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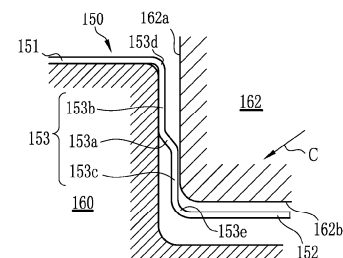
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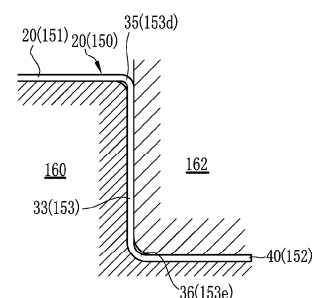
(54) **METHOD FOR MANUFACTURING PRESS-FORMED PRODUCT, PRESS-FORMED PRODUCT, AND PRESS FORMING METHOD**

(57) The present invention provides a technology that improves productivity while inhibiting defects in forming a high-strength steel sheet. A method for manufacturing a press-formed product of the present invention is a method for manufacturing, by press forming a blank sheet, a press-formed product having a top portion that has an outer peripheral edge including a curved portion, a vertical wall continuous with the outer peripheral edge of the top portion, and a flange continuous with the vertical wall, the method being characterized in that a step of forming a curved vertical wall portion of the vertical wall continuous with the curved portion includes: a preforming step of forming a stepped curved vertical wall portion of which a lower vertical wall portion from a step provided at a predetermined position in a height direction of the curved vertical wall portion to the flange projects toward the flange relative to an upper vertical wall portion from the step to the top portion; and a main forming step of smoothing out the stepped curved vertical wall portion into a flat curved vertical wall portion using a die having a cam structure.

[Fig. 5]
(a)



(b)



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Description

Technical Field

[0001] The present invention relates to a method for manufacturing press-formed product, a press-formed product, and a press forming method.

Background Art

[0002] There is demand for reducing the weights of automobile parts from the viewpoints of addressing environmental pollution, improving fuel efficiency, etc. As part of efforts to reduce the weights of automobile parts, for example, approaches have been adopted such as reducing the automobile parts in sheet thickness and using high-strength steel sheets with higher strength than conventional materials. It is known that a high-strength steel sheet has a smaller amount of stretching than, and is therefore inferior in formability to, a steel sheet with low strength. As such, when a high-strength steel sheet is used to form a part shape that is formable with a conventionally used steel sheet, forming defects such as cracks and wrinkles may occur. Methods for inhibiting defects such as cracks and wrinkles occurring in forming such a high-strength steel sheet include, for example, Patent Literature 1 and Patent Literature 2.

[0003] Patent Literature 1 discloses a method for improving formability by performing press forming in multiple forming steps. Patent Literature 2 discloses a method for manufacturing an elaborately designed high-strength part by press forming a material softened by heating and then quenching the material.

Citation List

Patent Literature

[0004]

Patent Literature 1: Japanese Patent No. 5867657
Patent Literature 2: Japanese Laid-open No. 5952881

Summary of Invention

Technical Problem

[0005] For example, in a roughly L-shaped part used for a lower part of a front pillar lower, in the process of forming a vertical wall portion that is curved (hereinafter, "curved vertical wall portion"), wrinkles and cracks tend to occur at a boundary portion between a top portion and the curved vertical wall or a boundary portion between a flange and the curved vertical wall portion. For example, to reduce the occurrence of cracks at a die shoulder, it is effective to gather the material at the die shoulder so as to restrain stretching of the material in directions along the

die shoulder. Specific measures include performing drawing, or promoting rotation of the material during forming by adjusting the shape of the die. With these measures, the material may gather not only at the die shoulder for forming the curved vertical wall portion but also at a punch shoulder, potentially causing wrinkles at the punch shoulder. In particular, in forming using a high-strength steel sheet, it is necessary to raise the pad pressure to reduce the occurrence of wrinkles. However, given the shape of the die and the size of the pad, it is generally difficult to set a high pad pressure. Moreover, the effect of a measure against wrinkles at the punch shoulder and the effect of a measure against cracks at the die shoulder are incompatible with each other. Accordingly, it is difficult to adopt a measure against wrinkles at the punch shoulder and a measure against cracks at the die shoulder at the same time.

[0006] The aforementioned method described in Patent Literature 1 can improve the formability by appropriately designing the shape in each step. However, one problem with the method described in Patent Literature 1 is that, as the number of forming steps increases, the productivity decreases or the cost of the die increases. In the method described in Patent Literature 2, not only is it necessary to heat the blank sheet to a transformation point or higher before performing press forming, but it is also necessary to perform quenching after press forming. Thus, the method described in Patent Literature 2 is also limited in improving the productivity.

[0007] The present invention has been developed in view of the above problems, and an objective thereof is to provide a technology that can improve the productivity in press forming while inhibiting defects such as cracks and wrinkles occurring in forming a high-strength steel sheet.

Solution to Problem

[0008] A method for manufacturing a press-formed product according to one aspect is a method for manufacturing, by press forming a blank sheet of a metal sheet, a press-formed product having a top portion that has an outer peripheral edge including a curved portion, a vertical wall continuous with the outer peripheral edge of the top portion, and a flange continuous with the vertical wall, the method being characterized in that a step of forming a curved vertical wall portion of the vertical wall continuous with the curved portion includes: a first forming step of forming a stepped curved vertical wall portion of which a lower vertical wall portion from a step provided at a predetermined position in a height direction of the curved vertical wall portion to the flange projects toward the flange relative to an upper vertical wall portion from the step to the top portion; and a second forming step of smoothing out the stepped curved vertical wall portion into a flat curved vertical wall portion using a die having a cam structure.

[0009] It is preferable that, as seen in a plan view of the press-formed product, the curved portion have an arc

shape; and that, in the second forming step, the stepped curved vertical wall portion be smoothed out by thrusting the die having a cam structure against the lower vertical wall portion at an angle of 0 degrees or more and 75 degrees or less, relative to a plane parallel to an upper surface of the top portion, along a straight line connecting a center point of the curved portion and a midpoint of the curved portion as seen in a plan view of the press-formed product.

[0010] It is preferable that the step of forming the curved vertical wall portion include a third forming step that is executed before the first forming step and that forms a boundary portion between the top portion and the curved vertical wall portion in the blank sheet.

[0011] A press-formed product according to another aspect is manufactured by the above-described method for manufacturing a press-formed product.

[0012] A press forming method according to another aspect is a press forming method including press forming a blank sheet into an intermediate formed product by relative movement of a die and a punch, the press forming method being characterized in that: the die has a top portion-forming surface that forms a top portion of the intermediate formed product, a die-side vertical wall-forming surface that forms a vertical wall continuous with an outer peripheral edge of the top portion, and a die-side flange-forming surface that forms a flange continuous with the vertical wall; the die-side vertical wall-forming surface has a die-side step-forming portion that forms a step at a predetermined position in a curved vertical wall portion in a height direction of the vertical wall, the curved vertical wall portion continuous with a curved portion provided at the outer peripheral edge of the top portion, the step being such that a lower vertical wall portion from the predetermined position to the flange continuous with the vertical wall projects toward the flange relative to an upper vertical wall portion from the top portion to the predetermined position; the punch has a punch-side flange-forming surface that forms the flange of the intermediate formed product, and a punch-side vertical wall-forming surface including a punch-side step-forming portion that forms the step of the curved vertical wall portion between itself and the die-side vertical wall-forming surface when the punch and the die move relative to each other; as the die and the punch move relative to each other, the blank sheet is bent by the top portion-forming surface and the die-side vertical wall-forming surface of the die to form the top portion; thereafter, the blank sheet is clamped between the die-side step-forming portion and the punch-side step-forming portion to form a curved vertical wall portion having the step; and the blank sheet is bent by the die-side flange-forming surface and the die-side vertical wall-forming surface to form the flange.

Advantageous Effects of Invention

[0013] The present disclosure enables improved productivity in press forming while suppressing defects such

as cracks and wrinkles during forming of a high-strength steel sheet. Accordingly, the present disclosure makes it possible to easily form an elaborately designed part without reducing the productivity.

Brief Description of Drawings

[0014]

[Fig. 1] Fig. 1 is a schematic perspective view showing one example of a press-formed product of the present invention.

[Fig. 2] Fig. 2 is a schematic view showing the flow of a method for manufacturing a press-formed product.

[Fig. 3] Fig. 3 is a schematic end view showing the procedure of a preforming step.

[Fig. 4] Fig. 4 is a schematic perspective view showing one example of a preformed product.

[Fig. 5] Fig. 5 is a schematic end view showing the procedure of a main forming step.

[Fig. 6] Fig. 6 is a schematic view showing one example of a moving direction of a cam die.

[Fig. 7] Fig. 7 is a schematic view obtaining a procedure of determining the moving direction of the cam die.

[Fig. 8] Fig. 8(a) is a schematic view showing regions of wrinkles and cracks that occur when a press-formed product is manufactured by one press forming, and Fig. 8(b) is a schematic view showing a region of cracks that occur when a press-formed product is manufactured by performing the main forming step without using the cam die.

[Fig. 9] Fig. 9 is a schematic perspective view showing one example of a blank sheet in which a boundary portion between a ceiling and a vertical wall is formed by press forming.

[Fig. 10] Fig. 10 is a schematic view showing a flow of a material in a press-formed product as a result of performing conventional press forming.

[Fig. 11] Fig. 11(a) is a schematic end view showing a case where a material flows in from a top portion when a punch is moved perpendicularly in the main forming step, and Fig. 11(b) is a schematic end view showing a case where a material flows in from a flange in the main forming step.

Description of Embodiments

[0015] In the following, an embodiment will be described using the drawings.

[0016] A press-formed product described in this embodiment is, as one example, a press-formed product used for a lower part of a front pillar lower of an automobile. The shape of the press-formed product is, for example, a substantially L-shape as seen in a plan view of the press-formed product. However, the shape of the press-formed product is not limited to a substantially L-shape as seen in a plan view of the press-formed product,

and may instead be a substantially T-shape or a cross shape.

[0017] Fig. 1 is a schematic perspective view showing one aspect of the press-formed product. A press-formed product 10 is formed by performing press forming on a blank sheet. The blank sheet is, for example, a high-strength steel sheet (high-tension material) with a sheet thickness of 1.2 mm and tensile strength of 1180 MPa or more.

[0018] The press-formed product 10 includes a top portion 20, a vertical wall 30, and a flange 40. The vertical wall 30 is a portion connecting the top portion 20 and the flange 40. The vertical wall 30 has a flat vertical wall portion 31 extending in one direction, a flat vertical wall portion 32 extending in a direction intersecting that one direction, and a curved vertical wall portion 33 connecting these flat vertical wall portions 31 and 32. The curved vertical wall portion 33 is curved so as to be convex toward the top portion 20. That is, a curved portion 34 along the curved vertical wall portion 33 is provided at an outer peripheral edge of the top portion 20. The curved portion 34 is curved in an arc shape, for example, as seen in a plan view of the press-formed product 10.

[0019] Next, a method for manufacturing the press-formed product 10 will be described. As shown in Fig. 2, the press-formed product 10 is formed through two steps: a preforming step and a main forming step. The preforming step involves press forming a blank sheet that has been cut into a predetermined shape. The main forming step involves performing forming, using a cam die, on a preformed product formed by the preforming step.

[0020] It is preferable that the aforementioned preforming step and main forming step be performed as continuous steps. The preforming step and the main forming step are not necessarily required to be continuous. For example, after the preforming step is performed at a certain factory, the main forming step may be performed on the formed preformed product at another factory different from that certain factory. Here, the preforming step corresponds to the first forming step described in the claims. The main forming step corresponds to the second forming step described in the claims.

(Preforming Step)

[0021] In the following, the preforming step will be described with reference to Fig. 3(a) and Fig. 3(b). The preforming step is a step of forming a preformed product 150 (see Fig. 4) by press forming a blank sheet 100. The press forming used to form the preformed product 150 may include forming, drawing, etc.

[0022] First, a pressing die set 120 will be described. The pressing die set 120 used for the preforming step includes a die 121 and a punch 123. The die 121 is provided with a top portion-forming surface 121a, a vertical wall-forming surface 121b, and a flange-forming surface 121c. The top portion-forming surface 121a forms a top portion 151 of the preformed product 150

between itself and the punch 123. The vertical wall-forming surface 121b forms a curved vertical wall portion 153 of the preformed product 150 between itself and the punch 123. The flange-forming surface 121c forms a flange 152 of the preformed product 150 between itself and the punch 123.

[0023] A step-forming portion 121d is provided at a predetermined position in a height direction of the vertical wall-forming surface 121b. Specifically, a portion of the vertical wall-forming surface 121b from the flange-forming surface 121c to the step-forming portion 121d projects toward the flange-forming surface 121c relative to a portion thereof from the top portion-forming surface 121a to the step-forming portion 121d.

[0024] Here, the vertical wall-forming surface 121b corresponds to the die-side vertical wall-forming surface described in the claims. The flange-forming surface 121c corresponds to the die-side flange-forming surface described in the claims. The step-forming portion 121d corresponds to the die-side step-forming portion described in the claims. The portion from the top portion-forming surface 121a to the step-forming portion 121d corresponds to the upper vertical wall portion in the claims. Further, the portion from the flange-forming surface 121c to the step-forming portion 121d corresponds to the lower vertical wall portion in the claims.

[0025] The punch 123 is provided with a flange-forming surface 123a and a vertical wall-forming surface 123b. The flange-forming surface 123a forms the flange 152 of the preformed product 150 between itself and the die 121. The vertical wall-forming surface 123b forms the curved vertical wall portion 153 of the preformed product 150 between itself and the die 121.

[0026] A step-forming portion 123c is provided at a predetermined position in a height direction of the vertical wall-forming surface 123b. Specifically, of the vertical wall-forming surface 123b, a portion extending from the flange-forming surface 123a to the step-forming portion 123c is recessed inward relative to the remaining portion.

[0027] Here, the flange-forming surface 123a corresponds to the punch-side flange-forming surface described in the claims. The vertical wall-forming surface 123b corresponds to the punch-side vertical wall-forming surface described in the claims. Further, the step-forming portion 123c corresponds to the punch-side step-forming portion described in the claims.

[0028] As shown in Fig. 3(a), when the preforming step starts, the punch 123 moves in direction B in the drawing and presses the blank sheet 100 held on the die 121. That is, direction B in Fig. 3(a) is the pressing direction in the preforming step. As the punch 123 moves in the pressing direction, the blank sheet 100 is bent.

[0029] As described above, the punch 123 is provided with the step-forming portion 123c corresponding to the curved vertical wall portion 153 of the preformed product 150. The die 121 is provided with the step-forming portion 121d corresponding to the curved vertical wall portion

153 of the preformed product 150.

[0030] When the punch 123 moves in the pressing direction, the blank sheet 100 is clamped between the die 121 and the punch 123. At this point, an inflow of the material from the side of the flange 152 and the side of the top portion 151 to the curved vertical wall portion 153 is secured. This is such a state that cracks are less likely to occur while some wrinkles are likely to occur at the curved vertical wall portion 153.

[0031] As shown in Fig. 3(b), when press forming continues, the blank sheet 100 is clamped between the step-forming portion 121d of the die 121 and the step-forming portion 123c of the punch 123. Thus, the curved vertical wall portion 153 having a step 153a is formed. At this point, an excess portion of the material that causes wrinkles is absorbed by formation of the step 153a. As a result, occurrence of wrinkles at the step 153a is reduced.

[0032] When the punch 123 moves in the pressing direction, the blank sheet 100 is clamped between the flange-forming surface 121c of the die 121 and the flange-forming surface 123a of the punch 123. Thus, the flange 152 is formed. At the same time, a boundary portion 153d (see Fig. 4) between the top portion 151 and the curved vertical wall portion 153, as well as a boundary portion 153e (see Fig. 4) between the flange 152 and the curved vertical wall portion 153, in the press-formed product 10 are also formed.

[0033] As shown in Fig. 4, in the preformed product 150, a height H2 of the curved vertical wall portion 153 is set to be lower than a height H1 of vertical walls 154, 155. The height H2 of the curved vertical wall portion 153 is set to such a height that wrinkles and cracks do not occur. Specifically, the height H2 of the curved vertical wall portion 153 is preferably not smaller than a radius R2 (see Fig. 3(b)) of a shoulder portion of the punch 123, and is more preferably not smaller than the total value of a radius R1 (see Fig. 3(b)) of a shoulder portion of the die 121 and the radius R2 of the shoulder portion of the punch 123. The preformed product 150 corresponds to the intermediate formed product described in the claims.

[0034] Here, it is preferable that the step 153a of the curved vertical wall portion 153 formed in the preforming step be set as follows:

$$R1 \geq R3 \geq 5 \text{ mm} \dots (1)$$

$$R2 \geq R4 \geq 5 \text{ mm} \dots (2)$$

$$R1 + R2 \geq R3 + R4 + L \dots (3)$$

R1: the radius of curvature of the shoulder portion of the die (the boundary portion between the top portion 151 and the upper vertical wall portion 153b)

R2: the radius of curvature of the shoulder portion of the punch (the boundary portion between the lower vertical wall portion 153c and the flange 152)

R3: the radius of curvature of the boundary portion (on the die side) between the step 153a and the upper vertical wall portion 153b

R4: the radius of curvature of the boundary portion (on the punch side) between the step 153a and the lower vertical wall portion 153c

L: the amount of projection of the lower vertical wall portion 153c relative to the upper vertical wall portion 153b

[0035] For example, when the radii of curvature R3, R4 are smaller than 5 mm, the risk of occurrence of cracks when forming the step 153a increases. When the radius of curvature R3 exceeds the radius of curvature R1, or when the radius of curvature R4 exceeds the radius of curvature R2, or when the sum of the amount of projection L, the radius of curvature R3, and the radius of curvature R4 exceeds the sum of the radius of curvature R1 and the radius of curvature R2, the step 153a becomes so large that the likelihood of occurrence of wrinkles both above and below the step 153a increases. Therefore, the above Formula (1) to Formula (3) are specified based on these factors.

[0036] Generally, a formed height H0 of the curved vertical wall portion can be obtained, for example, from the following Formula (4):

$$\varepsilon = (R0 - \tan\theta) / (R0 - H0 / \cos\theta)^{-1} \dots (4)$$

ε : stretching along the curved vertical wall portion

θ : an inclination of the curved vertical wall portion relative to the moving direction of the punch

H0: the formed height of the curved vertical wall portion

R0: the radius of curvature of the curved vertical wall portion

[0037] Here, the formed height H0 of the curved vertical wall portion when the value of the stretching ε and limit strain of the material in a state of plane strain become equal is a maximum formable height. The limit strain in the state of plane strain can be obtained by a commonly known technique such as the Nakajima method¹ or the Marciniak method.

(Main Forming Step)

[0038] The main forming step is a step of performing press forming on the stepped curved vertical wall portion 153 of the preformed product 150 using a die having a cam mechanism (hereinafter referred to as "cam die") 162. As a result of the main forming step, the step 153a of the curved vertical wall portion 153 becomes flat.

[0039] As shown in Fig. 5(a), the preformed product 150 is held on a die 160. When the main forming step starts, the cam die 162 moves in direction C in Fig. 5(a). Direction C in Fig. 5(a) is the pressing direction in the

main forming step. When the cam die 162 moves in the pressing direction, the stepped curved vertical wall portion 153 of the preformed product 150 is clamped between the cam die 162 and the die 160. As a result, the step 153a disappears and the amount of projection L of the lower vertical wall portion 153c becomes zero (see Fig. 5(b)). When the cam die 162 moves in the pressing direction, an inflow of the material from the top portion 151 to the curved vertical wall portion 153 and an inflow of the material from the flange 152 to the curved vertical wall portion 153 are reduced. As a result, the phenomenon of wrinkles occurring at the boundary portion 153d between the top portion 151 and the curved vertical wall portion 153, as well as the phenomenon of cracks occurring at the boundary portion 153e between the flange 152 and the curved vertical wall portion 153 are prevented.

[0040] Here, the moving direction (pressing direction) of the cam die 162 in the main forming step will be described. A description will be given of a case where, as shown in Fig. 6(a), the curved vertical wall portion 153 has an arc shape, for example, as seen in a plan view of the preformed product 150. The pressing direction of the cam die 162 (reference sign C in Fig. 6(a)) is a direction along a straight line L1 connecting a center point P1 of the curved vertical wall portion 153 and a midpoint P2 of the curved vertical wall portion 153 as seen in a plan view of the preformed product 150. As shown in Fig. 6(b), the pressing direction of the cam die 162 is a direction inclined a predetermined angle $\theta 1$ downward relative to a plane including an upper surface of the top portion 151 in section D-D' shown in Fig. 6(a).

[0041] The angle $\theta 1$ is set as follows. For example, when the angle $\theta 1$ is set near 90° , the step 153a of the preformed product 150 may fail to be appropriately stretched during forming by the cam die 162. In this case, cracks may occur as the material flows from the flange 152 into the step 153a. Therefore, the angle θ is preferably within a range of $0^\circ \leq \theta \leq 75^\circ$ and more preferably within a range of $0^\circ \leq \theta 1 \leq 45^\circ$.

[0042] The pressing direction in the main forming step may be determined by the following method. For example, as shown in Fig. 7(a), as seen in a plan view of the die 160 used for the main forming step, a straight line connecting a midpoint P3 of a curve-forming portion 161 of the die 160 and a midpoint P4 of the curve-forming portion 161 of the die 160 is called a straight line L2. As shown in Fig. 7(b), a straight line connecting a midpoint P5 of a boundary portion 160c between a side surface 160a and a bottom surface 160b of the die 160 and a center point P6 of this boundary portion 160c is referred to as a straight line L3. An intersection point between the straight line L2 and the straight line L3 is referred to as an intersection point P7.

[0043] As shown in Fig. 7(c), as seen in a plan view of the die 121 used for the preforming step, a straight line connecting a midpoint P8 of a curve-forming portion 122 of the die 121 and a center point P9 of the curve-forming portion 122 is referred to as a straight line L4. As shown in

Fig. 7(d), a straight line connecting a midpoint P10 of a boundary portion 121e between the vertical wall-forming surface 121b and the flange-forming surface 121c of the die 121 and a center point P11 of this boundary portion 121e is referred to as a straight line L5. An intersection point between the straight line L4 and the straight line L5 is referred to as an intersection point P12.

[0044] As shown in Fig. 7(e), the direction from the intersection point P12 to the intersection point P7 is the moving direction of the cam die 162 (the pressing direction in the main forming step). When the pressing direction in the main forming step is called a z-direction and two directions perpendicular to the z-direction are called an x-direction and a y-direction, a vector v from the point P12 to the point P7 is calculated from the coordinates of the point P12 (x_{P12} , y_{P12} , z_{P12}) and the coordinates of the point P7 (x_{P7} , y_{P7} , z_{P7}). From the direction of the calculated vector v , a range of $\pm 30^\circ$ around the z-axis or the y-axis centered at the point P7 or the point P12 is set as the pressing direction in the main forming step. If the cam die 162 is moved beyond the range of $\pm 30^\circ$ around the z-axis or the y-axis, forming the step 153a becomes difficult.

[0045] In this embodiment, the range of $\pm 30^\circ$ around the z-axis or the y-axis centered at the point P7 or the point P12 from the direction of the calculated vector is set as the moving direction of the cam die 162. However, a range of $\pm 10^\circ$ around the z-axis or the y-axis centered at the point P5 or the point P8 may instead be set as the moving direction of the cam die 162.

[0046] In the following, whether wrinkles and cracks occur will be described. As shown in Fig. 8(a), in a press-formed product 200 formed by one press forming, the material flows from a top portion 201 into a curved vertical wall portion 202 while gathering. Further, the material flows from a flange 204 into the curved vertical wall portion 202 while spreading. Thus, wrinkles occur in a region 203a of a boundary portion 203 between the top portion 201 and the curved vertical wall portion 202. In addition, cracks occur in regions 205a, 205b of a boundary portion 205 between the flange 204 and the curved vertical wall portion 202.

[0047] As shown in Fig. 8(b), when the main forming step is performed without using the cam die after the preforming step is performed, in a formed press-formed product 250, wrinkles do not occur at a boundary portion 253 between a top surface 251 and a curved vertical wall portion 252. On the other hand, when the main forming step is performed without using the cam die, the material flows from a flange 254 into the curved vertical wall portion 252 while spreading. Thus, cracks occur in a region 255a of a boundary portion 255 of the flange 254.

[0048] In the main forming step of this embodiment, the step 153a of the preformed product 150 is stretched by the cam die. In forming using the cam die, the material from the top portion 20 does not flow into the boundary portion 35 between the top portion 20 and the curved vertical wall portion 33. Further, the material from the flange 40 does not flow into the boundary portion 36

between the curved vertical wall portion 33 and the flange 40. As a result, occurrence of wrinkles at the boundary portion 35 and occurrence of cracks at the boundary portion 36 are inhibited.

[0049] In the above-described embodiment, as the method for manufacturing the press-formed product 10, the case has been described in which the preforming step of press forming the preformed product 150 and the main forming step of performing forming using the cam die on the stepped curved vertical wall portion 153 of the preformed product 150 are performed. However, the method for manufacturing the press-formed product 10 is not limited thereto. As shown in Fig. 9, for example, it is also possible to perform press forming on the blank sheet 100 to form a boundary portion 303 between a top portion 301 and a curved vertical wall portion 302 beforehand and then perform the above-described preforming step. In this case, by forming the boundary portion 303 between the top portion 301 and the curved vertical wall portion 302 beforehand, in the above-described preforming step, the material from the top portion 301 is inhibited from flowing into the curved vertical wall portion in the process of forming the stepped curved vertical wall portion. Thus, occurrence of wrinkles at the boundary portion between the top portion and the vertical wall is inhibited.

[0050] When the curved vertical wall portion is formed after the boundary portion 303 between the top portion 301 and the curved vertical wall portion 302 is formed beforehand, the curved vertical wall portion can be formed to be higher than when the curved vertical wall portion is formed without the boundary portion 303 between the top portion 301 and the vertical wall being formed.

<Summary of Advantages>

[0051] The method for manufacturing a press-formed product according to the present invention is a method for manufacturing, by press forming the blank sheet 100 of a metal sheet, the press-formed product 10 having the top portion 20 that has the outer peripheral edge including the curved portion, the vertical wall 30 continuous with the outer peripheral edge of the top portion 20, and the flange 40 continuous with the vertical wall 30, the method being characterized in that the step of forming the curved vertical wall portion 33 of the vertical wall 30 continuous with the curved portion includes: the preforming step of forming the stepped curved vertical wall portion 153 of which the lower vertical wall portion 153c from the step 153a provided at a predetermined position in the height direction of the curved vertical wall portion 33 to the flange 40 projects toward the flange 40 relative to the upper vertical wall portion 153b from the step 153a to the top portion 20; and the main forming step of leveling out the upper vertical wall portion 153b and the lower vertical wall portion 153c using the cam die 162.

[0052] For example, as shown in Fig. 10, when manufacturing a press-formed product 400 by one press

forming step, at a ridge portion 401a between a top portion 402 and a curved vertical wall portion 401, the material of the top portion 402 is pulled toward the curved vertical wall portion 401 while gathering (in directions H in Fig. 9). At a ridge portion 401b between the curved vertical wall portion 401 and a flange 403, the material of the flange 403 is pulled to the curved vertical wall portion 401 while spreading (in directions I in Fig. 10). Therefore, wrinkles are likely to occur at the ridge portion 401a and cracks are likely to occur at the ridge portion 401b.

[0053] On the other hand, in the method for manufacturing the press-formed product 10 of the embodiment, first, the preformed product 150 having the stepped curved vertical wall portion 153 is formed by the preforming step. At this point, excess portions of the material flowing from the side of the top portion 151 into the curved vertical wall portion 153 and the material flowing from the flange 152 into the curved vertical wall portion 153 are absorbed by the step 153a. In the main forming step, an inflow of the material from the top portion 151 and the flange 152 into the curved vertical wall portion 153 is inhibited during the process of forming the stepped curved vertical wall portion 153. As a result, occurrence of wrinkles and cracks at the boundary portion 35 between the top portion 20 and the curved vertical wall portion 33 and at the boundary portion 36 between the flange 40 and the curved vertical wall portion 33 is prevented.

[0054] As seen in a plan view of the press-formed product 10, the curved vertical wall portion 153 has an arc shape, and the main forming step forms the vertical wall 30 by thrusting the cam die 162 against the lower vertical wall portion 153c at an angle of 0 degrees or more and 75 degrees or less, relative to a plane parallel to the upper surface of the top portion 20, along the straight line connecting the center point P1 of the curved vertical wall portion 153 and the midpoint P2 of the curved vertical wall portion 153 as seen in a plan view of the press-formed product 10.

[0055] For example, if the cam die 162 is moved in direction J in Fig. 11(a) in the main forming step, it may become difficult for the cam die 162 to appropriately stretch the step 153a. In this case, for example, the material of the top portion 151 flows into the curved vertical wall portion 153, causing wrinkles at the boundary portion between the top portion 151 and the curved vertical wall portion 153. Further, as shown in Fig. 11(b), when the cam die 162 is moved in the direction J in Fig. 11(b), after the curved vertical wall portion 153 is stretched, the material of the flange 152 gets caught on the cam die 162 and flows into the curved vertical wall portion 153. In this case, cracks occur at the boundary portion between the curved vertical wall portion 153 and the flange 152.

[0056] On the other hand, in the embodiment, the cam die 162 is moved in direction C in Fig. 5(a) in the main forming step. Moving the cam die 162 in direction C in Fig.

5(a) prevents an inflow of the material from the top portion 151 into the curved vertical wall portion 153 as well as an inflow of the material from the flange 152 into the curved vertical wall portion 153. Thus, occurrence of wrinkles at the boundary portion between the top portion 151 and the curved vertical wall portion 153 as well as occurrence of cracks at the boundary portion between the flange 152 and the curved vertical wall portion 153 can be prevented.

[0057] The step of forming the vertical wall 30 includes the third forming step that is executed before the pre-forming step and that forms the boundary portion between the top portion 20 and the vertical wall 30 in the blank sheet 100.

[0058] Thus, in the third forming step, press forming is performed on the blank sheet 100 to form the boundary portion 303 between the top portion 301 and the vertical wall. The boundary portion 303 formed by the third forming step inhibits the material from flowing from the top portion 301 into the vertical wall in the process of forming the vertical wall by press forming. As a result, occurrence of wrinkles at the boundary portion between the top portion 301 and the vertical wall is inhibited.

[0059] Further, in the process of forming the vertical wall by press forming, the material is inhibited from flowing from the top portion 301 into the vertical wall. As a result, the height of the curved vertical wall portion 401 can be made higher than the height of the curved vertical wall portion in the case where the curved vertical wall portion 401 is formed without the boundary portion 303 being formed between the top portion 301 and the vertical wall.

Reference Signs List

[0060]

10: Press-formed product
 20: Top portion
 30: Vertical wall
 33: Curved vertical wall portion
 40: Flange
 100: Blank sheet
 150: Preformed product
 153: Curved vertical wall portion
 153a: Step
 153b: Upper vertical wall portion
 153c: Lower vertical wall portion

Claims

1. A method for manufacturing a press-formed product, comprising press forming a blank sheet of a metal sheet, the press-formed product having a top portion that has an outer peripheral edge including a curved portion, a vertical wall that continuous with the outer peripheral edge of the top portion, and a flange continuous with the vertical wall, **characterized in**

that

a step of forming a curved vertical wall portion of the vertical wall continuous with the curved portion includes:

a first forming step of forming a stepped curved vertical wall portion of which a lower vertical wall portion from a step provided at a predetermined position in a height direction of the curved vertical wall portion to the flange projects toward the flange relative to an upper vertical wall portion from the step to the top portion; and
 a second forming step of smoothing out the stepped curved vertical wall portion into a flat curved vertical wall portion using a die having a cam structure.

2. The method for manufacturing a press-formed product according to claim 1, wherein:

as seen in a plan view of the press-formed product, the curved portion has an arc shape; and
 in the second forming step, the stepped curved vertical wall portion is smoothed out by thrusting the die having the cam structure against the lower vertical wall portion at an angle of 0 degrees or more and 75 degrees or less, relative to a plane parallel to an upper surface of the top portion, along a straight line connecting a center point of the curved portion and a midpoint of the curved portion as seen in a plan view of the press-formed product.

3. The method for manufacturing a press-formed product according to claim 1, wherein the step of forming the curved vertical wall portion includes a third forming step that is executed before the first forming step and that forms a boundary portion between the top portion and the curved vertical wall portion in the blank sheet.

4. A press-formed product, **characterized by** being manufactured by the method for manufacturing a press-formed product according to any one of claim 1 to claim 3.

5. A press forming method for press forming a blank sheet into an intermediate formed product by relative movement of a die and a punch, **characterized in that:**

the die has a top portion-forming surface that forms a top portion of the intermediate formed product, a die-side vertical wall-forming surface that forms a vertical wall continuing to an outer peripheral edge of the top portion, and a die-side flange-forming surface that forms a flange con-

tinuing to the vertical wall;
the die-side vertical wall-forming surface has a
die-side step-forming portion that forms a step at
a predetermined position in a curved vertical
wall portion in a height direction of the vertical 5
wall, the curved vertical wall portion continuing
to a curved portion provided at the outer peripheral
edge of the top portion, the step being such
that a lower vertical wall portion from the pre-
determined position to the flange continuing to 10
the vertical wall projects toward the flange relative
to an upper vertical wall portion from the
top portion to the predetermined position;
the punch has a punch-side flange-forming surface 15
that forms the flange of the intermediate
formed product, and a punch-side vertical wall-
forming surface including a punch-side step-
forming portion that forms the step of the curved
vertical wall portion between itself and the die- 20
side vertical wall-forming surface when the
punch and the die move relative to each other;
as the die and the punch move relative to each
other, the blank sheet is bent by the top portion-
forming surface and the die-side vertical wall- 25
forming surface of the die to form the top portion;
thereafter, the blank sheet is clamped between
the die-side step-forming portion and the punch-
side step-forming portion to form a curved ver-
tical wall portion having the step; and
the blank sheet is bent by the die-side flange- 30
forming surface and the die-side vertical wall-
forming surface to form the flange.

35

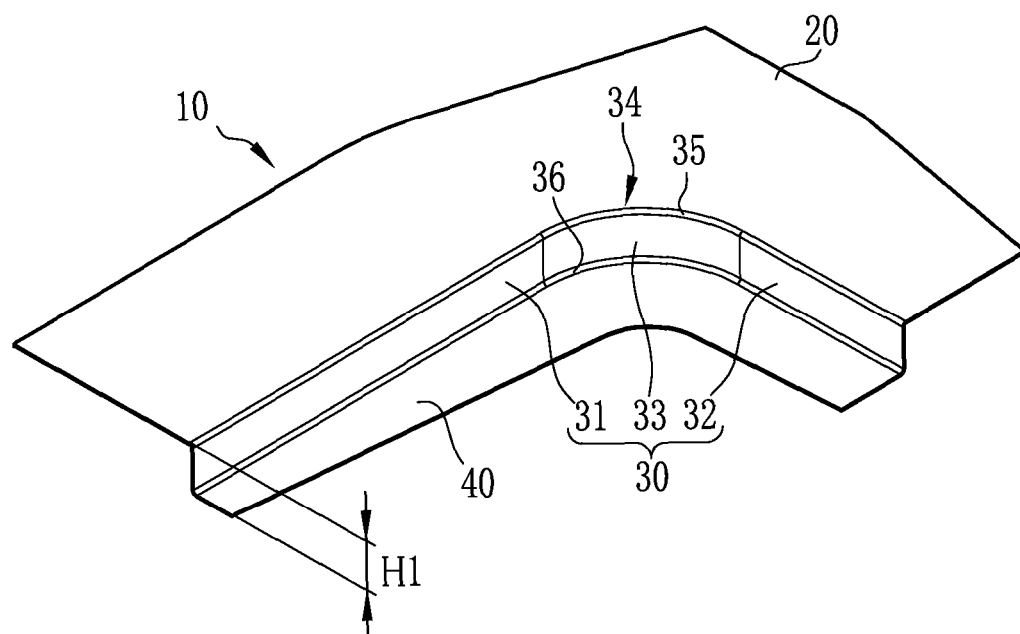
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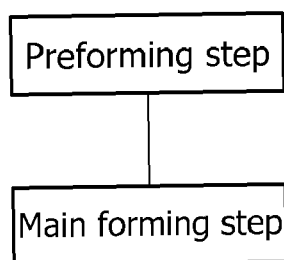
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[Fig. 1]

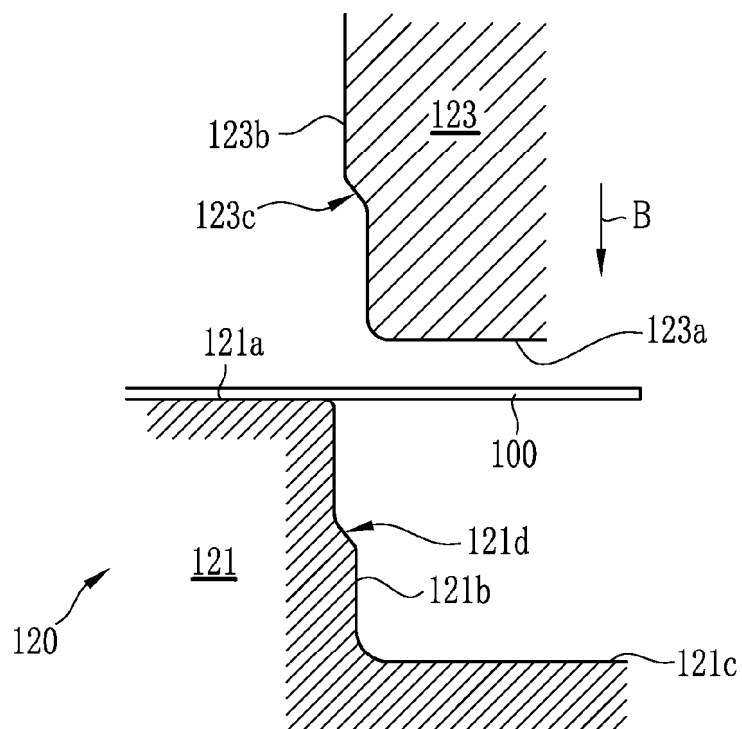


[Fig. 2]

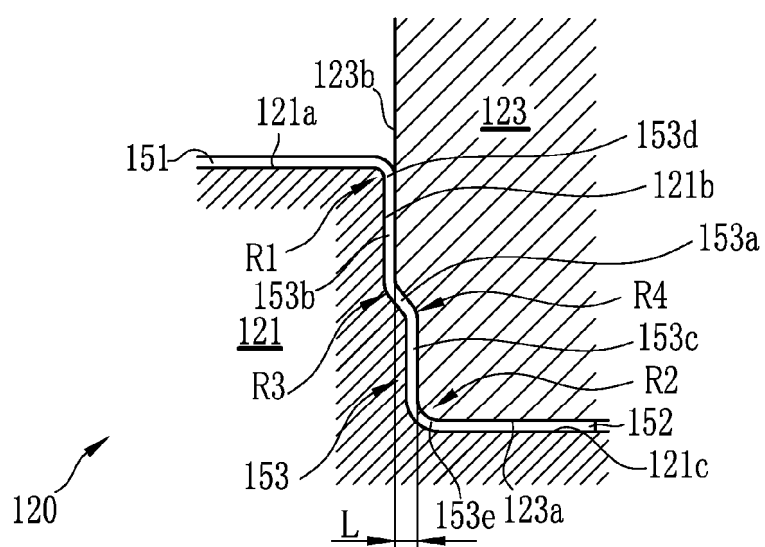


[Fig. 3]

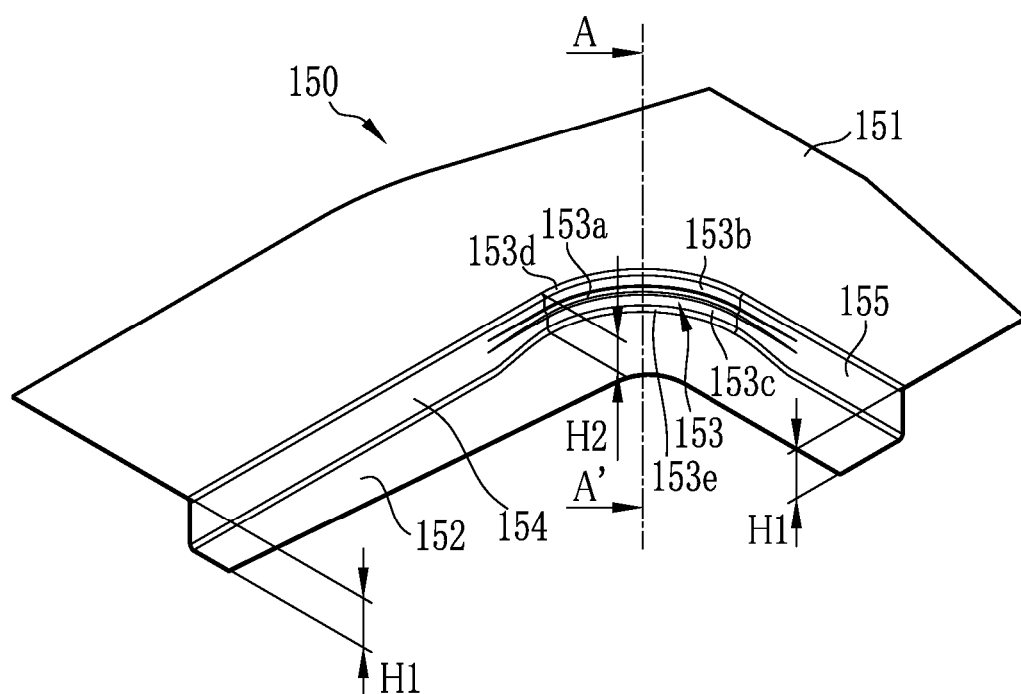
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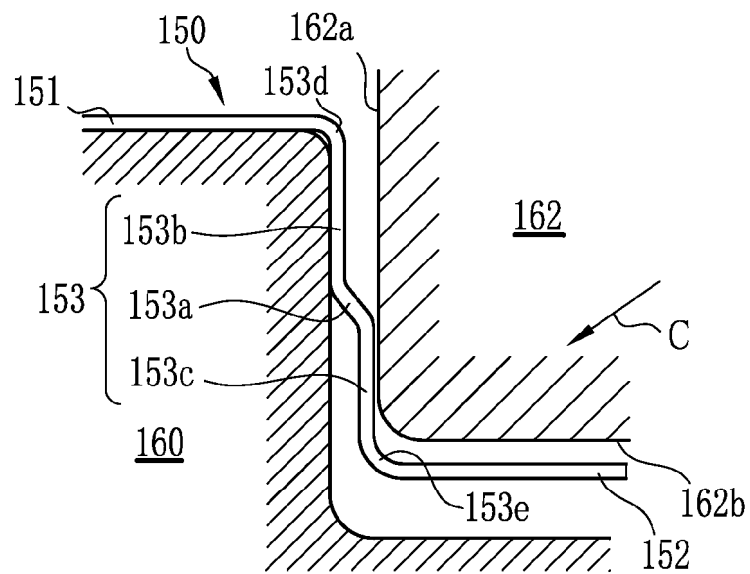
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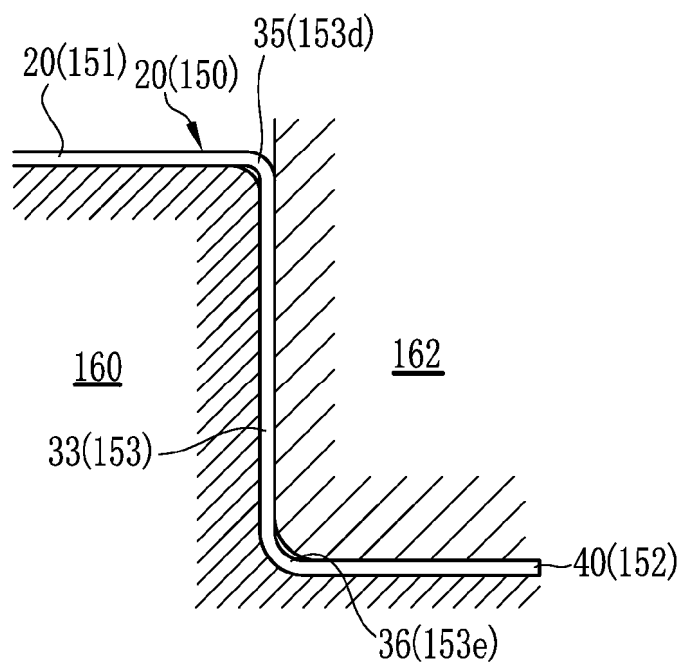
[Fig. 4]



[Fig. 5]
(a)

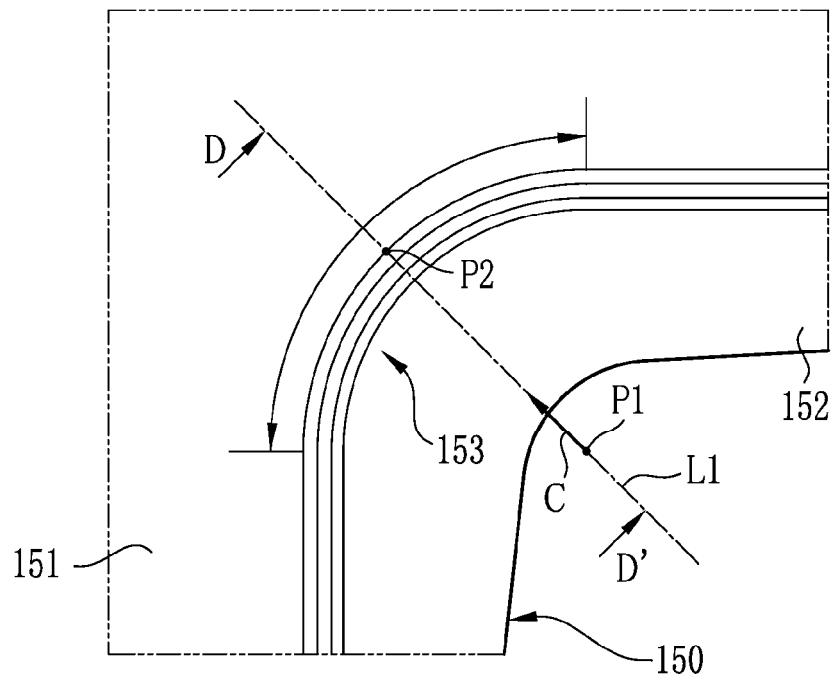


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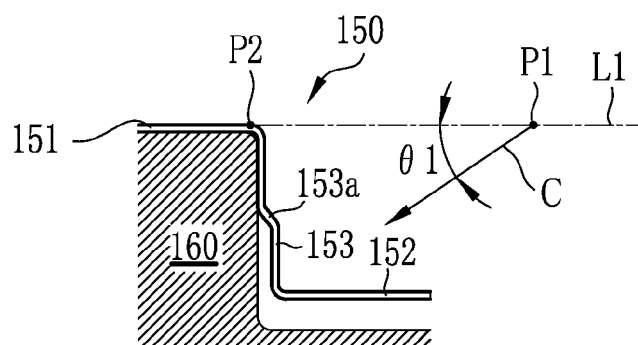


[Fig. 6]

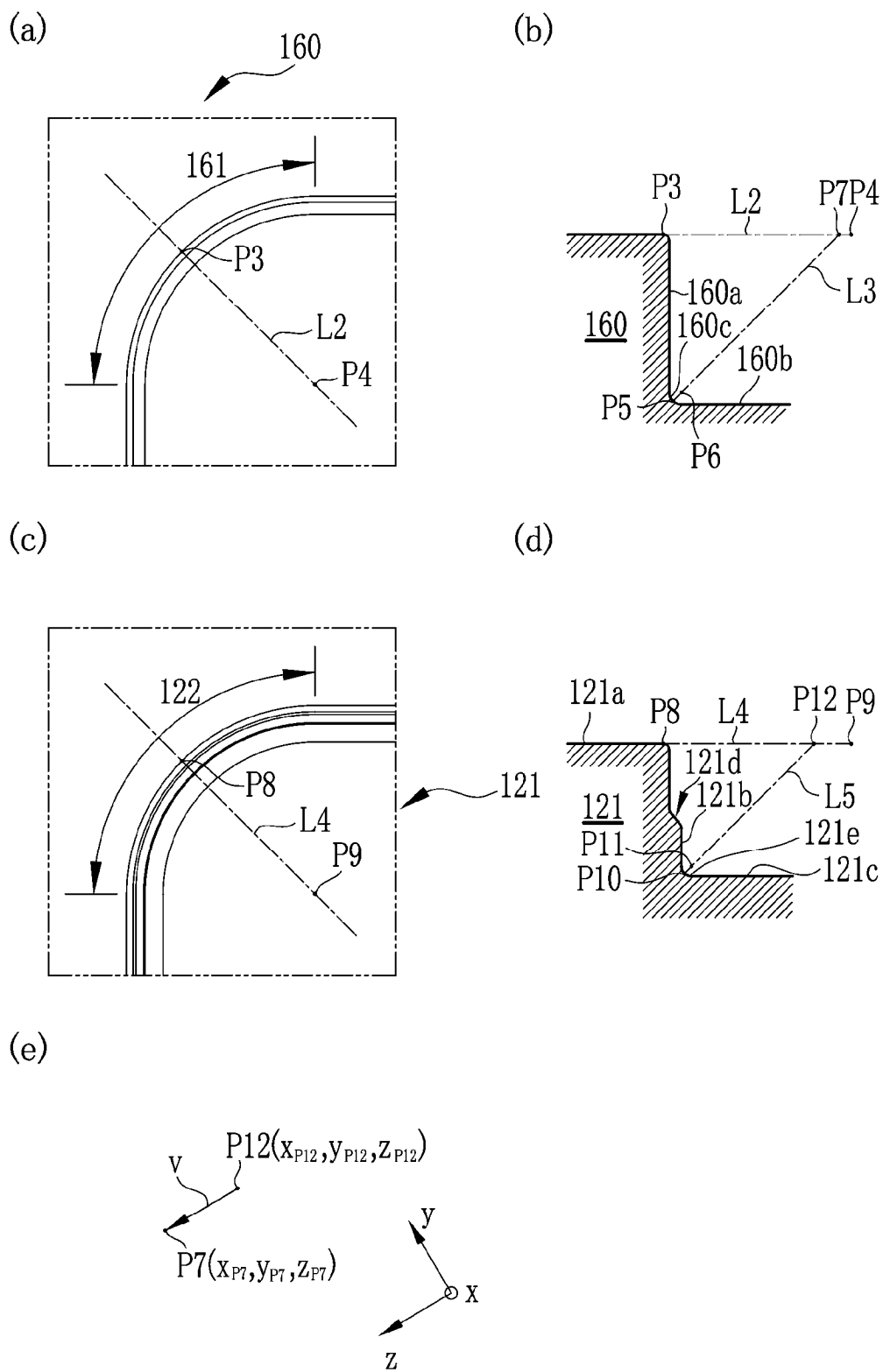
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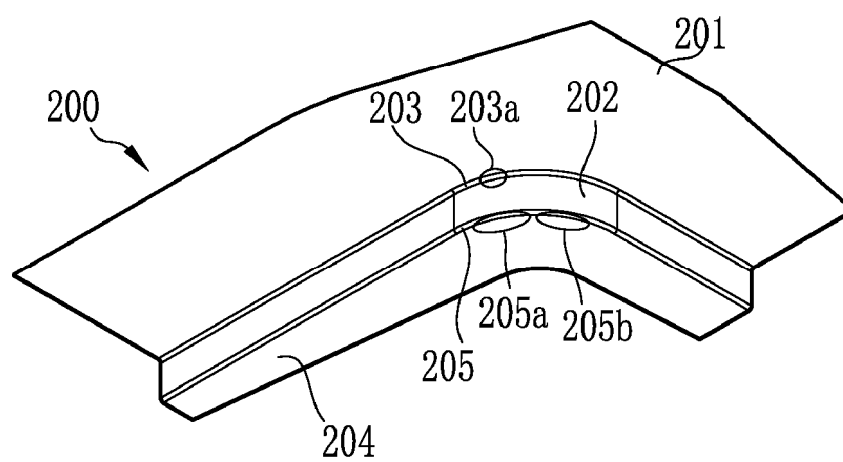


[Fig. 7]

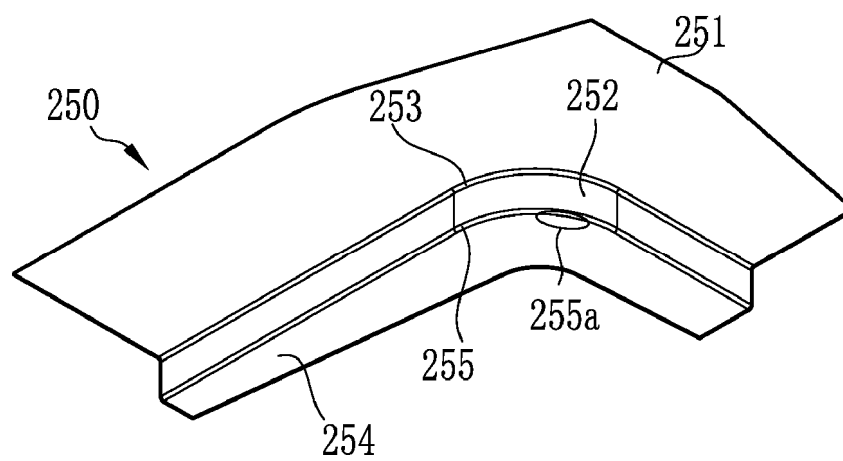


[Fig. 8]

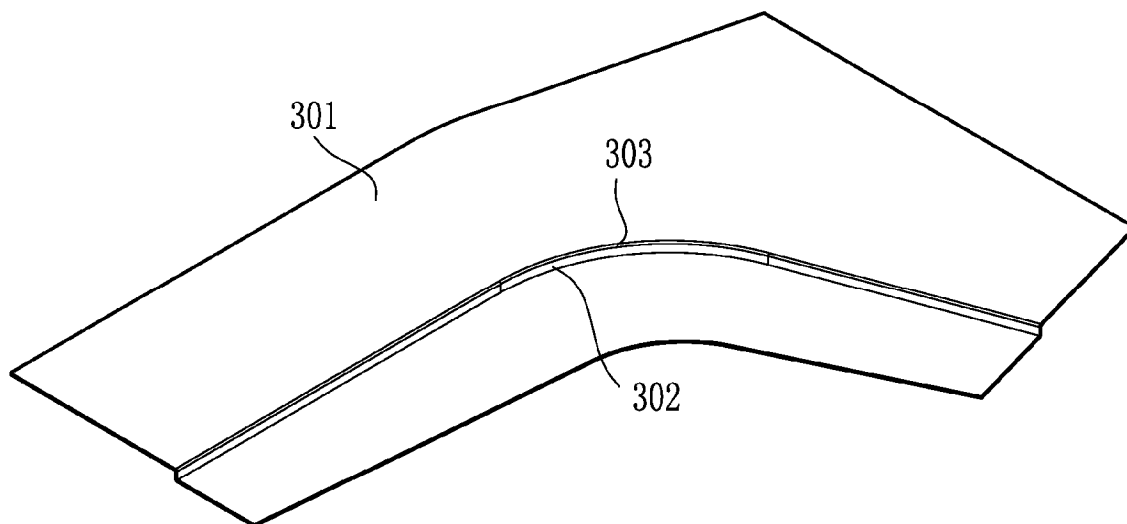
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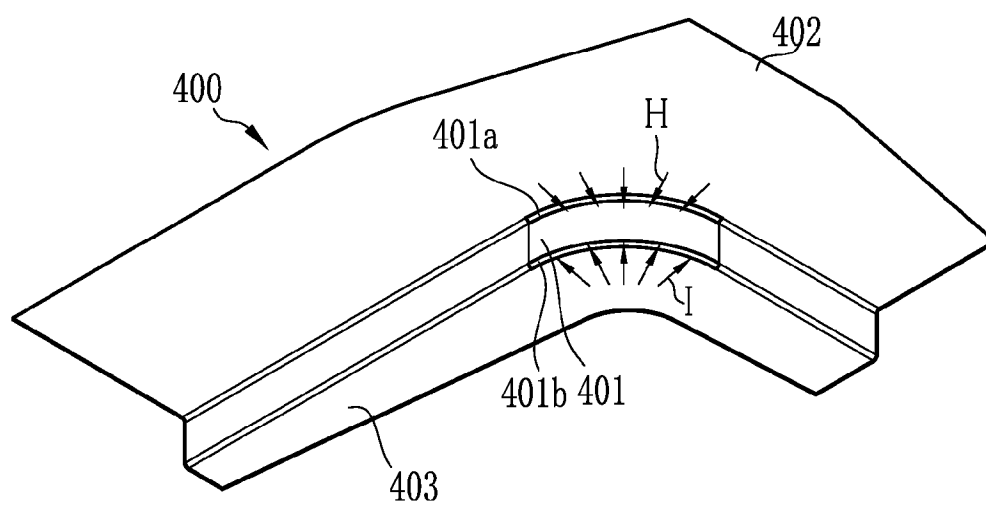
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[Fig. 9]

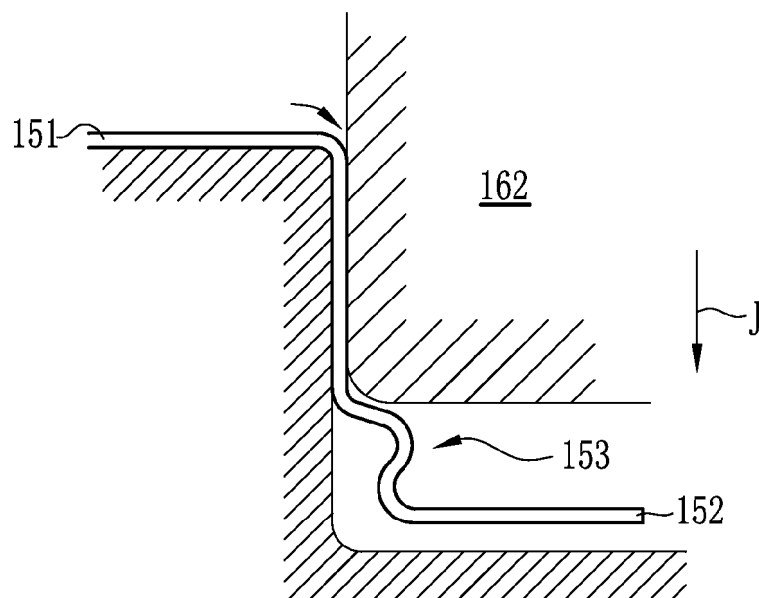


[Fig. 10]

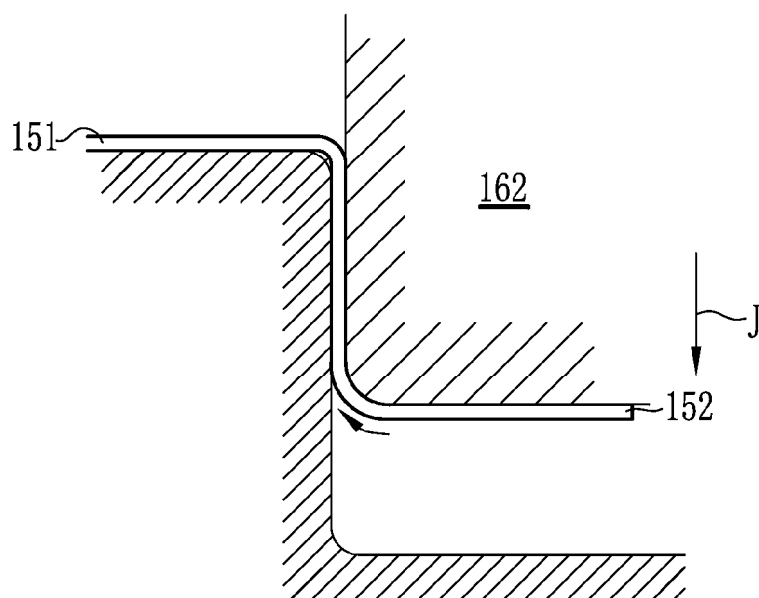


[Fig. 11]

(a)



(b)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/023030

A. CLASSIFICATION OF SUBJECT MATTER**B21D 22/26**(2006.01)i

FI: B21D22/26 C; B21D22/26 D

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D22/26

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2024
 Registered utility model specifications of Japan 1996-2024
 Published registered utility model applications of Japan 1994-2024

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2016-203256 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 08 December 2016 (2016-12-08) paragraphs [0020]-[0076], fig. 1-7	5
A	paragraphs [0020]-[0076], fig. 1-7	1-4
A	WO 2019/167793 A1 (JFE STEEL CORPORATION) 06 September 2019 (2019-09-06) paragraphs [0013]-[0038], fig. 1-11	1-5
A	WO 2016/075937 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 19 May 2016 (2016-05-19) paragraphs [0042]-[0059], fig. 9-12	1-5

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“&” document member of the same patent family

Date of the actual completion of the international search

12 July 2024

Date of mailing of the international search report

30 July 2024

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2024/023030

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REFERENCES CITED IN THE DESCRIPTION

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- JP 5952881 A [0004]