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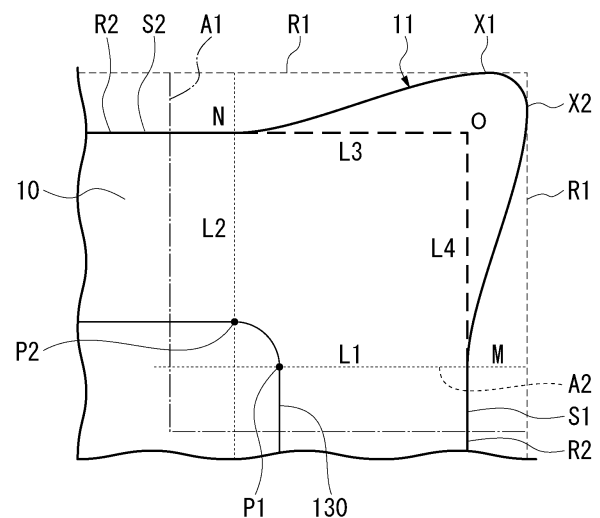
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(54) **MANUFACTURING METHOD AND BLANK FOR PRESS-FORMED PRODUCT**

(57) A method for manufacturing a press-formed product includes clamping a blank (10) between a support surface (140) of a first press die (100) and a support surface (340) of a third press die (300), and pressing a second press die (200) into the first press die (100) to draw the blank (10), wherein a ridge (130) of an edge of a press hole (123) of the first press die (100) has a curved region (131) that extends in a curved manner, and when a corner end portion (11) is defined, the corner end portion (11) of the blank (10) between an intersection point M and an intersection point N includes both line segments MO and NO, and a part of the corner end portion (11) is outside a region between the line segment MO and the line segment NO.

FIG. 5B



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Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] The development of electric vehicles is progressing rapidly with a goal of reducing CO₂ emissions in accordance with regulations based on corporate average fuel efficiency (CAFE). Currently, high-priced electric vehicles are mainstream, but in order to reduce the cost of electric vehicles, it is necessary to develop parts that use metals such as steel. As an example, forming techniques that use steel are being developed for battery boxes, front pillar lowers, door inners, and the like.

[0003] Typically, these parts (for example, trays) are constructed to include a bottom sheet portion, a longitudinal wall portion, and a flange portion, with the longitudinal wall portion having curved corner portions (also called corner portions), and are manufactured by welding and assembling a plurality of members together. However, in the conventional forming technology, when a radius of curvature of the corner portion is relatively small or a depth of press forming is deep, wrinkles may occur in the flange near the corner portion. Specifically, it is common to manufacture products shaped like trays by drawing. The flanges adjacent to the corner portions of the tray may develop wrinkles as a result of being drawn. This type of flange forming is called shrink flanging, because a circumferential width of the flange shrinks as it is formed. Wrinkles occur as a result of the circumferential width of the flange shrinking. This tendency becomes more evident when a processing target is a high-strength material. Also, as the height of the longitudinal wall of the tray increases, the shrinkage of the flange increases, and thus it is more likely for wrinkles to form on the flange. Wrinkles generated on the shrink flanging remain even when a workpiece is pulled from the flange into the longitudinal wall of the tray. That is, wrinkles also occur on the longitudinal wall of the tray. Even when the radius of curvature of the corner portion of the tray is small, wrinkles are likely to occur on the flange and the longitudinal wall. Furthermore, when the radius of curvature of the corner portion of the tray is small, cracks may occur along a ridge of the longitudinal wall that extends from the corner portion of the tray. As the radius of curvature of the corner portion of the tray becomes smaller, the cracks are more likely to occur. Also, as the strength of the processing target becomes higher, the cracks are more likely to occur.

[0004] As a method for curbing wrinkles in the flange portion, for example, a technology disclosed in Patent Document 1 provides beads on a pressing surface of a die to attempt to control a direction in which a material flows during drawing. However, in the technology of

Patent Document 1, there is a high possibility that bead marks or scratches will be left on a product after press forming, which may impair an exterior thereof. Furthermore, in the technology of Patent Document 1, when high-strength steel is press-formed, there is a high possibility that desired effects will not be achieved, which makes it difficult to carry out stable production.

Citation List

Patent Document

[0005] Patent Document 1: Japanese Patent Publication No. 2560416

SUMMARY OF INVENTION

Technical Problem

[0006] The inventors thoroughly investigated the causes of curbing the occurrence of wrinkles and cracks.

[0007] Geometrically, since the outer flange of the corner portion of the tray narrows in width as it is pulled in toward the longitudinal wall, it is caused to shrink. In addition, in formed products in which wrinkles occurred on the outer flanges of the corner portions of the tray, wrinkles also occur on edges of the formed products. This leads one to believe that the entire outer flange of the corner portion of the tray has shrunk and deformed.

[0008] Since inflow resistance from the flange to the longitudinal wall of the tray differs between a point at which a ridge between the flange and the longitudinal wall of the tray is straight and the corner portion, when noting relative positions of the flange adjacent to the point at which the ridge is straight and the flange adjacent to a ridge of the corner portion before and after forming, the flange adjacent to the ridge of the corner portion and the surrounding area thereof bulge away from the ridge after forming. This led the inventors to consider that an end portion of the flange (an edge of the workpiece) was actually being stretched. This hypothesis was confirmed as correct by a finite element analysis and by actually forming a blank by adding a scratch.

[0009] After further investigation, the inventors thought that when a rectangular region that perpendicularly intersects a bisector of a corner of a blank is imagined within the blank, the rectangular region will be deformed into a convex arch shape toward the corner of the blank during forming. The inventors concluded that wrinkles were generated due to compressive deformation of the concave side of the arch shape. The inventors concluded that the convex side of the arch shape undergoes tensile deformation, but when this tensile deformation is relaxed, the deformation to the arch shape will be relaxed, and as a result, the compressive deformation on the concave side of the arch shape will also be relaxed, thereby curbing the occurrence of wrinkles. Specifically, the inventors came to a conclusion that deformation into the

arch shape can be curbed by making a distance between an edge of a corner portion of a die hole and an edge of a blank wider than conventionally, compared to a distance between an edge of a die hole that straightly extends and an edge of a blank. The inventors also came to a conclusion that the occurrence of wrinkles can be curbed by adjusting a positional relationship between the edge of the die hole and the edge of the blank in this way. Furthermore, the inventors came up with an idea that cracks that occur at the ridge of the longitudinal wall extending from the corner portion of the tray are curbed when the radius of curvature of the corner portion of the above-described tray is small.

[0010] Here, movement of points in a processing target before and after press forming will be described.

[0011] FIGS. 17A and 17B are explanatory diagrams showing the movement of points (a, b, c, and d) in a processing target before and after conventional press forming, based on a result of a finite element analysis. FIG. 17A is an explanatory diagram showing points in the processing target before conventional press forming based on the result of the finite element analysis. FIG. 17B is an explanatory diagram showing points in the processing target after press forming based on the result of the finite element analysis.

[0012] The points a and b are points that were at an end portion of the curved portion of the ridge of the die (the edge of the die hole) after forming. The points c and d are points at an end portion of a press-formed product that are on a line perpendicular to an extension direction of the ridge of the die which passes through the end portion of the curved portion of the die after forming. When a function in a finite element analysis software to inversely calculate a blank shape from a product shape like a development diagram is used, the points (a, b, c, and d) in the processing target in FIG. 17B become positions in FIG. 17A before forming.

[0013] An inflow of the processing target during forming includes an inflow F_A that is suctioned into a straight ridge of a die, and an inflow F_B that is suctioned into a curved portion of the ridge of the die. The inflow F_A has deformation resistance in which the processing target is bent at the ridge of the die. In addition to the deformation resistance in which the processing target is bent at the ridge of the die, the inflow F_B also has deformation resistance in which the processing target is compressed in a direction transverse to an inflow direction as the processing target approaches the curved portion of the ridge of the die. In other words, the deformation resistance of the inflow F_B is higher than that of the inflow F_A . Therefore, inflow amounts of the inflow F_A and the inflow F_B are not uniform. As a result of the inflow amounts of the inflow F_A and the inflow F_B not being uniform, the width of the flange of the formed product (the width from the ridge of the die to the edge of the formed product) becomes wider at a point at which the inflow F_B occurs. In addition, even at a point surrounding a point at which the inflow F_B occurs, at which the inflow F_A occurs, the width of the

flange of the formed product becomes wider due to the processing target pushed out from the point at which the inflow F_B occurs. From another perspective, even at the point surrounding the point at which the inflow F_B occurs, in which the inflow F_A occurs, the width of the flange of the formed product becomes wider due to the processing target caught up in the inflow F_A and pulled out of the point at which the inflow F_B occurs.

[0014] A region H surrounded by the points a, b, c, and d is deformed into an arch-like convex shape in the same direction as the curved portion of the ridge of the die is curved convexly by forming. The region H shown by hatching in FIG. 17A corresponds to the flange of the corner portion after forming. After forming, the region H in FIG. 17A is deformed into a region H shown by hatching in FIG. 17B. As shown in FIGS. 17A and 17B, the points a, b, c, and d move with forming. For example, the point a follows an inflow trajectory as shown in FIG. 17B.

[0015] As a result of forming, the points a and b come closer to each other, and thus wrinkles occur in the formed product. The inventors concluded that when the arch-shaped deformation of the region H surrounded by the points a, b, c, and d could be alleviated, the occurrence of wrinkles could be curbed. It is believed that when stretching between the points c and d can be curbed, the arch-shaped deformation can be alleviated.

[0016] The inventors thought that stretching between the points c and d could be curbed by stretching the corners of the blank outward. FIGS. 18A and 18B are explanatory diagrams showing the movement of the points (a, b, c, and d) in the processing target before and after press forming according to the present disclosure, based on the result of the finite element analysis. FIG. 18A is an explanatory diagram showing points in the processing target before press forming according to the present disclosure, based on the result of the finite element analysis. FIG. 18B is an explanatory diagram showing the points in the processing target after press forming according to the present disclosure, based on the result of the finite element analysis.

[0017] A dotted line in FIG. 18A shows a shape of a conventional blank. A point e is an intersection point between a line passing through the points b and c and the edge of the blank. Similarly, a point f is an intersection point between a line passing through the points a and d and the edge of the blank. As shown in FIG. 18A, the blank (the workpiece) spreads outward with respect to the points c and d. Thus, it was found that the stretching between the points c and d was alleviated by forming. There are two main reasons for this. First, even when the workpiece is pulled into the curved portion of the ridge of the die by the same length, a rate of drawing closer with respect to a distance between the point e and the point f is smaller than a rate at which the distance between the points c and d approaches. In other words, a portion of the blank that is closer to an end than the point c and point d prevents the point c and the point d of the blank from approaching each other. Secondly, since portions that

are pulled in by the inflow F_A are enlarged between the point c and the point e (between the point d and the point f), stress that stretches between the point c and the point d is alleviated. When the stress is alleviated, the stretching deformation is also alleviated.

[0018] The present disclosure has been made in consideration of the above, and has an objective of providing a method for manufacturing a press-formed product, and a blank that can curb occurrence of wrinkles in a flange portion of the press-formed product and cracks in and around a corner portion.

Solution to Problem

[0019]

(1) A method for manufacturing a press-formed product according to an aspect of the present disclosure includes clamping a blank between a support surface of a first press die and a support surface of a third press die, and pressing a second press die into the first press die to draw the blank, wherein a ridge of an edge of a press hole of the first press die has a curved region that extends in a curved manner, and when seen in a direction perpendicular to the blank, and when a first normal line passing through a first end portion of the curved region in an extension direction of the ridge is defined as a straight line L1, a second normal line passing through a second end portion of the curved region in the extension direction of the ridge is defined as a straight line L2, an intersection point between the straight line L1 and an end portion of the blank is defined as an intersection point M, an intersection point between the straight line L2 and an end portion of the blank is defined as an intersection point N, a straight line passing through the intersection point M and perpendicular to the straight line L1 is defined as a straight line L4, a straight line passing through the intersection point N and perpendicular to the straight line L2 is defined as a straight line L3, an intersection point between the straight lines L3 and L4 is defined as an intersection point O, a line segment connecting the intersection point M and the intersection point O is defined as a line segment MO, and a line segment connecting the intersection point N and the intersection point O is defined as a line segment NO, and when the blank is clamped between the first press die and the third press die, a corner end portion of the blank between the intersection point M and the intersection point N includes both the line segment MO and the line segment NO, and a part of the corner end portion is outside a region between the line segment MO and the line segment NO.

In the method for manufacturing a press-formed product configured as described above, since an appropriate flow control region can be defined for the blank, it is possible to curb occurrence of wrinkles

in a flange portion of the press-formed product and cracks in and around a corner portion.

(2) In a blank according to an aspect of the present disclosure, in a square region included in a corner of a first rectangle, each side of which passes only through an edge and outside of the blank, with the length of one side being 40% of a short side of the first rectangle, the blank is in contact with both of two sides of a second rectangle that each side passes only through an edge and inside of the blank, and in a rectangular region that passes through two contact points between two sides of the second rectangle and the blank and of which a corner overlaps the first rectangle, the blank is in contact with both two sides of the first rectangle.

(3) The blank described in (2) may be in contact with both of the two sides of the first rectangle within a range of 10% of the length of the short side of the first rectangle from the corner of the first rectangle.

[0020] In the blank having the above configuration, since a flow control region is defined on a sheet surface of the corner portion of the blank corresponding to the corner region of the die, it is possible to curb the occurrence of wrinkles in a flange portion of the press-formed product and cracks in and around a corner portion.

Advantageous Effects of Invention

[0021] According to the method for manufacturing a press-formed product and the blank disclosed herein, it is possible to curb the occurrence of wrinkles in the flange portion of the press-formed product and cracks in and around the corner portion.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

[FIG. 1] A schematic perspective view showing the vicinity of a corner region of a first press die according to an embodiment of the present disclosure.

[FIG. 2] A schematic plan view showing the vicinity of the corner region of the first press die according to the embodiment of the present disclosure, when seen in a plan view in a direction perpendicular to a bottom surface.

[FIG. 3] A schematic cross-sectional view of the first press die taken along a plane passing through a position A-A' in FIG. 2.

[FIG. 4] A schematic perspective view showing a set of press dies according to an embodiment of the present disclosure.

[FIG. 5A] A schematic plan view showing a method for manufacturing a press-formed product according to an embodiment of the present disclosure.

[FIG. 5B] A plan view showing a vicinity of a part of a corner end portion shown in FIG. 5A.

[FIG. 5C] A schematic plan view showing a method for manufacturing a press-formed product of a comparative example.

[FIG. 6] A schematic plan view showing a modified example of the method for manufacturing a press-formed product according to the embodiment of the present disclosure.

[FIG. 7] A schematic plan view showing a modified example of a blank according to an embodiment of the present disclosure.

[FIG. 8] A schematic perspective view showing a corner region according to the embodiment of the present disclosure.

[FIG. 9A] A diagram showing an example of a product in which the present disclosure can be preferably used.

[FIG. 9B] A diagram showing an example of a product in which the present disclosure can be preferably used.

[FIG. 10] A diagram showing an example of a product in which the present disclosure can be preferably used.

[FIG. 11] A diagram showing an example of a product in which the present disclosure can be preferably used.

[FIG. 12] A diagram showing an example of a product in which the present disclosure can be preferably used.

[FIG. 13A] A schematic plan view of a blank of Experimental example 1.

[FIG. 13B] A diagram showing a distribution of a maximum principal strain obtained by a finite element analysis when the blank of Experimental example 1 is press-formed.

[FIG. 14] A schematic plan view of a blank of Experimental example 2.

[FIG. 15] A schematic plan view of a blank of Experimental example 3.

[FIG. 16] A schematic plan view of a blank of Experimental example 4.

[FIG. 17A] An explanatory diagram showing points in a processing target before conventional press forming based on a result of the finite element analysis.

[FIG. 17B] An explanatory diagram showing the points in the processing target after the conventional press forming based on the result of the finite element analysis.

[FIG. 18A] An explanatory diagram showing points in a processing target before press forming according to the present disclosure based on the result of the finite element analysis.

[FIG. 18B] An explanatory diagram showing points to be processed after press forming according to the present disclosure, based on the result of the finite element analysis.

DESCRIPTION OF EMBODIMENTS

[0023] The inventors studied a shape of a blank to be press-formed in order to curb wrinkles that occur in a flange portion of a press-formed product, and found that a flow direction of a material during press forming can be controlled by providing an excess portion to the shape of the conventional blank, leading to curb of wrinkles in the flange portion and cracks in and around a corner portion. However, the present inventors also found that simply providing the excess portion is not enough to effectively curb such wrinkles. After careful consideration, they found that wrinkles in the flange portion of the press-formed product can be effectively curbed by setting an appropriate region according to a shape of the blank and a shape of a die.

[0024] Hereinafter, embodiments of the present disclosure will be described with reference to examples, but it is obvious that the present disclosure is not limited to the examples described below. In the following description, specific numerical values and materials may be given as examples, but other numerical values and materials may be applied as long as the effects of the present disclosure are obtained. In addition, components of the following embodiments can be combined with each other.

(Method for manufacturing press-formed product)

[0025] A method for manufacturing a press-formed product according to this embodiment includes clamping a blank between a support surface of a first press die and a support surface of a third press die (a blank clamping step), and pressing a second press die into the first press die to draw the blank (a blank drawing step).

[0026] First, an example of a press die capable of carrying out the blank clamping step and the blank drawing step will be described.

(Press die)

[0027] FIG. 1 shows an example of a press die (a first press die 100) that can be used in the method for manufacturing a press-formed product according to this embodiment. Also, FIG. 2 is a schematic diagram showing a vicinity of a corner region 121 of a side surface 120 of the first press die 100, and shows a plan view seen in a direction perpendicular to a bottom surface 110. In the examples of FIGS. 1 and 2, an X-axis is parallel to a direction in which one planar region (a planar region 122a) of the side surface 120 extends, a Y-axis is parallel to a direction in which the other planar region (a planar region 122b) of the side surface 120 extends, and a Z-axis is parallel to a perpendicular line to the bottom surface 110.

[0028] FIG. 1 is a schematic perspective view showing a vicinity of a corner region 121 of a side surface 120 of a first press die 100. The first press die 100 shown in FIG. 1 has the bottom surface 110, the side surface 120 that

risers from the bottom surface 110 and has the corner region 121 that is curved when seen in a plan view in a direction perpendicular to the bottom surface 110, and a support surface 140 that is connected to the side surface 120 via a ridge 130.

[0029] The bottom surface 110 may be a substantially planar surface. The bottom surface 110 is connected to the side surface 120 at an outer edge 111 thereof. The entire outer edge 111 of the bottom surface 110 may be connected to the side surface 120, or only a part of the outer edge 111 may be connected to the side surface 120. A part of the outer edge 111 has a corner portion 111a corresponding to the corner region 121 of the side surface 120. The bottom surface 110 and the side surface 120 may be connected via the bottom surface side ridge 112 that is provided along the outer edge 111. In a cross-sectional view perpendicular to an extension direction of the bottom surface side ridge 112 at each of points on the bottom surface side ridge 112, the bottom surface 110 and the side surface 120 are smoothly connected via the bottom surface side ridge 112. A portion of the bottom surface side ridge 112 that is connected to the corner region 121 of the side surface 120 is referred to as a corner section 112a. The bottom surface 110 may have a concave or convex portion that faces in an out-of-plane direction of the bottom surface 110 in order to provide an uneven portion in the press-formed product.

[0030] The side surface 120 is connected to the bottom surface 110 and rises in the out-of-plane direction of the bottom surface 110. A part or whole of the side surface 120 may be parallel to a perpendicular line of the bottom surface 110, or may be inclined with respect to the perpendicular line of the bottom surface 110. As shown in FIG. 1 or 2, the side surface 120 has the corner region 121 that is curved when seen in a plan view in a direction perpendicular to the bottom surface 110. The corner region 121 is connected to planar regions 122 (a planar region 122a and a planar region 122b) of the side surface 120 at terminal portions 121a and 121b. The corner region 121 may be connected to another corner region having a different radius of curvature in a plan view perpendicular to the bottom surface 110, or may be connected to a region of the side surface 120 that is gently curved. Alternatively, the terminal portion of the corner region 121 may be an end portion of the side surface 120. In the example of FIGS. 1 and 2, in the plan view in the direction perpendicular to the bottom surface 110, the planar regions 122a and 122b are orthogonal to each other, but an angle formed by the planar regions 122a and 122b in the plan view in the direction perpendicular to the bottom surface 110 is not limited thereto.

[0031] The side surface 120 is connected to the support surface 140 via a ridge 130 at an end portion opposite to the end portion to which the bottom surface 110 is connected. In a cross-sectional view perpendicular to the extension direction of the ridge 130 at each of points on the ridge 130, the support surface 140 is provided on the side opposite the bottom surface 110 with respect to the

side surface 120. A portion of the ridge 130 that is connected to the corner region 121 of the side surface 120 is referred to as a curved region 131. The curved region 131 of the ridge 130 is connected to a straight region 132 (a straight region 132a and a straight region 132b) of the ridge 130 at terminal portions 131a and 131b. The curved region 131 may be connected to another curved region having a different radius of curvature in the plan view perpendicular to the bottom surface 110, or may be connected to a region of the ridge 130 that is gently curved. Alternatively, a terminal portion of the curved region 131 may be an end portion of the ridge 130. Each of terminal portions (a terminal portion 131a and a terminal portion 131b) of the curved region 131 includes a terminal point (a first end portion) P1 and a terminal point (a second end portion) P2, which will be described below.

[0032] FIG. 3 is a schematic cross-sectional view of the first press die 100 taken along a plane passing through a position A-A' in FIG. 2. As shown in FIG. 3, the bottom surface 110 and the corner region 121 of the side surface 120 are smoothly connected via the corner section 112a of the bottom surface side ridge 112, and the corner region 121 of the side surface 120 and the support surface 140 are smoothly connected via the curved region 131 of the ridge 130. In the example of FIG. 3, the corner region 121 of the side surface 120 is inclined with respect to a perpendicular line of the bottom surface 110. However, the corner region 121 may be perpendicular to the bottom surface 110 in each of cross sections perpendicular to the bottom surface 110. The first press die 100 has a press hole 123. The first press die 100 and a second press die 200 (described below) move relatively in a direction in which they approach each other, and thus the second press die 200 is pressed into the press hole 123. The ridge 130 of an edge of the press hole 123 (an edge on the second press die 200 side) has the curved region 131 that extends in a curved manner.

[0033] The first press die 100 may have one or more corner regions 121. The bottom surface 110 of the first press die 100 corresponds to a bottom sheet portion of the press-formed product, the side surface 120 corresponds to a longitudinal wall portion of the press-formed product, and the support surface 140 corresponds to a flange portion of the press-formed product.

[0034] Press forming is performed by a set of press dies 1000 including the above-described first press die 100, second press die 200, and third press die 300. An example of the set of press dies 1000 including the first press die 100, the second press die 200 and the third press die 300 is shown in FIG. 4. FIG. 4 shows the press dies 1000 including the first press die 100 having four corner regions 121, but the press dies are not limited to such a shape, and the number of corner regions 121 and the shape of the bottom surface 110 are not particularly limited.

[0035] The second press die 200 has a bottom surface 210 corresponding to the bottom surface 110 of the first press die 100, a side surface 220 corresponding to the

side surface 120 of the first press die 100, and a corner region 221 corresponding to the corner region 121 of the first press die 100. Outer surface shapes of the bottom surface 210 and the side surface 220 of the second press die 200 correspond to outer surface shapes of the bottom surface 110 and the side surface 120 of the first press die 100. In a state in which a blank which is a workpiece is disposed between the first press die 100 and the second press die 200, the blank is plastically deformed between the first press die 100 and the second press die 200 by relatively moving the first press die 100 and the second press die 200 in a direction (a pressing direction) in which the bottom surface 110 of the first press die 100 and the bottom surface 210 of the second press die 200 approach each other. The first press die 100 is also called a die. The second press die 200 is also called a punch.

[0036] The third press die 300 has a support surface 340 corresponding to the support surface 140 of the first press die 100. The support surface 140 of the first press die 100 and the support surface 340 of the third press die 300 are disposed to face each other, and the blank which is the workpiece can be clamped by the support surface 140 of the first press die 100 and the support surface 340 of the third press die 300. The blank is clamped by the support surface 140 of the first press die 100 and the support surface 340 of the third press die 300 so as to be unable to move in an out-of-plane direction but to be able to move in an in-plane direction. When the first press die 100 and the second press die 200 are moved relative to each other in a state in which the blank is clamped by the first press die 100 and the third press die 300, the second press die 200 moves relative to the third press die 300. The third press die 300 is also referred to as a holder.

[0037] The first press die 100, the second press die 200 and the third press die 300 may be configured of a single member, or each of them may be configured of a split die that is divided. Furthermore, the press dies 1000 may include a die other than these dies.

[0038] A corner end portion 11 of the blank 10 will be described. FIG. 5A is a schematic plan view showing the method for manufacturing a press-formed product according to the embodiment of the present disclosure. FIG. 5A is a plan view in a direction perpendicular to a sheet surface of a sheet-shaped blank 10. FIG. 5B shows a vicinity of some of the corner end portions 11 of the blank 10 shown in FIG. 5A. FIG. 5B shows positions of the ridge 130 of the die hole (the press hole 123) and the edge of the blank 10 when the blank 10 is placed on the die (the first press die 100) and clamped by the blank holder (the third press die 300).

[0039] When seen in a vertical direction of the blank 10, a first normal line that passes through a first end portion P1 in the extension direction of the ridge 130 of the curved region 131 is defined as a straight line L1, a second normal line that passes through a second end portion P2 in the extension direction of the ridge 130 of the curved region 131 is defined as a straight line L2, an intersection point of L1 and the end portion of blank 10 is defined as an

intersection point M, an intersection point of the straight line L2 and the end portion of blank 10 is defined as an intersection point N, a straight line that passes through the intersection point M and is perpendicular to the straight line L1 is defined as a straight line L4, a straight line that passes through the intersection point N and is perpendicular to the straight line L2 is defined as a straight line L3, an intersection point of the straight line L3 and the straight line L4 is defined as an intersection point O, a line segment that connects the intersection point M and the intersection point O is defined as a line segment MO, and a line segment that connects the intersection point N and the intersection point O is defined as a line segment NO. An end portion of the blank 10 between the intersection point M and the intersection point N is defined as the corner end portion 11. The corner end portion 11 is a portion of the blank 10 on the outer side from a line segment MN that connects the intersection point M and the intersection point N. As shown in FIG. 5B, when the blank 10 is clamped between the first press die 100 and the third press die 300, the corner end portion 11 includes all of the line segment MO and the line segment NO, and a part of the corner end portion 11 is outside a region between the line segment MO and the line segment NO. The line segment MO and the line segment NO has a shape of an end portion of a conventional blank. An edge of the corner end portion 11 of the blank 10 is outside the region between the line segment MO and the line segment NO, and the edge of the corner end portion 11 of the blank 10 is not inside the region between the line segment MO and the line segment NO.

[0040] Thus, a part of the corner end portion 11 of the blank 10 is outside the region between the line segment MO and the line segment NO. In other words, the blank 10 has a shape in which the corner end portion 11 protrudes outward. In other words, the corner end portion 11 has a convex shape toward the outside of the corner of the blank 10. It can also be said that the corner end portion 11 has an arch shape toward the outside of the corner of the blank 10. By forming the corner end portion 11 of the blank 10 in such a shape, tensile deformation at the corner end portion 11 is alleviated, and the occurrence of wrinkles is curbed.

[0041] It is not necessary that the corner end portion 11 is set at all corner portions in the blank 10, and the corner end portion 11 may be set at only some of the corner portions.

[0042] In the method for manufacturing a press-formed product according to this embodiment, since an appropriate corner end portion 11 can be defined for a blank, the occurrence of wrinkles in a flange portion of the press-formed product and cracks in and around a corner portion can be curbed. In the corner portion, cracks at the corner section 112a can be particularly curbed. The corner section 112a is a portion that continues to be stretched from a start to an end of press forming, and is thus a portion in which cracks are most likely to occur.

(Modified example of the method for manufacturing a press-formed product)

[0043] FIG. 6 is a schematic plan view showing a modified example of the method for manufacturing a press-formed product according to one embodiment of the present disclosure. FIG. 6 shows positions of the ridge 130 of the die hole and the edge of the blank 10 when the blank 10 is placed on the die (the first press die 100) and clamped by the blank holder (the third press die 300). FIG. 6 shows a vicinity of one of the corner end portions 11 of the blank 10.

[0044] Also, in the modified example shown in FIG. 6, as in FIG. 5B, a part of the corner end portion 11 of the blank 10 is outside the region between the line segment MO and the line segment NO. In other words, the blank 10 has a shape in which the corner portion protrudes outward. In other words, the corner end portion 11 has a convex shape toward the outside of the corner of the blank 10. It can also be said that the corner end portion 11 has an arch shape toward the outside of the corner of the blank 10. By forming the corner end portion 11 of the blank 10 in such a shape, tensile deformation at the corner end portion 11 is alleviated, and the occurrence of wrinkles is curbed.

(Blank)

[0045] The blank 10 according to this embodiment will be described in detail. In this embodiment, the blank 10 having a rectangular shape will be described using FIGS. 5A and 5B. FIG. 5B shows a vicinity of a part of the corner end portion 11 of the blank 10, but the corner end portion 11 is a portion in which a first side S1 and a second side S2 of the blank 10 which are approximately straight intersect when seen in a plan view in a direction perpendicular to the sheet surface of the blank 10.

[0046] The fields of view in FIGS. 5A and 5B assume a square region A1 included in a corner of a first rectangle R1, each side of which passes only through the edge and outside of the blank 10, with the length of one side being 40% of a short side of a rectangular cut sheet. As shown in FIG. 5C, when the blank 10 is formed so deeply that a corner portion of a ridge 1300 of a die does not enter the region A1, there is a concern that cracks will occur even when the knowledge of the present disclosure is used. When forming is performed to such an extent that the corner portion of the ridge 1300 of the die does not enter this region A1 and cracks do not occur, the width of the flange will be excessive, which means poor yield. In the above-described region A1, the blank 10 is in contact with both of two sides of a second rectangle R2 that each side passes only through the edge and inside of the blank 10, and in a rectangular region A2 passes through two contact points between the two sides of the second rectangle R2 and the blank 10 and of which a corner overlaps the first rectangle R1, the blank 10 is in contact with both of two sides of the first rectangle R1. As shown in FIG. 5B, in

the region A2, the blank 10 is in contact with two points X1 and X2 on both of the two sides of the first rectangle R1. Also, the edges of the blank 10 and the edges of the rectangular cut sheet may coincide with each other from the two points X1 and X2 to a corner of the rectangular cut sheet. Furthermore, preferably, the two points X1 and X2 are within a range of 10% of the length of a short side of the rectangular cut sheet from the corner of the rectangular cut sheet. In such a way, the tensile deformation of the corner end portion 11 of the blank 10 can be further alleviated.

[0047] Each of the sides of the first rectangle R1 passes only through the edge and outside of the blank. The first rectangle R1 is formed in a shape of a rectangular cut sheet. Each of the sides of the second rectangle R2 passes only through the edge and inside of the blank. The second rectangle has an intersection point O as a corner and passes through the intersection points N and M.

[0048] In the square region A1 included in a corner of the first rectangle R1 and of which the length of one side is 40% of the shorter side of the first rectangle R1, the blank 10 is in contact with both of the two sides of the second rectangle R2. In the region shown in FIG. 5B, the edge of blank 10 passes through the intersection points M and N.

[0049] In the rectangular region A2 in which two contact points between two sides of the second rectangle R2 and the blank overlap the first rectangle R1, the blank 10 is in contact with both of the two sides of the first rectangle R1. In a region surrounded by the edge of the cut sheet and the straight lines L1 and L2, the edge of the blank 10 is in contact with the edge of the cut sheet. However, in actual cutting of the blank 10, it is not necessary to use the edge of the cut sheet for the blank.

[0050] When the positions of the intersection points M and N of the blank 10 having such a shape and the ridge 130 of the die hole (the press hole 123) of the die as described are disposed in the above-described method for manufacturing a press-formed product, and then press forming is performed, the method for manufacturing a press-formed product disclosed herein can be implemented.

(Modified example of blank)

[0051] FIG. 7 is a schematic plan view showing a modified example of the blank according to one embodiment of the present disclosure.

[0052] In the examples of FIGS. 5A to 7, a rectangular blank 10 is shown, but the shape of the blank 10 is not limited thereto, and the corner end portion 11 may be provided only at the corner portion that is a target of setting task achievement. A part of the corner end portion 11 may become a part of the flange of the press-formed product after press forming. The flange of the press-formed product may be trimmed to adjust the shape. In this case, the blank 10 has a shape that has the corner end portions 11 at the corners of the blank 10.

[0053] The blank 10 may be a steel sheet, an aluminum alloy sheet, a titanium alloy sheet, or a composite material thereof. From the viewpoint of material elongation, it is more preferable to use a steel sheet having a tensile strength of 270 to 440 MPa as the blank 10. The blank 10 may also be a high-strength steel sheet, for example, a steel sheet having a tensile strength of 980 MPa or more. Even when the blank 10 according to the present embodiment has a high tensile strength, the effect of curbing wrinkles and cracks can be obtained. Furthermore, the blank 10 may be subjected to a process such as plating for the purpose of rust prevention and corrosion prevention.

[0054] In the blank 10 according to this embodiment, the corner end portion 11 is defined on the sheet surface of the corner portion of the blank 10. Therefore, it is possible to curb the occurrence of wrinkles in the flange portions and cracks in and around the corner portions of the press-formed product produced by press-forming the blank 10.

[0055] In the above embodiment, the corner region in which the above-described corner end portion 11 is a setting target is a corner region that is convex from the bottom surface side to the support surface side with respect to the side surface when seen in a plan view in a direction perpendicular to the bottom surface of the first press die. That is, in a plan view in the direction perpendicular to the bottom surface of the first press die, the corner region that is convex from the support surface side to the bottom surface side with respect to the side surface is not included in a target of the above embodiment. For example, a side region B of the first press die shown in FIG. 8 is convex from the support surface side to the bottom surface side with respect to the side surface, and is not a target to be subject to the method for setting the corner end portion 11 according to the present disclosure.

[0056] In the above embodiment, when a plurality of corner regions having different radii of curvature in a plan view perpendicular to the bottom surface are connected, the plurality of corner regions are treated as one corner region to set the above corner end portion. For example, a side surface region C of the first press die shown in FIG. 8 includes a plurality of corner regions, namely, a corner region 121' and a corner region 121'' having different radii of curvature. The side surface region C of the first press die shown in FIG. 8 is convex from the bottom surface side to the support surface side with respect to the side surface, and can be the setting target of the method for setting the corner end portion 11 according to the present disclosure.

[0057] More preferably, a sheet thickness of the blank according to the above embodiment is appropriately set according to characteristics required for the press-formed product obtained by press-forming the blank. The sheet thickness of the blank may be an average sheet thickness of a metal sheet that is a workpiece. The average sheet thickness may be an average value of sheet thicknesses at a plurality of arbitrary points on the

metal sheet (for example, three points in a range formed onto the longitudinal wall portion or the bottom sheet portion). The sheet thickness of the metal sheet may be substantially the same as a sheet thickness of a longitudinal wall preformed portion or a bottom sheet preformed portion of a preformed product, or a sheet thickness of the longitudinal wall portion or the bottom sheet portion of the press-formed product. The sheet thickness of the metal sheet may be substantially the same as a clearance between the first die and the second die, or a clearance between a fourth die and a fifth die.

[0058] When the radius of curvature of the corner portion is small, problems such as cracks and wrinkles become apparent. Even in such a case, the press forming method of the present disclosure can curb the occurrence of cracks and wrinkles. In a blank 10 having a tensile strength of 980 MPa or more, a curve in the extension direction of the ridge 130 of the die hole (the press hole 123) of the die, at which the problem of cracks becomes apparent, has a smallest radius of curvature of 20 mm or less. This radius of curvature corresponds to 30 times the sheet thickness of the blank. In other words, in the blank having a tensile strength of 980 MPa or more, when the smallest radius of curvature of the curve in the extension direction of the ridge 130 of the edge of the die hole is 30 times or less than that of the blank, the press forming method of the present disclosure can curb the occurrence of cracks and wrinkles.

[0059] Furthermore, when the press depth is deep, the problem of cracks and wrinkles becomes apparent. Even in such a case, the occurrence of cracks and wrinkles can be curbed by the press forming method of the present disclosure.

[0060] In the above embodiment, an angle between a tangent line of the ridge at the terminal point P1 and a tangent line of the ridge at the terminal point P2 is not particularly limited, and may be, for example, an acute angle as shown in FIG. 6. In a plan view perpendicular to the bottom surface of the first press die, preferably, the angle between the tangent line of the ridge at the terminal point P1 and the tangent line of the ridge at the terminal point P2 is 30° or more and 150° or less. In the above embodiment, the planar region of the side surface of the first press die is preferably a region having a radius of curvature of 500 mm or more in a plan view perpendicular to the bottom surface. In the above embodiment, more preferably, the height of the side surface of the first press die is 20 times or more and 200 times or less the sheet thickness of the blank 10.

[0061] In the above embodiment, the width of the flange portion of the blank 10 may be asymmetric. That is, the length of the line segment OM may be different from the length of the line segment ON. Even in such a case, since an appropriate flow control region can be defined for the blank 10, the occurrence of wrinkles in the flange portion of the press-formed product and cracks in and around the corner portion can be curbed.

[0062] In the above embodiment, the press-formed

product may be a final product, or may be an intermediate product that is to be further processed (by press forming, cutting, bending, welding, heating and cooling, plating, painting) to form a final product.

[0063] The press-formed product according to the above embodiment can be preferably used for vehicle parts such as battery boxes, front pillar lowers, door inners, which are represented by vehicle battery boxes and have corner portions corresponding to the corner regions of the first press die. FIGS. 9A to 12 are diagrams showing an example of a product for which the method for manufacturing a press-formed product and the blank according to the present disclosure can be preferably used. A press-formed product shown in FIG. 9A is a corner component 301 of a battery box, and has two corner portions 331 and 331'. A press-formed product shown in FIG. 9B is a corner component 302 of a battery box, and has a corner portion 332. These press-formed products may be joined with other members to form the entire battery box. A press-formed product shown in FIG. 10 is a front pillar 303 having a corner portion 333. The present disclosure can also be preferably applied to such a member of which entirety is curved in an L-shape. A press-formed product shown in FIG. 11 is a stiffener 304 for a C-pillar, and has a longitudinal wall that is higher in the vicinity of a corner portion 334. In this way, the present disclosure can be preferably applied to a member in which the height of the longitudinal wall is not uniform. A press-formed product shown in FIG. 12 is a door inner 305. The present disclosure can also be preferably applied to press-formed products such as the door inner 305 that have a plurality of corner portions 335 and 335' with different radii of curvature and opening angles.

[Examples]

[0064] Examples of the present disclosure will be described below.

[0065] In this example, press forming was performed on each of blanks having a corner portions having shapes as shown in FIGS. 13A, 14, 15, and 16, and a strain distribution in the flange portion of the press-formed product was verified by a finite element analysis. FIGS. 13A, 14, 15, and 16 show the vicinity of a corner portion of each of the blanks. Common to all the blanks, the tensile strength of the blank was 270 MPa and the sheet thickness was 0.8 mm.

[0066] A distribution of maximum principal strain obtained by the finite element analysis when each of blanks 500, 600, 700, and 10 is press-formed was verified. The principal strains are three components of a normal strain when a coordinate system Cp, in which a shear strain is zero, is used as a reference. The principal strains are defined in order from the largest to the smallest as "maximum principal strain (ϵ_1)," "intermediate principal strain (ϵ_2)," and "minimum principal strain (ϵ_3).". The maximum principal strain is generally used to evaluate a maximum tensile strain applied to a material. When the

maximum principal strain is large, it can be determined that cracks occur easily. The maximum principal strain can be found using general finite element analysis software. Software generally used in a forming analysis has a function to inversely calculate the shape of the blank from a shape of the product as shown in a development diagram (a developed blank analysis). Using this function for analysis, those skilled in the art generally perform a blank design based on the shape of the developed blank.

(Experimental example 1)

[0067] FIG. 13A is a schematic plan view of the blank 500 of Experimental example 1. A corner end 511 of the blank 500 is inside a region between the line segment MO and the line segment NO, that is, the blank 500 is a conventional example.

[0068] In FIG. 13B, the blank 500 is shown by a two-dot chain line, and a shape after forming is shown by a solid line. A portion at which the maximum principal strain in Experimental example 1 was shown was a portion (near a curved region) surrounded by a dotted circle in FIG. 13B, and the maximum value was 0.85.

(Experimental example 2)

[0069] FIG. 14 is a schematic plan view of the blank 600 of Experimental example 2. A corner end portion 611 of the blank 600 is inside the region between the line segment MO and the line segment NO, that is, the blank 600 is a conventional example.

[0070] A portion at which the maximum value of the maximum principal strain in Experimental example 2 was shown was a portion surrounded by a dotted circle in FIG. 13B, and the maximum value was 1.09. In other words, it was found that typical blank designs by those skilled in the art tend to result in press-formed products that are prone to cracking.

(Experimental example 3)

[0071] FIG. 15 is a schematic plan view of the blank 700 of Experimental example 3. A part of a corner end portion 711 of the blank 700 is outside the region between the line segment MO and the line segment NO, but the corner end portion 711 does not include all of the line segment MO and the line segment NO.

[0072] A portion at which the maximum value of the maximum principal strain in Experimental example 3 was shown was a portion surrounded by a dotted circle in FIG. 13B, and the maximum value was 0.92. In other words, it was found that even when a part of the corner end portion 711 is outside the region between the line segment MO and the line segment NO, if the corner end portion 711 does not include all of the line segment MO and the line segment NO, the press-formed product is prone to cracking.

(Experimental example 4)

[0073] FIG. 16 is a schematic plan view of the blank 10 of Experimental example 4. The entire corner end portion 11 of the blank 10 is outside the region between the line segment MO and the line segment NO. In other words, the blank 10 is an example of the invention.

[0074] A portion at which the maximum value of the maximum principal strain in Experimental example 4 was shown was a portion surrounded by a dotted circle in FIG. 13B, and the maximum value was 0.73. The blank 10 showed an improvement in the maximum principal strain compared to the conventional example.

[0075] From the examples, it was found that in order to achieve an improvement compared to the conventional example, it is necessary for the corner end portion 11 to include both the line segment MO and the line segment NO, and for a part of the corner end portion 11 to be outside the region between the line segment MO and the line segment NO.

INDUSTRIAL APPLICABILITY

[0076] The method for manufacturing a press-formed product and the blank of the present disclosure can curb the occurrence of wrinkles in the flange portion of the press-formed product and cracks in and near the corner portion, making it extremely useful industrially.

REFERENCE SIGNS LIST

[0077]

10 Blank	
11 Corner end portion	35
12 Edge portion	
100 First press die	
110 Bottom surface	
120 Side surface	
121 Corner region	40
130 Ridge	
131 Curved region	
140 Support surface	
200 Second press die	45
300 Third press die	

Claims

1. A method for manufacturing a press-formed product, comprising:

clamping a blank between a support surface of a first press die and a support surface of a third press die; and
pressing a second press die into the first press die to draw the blank,
wherein a ridge of an edge of a press hole of the

first press die has a curved region that extends in a curved manner,

when seen in a direction perpendicular to the blank, and

when a first normal line passing through a first end portion of the curved region in an extension direction of the ridge is defined as a straight line L1, a second normal line passing through a second end portion of the curved region in the extension direction of the ridge is defined as a straight line L2, an intersection point between the straight line L1 and an end portion of the blank is defined as an intersection point M, an intersection point between the straight line L2 and an end portion of the blank is defined as an intersection point N, a straight line passing through the intersection point M and perpendicular to the straight line L1 is defined as a straight line L4, a straight line passing through the intersection point N and perpendicular to the straight line L2 is defined as a straight line L3, an intersection point between the straight lines L3 and L4 is defined as an intersection point O, a line segment connecting the intersection point M and the intersection point O is defined as a line segment MO, and a line segment connecting the intersection point N and the intersection point O is defined as a line segment NO, and
when the blank is clamped between the first press die and the third press die, a corner end portion of the blank between the intersection point M and the intersection point N includes both the line segment MO and the line segment NO, and a part of the corner end portion is outside a region between the line segment MO and the line segment NO.

2. A blank,

wherein in a square region included in a corner of a first rectangle, each side of which passes only through an edge and outside of the blank, with a length of one side being 40% of a short side of the first rectangle, the blank is in contact with both of two sides of a second rectangle that each side passes only through an edge and inside of the blank, and

in a rectangular region that passes through two contact points between two sides of the second rectangle and the blank and of which a corner overlaps the first rectangle, the blank is in contact with both of two sides of the first rectangle.

3. The blank according to claim 2, wherein the blank is in contact with both of the two sides of the first rectangle within a range of 10% of the length of the short side of the first rectangle from the corner of the first rectangle.

FIG. 1

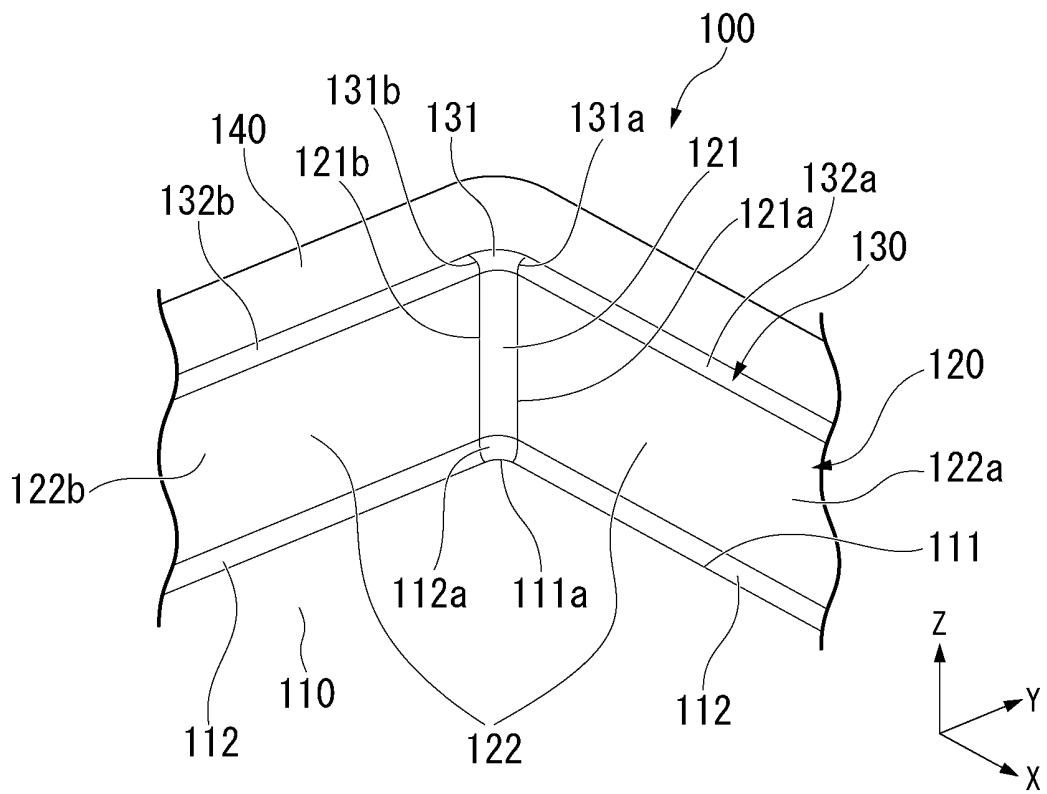


FIG. 2

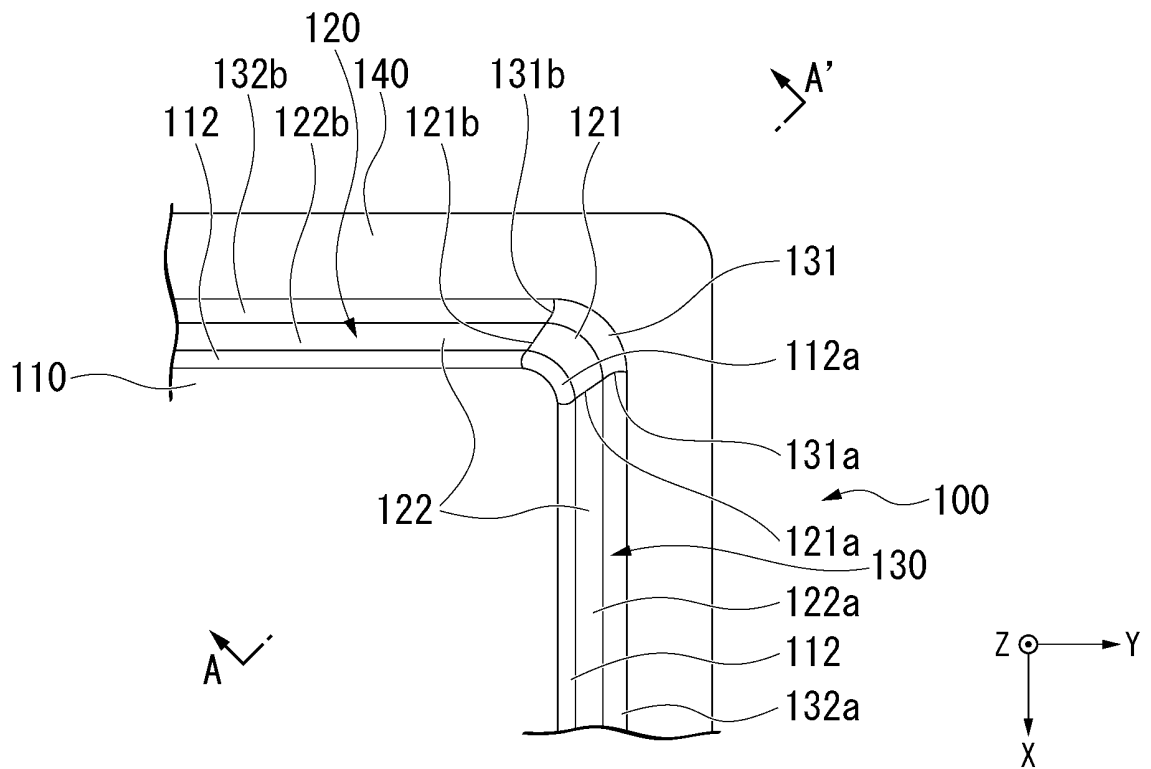


FIG. 3

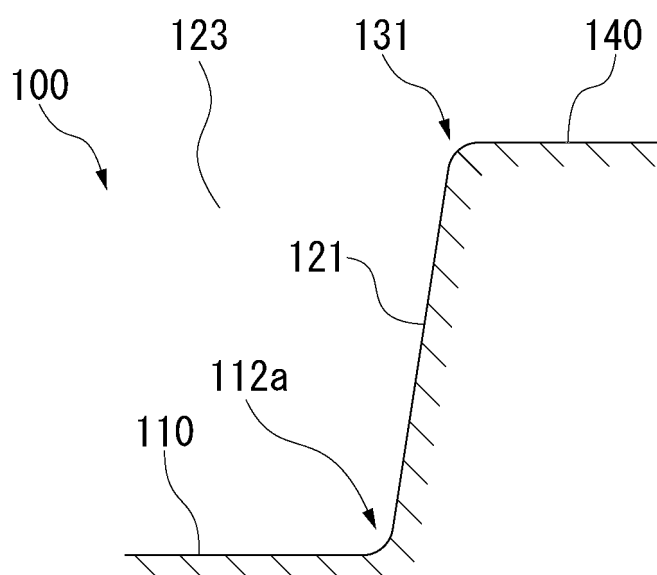


FIG. 4

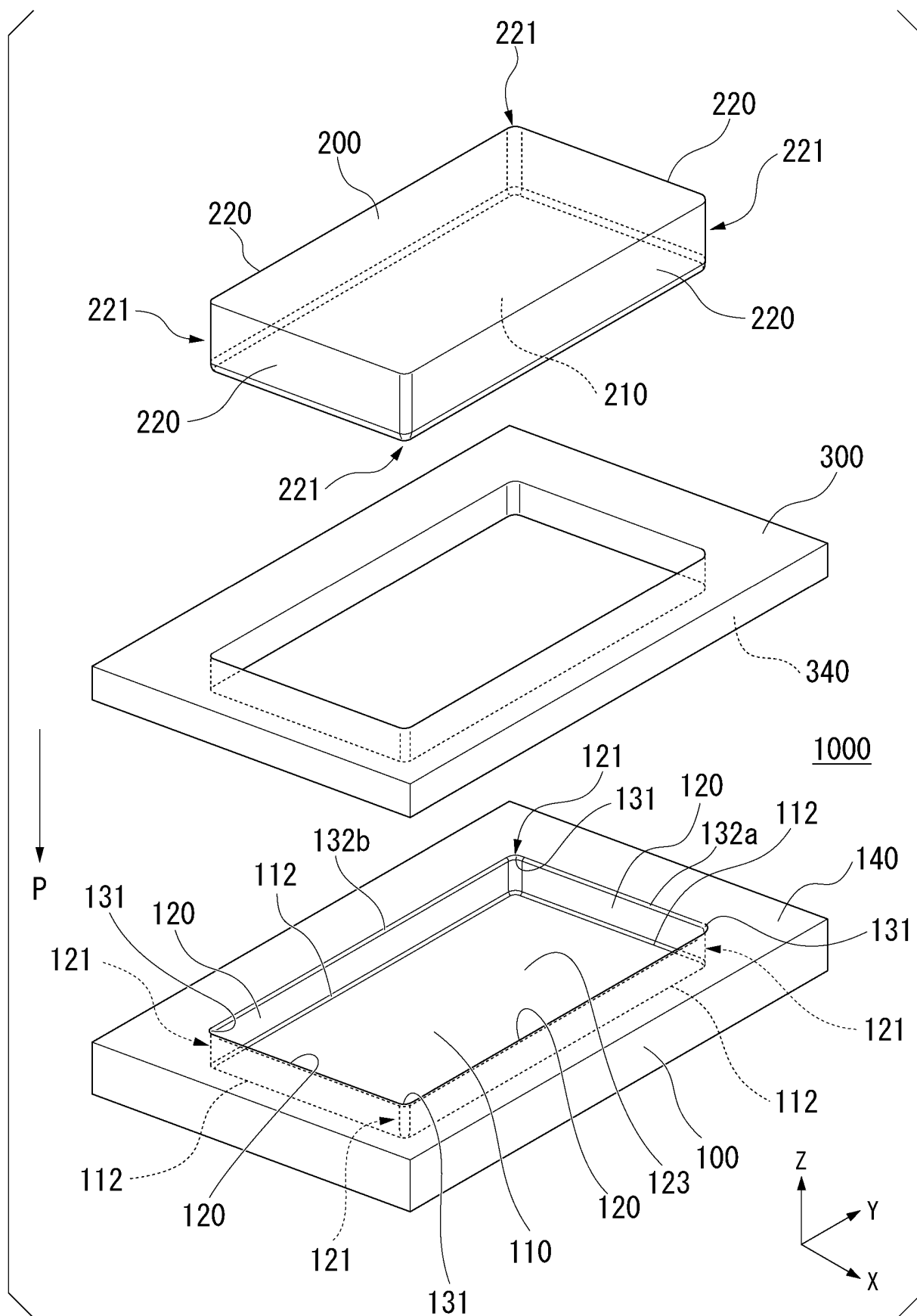


FIG. 5A

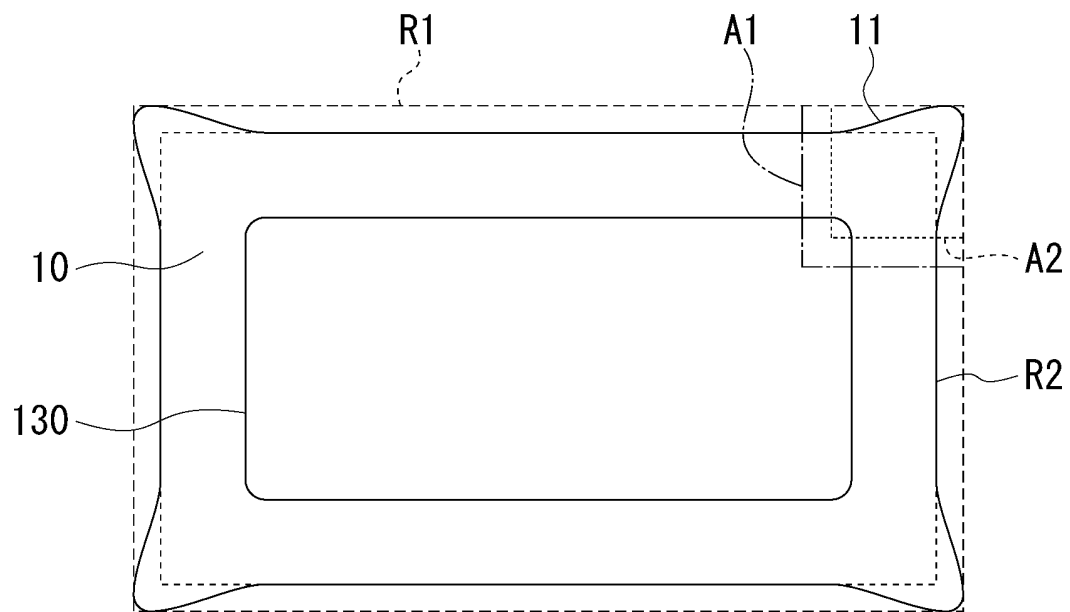


FIG. 5B

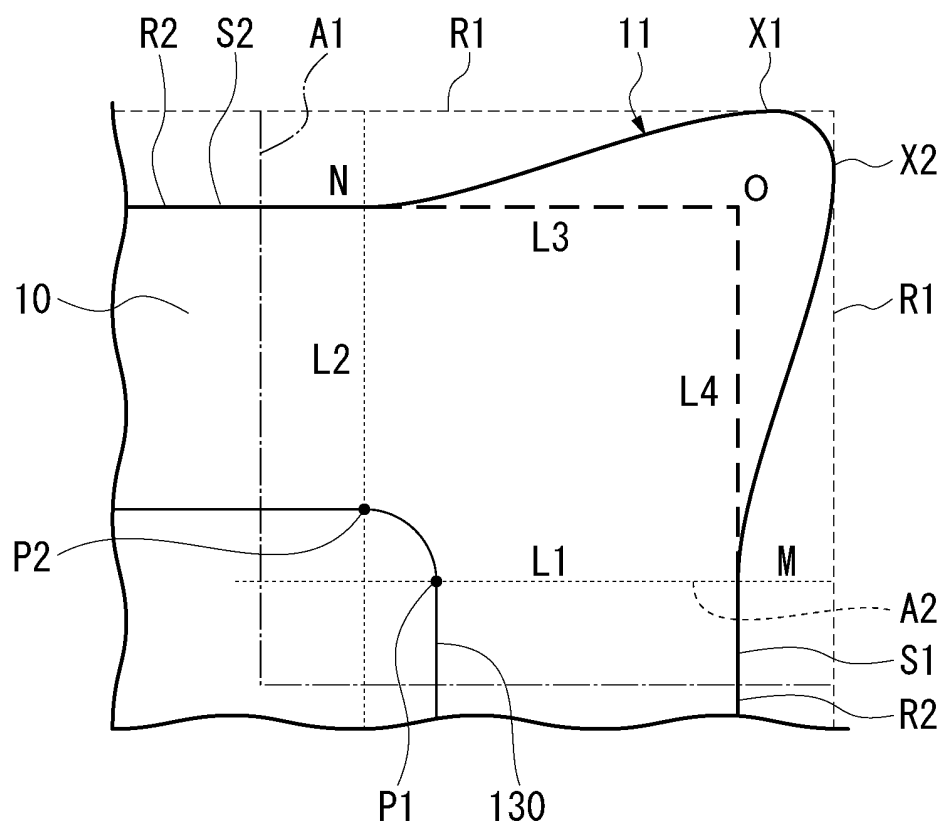


FIG. 5C

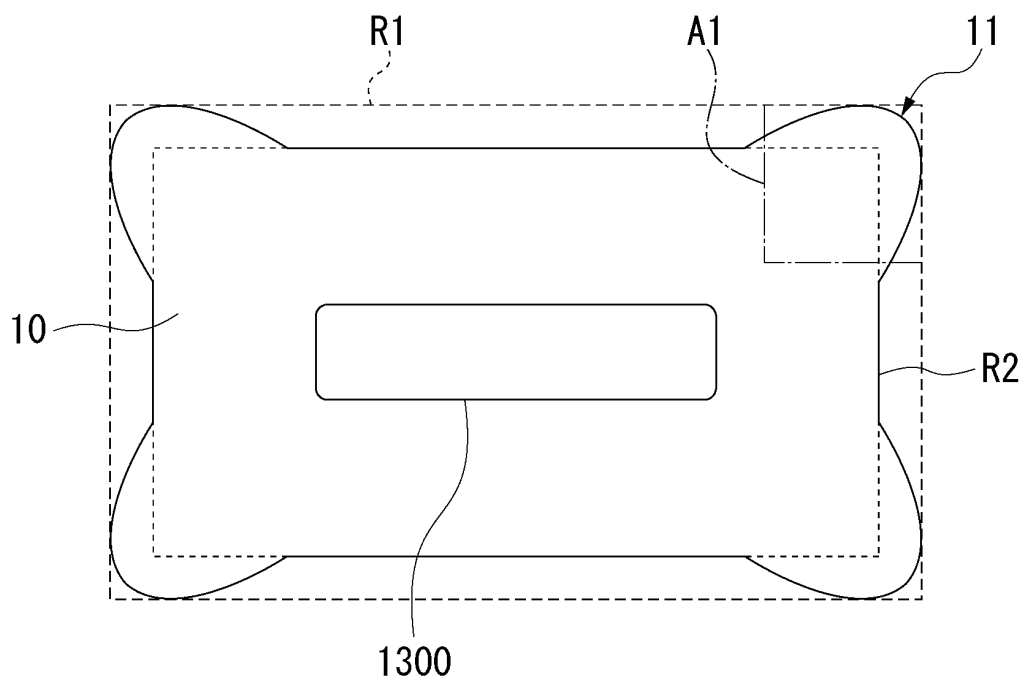


FIG. 6

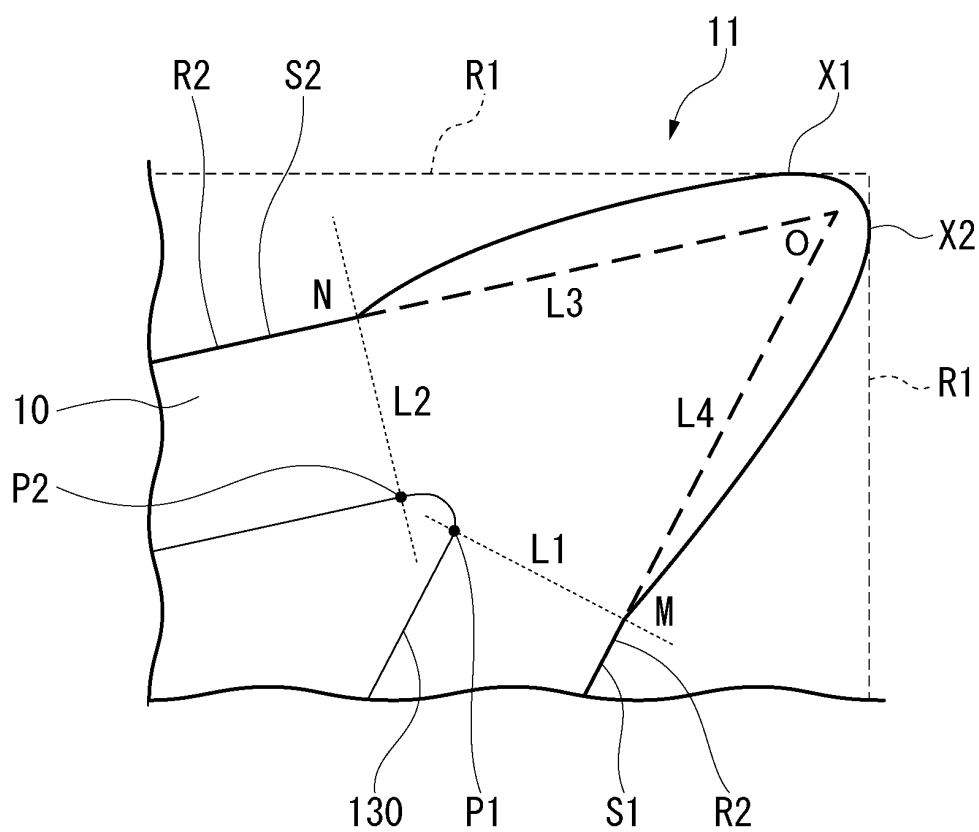


FIG. 7

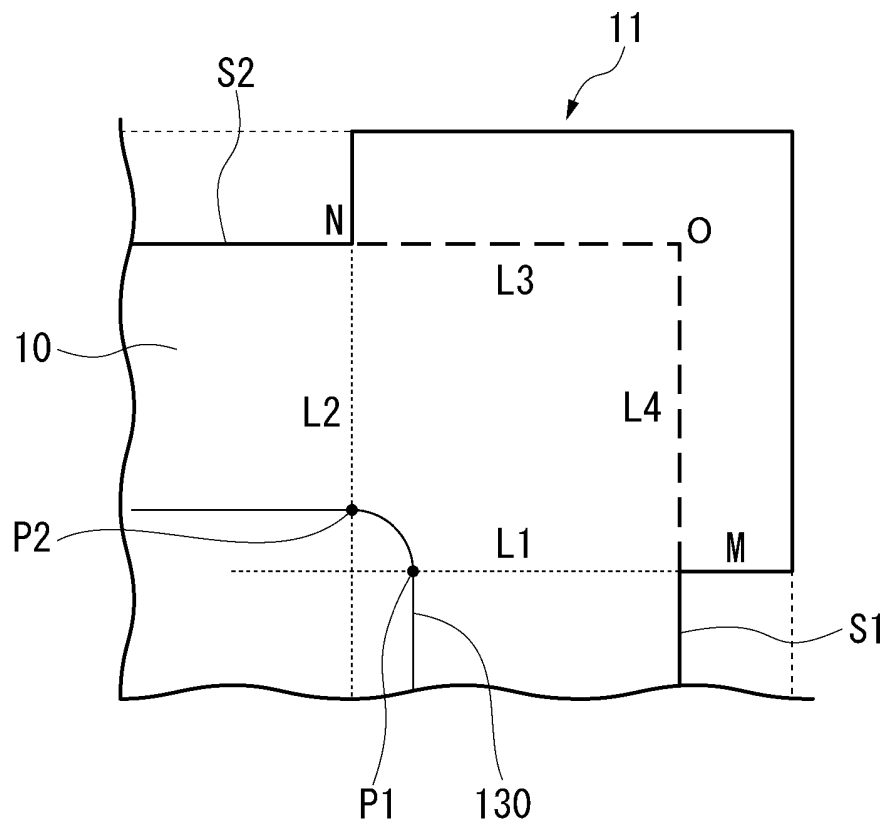


FIG. 8

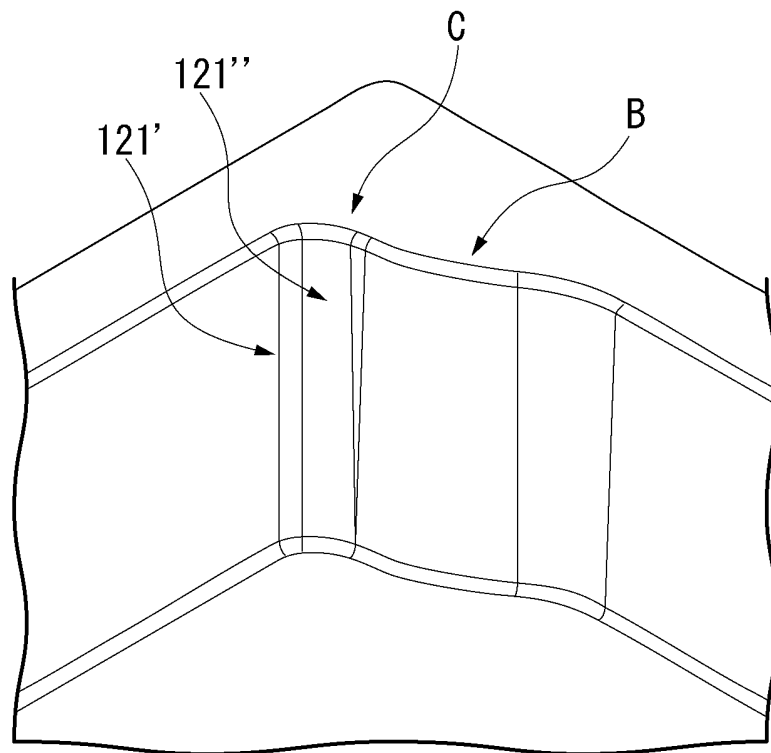


FIG. 9A

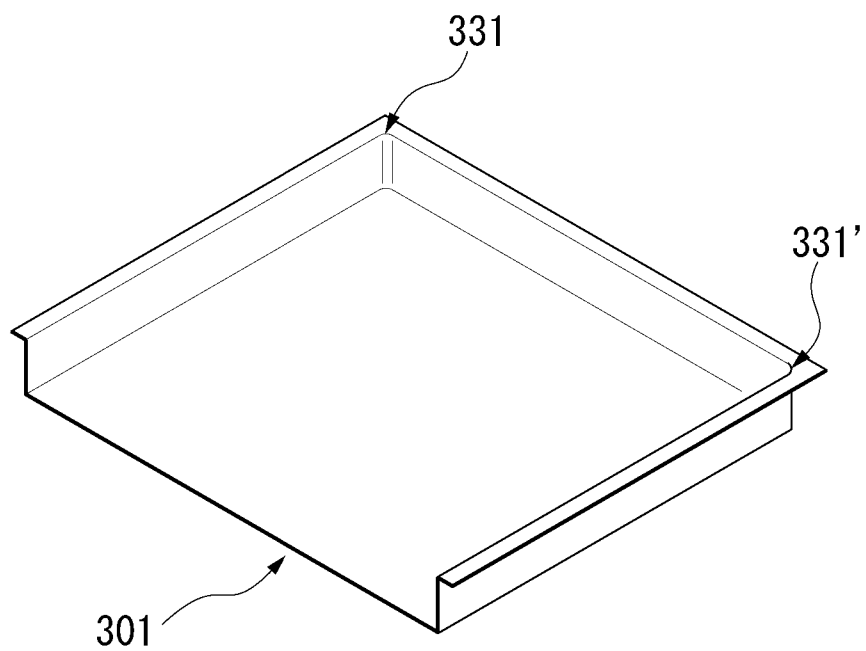


FIG. 9B

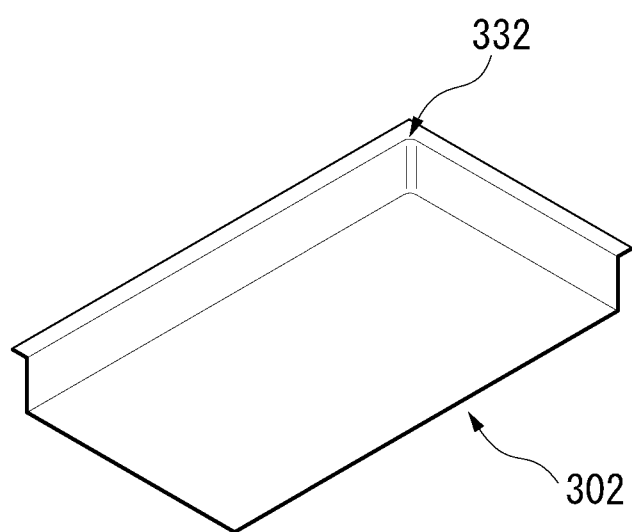


FIG. 10

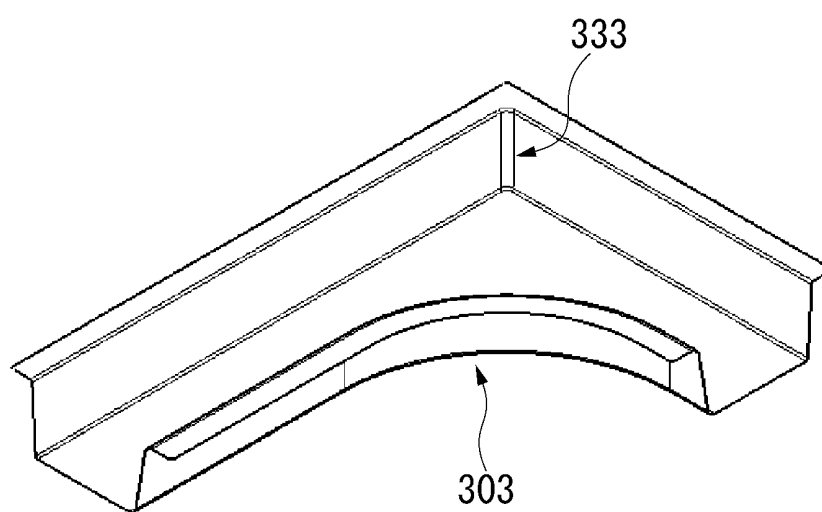


FIG. 11

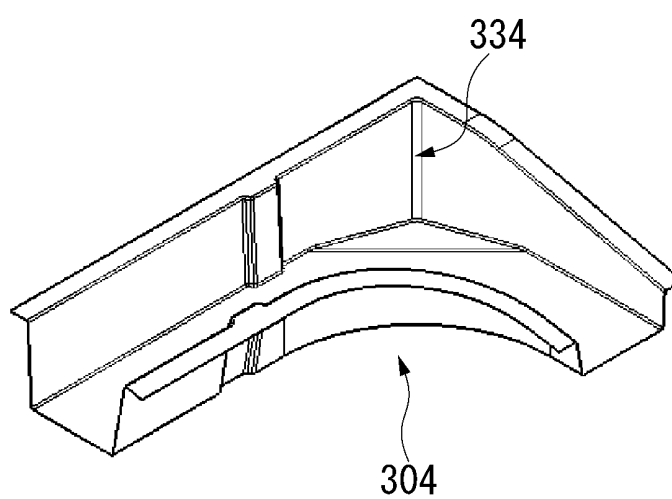


FIG. 12

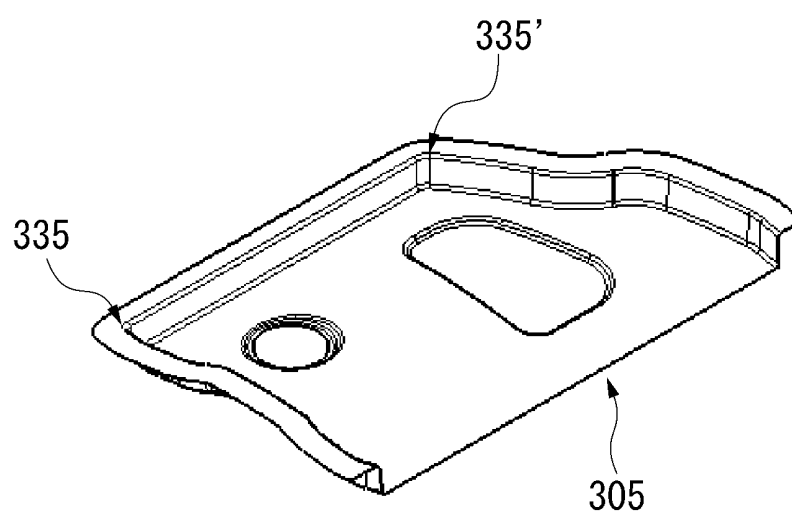


FIG. 13A

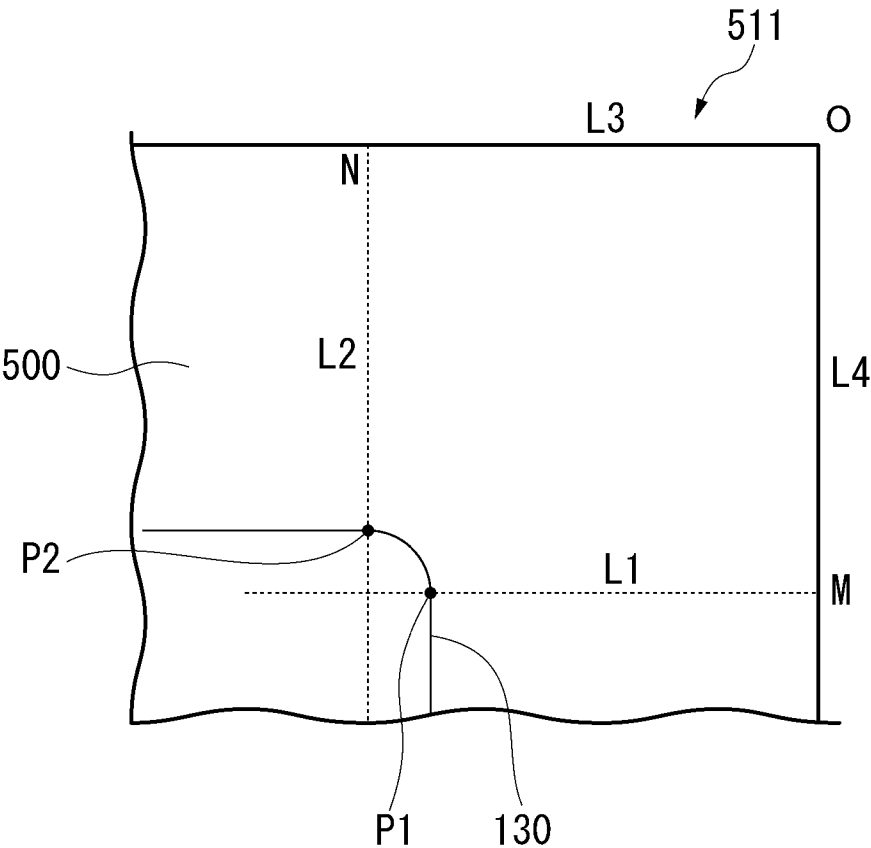


FIG. 13B

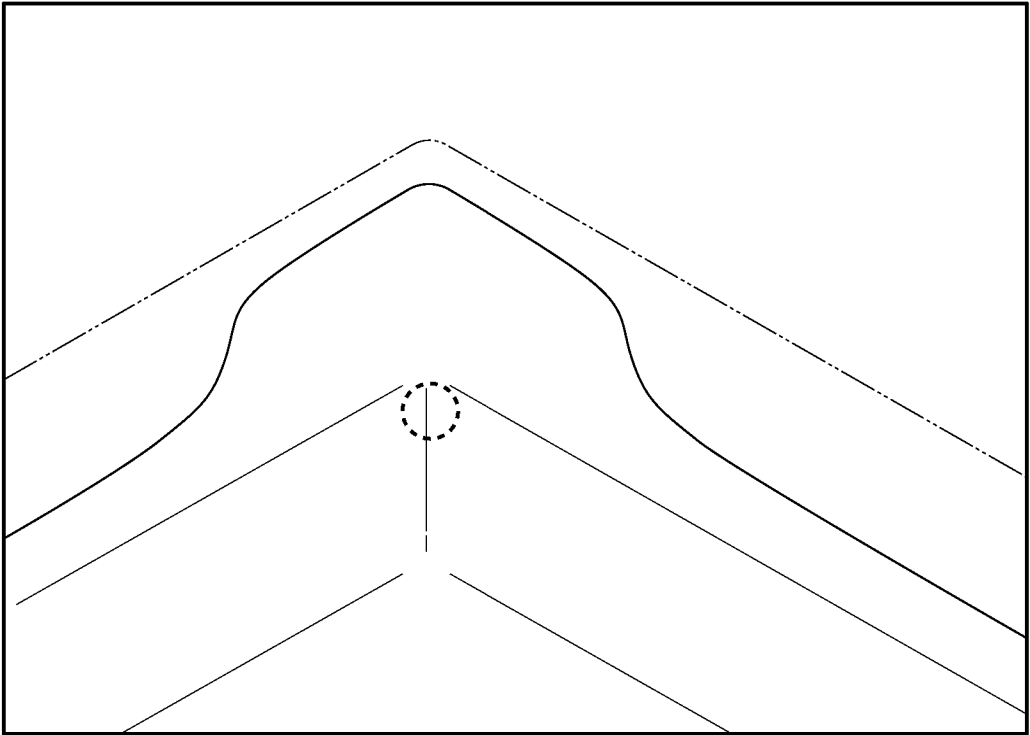


FIG. 14

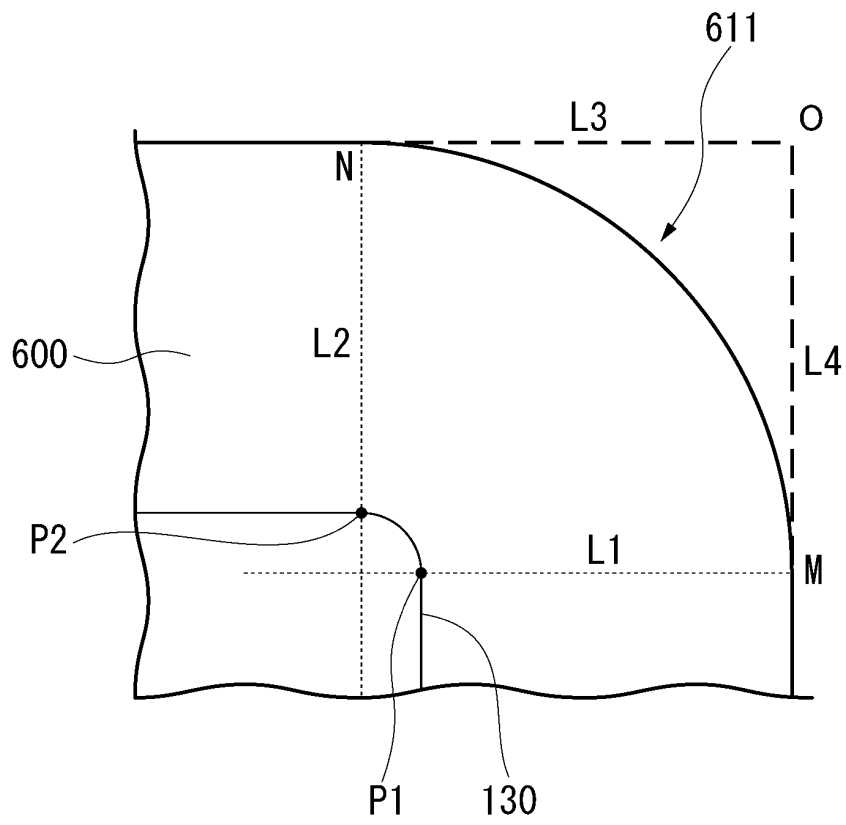


FIG. 15

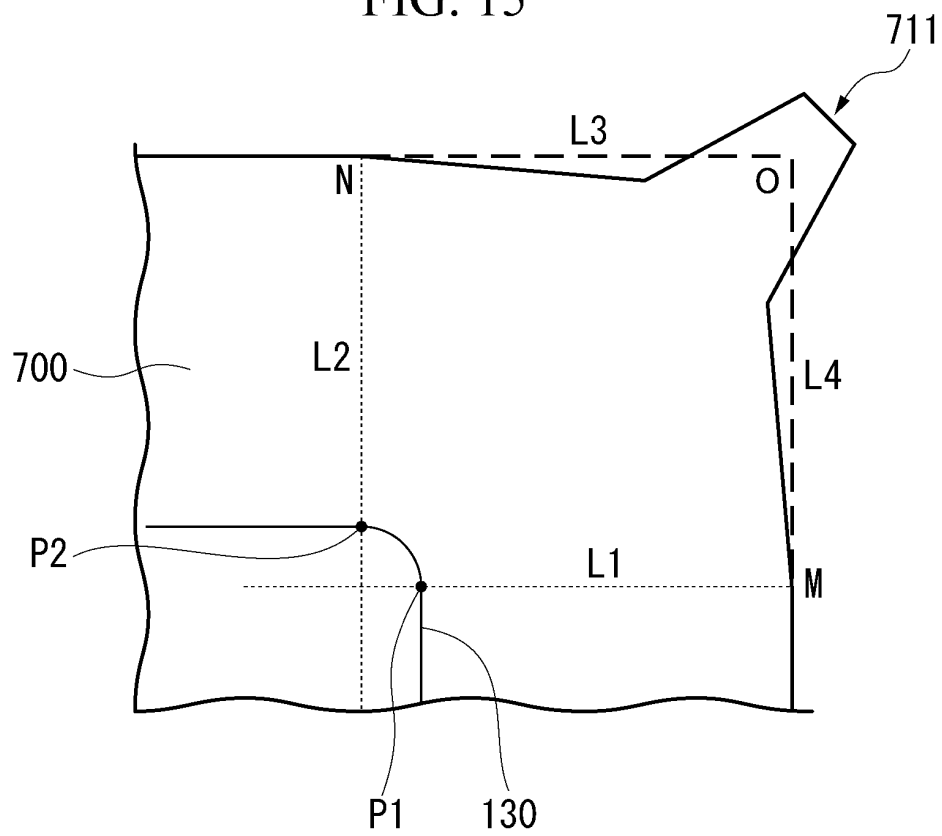


FIG. 16

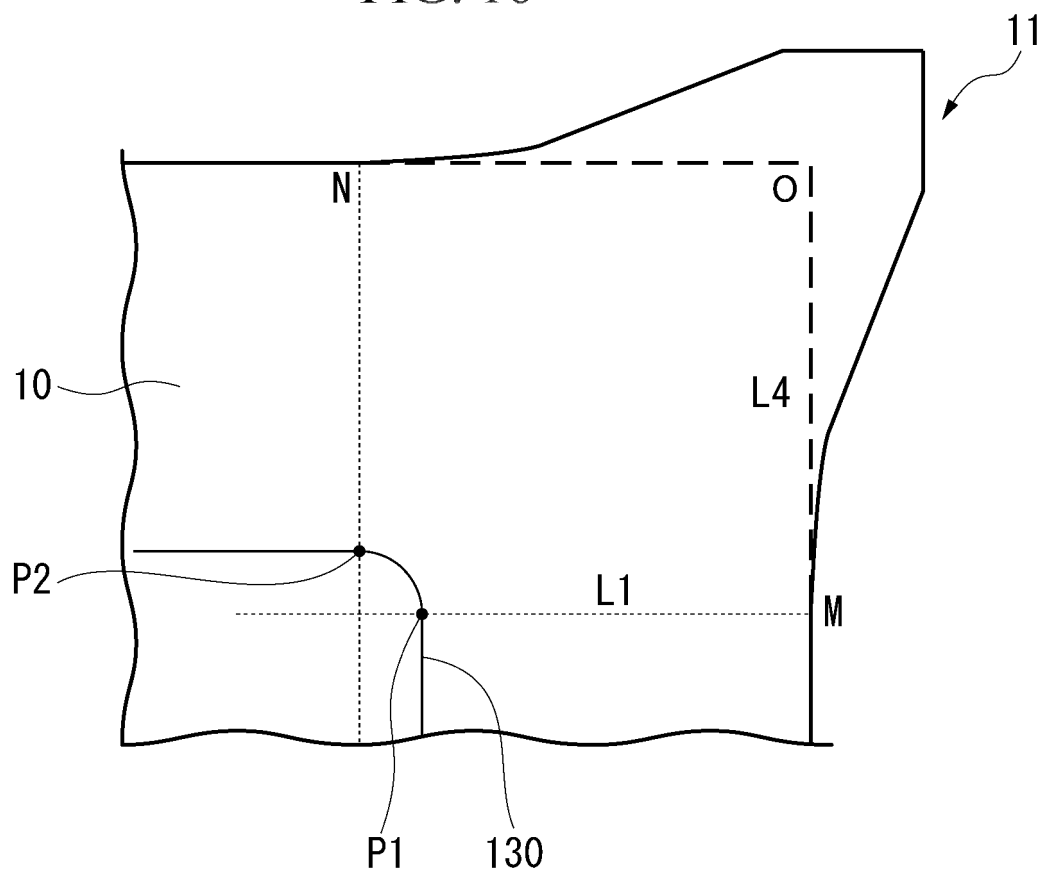


FIG. 17A

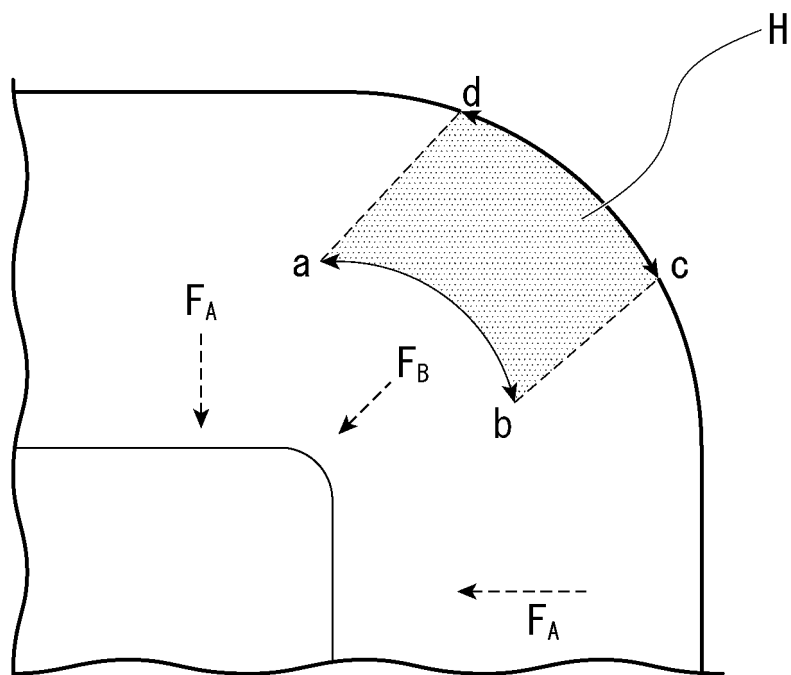


FIG. 17B

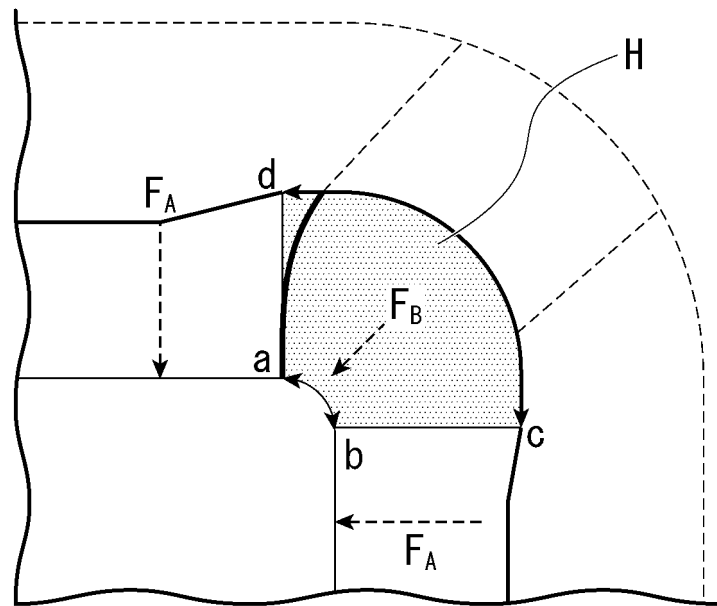


FIG. 18A

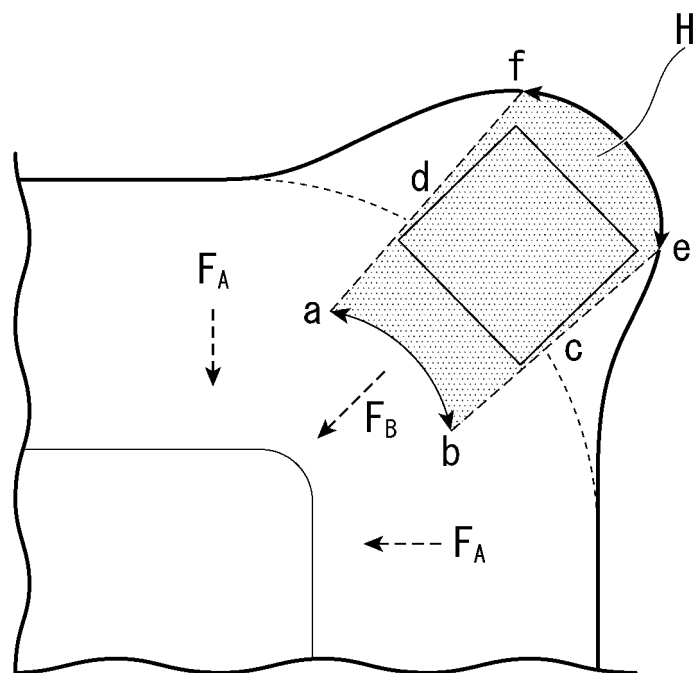
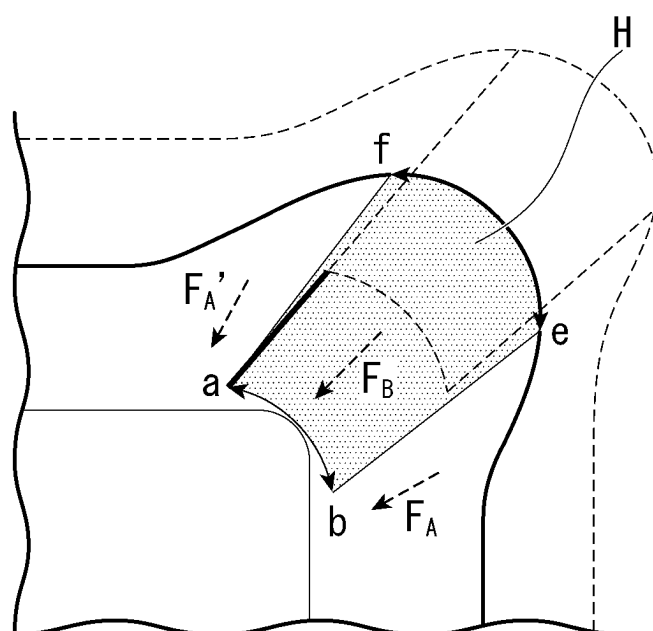


FIG. 18B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/031656

A. CLASSIFICATION OF SUBJECT MATTER

B21D 22/22(2006.01)i; **B21D 24/04**(2006.01)i
FI: B21D22/22; B21D24/04 Z; B21D24/04 A

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)

B21D22/22; B21D24/04

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2002-170529 A (HARA PRESS ENGINEERING KK) 14 June 2002 (2002-06-14) entire text, all drawings	1-3
A	JP 4-28424 A (NISSAN MOTOR CO., LTD.) 31 January 1992 (1992-01-31) entire text, all drawings	1-3
A	JP 2017-192972 A (MITSUBISHI ALUMINUM CO., LTD.) 26 October 2017 (2017-10-26) entire text, all drawings	1-3
A	JP 63-112029 A (NIPPONDENSO CO., LTD.) 17 May 1988 (1988-05-17) entire text, all drawings	1-3

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

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

29 September 2022

Date of mailing of the international search report

11 October 2022

Name and mailing address of the ISA/JP

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

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/031656

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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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