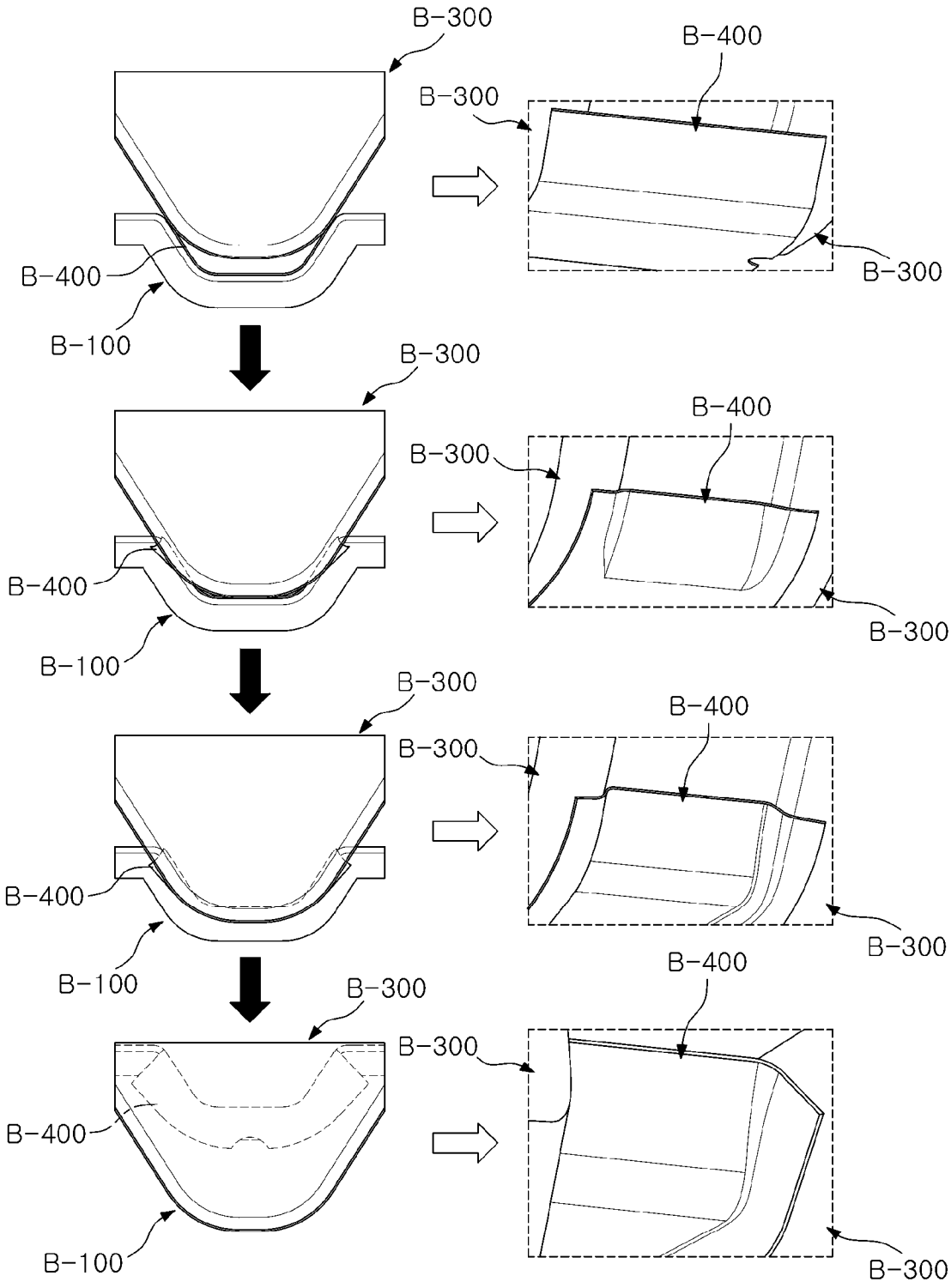
[FIG. 15]



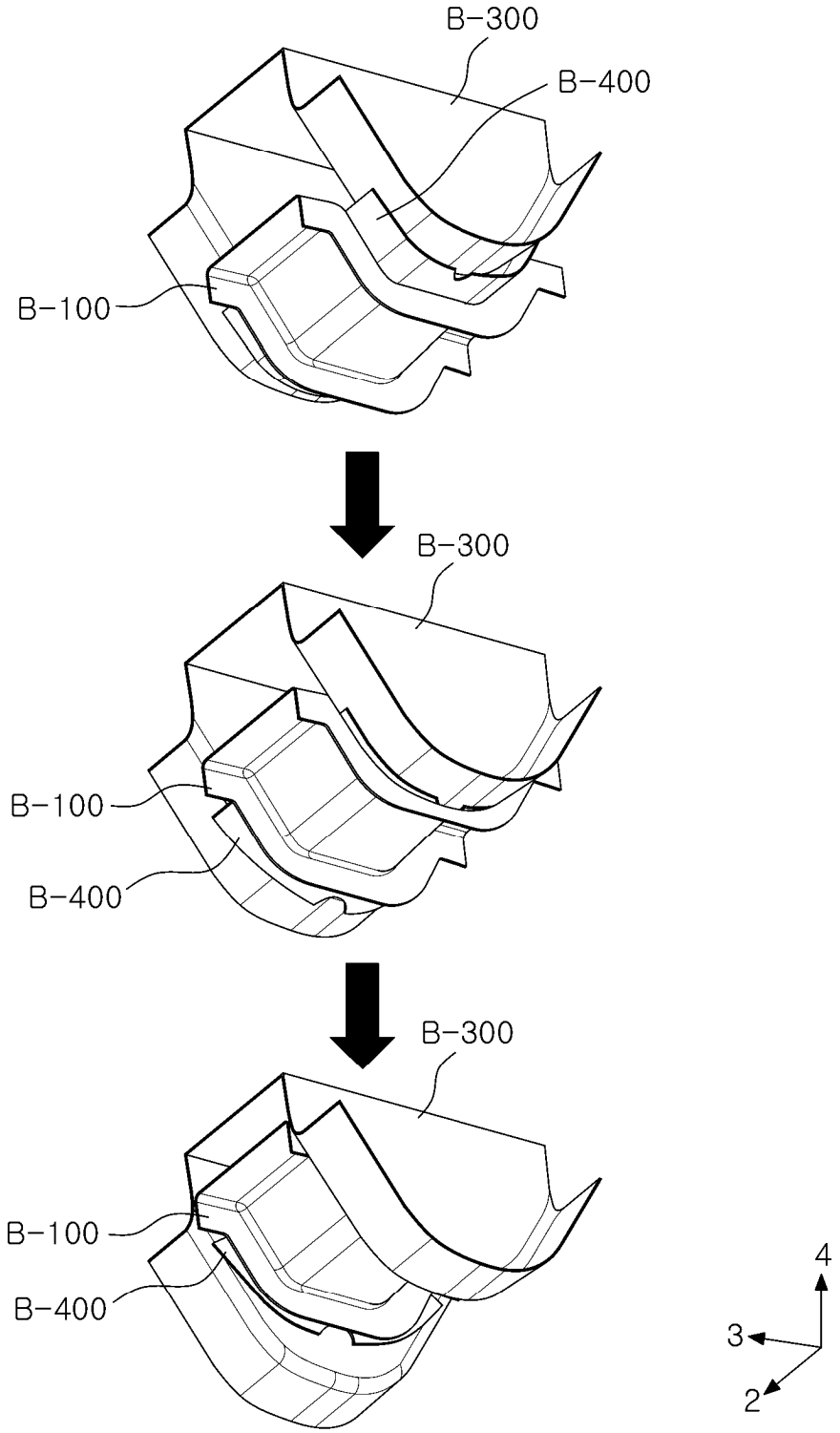
[FIG. 16]


B-210
B-200
B-220
B-230
B-400
B-100
B-210
B-220
B-230
B-400
B-200
B-100
4
2
3

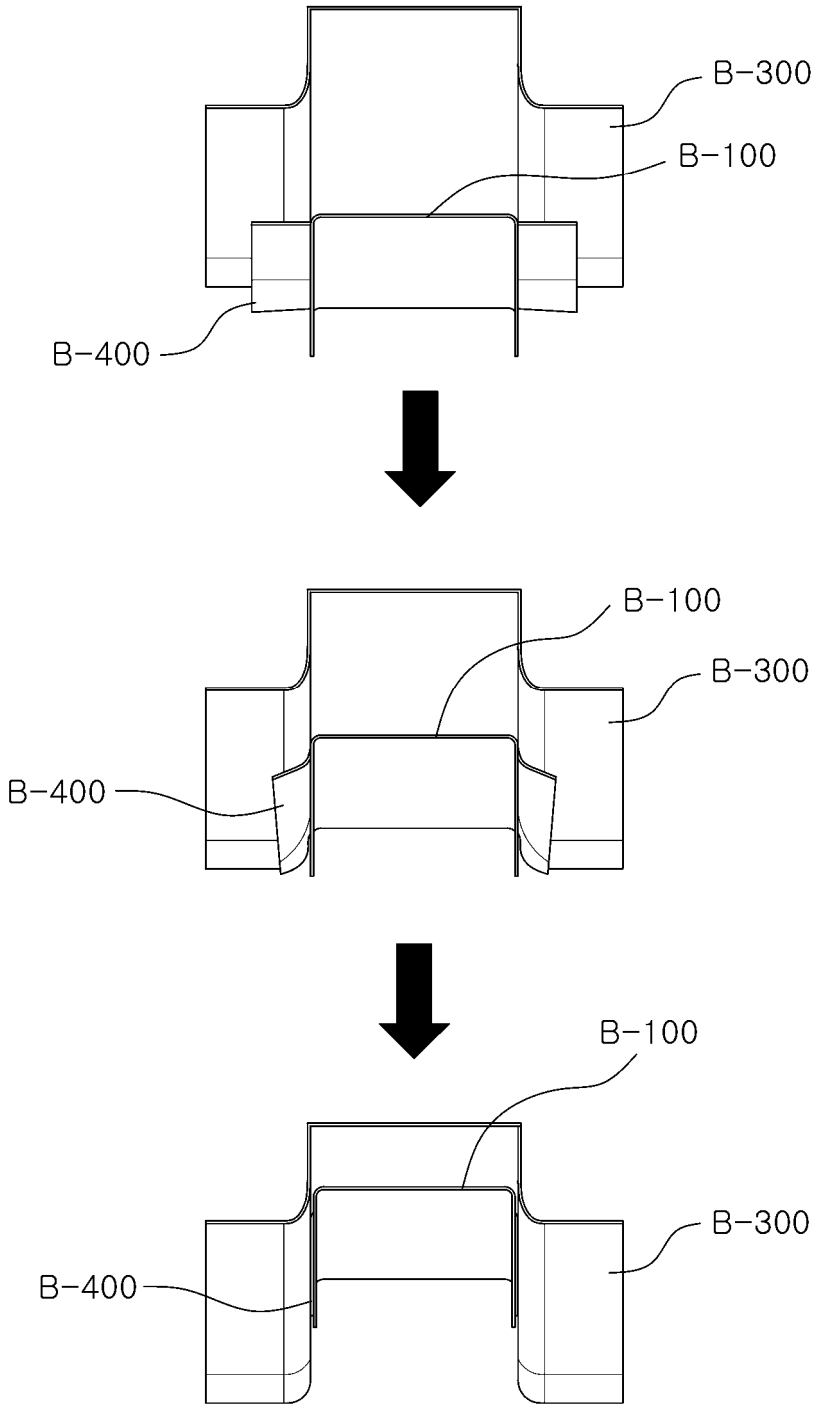
[FIG. 17]


B-300
B-400
B-300
B-300
B-400
B-100
B-300
B-400
B-300
B-300
B-400
B-100
B-300
B-400
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B-300
B-300
B-400
B-100

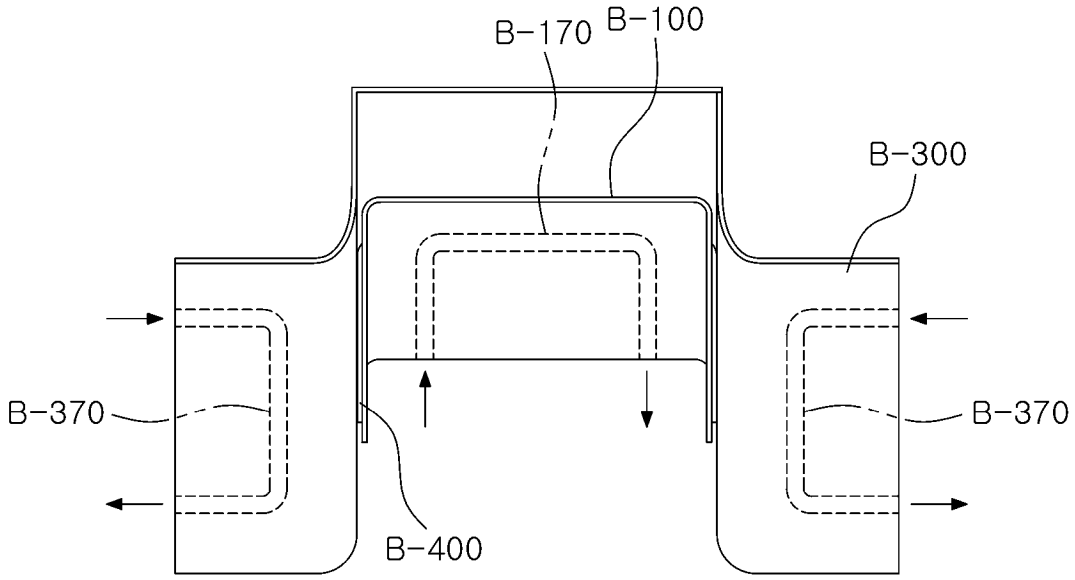
[FIG. 18a]



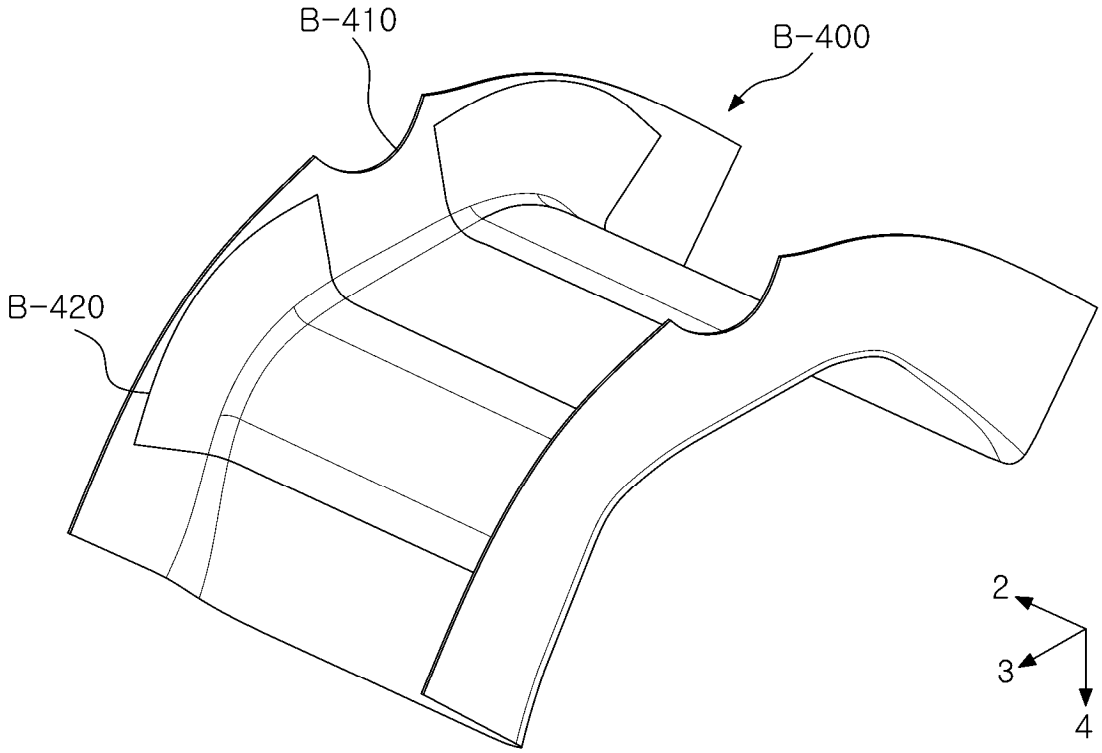
[FIG. 18b]



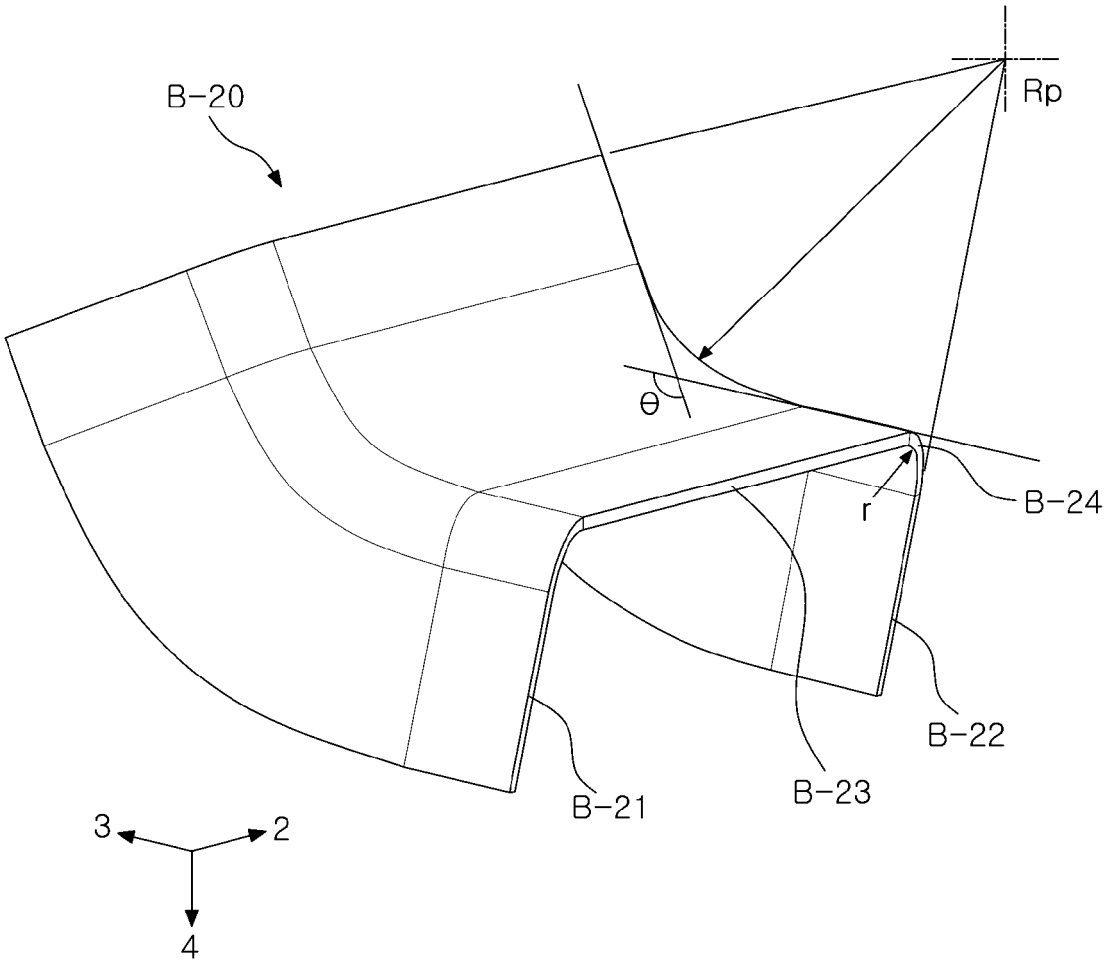
[FIG. 19]



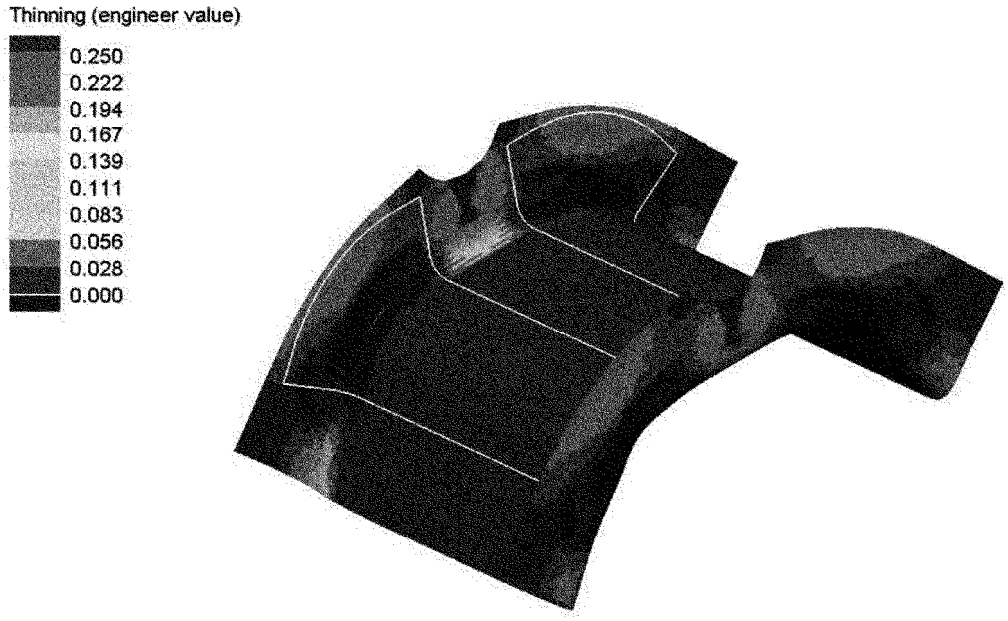
[FIG. 20]



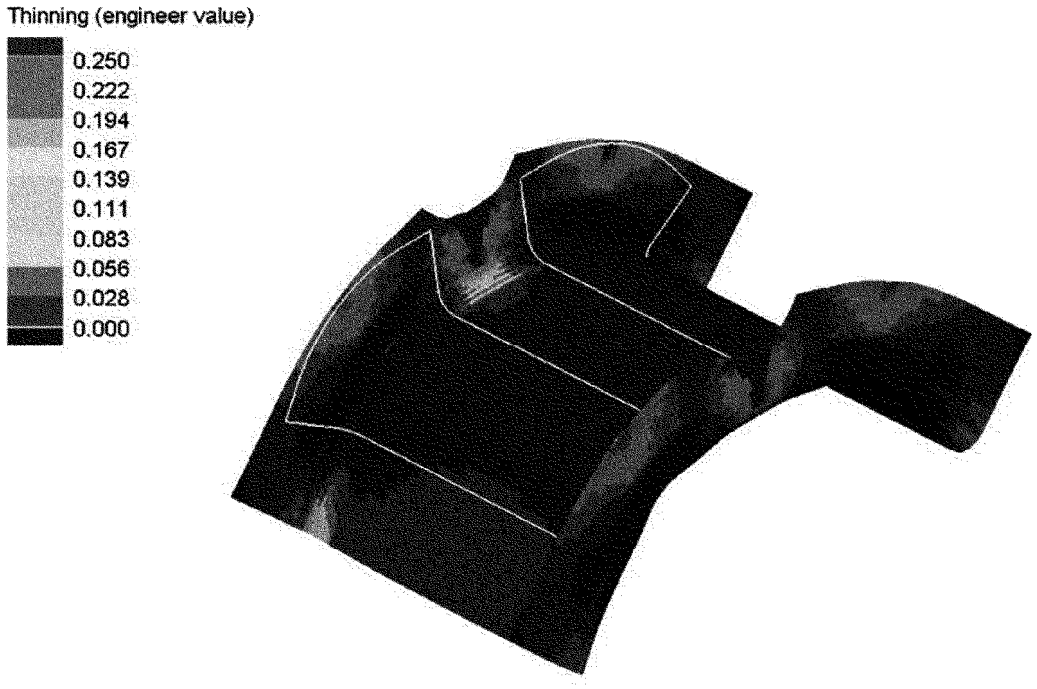
[FIG. 21]



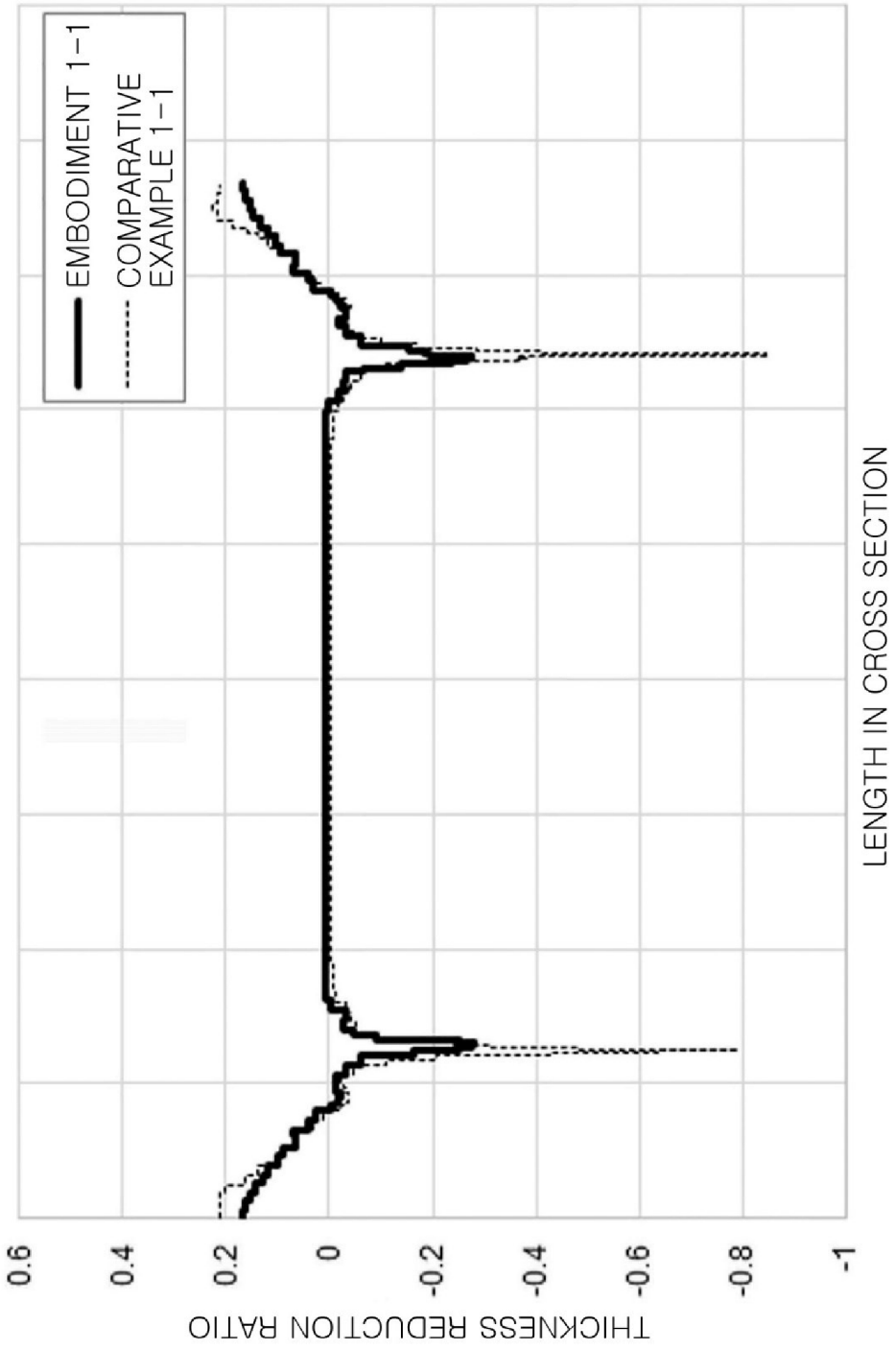
[FIG. 22]


Thinning (engineer value)
0.250
0.222
0.194
0.167
0.139
0.111
0.083
0.056
0.028
0.000

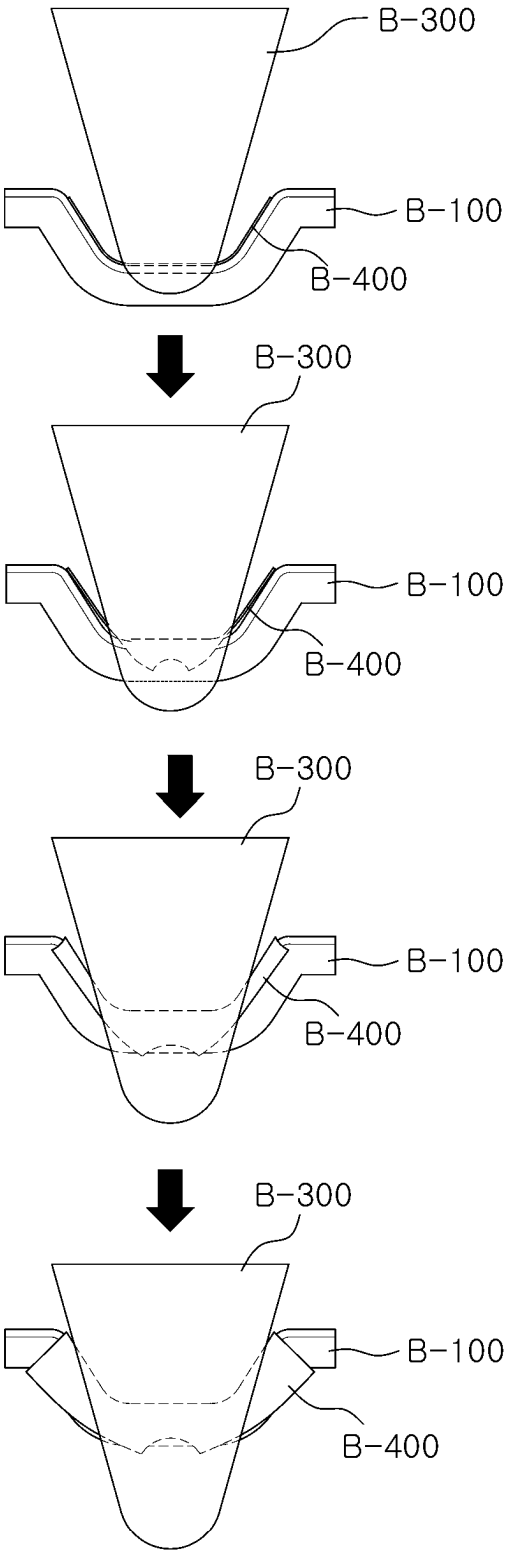
[FIG. 23]


Thinning (engineer value)
0.250
0.222
0.194
0.167
0.139
0.111
0.083
0.056
0.028
0.000

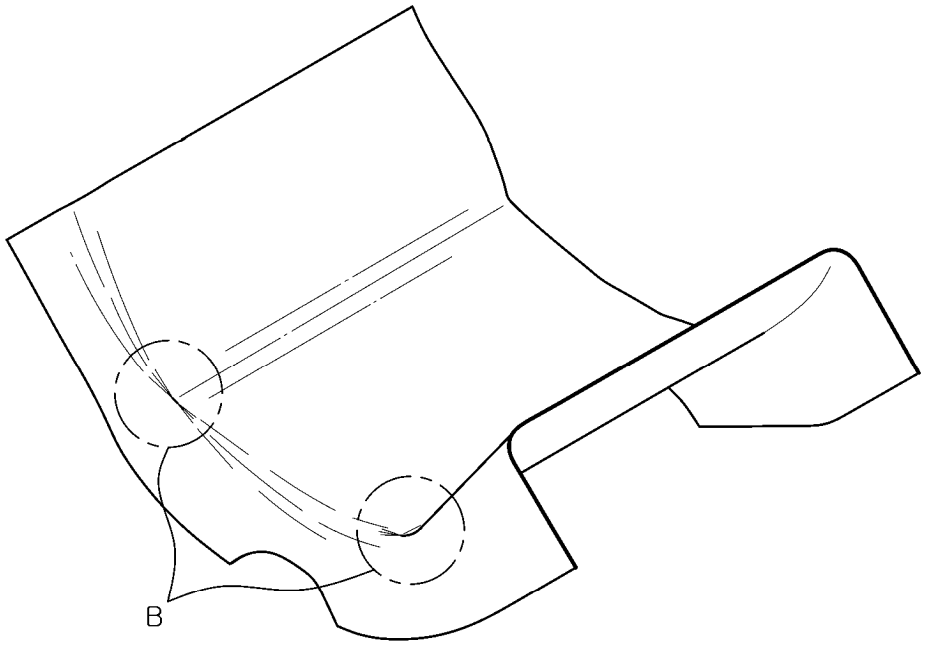
[FIG. 24]


EMBODIMENT 1-1
COMPARATIVE EXAMPLE 1-1
THICKNESS REDUCTION RATIO
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
LENGTH IN CROSS SECTION

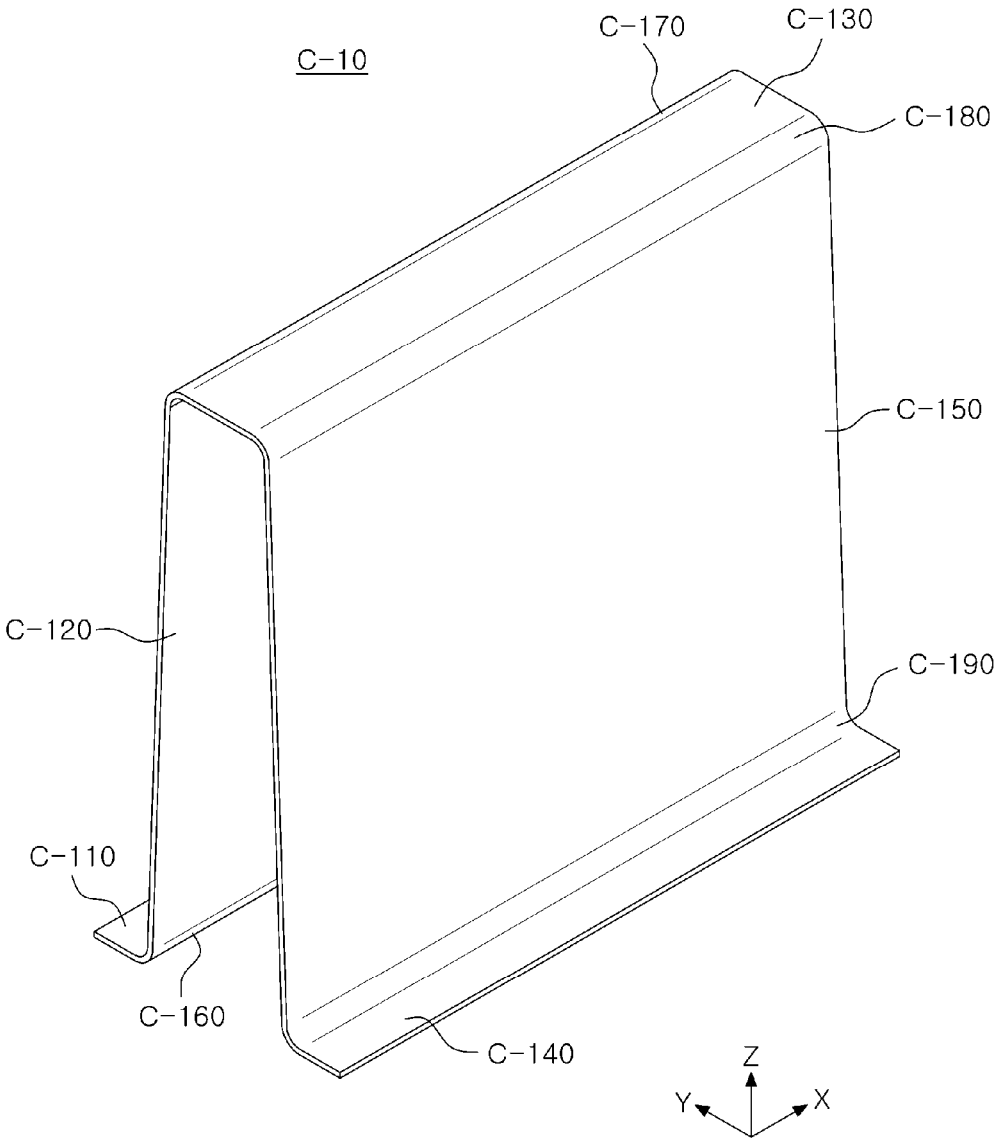
[FIG. 25]



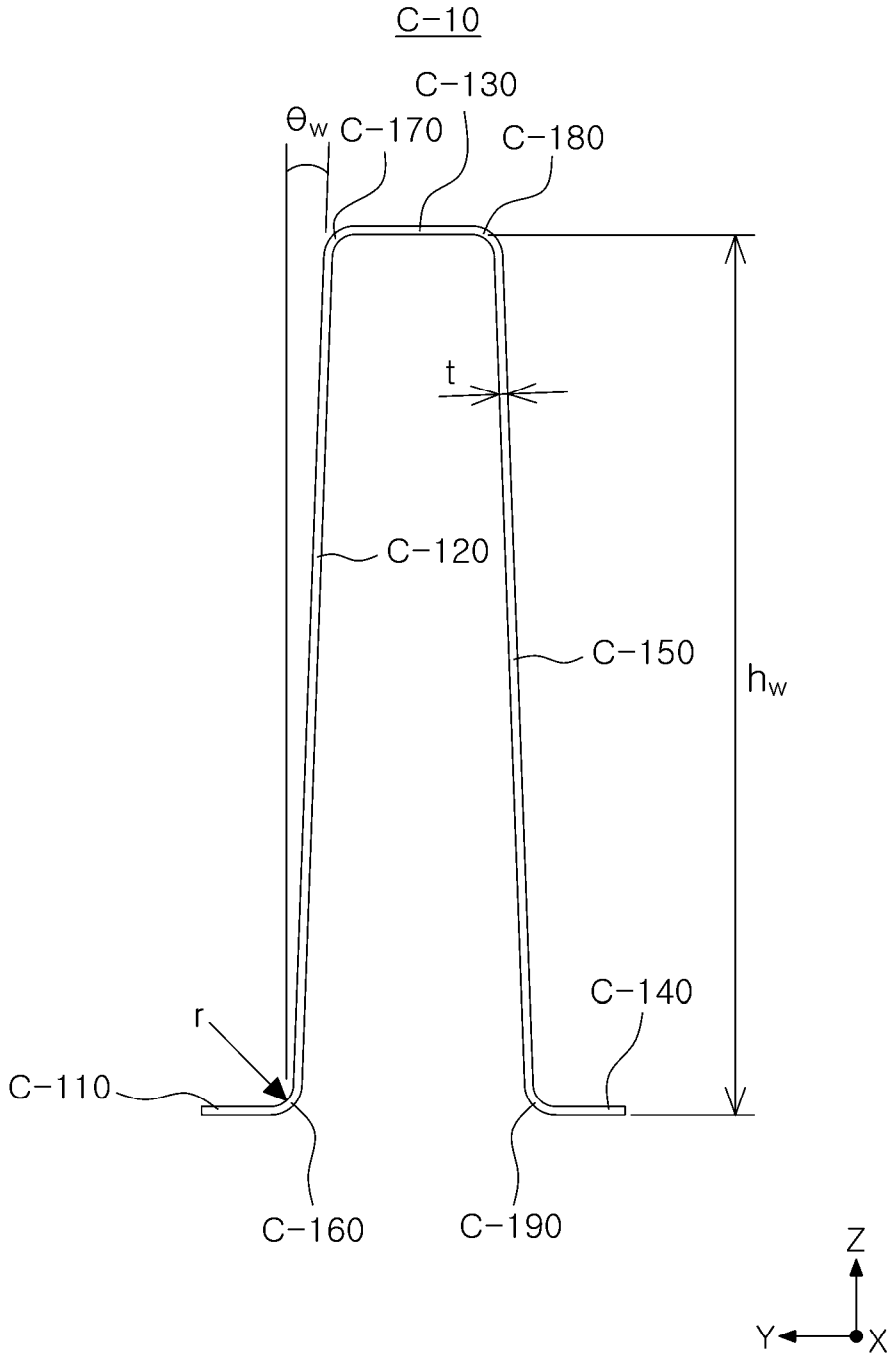
[FIG. 26]



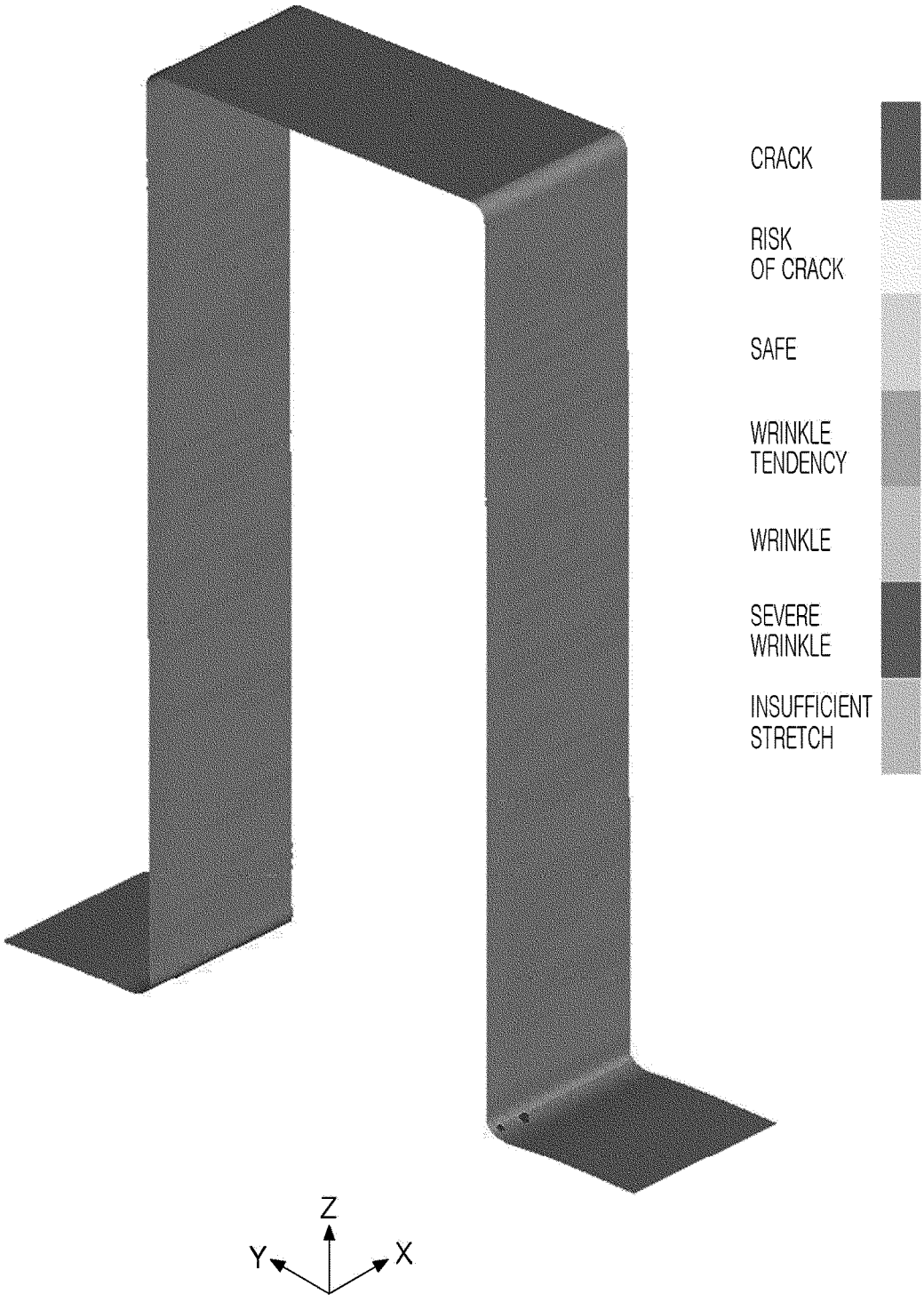
[FIG. 27]



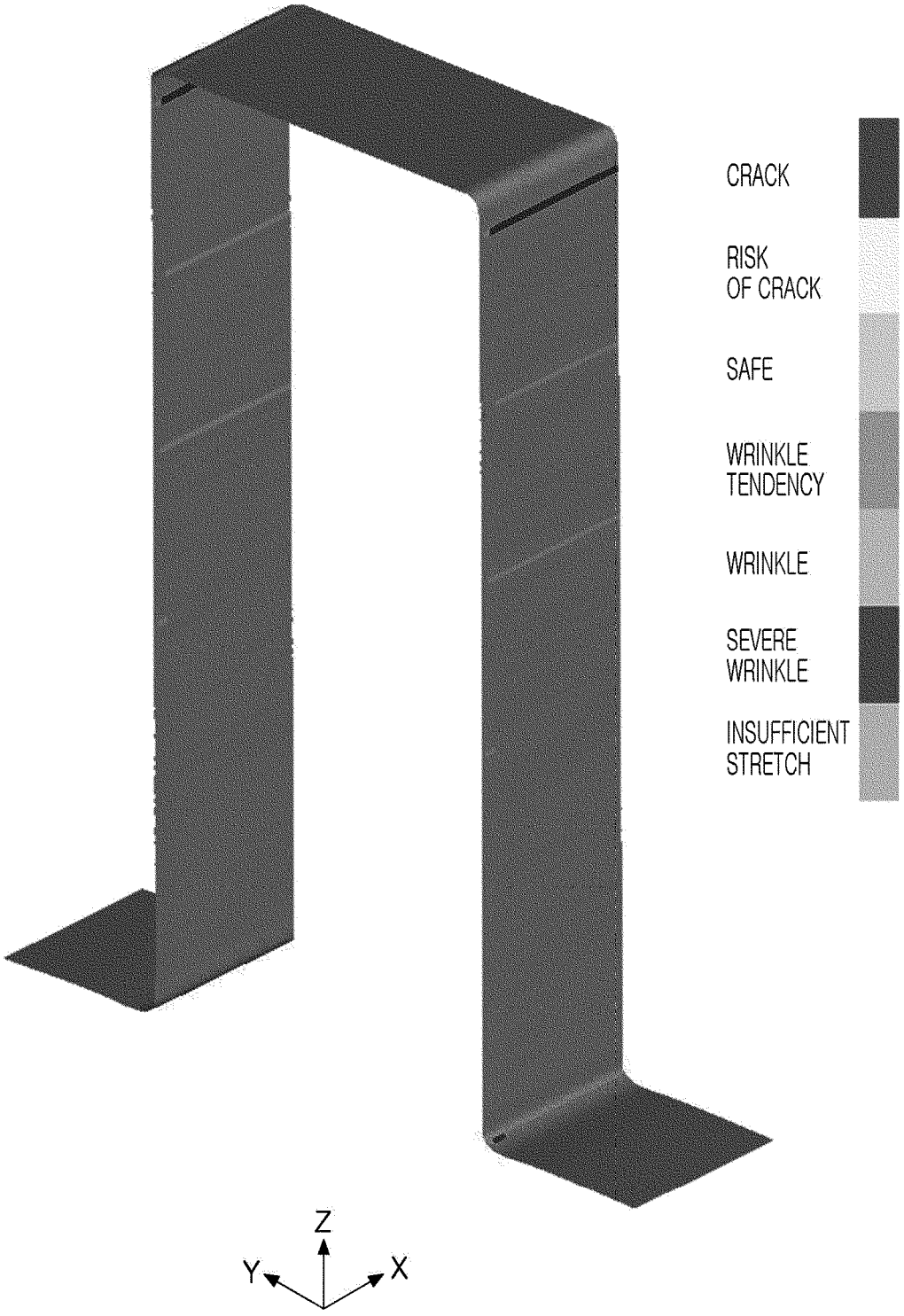
[FIG. 28]



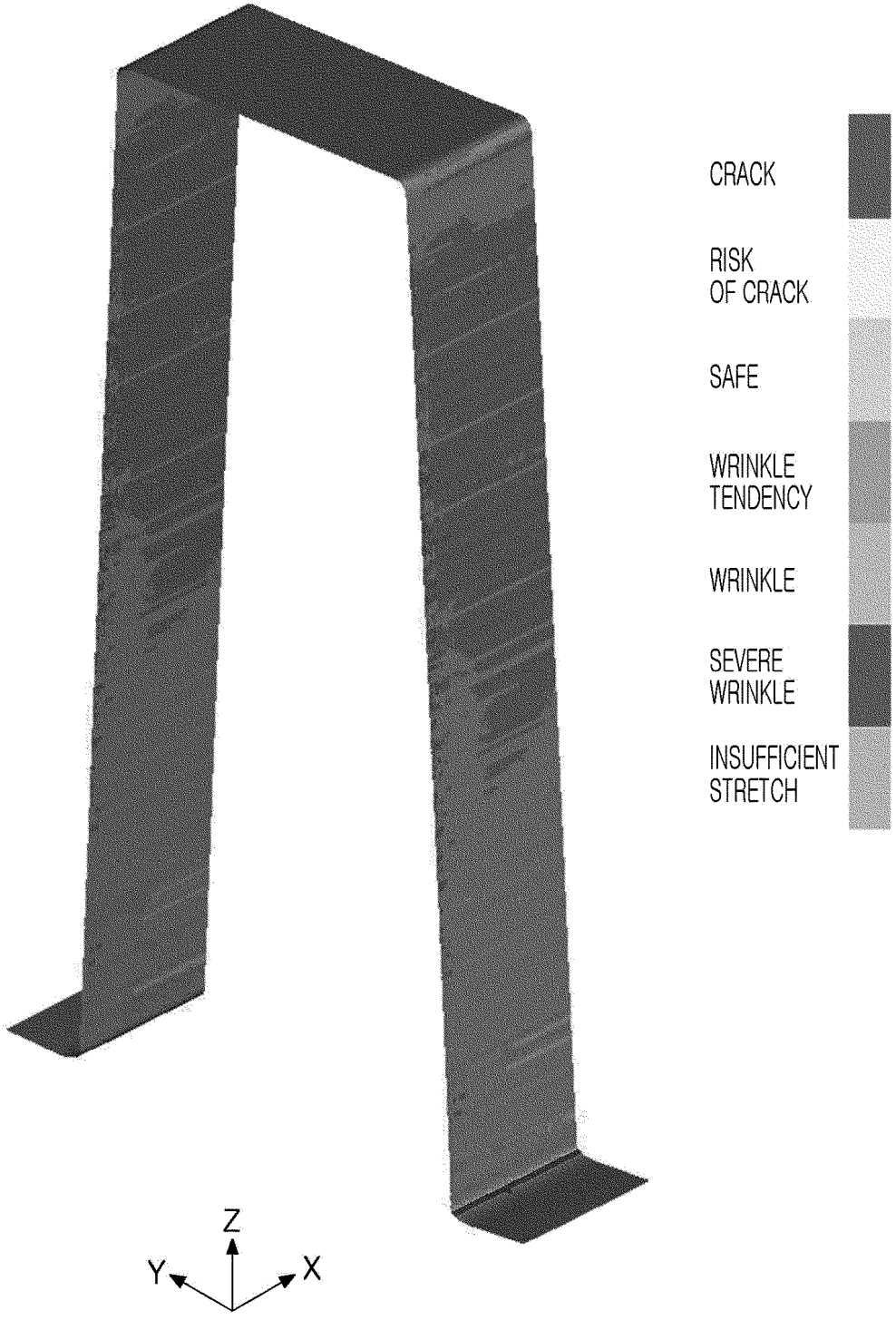
[FIG. 29a]


CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH
Z
Y
X

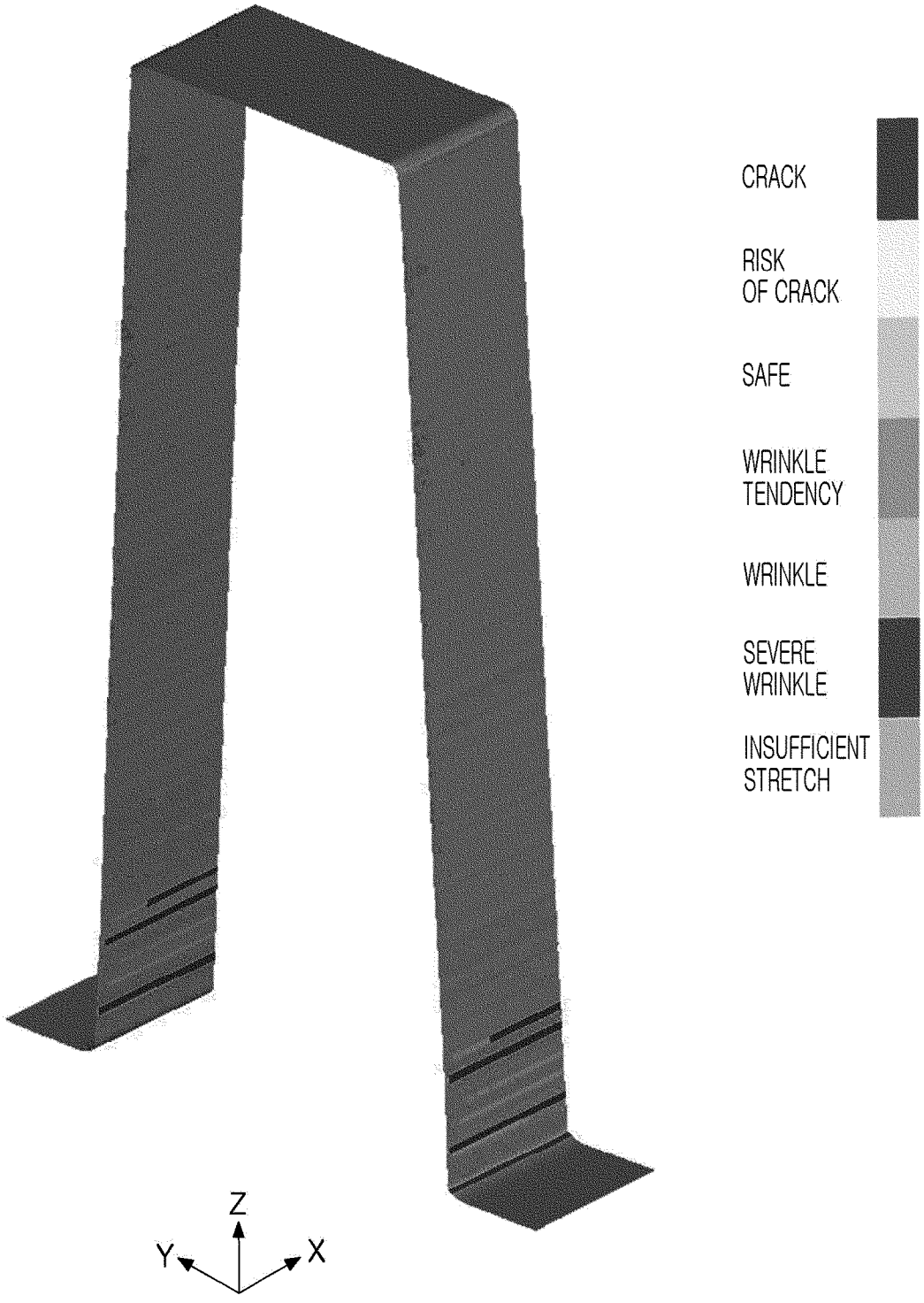
[FIG. 29b]


CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH
Z
Y
X

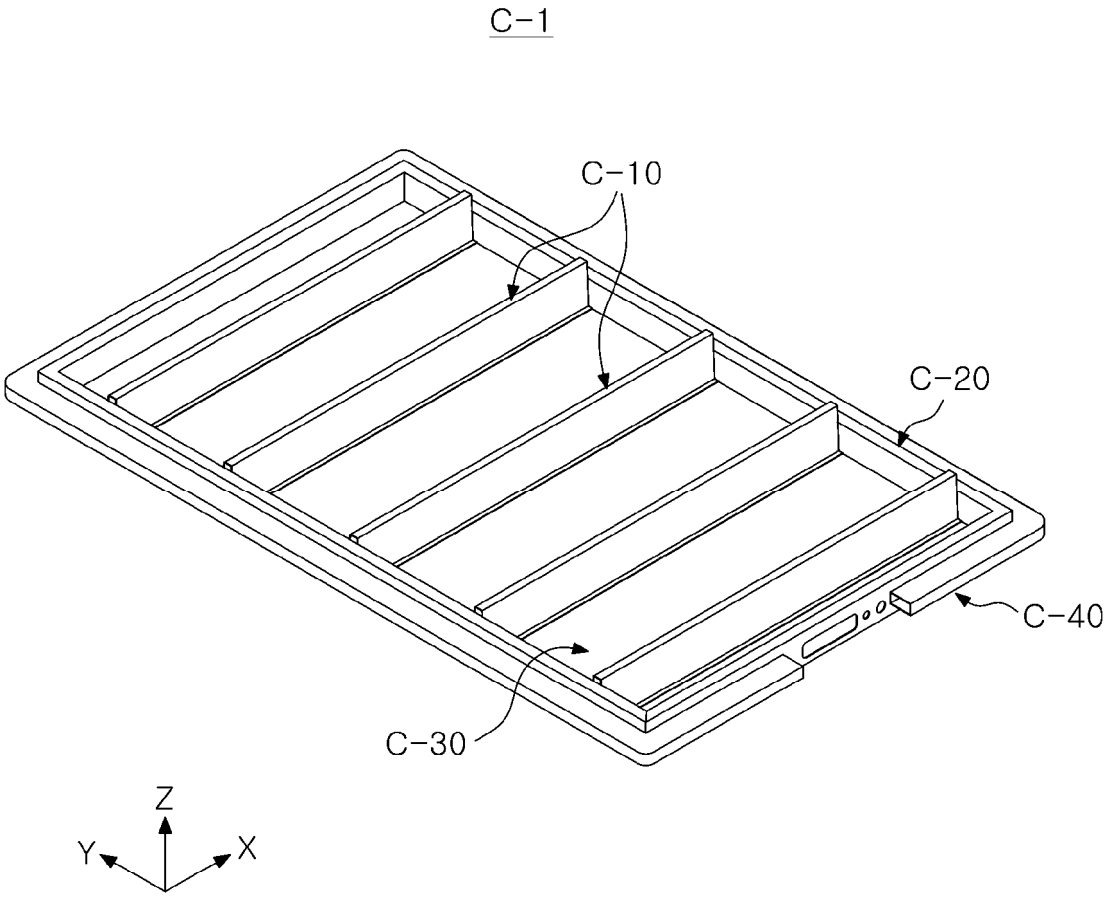
[FIG. 30a]


CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH
Z
Y
X

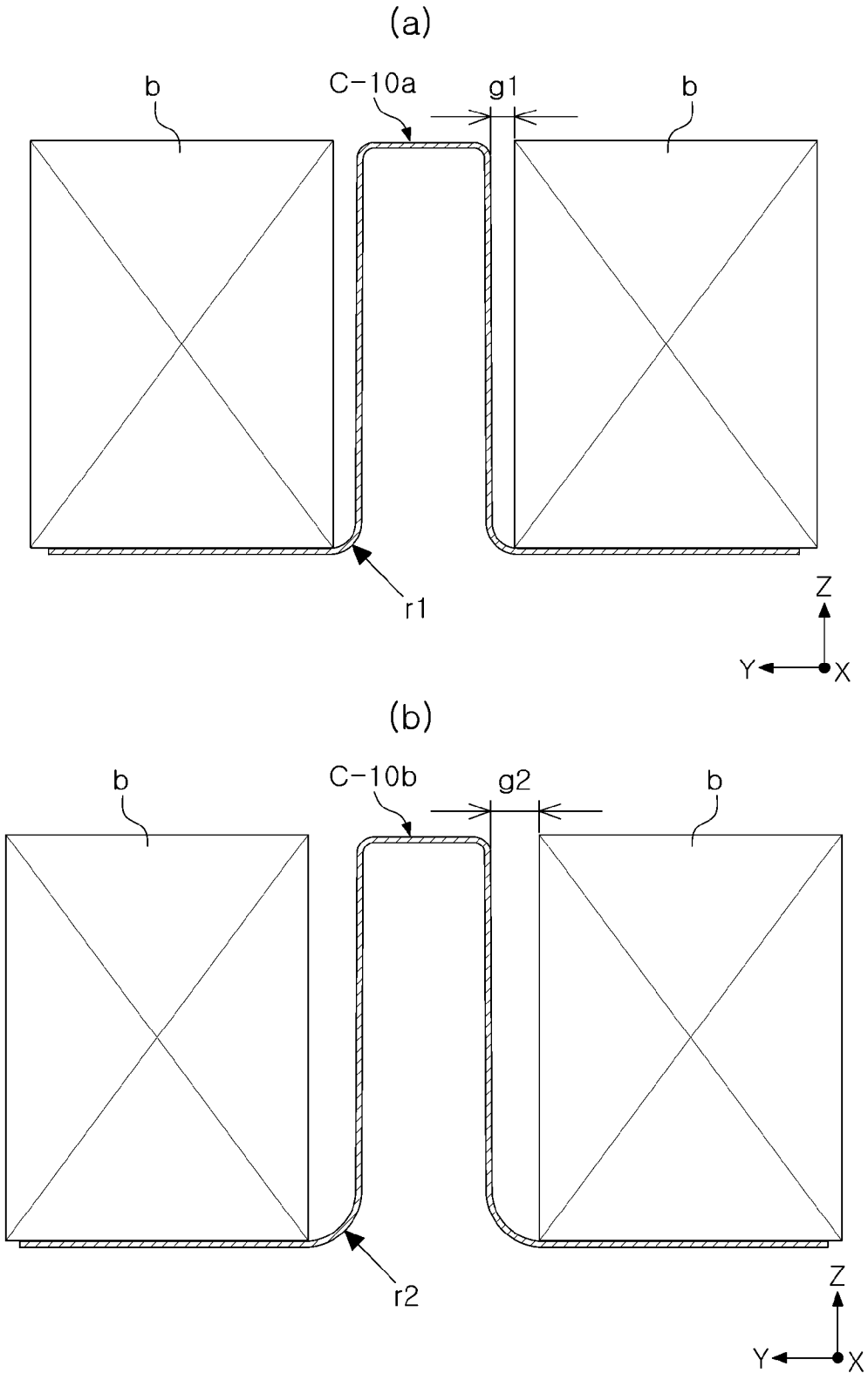
[FIG. 30b]


CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH
Z
Y
X

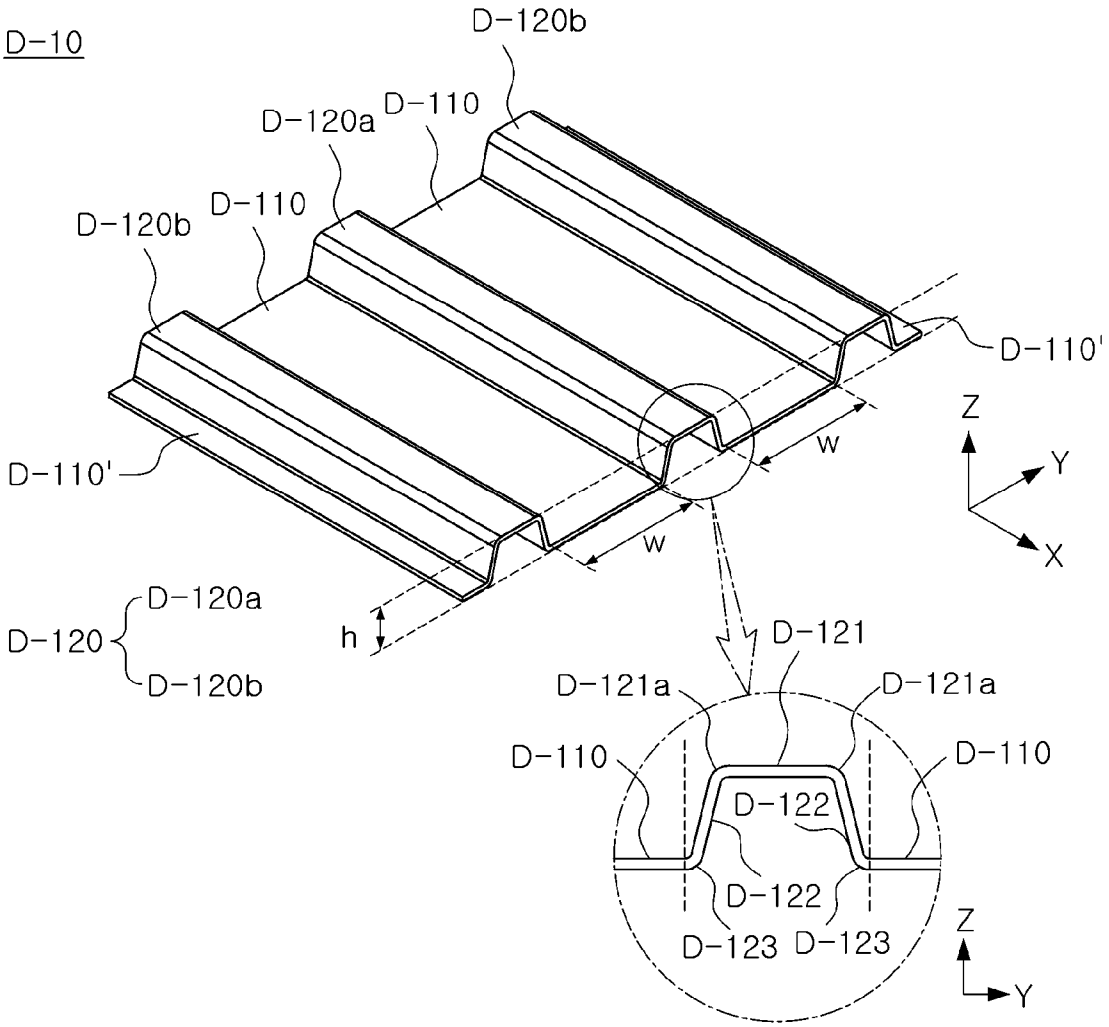
[FIG. 31]



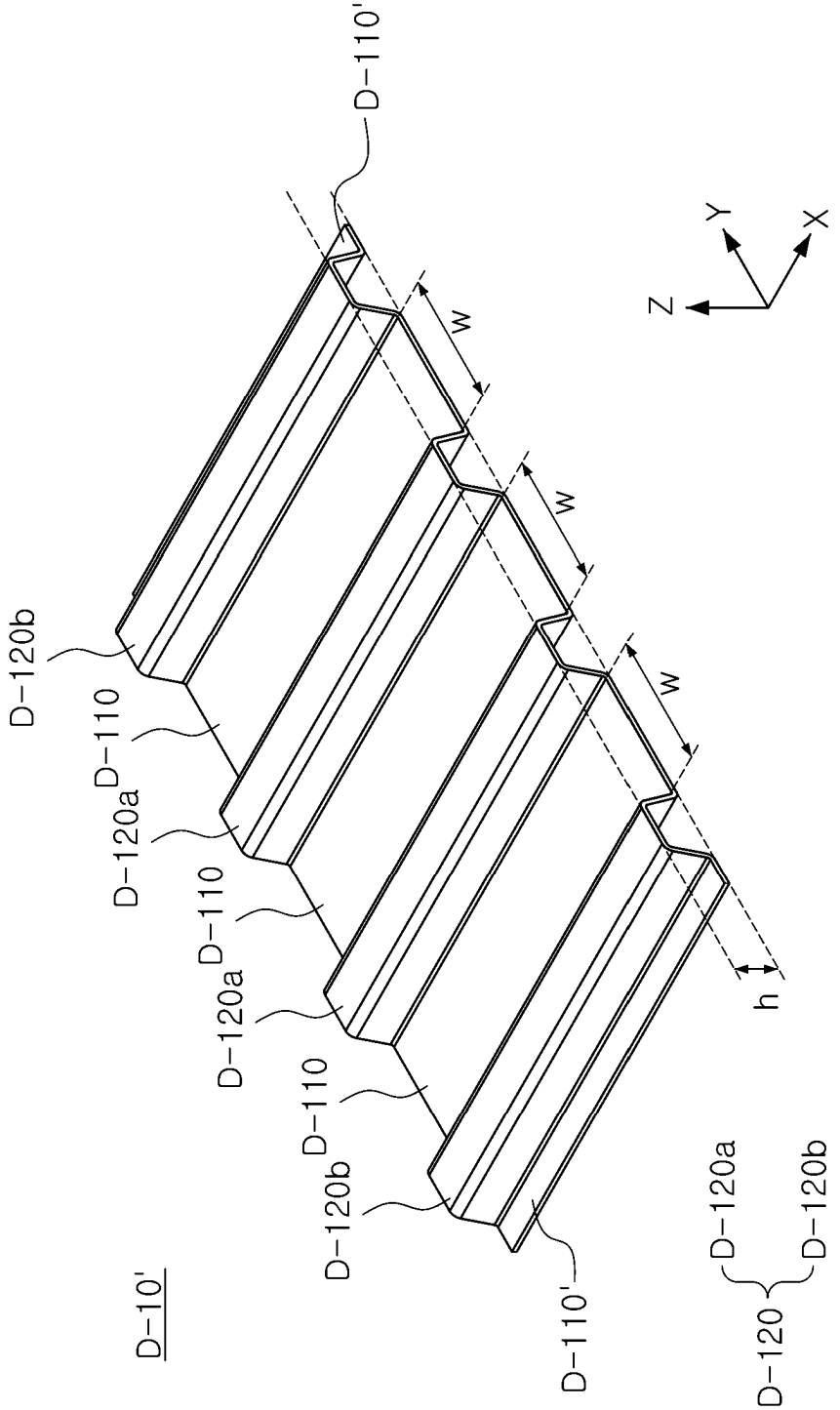
[FIG. 32]



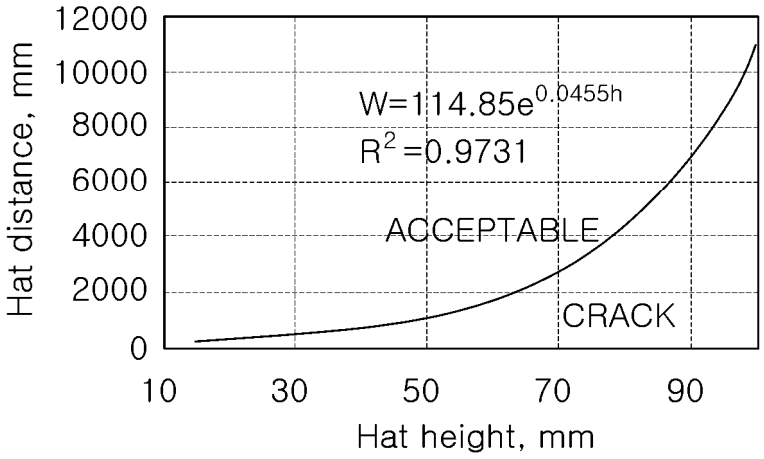
[FIG. 33]


D-10
D-120b
D-120a
D-110
D-120b
D-110
D-110'
D-110'
w
w
Z
Y
X
D-120
D-120a
D-120b
h
D-121
D-121a
D-121a
D-110
D-110
D-122
D-122
D-123
D-123
Z
Y

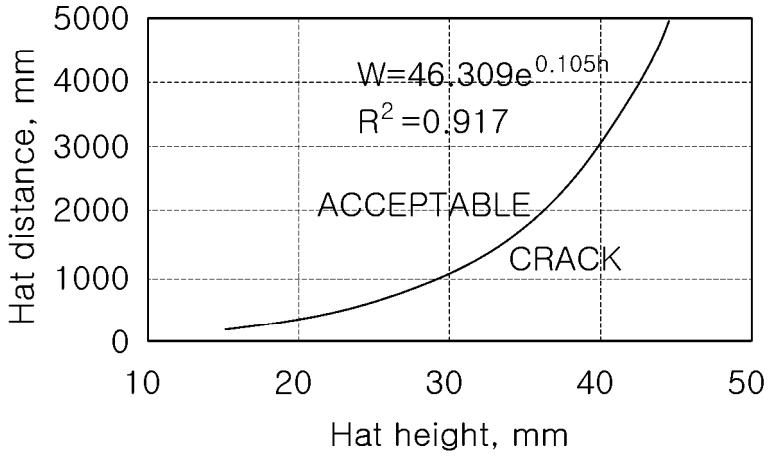
[FIG. 34]


D-10'
D-110'
D-120b
D-110
D-120a
D-110
D-120a
D-110
D-120b
D-110'
D-120
D-120a
D-120b
w
w
w
h
Y
X
Z

[FIG. 35]

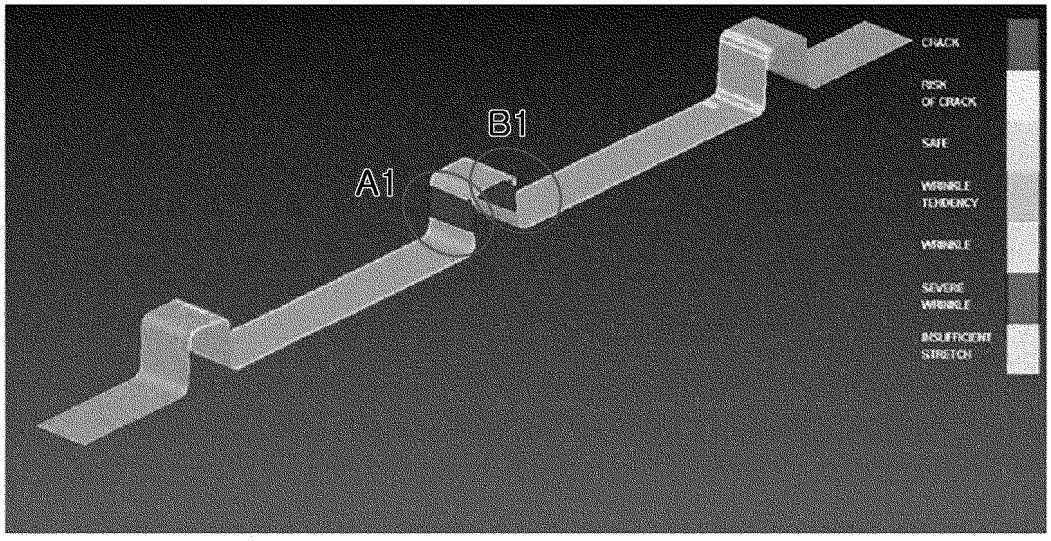

12000
10000
8000
6000
4000
2000
0
Hat distance, mm
W=114.85e^0.0455h
R^2=0.9731
ACCEPTABLE
CRACK
10
30
50
70
90
Hat height, mm

(a)

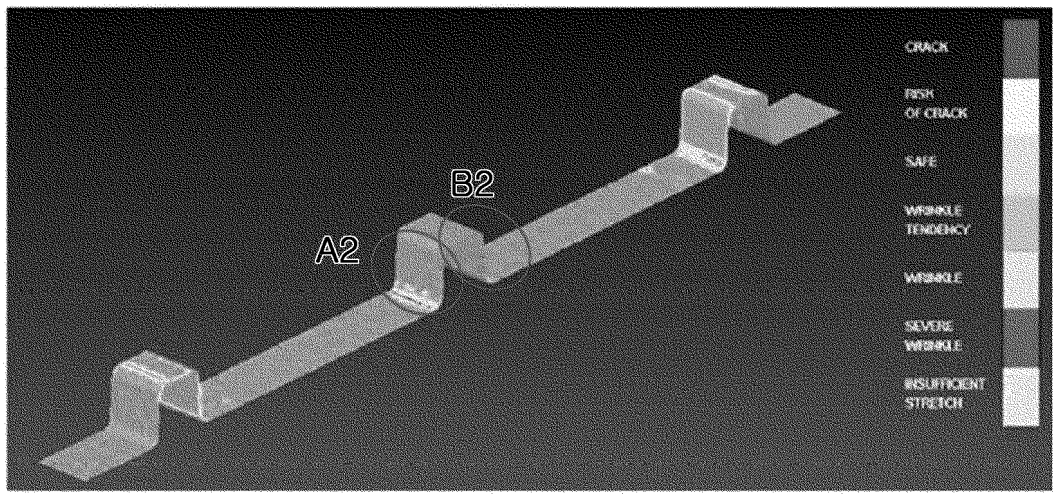

5000
4000
3000
2000
1000
0
Hat distance, mm
W=46.309e^0.105h
R^2=0.917
ACCEPTABLE
CRACK
10
20
30
40
50
Hat height, mm

(b)

[FIG. 36]

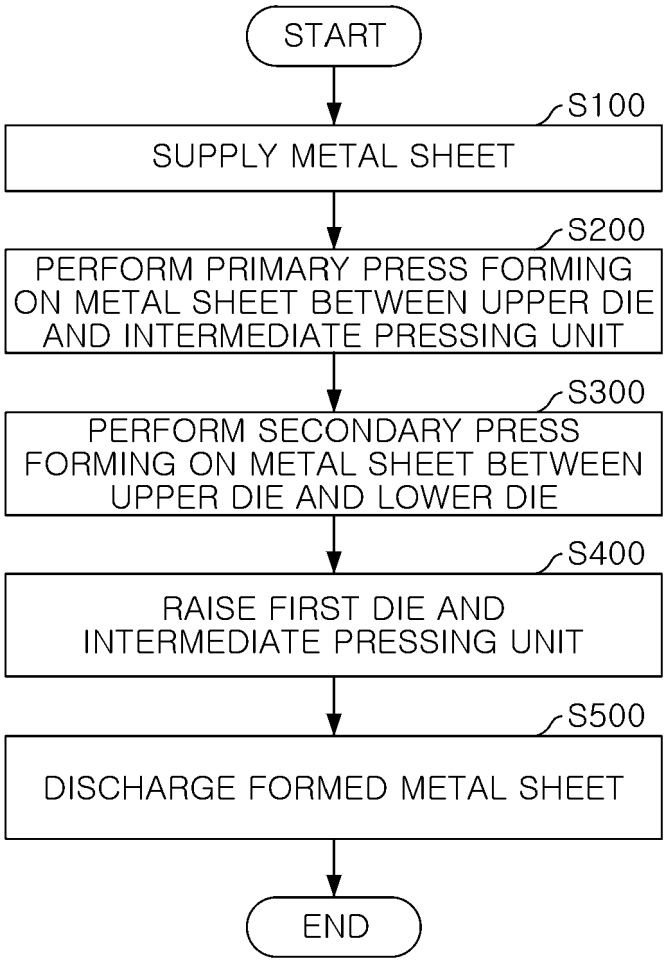

B1
A1
CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH

(a)

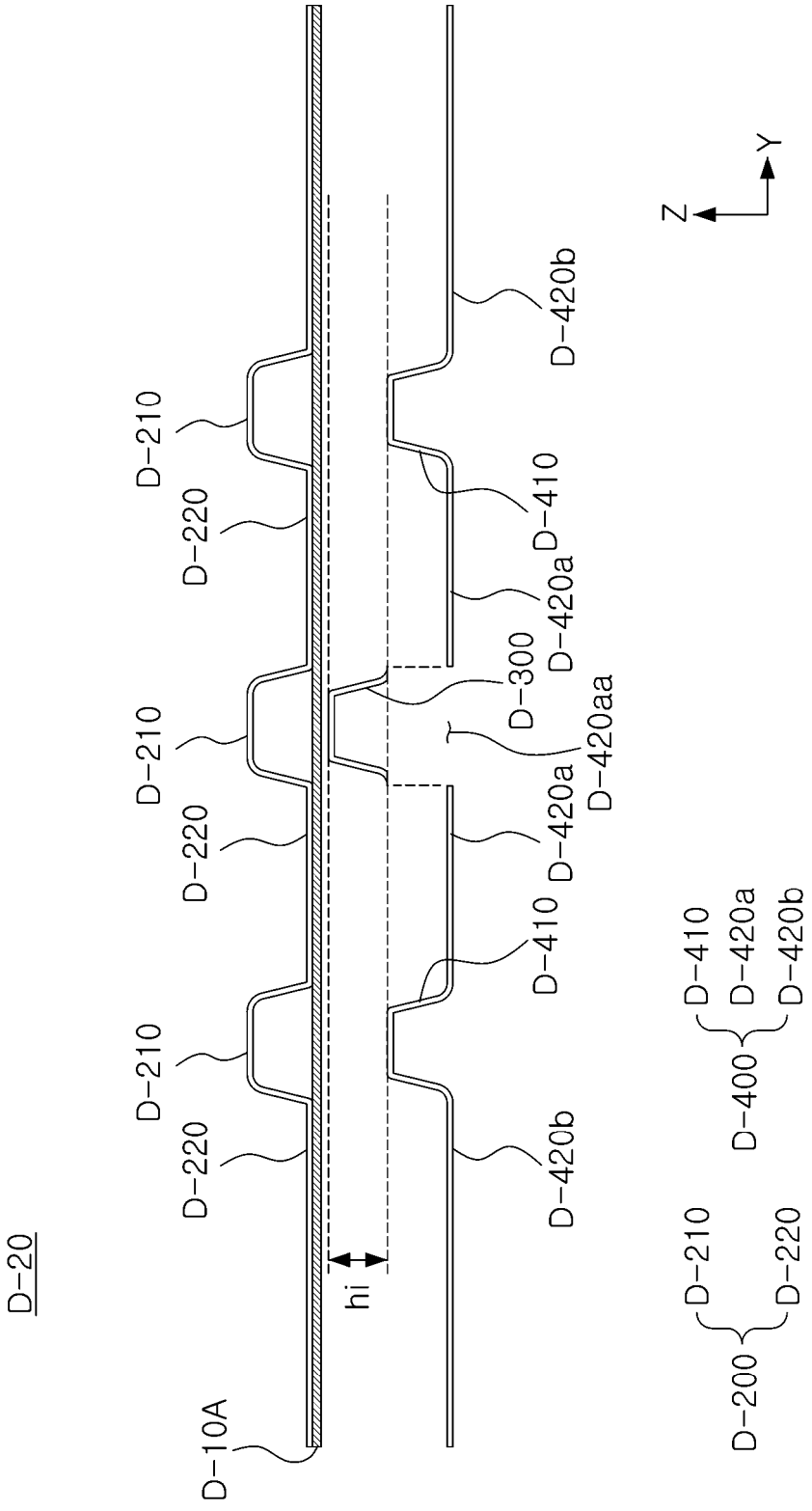

B2
A2
CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH

(b)

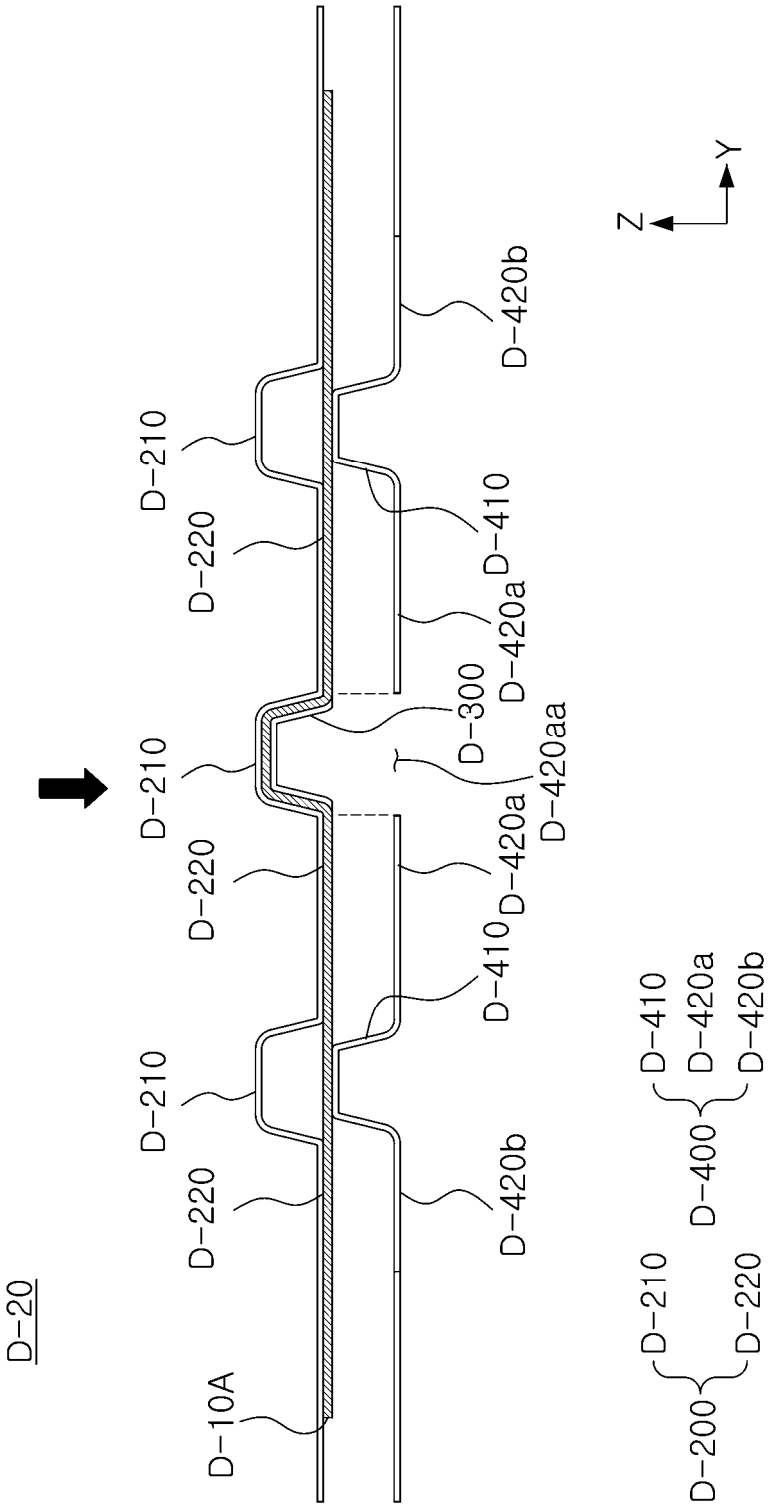
[FIG. 37]


START
S100
SUPPLY METAL SHEET
S200
PERFORM PRIMARY PRESS FORMING ON METAL SHEET BETWEEN UPPER DIE AND INTERMEDIATE PRESSING UNIT
S300
PERFORM SECONDARY PRESS FORMING ON METAL SHEET BETWEEN UPPER DIE AND LOWER DIE
S400
RAISE FIRST DIE AND INTERMEDIATE PRESSING UNIT
S500
DISCHARGE FORMED METAL SHEET
END

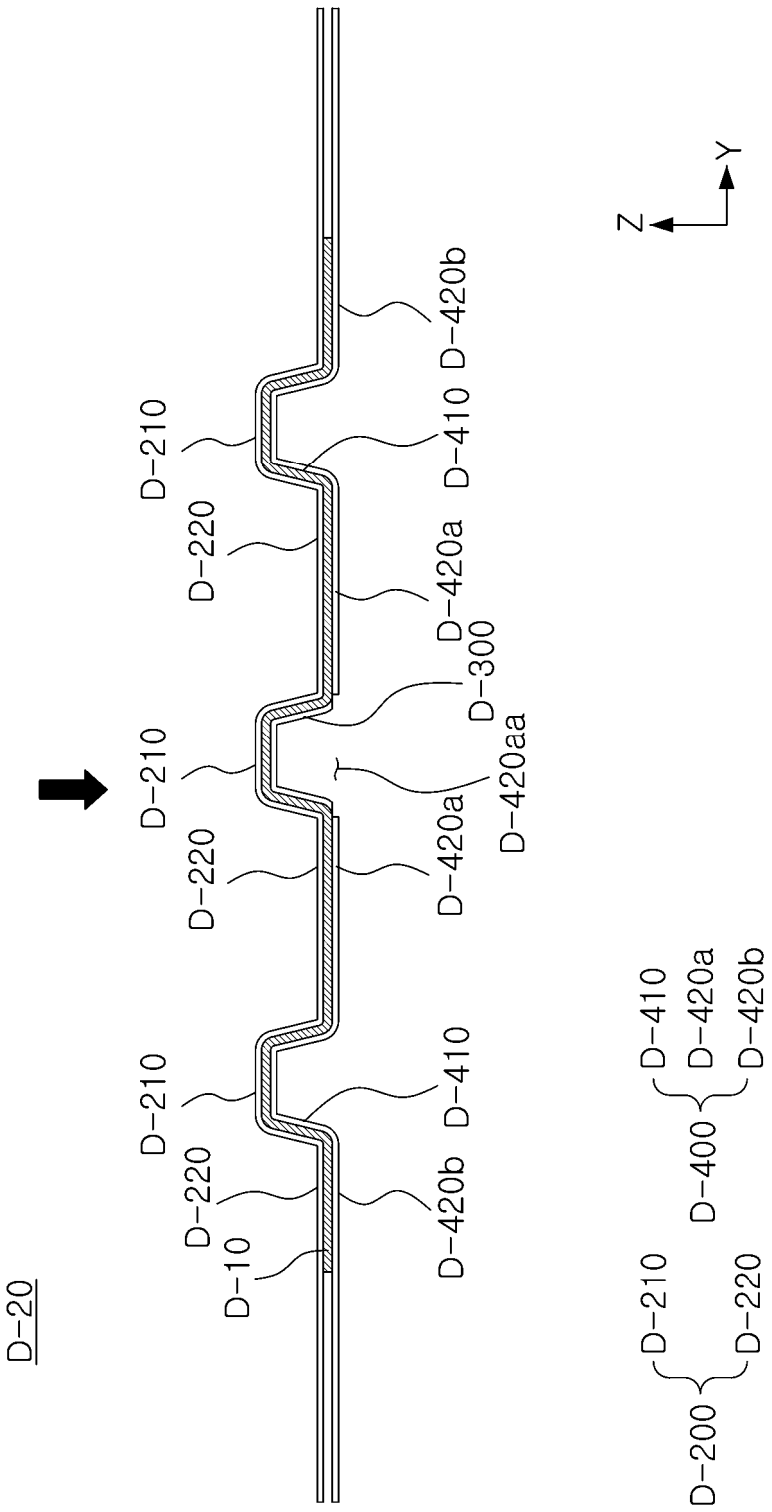
[FIG. 38]


D-20
D-10A
D-220
D-210
D-220
D-210
D-220
D-210
hi
D-420b
D-410
D-420a
D-300
D-420aa
D-420a
D-410
D-420b
Z
Y
D-410
D-420a
D-420b
D-400
D-210
D-220
D-200

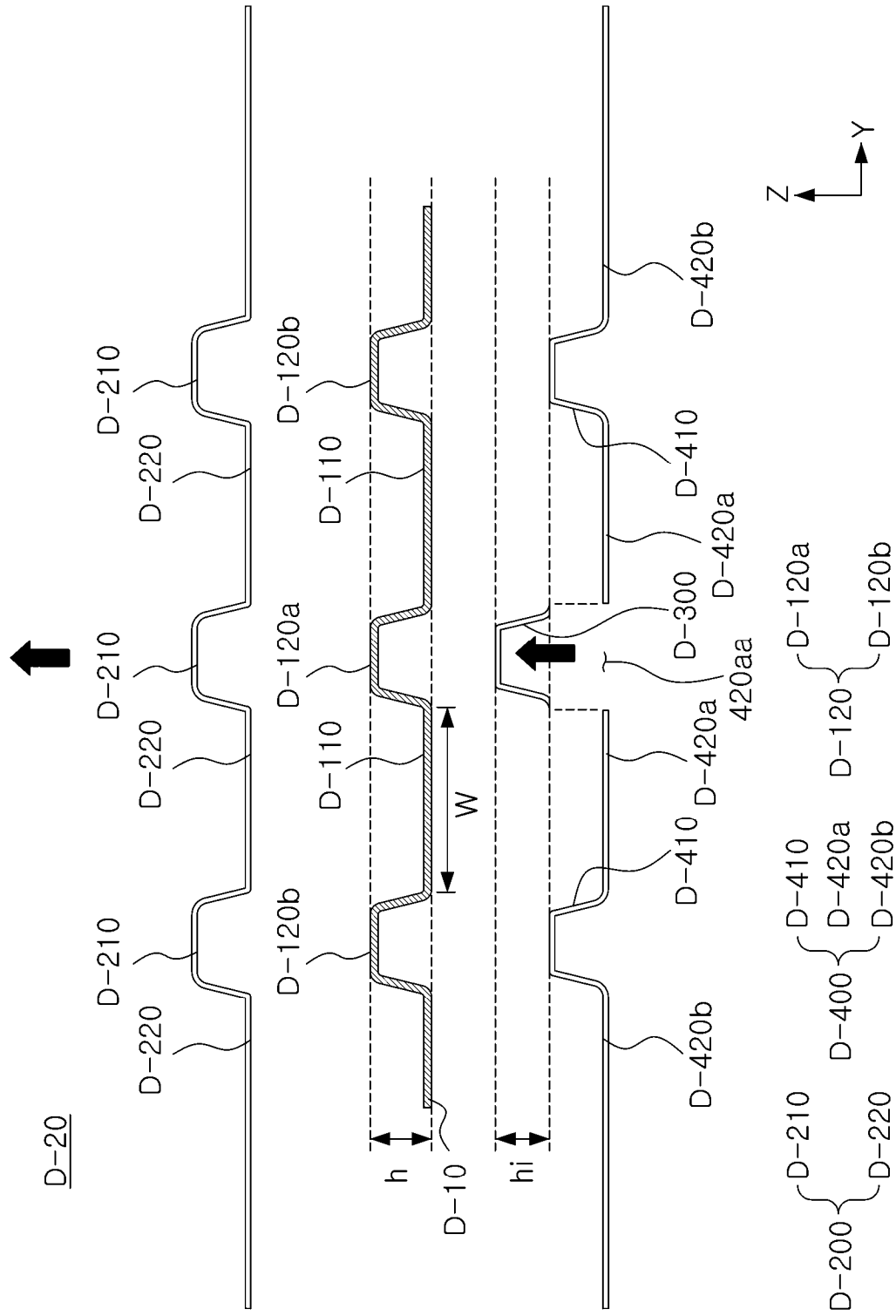
[FIG. 39]


D-20
D-10A
D-210
D-220
D-210
D-220
D-210
D-220
D-420b
D-410
D-420a
D-300
D-420aa
D-420a
D-410
D-420b
Z
Y
D-410
D-420a
D-420b
D-400
D-210
D-220
D-200

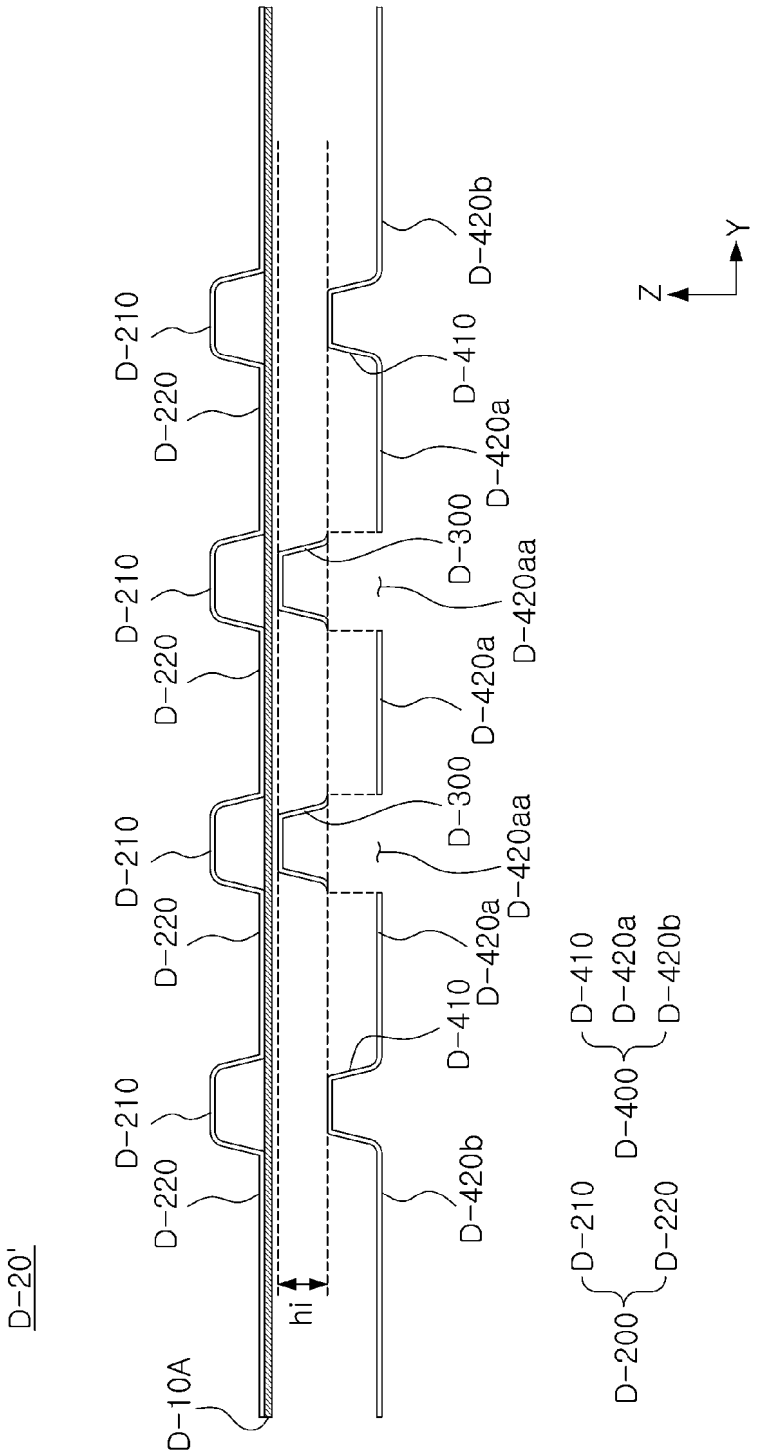
[FIG. 40]


D-20
D-10
D-220
D-210
D-420b
D-410
D-220
D-210
D-420a
D-420aa
D-300
D-220
D-210
D-420a
D-410
D-420b
Z
Y
D-200
D-210
D-220
D-400
D-410
D-420a
D-420b

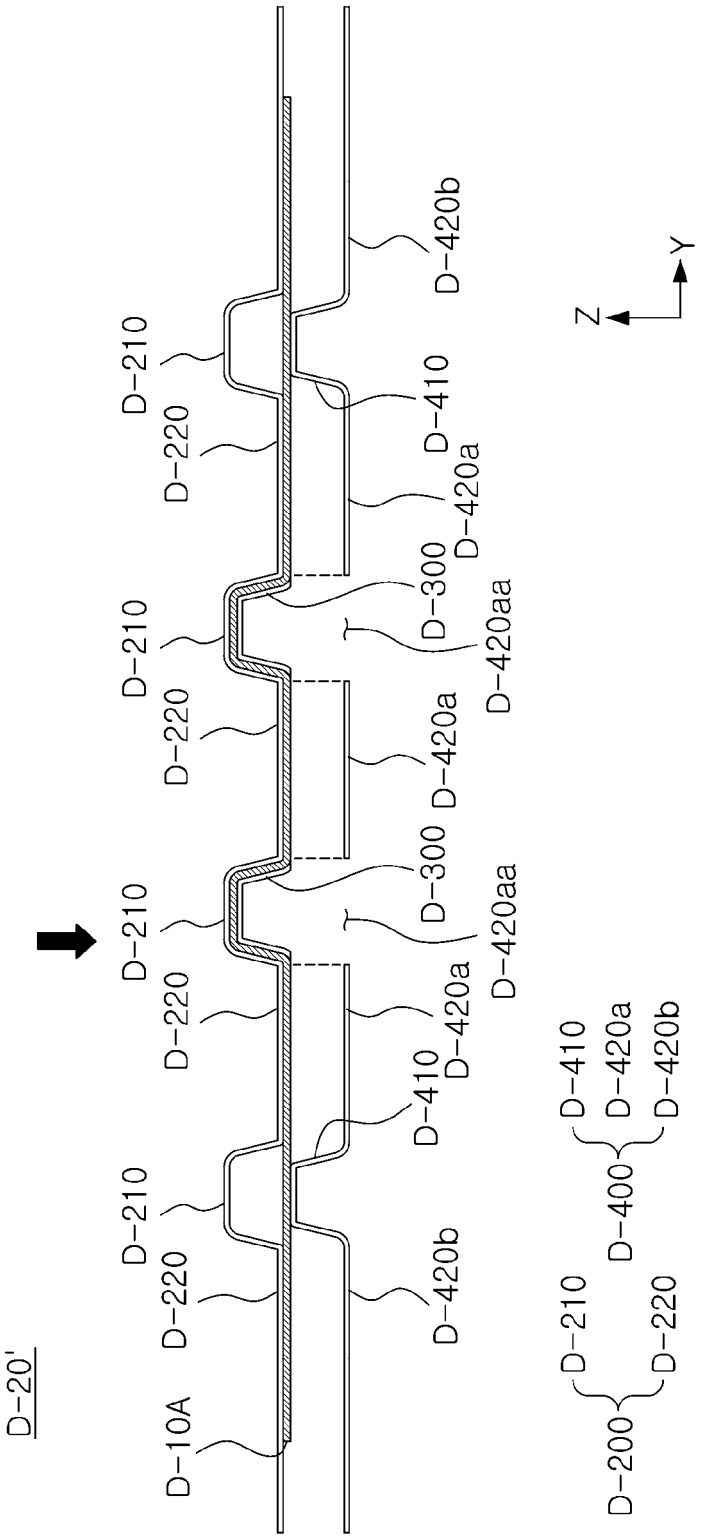
[FIG. 41]


D-20
D-210
D-220
D-210
D-220
D-210
D-220
D-120b
D-110
D-120a
D-110
D-120b
W
h
D-10
hi
D-420b
D-410
D-420a
D-300
420aa
D-420a
D-410
D-420b
D-120a
D-120
D-120b
D-410
D-420a
D-420b
D-400
D-210
D-220
D-200
Z
Y

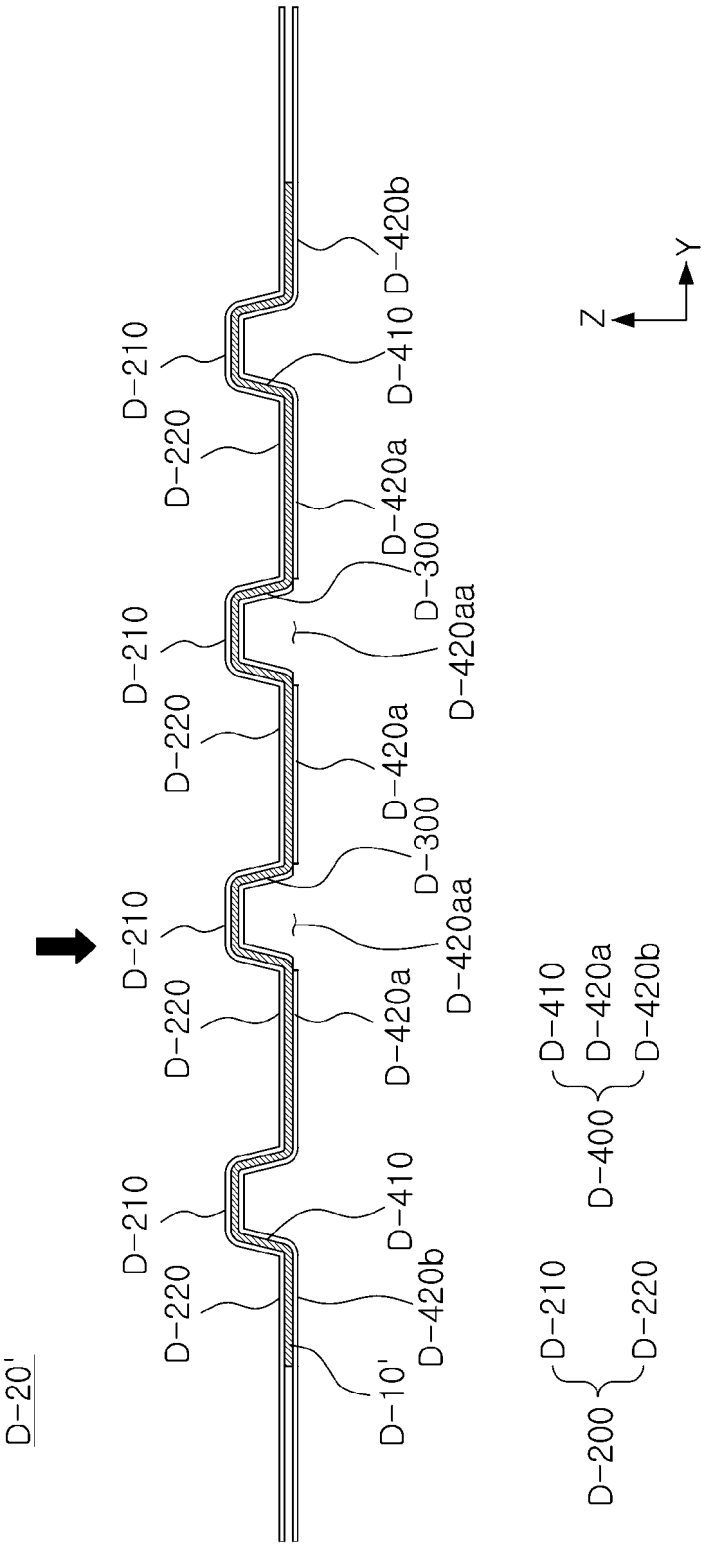
[FIG. 42]


D-20'
D-10A
D-210
D-220
D-300
D-410
D-420a
D-420aa
D-420b
hi
Z
Y
D-200
D-400

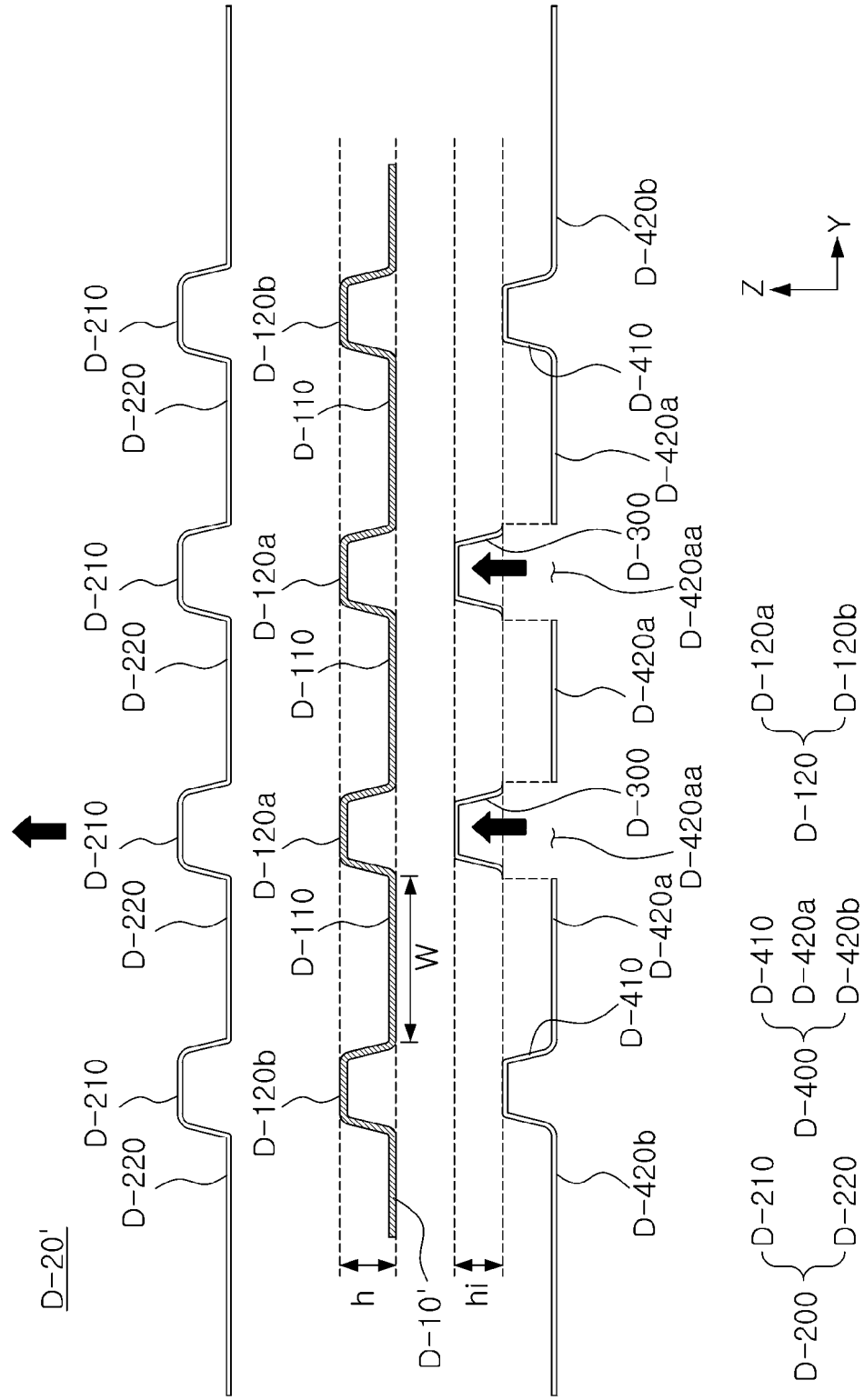
[FIG. 43]



[FIG. 44]



[FIG. 45]


D-20'
D-210
D-220
D-120b
D-110
D-120a
D-420b
D-410
D-420a
D-300
D-420aa
W
h
D-10'
hi
Z
Y
D-120
D-400
D-200

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/018852

A. CLASSIFICATION OF SUBJECT MATTER

B21D 53/88(2006.01)i; **B21D 22/02**(2006.01)i; **B21D 24/00**(2006.01)i; **B21D 39/02**(2006.01)i; **B21D 37/16**(2006.01)i; **B21D 5/02**(2006.01)i; **B21D 13/02**(2006.01)i

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)

B21D 53/88(2006.01); C21D 8/02(2006.01); C21D 9/56(2006.01); C22C 1/05(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/38(2006.01); C23C 2/06(2006.01)

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

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 열간 압연(hot rolled), 탄소(carbon), 실리콘(silicon), 망간(manganese), 크롬(chromium), GDS 프로파일(GDS profile), 두께(thickness)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-1830527 B1 (POSCO) 21 February 2018 (2018-02-21) See paragraphs [0026], [0079], [0111]-[0128], [0135], [0136], [0174] and [0176], tables 4-6 and claims 1, 3, 5, 6, 10, 15 and 18.	1-19
Y	JP 2012-122086 A (KOBE STEEL LTD.) 28 June 2012 (2012-06-28) See paragraphs [0078]-[0080], [0093] and [0138], table 1 and claim 1.	1-19
A	KR 10-2021-0000028 A (POSCO) 04 January 2021 (2021-01-04) See claims 1-7 and figures 1 and 2.	1-19
A	JP 2012-077317 A (JFE STEEL CORPORATION) 19 April 2012 (2012-04-19) See claims 1-5.	1-19
A	KR 10-2023-0077508 A (HYUNDAI STEEL COMPANY) 01 June 2023 (2023-06-01) See claims 1-10 and figure 1.	1-19

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 February 2025	**28 February 2025**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208**	
Facsimile No. **+82-42-481-8578**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/018852

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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		CN 109844142 B	03 September 2021
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		EP 3517636 B1	14 July 2021
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		US 11441205 B2	13 September 2022
		US 11624100 B2	11 April 2023
		US 11788166 B2	17 October 2023
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6296805 B **[0030]**
- US 20140056754 A **[0030]**
- KR 102020006635 **[0030]**
- KR 1020230092430 **[0030]**