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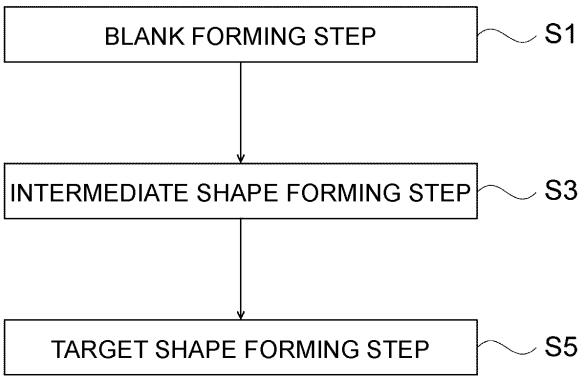
# (54) PRESS-MOLDING METHOD AND METHOD FOR MANUFACTURING PRESS-MOLDED ARTICLE

(57) A press-forming method and a method of manufacturing a press-formed product according to the present invention are performed to press-forming a press-formed product 210 into a target shape, the press-formed product 210 including a top portion 211, a vertical wall portion 215, and a flange portion 219 and including a concave curved portion 221 curved in a concave shape in a top view, the methods including: a step (S1) of forming a blank 100 provided with a concave shape 101 corresponding to a curve of the concave curved portion 221; a step (S3) of press-forming the formed blank 100 into a press-formed product 110 having an intermediate shape, the press-formed product 110 having a top portion 111, a vertical wall portion 115, and a flange portion 119, including a concave curved portion 121 curved in a concave shape in a top view, and provided with a cutout portion 125 located at a part of the flange portion 119 and the vertical wall portion 115 in a central portion of the curve 121a of the concave curved portion 121; and a step (S5) of press-forming the press-formed product 110 having the intermediate shape into the target shape.

FIG.1

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## Description

Field

**[0001]** The present invention relates to a press-forming method and a method of manufacturing a press-formed product of press-forming, as a target shape, a press-formed product having a top portion and a vertical wall portion continuous from the top portion and including a concave curved portion curved in a concave shape in a top view.

Background

**[0002]** In automobiles and home electric appliances, many press-formed products have been used as component members, and the press-formed products have been manufactured by press-forming a blank that is a metal plate. In recent years, a high-strength metal plate such as a high-tensile steel plate or an aluminum alloy plate having a tensile strength of 590 MPa or more has been used for press-forming. However, since such a metal plate has low ductility and a low Lankford value, there has been a problem in that cracking is likely to occur during press-forming.

**[0003]** As an example of a shape of the press-formed product in which cracking is likely to occur, there is a press-formed product having a top portion and a vertical wall portion continuous from the top portion with a ridge portion interposed therebetween and including a concave curved portion in which the top portion, the ridge portion, and the vertical wall portion are curved in a concave shape in top view. When such a press-formed product is press-formed from a blank that is a metal plate, cracking (stretch flange cracking) is likely to occur due to tensile deformation in a direction along a curve of the blank in a press-forming process, which causes a forming defect.

**[0004]** Therefore, conventionally, a technique for suppressing occurrence of stretch flange cracking in the press-forming process of the press-formed product having the concave curved portion in a top view has been proposed.

**[0005]** For example, Patent Literature 1 discloses a technique for suppressing occurrence of stretch flange cracking in a flange portion when a sheet metal formed product including a top portion having a concave outer peripheral edge portion and the flange portion (corresponding to a vertical wall portion of the present application) continuously curved from the concave outer peripheral edge portion is press-formed. In such technique, first, the flange portion including large curvature portions having a large curvature and a small curvature portion having a small curvature interposed between the large curvature portions is formed on a blank to obtain a pre-formed product. The curvature of the large curvature portion is larger than that of a curvature portion included in the flange portion of the sheet metal formed product, and the curvature of the small curvature portion is smaller than that of the curvature portion included in the flange portion of the sheet metal formed product. Further, a line length of the flange portion of the pre-formed product in a plan view is made shorter than a line length of the flange portion of the sheet metal formed product in the plan view. The cracking of the flange portion can be prevented by re-striking the pre-formed product obtained as such into a target shape.

**[0006]** In addition, Patent Literature 2 discloses a technique in which a top portion and a vertical wall portion that is connected to the top portion via a bent portion having an arc-shaped curved portion and has a flange portion disposed on the opposite side of the bent portion are provided, and a component including the top portion, the vertical wall portion, and the flange portion is formed from a raw metal plate. In such technique, the vertical wall portion and the flange portion are formed as an end portion of a portion corresponding to the lower side of the L shape of the raw metal plate slides on a portion corresponding to a top portion of a die tool of press forming while at least a part of a portion corresponding to a top portion of the raw metal plate is pressurized by a pad. As a result, cracking of the flange portion can be suppressed.

Citation List

Patent Literature

**[0007]**

Patent Literature 1: JP 2021-159951 A
Patent Literature 2: JP 5168429 B2

Summary

Technical Problem

**[0008]** However, according to the technique disclosed in Patent Literature 1, when the press-formed product having the top portion and the vertical wall portion continuous from the top portion with the ridge portion interposed therebetween and including the concave curved portion that is curved in the concave shape in the top view is press-formed, stretch flange cracking is likely to occur in some cases. In particular, when the radius of curvature of the concave curved portion is small (the curvature is large), a line length of a vertical wall portion of a press-formed product having an intermediate shape (the flange portion of the pre-formed product of Patent Literature 1) is too short to sufficiently reduce tensile strain concentrated on the vertical wall portion of the concave curved portion. As a result, since an end portion of the vertical wall portion at the concave curved portion is formed by being subjected to large tensile deformation in a direction along the curve, there is a problem in that tensile strain is concentrated and, as such, stretch flange cracking is likely to

occur.

**[0009]** Further, in the technique disclosed in Patent Literature 2, the vertical wall portion and the flange portion are formed while the end portion of the portion corresponding to the lower side of the L shape of the raw metal plate slides on the portion corresponding to the top portion of the die tool of press forming, so that the raw metal plate is moved during press-forming. As a result, there is a problem in that a change in the shape of a press-formed component increases, dimensional accuracy fluctuates, and an effect of suppressing stretch flange cracking also fluctuates.

**[0010]** The present invention has been made to solve the above-described problems, and an object of the present invention is to provide a press-forming method and a method of manufacturing a press-formed product capable of sufficiently suppressing stretch flange cracking of the press-formed product having a top portion and a vertical wall portion and including a concave curved portion that is curved in a concave shape in a top view.

Solution to Problem

**[0011]** To solve the above-described problems and achieve the object,

(1) A press-forming method according to the present invention press-forms a press-formed product into a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, and a concave curved portion curved in a concave shape in a top view, and includes: a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion of the target shape; an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape having a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the flange portion and the vertical wall portion or at a part of the flange portion, the vertical wall portion, and the top portion in a central portion of the curve of the concave curved portion; and a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape, wherein the press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

(2) A press-forming method according to the present invention press-forms a press-formed product into a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, and a concave curved portion curved in a concave shape in a top view, and includes: a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion; an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the vertical wall portion and the top portion in a central portion of the curve of the concave curved portion; and a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape, wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

(3) In the above-described press-forming method according to (1) or (2), in the intermediate shape forming step, a radius of curvature $R_E$ at an end portion of the curve of the concave curved portion having the intermediate shape is set to be larger than a radius of curvature $R_0$ at the concave curved portion having the target shape.

(4) A method according to the present invention of manufacturing a press-formed product having a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, and a concave curved portion curved in a concave shape in a top view, includes: a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion of the target shape; an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the flange portion and the vertical wall portion or at a part of the flange portion, the vertical wall portion, and the top portion in a central portion of the curve of the concave curved portion; and a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape, wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

(5) A method according to the present invention of manufacturing a press-formed product having a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, and a concave curved portion curved in a concave

shape in a top view, includes: a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion; an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the vertical wall portion and the top portion in a central portion of the curve of the concave curved portion; and a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape, wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

(6) In the above-described method of manufacturing a press-formed product according to (4) or (5), the press-forming is performed in the intermediate shape forming step such that a radius of curvature $R_E$ at an end portion of the curve of the concave curved portion having the intermediate shape is set to be larger than a radius of curvature $R_0$ at the concave curved portion having the target shape.

Advantageous Effects of Invention

**[0012]** In a press-forming method and a method of manufacturing a press-formed product according to the present invention, a blank provided with a concave shape corresponding to a curve of a concave curved portion is formed, and the formed blank is press-formed into a press-formed product having an intermediate shape provided with a cutout portion at a central portion of the curve of the concave curved portion. Here, press-forming is performed so that the concave shape provided in the blank becomes the cutout portion. Accordingly, it is possible to reduce tensile stress acting on the vicinity of the cutout portion and to disperse the tensile stress on both end sides of the curve at the concave curved portion. As a result, when the press-formed product having the intermediate shape is press-formed into a target shape, it is possible to sufficiently suppress stretch flange cracking, to enable stable press-forming without cracking, and to improve productivity and yield.

Brief Description of Drawings

**[0013]**

FIG. 1 is a flowchart illustrating a flow of processing in a press-forming method according to an embodiment.

FIG. 2 is a perspective view illustrating an example of a press-formed product to be formed in the present embodiment ((a) Z-shaped cross-sectional shape, (b) backward C-shaped cross-sectional shape, (c) hat cross-sectional shape).

FIG. 3 is a diagram illustrating a conventional technique of press-forming a press-formed product having a concave curved portion in a top view in one step.

FIG. 4 is a contour diagram illustrating an example of a result of a plate thickness reduction rate of the press-formed product press that was formed in one step according to the conventional technique.

FIG. 5 is a diagram illustrating a pre-formed product (a press-formed product having an intermediate shape) to be press-formed by a method under comparative conditions.

FIG. 6 is a contour diagram illustrating an example of a result of a plate thickness reduction rate of each of the pre-formed product (the press-formed product having the intermediate shape) and a sheet metal formed product (a press-formed product having a target shape) that were press-formed by the method under comparative conditions.

FIG. 7 is a diagram illustrating the press-formed products having the intermediate shape and the target shape that are press-formed by the press-forming method according to the embodiment.

FIG. 8 is a diagram illustrating a step of press-forming the press-formed product having the concave curved portion in the top view by the press-forming method according to the embodiment ((a) intermediate shape forming step, (b) target shape forming step).

FIG. 9 is a contour diagram illustrating an example of the result of the plate thickness reduction rate of the press-formed products respectively having the intermediate shape and the target shape that are press-formed by the press-forming method according to the embodiment.

FIG. 10 is a diagram illustrating a suitable position of a ridge portion at a concave curved portion of the press-formed product having the intermediate shape to be press-formed in the press-forming method according to the present invention.

FIG. 11 is a diagram illustrating a specific example of a cutout portion at the concave curved portion of the press-formed product having the intermediate shape to be press-formed in the press-forming method according to the present invention.

FIG. 12 is a diagram illustrating a target shape of a press-formed product having a hat cross-sectional shape to be formed in an example.

FIG. 13 is a diagram illustrating a step of press-forming each of the press-formed products having the intermediate shape and the target shape by the method according to the present invention in the example ((a) intermediate shape forming step, (b) target shape forming step) .

FIG. 14 is a diagram illustrating a conventional example in which a press-formed product having a

target shape is press-formed in one step in the example.

FIG. 15 is a contour diagram of a plate thickness reduction rate obtained for the press-formed product having the target shape in the conventional example in the example.

FIG. 16 is a contour diagram of a plate thickness reduction rate obtained for press-formed products having an intermediate shape and a target shape in a comparative example in the example ((a) press-formed product having intermediate shape, (b) press-formed product having target shape).

FIG. 17 is a contour diagram of a plate thickness reduction rate obtained for press-formed products having an intermediate shape and a target shape in a first invention example in the example ((a) press-formed product having intermediate shape, (b) press-formed product having target shape) .

FIG. 18 is a contour diagram of a plate thickness reduction rate obtained for press-formed products having an intermediate shape and a target shape in a second invention example in the example ((a) press-formed product having intermediate shape, (b) press-formed product having target shape).

Description of Embodiments

**[0014]** Hereinafter, embodiments of a press-forming method and a method of manufacturing a press-formed product according to the present invention will be described. Note that the present invention is not limited by the present embodiment.

**[0015]** Prior to describing the press-forming method and the method of manufacturing the press-formed product according to the embodiment of the present invention, a press-formed product to be formed in the present invention and circumstances leading to the present invention will be described.

<Press-Formed Product>

**[0016]** FIG. 2 is a perspective view illustrating a specific example of a press-formed product to be formed in the present invention.

**[0017]** A press-formed product 210 in FIG. 2(a) is an example of a press-formed product having a Z-shaped cross-sectional shape and including a top portion 211, a vertical wall portion 215 continuous from the top portion 211 with a ridge portion 213 interposed therebetween, and a flange portion 219 continuous from the vertical wall portion 215 with a die shoulder portion 217 interposed therebetween. The press-formed product 210 includes a concave curved portion 221 in which the ridge portion 213, the vertical wall portion 215, the die shoulder portion 217, and the flange portion 219 side are curved in a concave shape in a top view, and linear portions 223 respectively extending in a linear shape from both ends of the curve of the concave curved portion 221.

**[0018]** Further, a press-formed product 230 in FIG. 2(b) is an example of a press-formed product having a backward C-shaped cross-sectional shape and including a top portion 231 and vertical wall portions 235 respectively continuous from both end sides of the top portion 231 with ridge portions 233 interposed therebetween. The press-formed product 230 includes a concave curved portion 241 in which a ridge portion 233a and a vertical wall portion 235a side are curved in the concave shape in the top view, and linear portions 243 respectively extending in the linear shape from both ends of the curve of the concave curved portion 241.

**[0019]** Further, a press-formed product 250 in FIG. 2(c) is an example of a press-formed product having a hat cross-sectional shape and including a top portion 251, vertical wall portions 255 respectively continuous from both end sides of the top portion 251 with ridge portions 253 interposed therebetween, and flange portions 259 continuous from the vertical wall portion 255 with die shoulder portions 257 interposed therebetween. The press-formed product 250 includes a concave curved portion 261 in which a ridge portion 253a, a vertical wall portion 255a, a die shoulder portion 257a, and a flange portion 259a side are curved in the concave shape in the top view, and linear portions 263 respectively extending in the linear shape from both ends of the curve of the concave curved portion 261.

**[0020]** As such, the press-formed product to be formed in the present invention may be any press-formed product as long as the press-formed product includes a top portion and a vertical wall portion continuous from the top portion with a ridge portion interposed therebetween and includes a concave curved portion that is curved in the concave shape in the top view as illustrated in FIG. 2. Therefore, the press-formed product to be formed does not limit other specific shapes, for example, a cross-sectional shape, a radius of curvature of the curve of the concave curved portion, a length of the linear portion, and the like.

**[0021]** Hereinafter, a case in which the press-formed product 210 having the Z-shaped cross-sectional shape illustrated in FIG. 2(a) is press-formed as a target shape will be described as an example.

<Circumstances Leading to Present Invention>

**[0022]** Conventionally, the press-formed product 210 having the Z-shaped cross-sectional shape including the concave curved portion 221 in the top view as illustrated in FIG. 2(a) is press-formed into a target shape in one step using a tool of press forming 21 including a die 23, a punch 25, and a pad 27 as illustrated in FIG. 3. Here, the concave curved portion 221 formed by a die side concave curved portion forming portion 23a and a punch side concave curved portion forming portion 25a is subjected to stretch flange forming.

**[0023]** For the press-formed product 210 that is press-formed into the target shape in one step, the inventors of

the present invention performed finite element method analysis (FEM analysis) in the process of press-forming using the die 21 illustrated in FIG. 3 and determined a plate thickness reduction rate of the press-formed product 210 after the press-forming. Here, the plate thickness reduction rate is a value obtained by subtracting a plate thickness of each portion after press-forming from a plate thickness of a blank 100, that is a metal plate before press-forming, and dividing the obtained value by the plate thickness of the blank 100.

**[0024]** As illustrated in FIG. 4, in the press-formed product 210 that is press-formed in one step conventionally, the plate thickness reduction rate of the end portion of the flange portion 219 at the concave curved portion 221 is 21.5%, that is the largest value, and it can be seen that cracking is likely to occur due to stretch flange forming.

**[0025]** To suppress the occurrence of cracking due to such stretch flange forming, Patent Literature 1 described above proposes a method of performing press-forming in two steps including a flange-up step (pre-forming step) and a re-strike step.

**[0026]** In the method of Patent Literature 1, first, in the flange-up step, as illustrated in FIG. 5, a press-formed product 170 having an intermediate shape that is a pre-formed product is obtained. Then, in the subsequent re-strike step, the pre-formed product is re-struck into the press-formed product 210 having the target shape that is the sheet metal formed product.

**[0027]** In the method of Patent Literature 1, the press-formed product 170 having the intermediate shape includes two end portions 181b of the curve having a large curvature (small radius of curvature $R_E$) and a central portion 181a of the curve having a small curvature (large radius of curvature $R_C$) and interposed between the end portions 181b of the curve.

**[0028]** Here, as the press-formed product 170 having the intermediate shape, a condition is considered in which a ridge length (curve efgh) of a curve at a concave curved portion 181 is shorter than a ridge length (curve pq) of the curve at the concave curved portion 221 of the press-formed product 210 having the target shape illustrated in FIG. 5. Such condition satisfies a condition of "a line length of the flange portion of the pre-formed product in a plan view is made shorter than a line length of the flange portion of the sheet metal formed product in the plan view." disclosed in Patent Literature 1. Here, the ridge length (curve efgh) of the curve at the concave curved portion 181 of the press-formed product 170 having the intermediate shape refers to a length from a starting point e to an end point h in the direction along the curve of a ridge portion 173. The ridge length (curve pq) of the curve at the concave curved portion 221 of the press-formed product 210 having the target shape refers to a length from a start point p to an end point q in the direction along the curve of the ridge portion 213 indicated by a broken line.

**[0029]** Then, the inventors of the present application performed finite element method analysis for each step under the conditions illustrated in FIG. 5 to determine the plate thickness reduction rate of each of the press-formed product 170 having the intermediate shape and the press-formed product 210 having the target shape.

**[0030]** As illustrated in FIG. 6, the plate thickness reduction rate of the press-formed product 170 having the intermediate shape under the conditions illustrated in FIG. 5 was 24.4% at the maximum. Further, the plate thickness reduction rate of the press-formed product 210 having the target shape was 25.4% at the maximum. As such, under the conditions illustrated in FIG. 5, the plate thickness reduction rate was increased as compared with the case of press-forming in one step conventionally (FIG. 4), leading to frequent occurrence of stretch flange cracking. That is, it was found that the condition illustrated in FIG. 5 had almost no effect of suppressing stretch flange cracking.

**[0031]** Therefore, the inventors of the present application have intensively studied means for suppressing such stretch flange cracking. In the study, the inventors of the present application have focused on a portion at which stretch flange cracking occurs in a conventional method. That is, in the press-formed product 210 press-formed into the target shape by the conventional method, as illustrated in FIGS. 4 and 6, the plate thickness reduction rate is large at a central portion 221a of the curve of the flange portion 219 of the concave curved portion 221 or in the vicinity thereof. Therefore, attention has been paid to the fact that stretch flange cracking is likely to occur at the aforementioned portion.

**[0032]** Therefore, the inventors of the present application have intensively studied a method of reducing tensile stress acting on the concave curved portion or the vicinity thereof and dispersing the tensile stress on both end sides of the curve at the concave curved portion in the stretch flange forming in which the tensile stress acts on the concave curved portion. As a result, it has been conceived that, by forming a part of a concave curved portion in a notched shape in a press-formed product having an intermediate shape, tensile stress acting on the concave curved portion or the vicinity thereof is reduced and the tensile stress on both end sides of the curve at the concave curved portion is dispersed. It has been found that it is possible to suppress stretch flange cracking in the press-formed products respectively having the intermediate shape and the target shape by reducing the tensile stress at the concave curved portion.

**[0033]** The present invention has been made based on such examination results, and the configuration thereof is described as follows.

<Press-forming Method>

**[0034]** In the press-forming method according to the embodiment, the press-formed product 210 including the concave curved portion 221 that is curved in the concave shape in the top view as illustrated in FIG. 2(a) described

above as an example is press-formed into a target shape. As illustrated in FIG. 1, the press-forming method includes a blank forming Step S1, an intermediate shape forming Step S3, and a target shape forming Step S5. Since the press-formed product 210 is manufactured by executing the above-described press-forming method, the invention of the press-forming method can be configured as the invention of the method of manufacturing the press-formed product. Therefore, the embodiment of the press-forming method described below is common to the embodiment of the method of manufacturing the press-formed product. Each of the above steps will be described below with reference to FIGS. 7 and 8.

<<Blank Forming Step>>

**[0035]** The blank forming Step S1 is a step of forming the blank 100 (refer to FIG. 8(a)) provided with a concave shape 101 corresponding to the curve of the concave curved portion 221 of the press-formed product 210 having the target shape. The curve of the concave curved portion 221 refers to, for example, the curve of the ridge portion 213 at the concave curved portion 221.

<<Intermediate Shape Forming Step>>

**[0036]** The intermediate shape forming Step S3 is a step of press-forming the blank 100 into a press-formed product 110 having an intermediate shape illustrated in FIG. 7(a). Here, the press-formed product 110 having the intermediate shape includes a top portion 111, a vertical wall portion 115 continuous from the top portion 111 via a ridge portion 113 interposed therebetween, and a flange portion 119 continuous from the vertical wall portion 115 with a die shoulder portion 117 interposed therebetween. In addition, the press-formed product 110 having the intermediate shape includes a concave curved portion 121 that is curved in the concave shape in the top view and linear portions 123 that respectively extend in the linear shape from both ends of the curve of the concave curved portion 121. Further, a cutout portion 125 having a shape in which the flange portion 119 and the vertical wall portion 115 are partially cut out is provided at a central portion 121a of the curve of the concave curved portion 121. Then, in the intermediate shape forming Step S3, press-forming is performed so that a part of the concave shape 101 provided in the blank 100 becomes the cutout portion 125. Here, the cutout portion 125 provided at the vertical wall portion 115 of the concave curved portion 121 is a portion that should originally be the vertical wall portion 115 and a portion without any material. A length of the cutout portion 125 in a height direction is shorter than a length of the vertical wall portion 115 in the height direction in a portion other than the concave curved portion 121.

**[0037]** In the intermediate shape forming Step S3, for example, as illustrated in FIG. 8(a), an intermediate shape forming tool of press forming 1 including an intermediate shape forming die 3, an intermediate shape forming punch 5, and a pad 7 can be used to press-forming the press-formed product 110 having the intermediate shape.

**[0038]** The intermediate shape forming die 3 includes a die side intermediate shape concave curved portion forming portion 3a that forms the concave curved portion 121 having the intermediate shape and a die side intermediate shape linear portion forming portion 3b that forms the linear portion 123 having the intermediate shape.

**[0039]** The intermediate shape forming punch 5 includes a punch side intermediate shape concave curved portion forming portion 5a and a punch side intermediate shape linear portion forming portion 5b. The punch side intermediate shape concave curved portion forming portion 5a forms the concave curved portion 121 having the intermediate shape in cooperation with the die side intermediate shape concave curved portion forming portion 3a. The punch side intermediate shape linear portion forming portion 5b forms the linear portion 123 having the intermediate shape in cooperation with the die side intermediate shape linear portion forming portion 3b.

**[0040]** The pad 7 presses the blank 100 toward the intermediate shape forming punch 5 to press the blank 100. Note that, in the intermediate shape forming Step S3, the intermediate shape forming tool of press forming 1 does not necessarily include the pad 7, and the intermediate shape forming die 3 may include a top plate forming portion.

<<Target Shape Forming Step>>

**[0041]** The target shape forming Step S5 is a step of press-forming the press-formed product 110 having the intermediate shape that was press-formed in the intermediate shape forming Step S3 into the press-formed product 210 having the target shape illustrated in FIG. 7(b).

**[0042]** In the target shape forming Step S5, for example, as illustrated in FIG. 8(b), press-forming can be performed using a target shape forming tool of press forming 11 including a target shape forming die 13, a target shape forming punch 15, and a pad 17.

**[0043]** The target shape forming die 13 includes a die side target shape concave curved portion forming portion 13a that forms the concave curved portion 221 having the target shape and a die side target shape linear portion forming portion 13b that forms the linear portion 223 having the target shape.

**[0044]** The target shape forming punch 15 includes a punch side target shape concave curved portion forming portion 15a and a punch side target shape linear portion forming portion 15b. The punch side target shape concave curved portion forming portion 15a forms the concave curved portion 221 having the target shape in cooperation with the die side target shape concave curved portion forming portion 13a. The punch side target shape

linear portion forming portion 15b forms the linear portion 223 having the target shape in cooperation with the die side target shape linear portion forming portion 13b.

**[0045]** The pad 17 presses the top portion 111 of the press-formed product 110 having the intermediate shape toward the target shape forming punch 15 to press the press-formed product 110. Note that, in the target shape forming Step S5, the target shape forming tool of press forming does not necessarily include the pad 17, and the target shape forming die 13 may include a top plate forming portion.

<Operation Effects>

**[0046]** In the press-forming method according to the embodiment, first, in the blank forming Step S1, the blank 100 provided with the concave shape 101 corresponding to the curve of the concave curved portion 221 of the press-formed product 210 having the target shape is formed. Next, in the press-forming method according to the embodiment, in the intermediate shape forming Step S3, the formed blank 100 is press-formed into the press-formed product 110 having the intermediate shape in which the cutout portion 125 is provided at the central portion 121a of the curve of the concave curved portion 121.

**[0047]** In the press-formed product 110 having the intermediate shape press-formed as such, tensile stress acting on the vicinity of the cutout portion 125 becomes small. Further, the tensile stress is dispersed on both end sides of the curve at the concave curved portion 121. As a result, in the process of press-forming the press-formed product 110 having the intermediate shape into the press-formed product 210 having the target shape, it is possible to suppress stretch flange cracking and to press-forming the press-formed product having the target shape.

**[0048]** This is verified by finite element method analysis (FEM analysis) of the press-forming process in the press-forming method according to the embodiment illustrated in FIG. 8 as an example. In the verification, the finite element method analysis was performed for each of the process of press-forming the blank 100 provided with the concave shape 101 into the press-formed product 110 having the intermediate shape and the process of press-forming the press-formed product 110 having the intermediate shape into the press-formed product 210 having the target shape. Then, the plate thickness reduction rate was calculated for each of the press-formed product 110 having the intermediate shape and the press-formed product 210 having the target shape.

**[0049]** FIG. 9 is a contour diagram of the plate thickness reduction rate of each of the press-formed product 110 having the intermediate shape and the press-formed product 210 having the target shape. Here, in the press-formed product 110 having the intermediate shape, as illustrated in FIG. 10, the ridge portion 113 of the concave curved portion 121 having the intermediate shape is set to be on an outer side of the ridge portion 213 of the concave curved portion 221 having the target shape. The outer side of the ridge portion 213 having the target shape refers to a center side of the curve with respect to the curve pq at the concave curved portion 221 having the target shape. Further, the ridge length of the ridge portion 113 at the concave curved portion 121 (for example, 300 mm) is longer than the ridge length of the ridge portion 213 at the concave curved portion 221 having the target shape (for example, 250 mm).

**[0050]** As illustrated in FIG. 9, the maximum value of the plate thickness reduction rate of the press-formed product 110 having the intermediate shape was 14.8%, and the maximum value of the plate thickness reduction rate of the press-formed product 210 having the target shape was 18.5%. The result was smaller than the maximum value of the plate thickness reduction rate of the press-formed product 210 (= 21.5%) obtained by the method of press-forming in one step conventionally illustrated in FIG. 4. Similarly, the result was smaller than the maximum value of the plate thickness reduction rate of the press-formed product 210 (= 25.4%) obtained by the method of Patent Literature 1 illustrated in FIG. 6.

**[0051]** The results suggest that, according to the press-forming method of the embodiment, it is possible to suppress the occurrence of stretch flange cracking at the concave curved portion 221 in the press-forming process and to press-forming the press-formed product 210 having the target shape.

**[0052]** As described above, in the press-forming method according to the embodiment, first, the blank 100 (FIG. 8 (a)) provided with the concave shape 101 corresponding to the curve of the concave curved portion 221 of the press-formed product 210 having the target shape is formed. Next, in the press-forming method according to the embodiment, the formed blank 100 is press-formed into the press-formed product 110 having the intermediate shape in which the cutout portion 125 is provided at the central portion 121a of the curve of the concave curved portion 121 (FIG. 9(a)). Further, in the press-forming method according to the embodiment, the press-formed product 110 having the intermediate shape is press-formed into the press-formed product 210 having the target shape (FIG. 9(b)).

**[0053]** Accordingly, in the process of press-forming the press-formed product 110 having the intermediate shape, the tensile stress acting on the vicinity of the cutout portion 125 at the concave curved portion 121 can be reduced, and the tensile stress can be dispersed to both end sides of the curve at the concave curved portion 121.

**[0054]** As a result, when the press-formed product 110 having the intermediate shape is press-formed into the press-formed product 210 having the target shape, stretch flange cracking can be sufficiently suppressed, stable press-forming without cracking can be performed, and productivity and yield can be improved.

**[0055]** Furthermore, the press-forming method according to the embodiment does not require moving

the blank 100 during the press-forming as in the method described in Patent Literature 2. Therefore, according to the press-forming method according to the embodiment, it is possible to obtain a good press-formed product 210 having the target shape while suppressing a variation in dimensional accuracy, and it is possible to improve productivity and yield.

**[0056]** In the above description, as illustrated in FIG. 10 described above, the ridge portion 113 of the concave curved portion 121 having the intermediate shape is positioned on the outer side of the ridge portion 213 of the concave curved portion 221 having the target shape, but the present invention is not limited thereto.

**[0057]** However, in the present invention, as illustrated in FIG. 10, the ridge portion 113 of the concave curved portion 121 having the intermediate shape is preferably positioned on the outer side of the ridge portion 213 of the concave curved portion 221 having the target shape. Here, as compared with the concave curved portion 221 having the target shape, a material remains in the top portion 111, the ridge portion 113, and the vertical wall portion 115 at the concave curved portion 121. As a result, even when the vertical wall portion 115 and the flange portion 119 having the intermediate shape are partially cut out, the press-formed product 210 having the target shape including the top portion 211, the vertical wall portion 215, and the flange portion 219 can be reliably press-formed.

**[0058]** Furthermore, when the ridge portion 113 of the concave curved portion 121 having the intermediate shape is positioned on the outer side of the ridge portion 213 having the target shape, it is possible to secure a material that follows a material flow caused by local stretch flange deformation due to the forming of the concave curved portion 121 in the intermediate shape forming Step S3. Then, in the subsequent target shape forming Step S5, strain generated at the end portion of the flange portion 219 of the concave curved portion 221 having the target shape to be press-formed can also be dispersed in a wide range and be reduced, and the stretch flange cracking can be further suppressed.

**[0059]** In addition, when the ridge portion 113 of the concave curved portion 121 having the intermediate shape is positioned on the outer side of the ridge portion 213 having the target shape, the concave curved portion 121 may have a constant radius of curvature of curve. Alternatively, as illustrated in FIG. 10, the concave curved portion 121 having the intermediate shape may include the central portion 121a of the curve (radius of curvature $R_C$) and an end portion 121b of the curve (radius of curvature $R_E$) having different curvature radii. In addition, the radius of curvature $R_E$ at the end portion 121b of the curve of the concave curved portion 121 having the intermediate shape is not limited regarding a radius of curvature $R_0$ at the concave curved portion 221 having the target shape, and any of $R_0 < R_E$ and $R_0 > R_E$ is possible. It may be $R_0 = R_E$.

**[0060]** Furthermore, in the above case, the length (ridge length) of the ridge portion 113 at the concave curved portion 221 having the intermediate shape may be made longer than the length (ridge length) of the ridge portion 213 at the concave curved portion 221 having the target shape. As a result, it is preferable to secure a larger amount of material that follows the material flow caused by the local stretch flange deformation due to the forming of the concave curved portion 121 in the intermediate shape forming step.

**[0061]** In the above embodiment, the press-formed product 210 having the Z-shaped cross-sectional shape is to be formed, and as illustrated in (i) of FIG. 11(a), the flange portion 119 and the vertical wall portion 115 of the press-formed product 110 having the intermediate shape are partially cut out. However, in the present invention, as illustrated in (ii) of FIG. 11(a), the press-formed product 110 having the intermediate shape may be provided with a cutout portion 127 having a shape in which the flange portion 119, the vertical wall portion 115, and the top portion 111 at the concave curved portion 121 are partially cut out. As such, the "cutout portion" of the press-formed product 110 having the intermediate shape and includes the flange portion 119 refers to a portion that should originally be the vertical wall portion 115 or the top portion 111 and a portion without any material.

**[0062]** In addition, as described above, the press-formed product 230 having the backward C-shaped cross-sectional shape (FIG. 2(b)), the press-formed product having the L-shaped cross-sectional shape, or the press-formed product 250 having the hat cross-sectional shape (FIG. 2(c)) may be formed in the present invention.

**[0063]** When the press-formed product having the L-shaped cross-sectional shape is to be formed, first, a press-formed product 130 as illustrated in FIG. 11(b) is press-formed as an intermediate shape, and the press-formed product is press-formed into a press-formed product having a target shape. Here, as illustrated in FIG. 11(b), the press-formed product 130 having the intermediate shape includes a top portion 131 and a vertical wall portion 135 continuous from the top portion 131 with a ridge portion 133 interposed therebetween. The press-formed product 130 having the intermediate shape includes a concave curved portion 141 that is curved in the concave shape in the top view.

**[0064]** Then, as illustrated in FIG. 11(b), press-forming may be performed so that a part of the concave shape 101 provided in the blank 100 (FIG. 8(a)) becomes a cutout portion 147 at a central portion 141a of the curve of the concave curved portion 141. Here, the cutout portion 147 illustrated in FIG. 11(b) has a shape in which the vertical wall portion 135 and the top portion 131 at the central portion 141a of the curve of the concave curved portion 141 are partially cut out. As described above, the "cutout portion" in the press-formed product 130 having the intermediate shape in the forming of the press-formed product having the L-shaped cross-sectional shape refers to a portion that should originally be the top portion 131 and a portion without any material.

**[0065]** When the press-formed product 250 having the hat cross-sectional shape is to be formed, the press-formed product having the intermediate shape may be any press-formed product as long as the press-formed product is obtained by performing press-forming so that a part of the concave shape provided in the blank becomes a cutout portion at the central portion of the curve of the concave curved portion. Here, the cutout portion in the press-formed product having the intermediate shape may have a shape in which the flange portion and the vertical wall portion provided at the central portion of the curve of the concave curved portion or the flange portion, the vertical wall portion, and the top portion are partially cut out.

**[0066]** To obtain the press-formed product having the intermediate shape and including such a cutout portion, the radius of curvature of the concave shape 101 provided in the blank 100 may be appropriately adjusted in the blank forming step (refer to FIG. 8(a)). Specifically, for example, the radius of curvature of the concave shape of the blank may be made smaller than the radius of curvature of the ridge portion of the concave curved portion in the top view of the press-formed product having the target shape (refer to the radius of curvature $R_0$ in FIG. 10).

**[0067]** Alternatively, a position at which the blank 100 is placed in the intermediate shape forming tool of press forming may be adjusted in the intermediate shape forming step so that the press-formed product having the intermediate shape includes the cutout portion. By executing each step of the above-described press-forming method, a target press-formed product can be produced, and the manufactured press-formed product is sufficiently suppressed from having stretch flange cracking.

Example

**[0068]** An analysis was made to demonstrate the operation effects of the press-forming method and the method of manufacturing the press-formed product according to the present invention, and the analysis will be described below.

**[0069]** In the present example, the press-formed product 250 having the hat cross-sectional shape illustrated in FIG. 12 was a forming target. Here, in the press-formed product 250, as illustrated in FIG. 12, a forming height was set to 50 mm, the radius of curvature of the curve of the concave curved portion 261 was set to 150 mm, and bending R of each of the ridge portion 253 and the die shoulder portion 257 was set to 10 mm. Further, in the press-formed product 250, the length of the curved portion of the ridge portion 253 at the concave curved portion 261 was set to 236 mm.

**[0070]** First, the blank 100 provided with the concave shape 101 corresponding to the curve of the concave curved portion 261 was formed (refer to FIG. 13(a)). Here, the radius of the curve of the concave shape 101 was set to 80 mm.

**[0071]** Next, as illustrated in FIG. 13(a), the blank 100 was press-formed into a press-formed product 150 having the intermediate shape (refer to FIG. 13(b)) using an intermediate shape forming tool of press forming 31 including an intermediate shape forming die 33, an intermediate shape forming punch 35, and a pad 37. Here, regarding a concave curved portion 161 having the intermediate shape, a case in which a central portion 161a of the curve is linear and the radius of curvature $R_E$ of an end portion 161b of the curve is set to 80 mm was defined as a first invention example. In the first invention example, the ridge portion length of the concave curved portion 161 having the intermediate shape was set to 273 mm. Further, regarding the concave curved portion 161 having the intermediate shape, a case in which the central portion 161a of the curve is linear and the radius of curvature $R_E$ of the end portion 161b of the curve is set to 160 mm was defined as a second invention example. The second invention example has a condition that the radius of curvature $R_E$ of the end portion 161b of the curve of the concave curved portion 161 having the intermediate shape is larger than the radius of curvature $R_0$ of the concave curved portion 261 having the target shape. In the second invention example, the ridge portion length of the concave curved portion 161 having the intermediate shape was set to 322 mm. As illustrated in FIG. 13(b), the press-formed product 150 having the intermediate shape included the concave curved portion 161 that is curved in the concave shape in the top view and linear portions 163 respectively extending from both ends of the concave curved portion 161. Further, in the press-formed product 150 having the intermediate shape, a cutout portion 165 was provided at a part of a flange portion 159 and a vertical wall portion 155 in the central portion 161a of the curve of the concave curved portion 161.

**[0072]** Subsequently, as illustrated in FIG. 13(b), the press-formed product 150 having the intermediate shape was press-formed into the press-formed product 250 having the target shape using a target shape forming tool of press forming 41 including a target shape forming die 43, a target shape forming punch 45, and a pad 47.

**[0073]** In addition, in the present example, as a comparison target, as illustrated in FIG. 14, a case where the blank 100 is press-formed into the press-formed product 250 having the target shape illustrated in FIG. 12 in one step using a tool of press forming 51 including a die 53, a punch 55, and a pad 57 was defined as a conventional example. Further, a case in which the press-formed product 250 having the target shape is press-formed in two steps under the condition using a tool of press forming having the shape illustrated in FIG. 5 described above was defined as a comparative example. In the comparative example, the central portion 181a of the curve of the concave curved portion 181 having the intermediate shape was linear, and the radius of curvature $R_E$ of the end portion 181b of the curve was set to 80 mm. In the comparative example, the ridge portion length of the concave curved portion 181 having the intermediate

shape was set to 211 mm. Then, for each of the conventional example and the comparative example, finite element method analysis was performed for the process of press-forming to determine the plate thickness reduction rate.

**[0074]** FIG. 15 is a contour diagram of the plate thickness reduction rate of the press-formed product 250 having the target shape in the conventional example. FIG. 16 is a contour diagram of the plate thickness reduction rate of each of the press-formed product 150 having the intermediate shape and the press-formed product 250 having the target shape in the comparative example. FIG. 17 is a contour diagram of the plate thickness reduction rate of each of the press-formed product 150 having the intermediate shape and the press-formed product 250 having the target shape in the first invention example. FIG. 18 is a contour diagram of the plate thickness reduction rate of each of the press-formed product 150 having the intermediate shape and the press-formed product 250 having the target shape in the second invention example. Note that, in the conventional example, since press-forming is performed in one step, only the result of the press-formed product 250 having the target shape is illustrated.

**[0075]** In the conventional example, as illustrated in FIG. 15, a portion at which the plate thickness decreased the most was an end portion of the flange portion 259 at the concave curved portion 261, and the maximum value of the plate thickness reduction rate was 20.5%.

**[0076]** In the comparative example, as illustrated in FIG. 16, since a line length of a curve of a ridge portion 193 of a press-formed product 190 having the intermediate shape is short, the plate thickness reduction rate of a central portion 201a of the curve of a concave curved portion 201 is relatively small. However, the maximum value of the plate thickness reduction rate of end portions 201b of the curve on both end sides of the concave curved portion 201 was 24.4%, that is significantly increased as compared with the maximum value of the plate thickness reduction rate in the press-formed product 250 having the target shape according to the conventional example (= 20.5%). Furthermore, in the press-formed product 250 obtained by press-forming the press-formed product 190 having the intermediate shape into the target shape, the maximum value of the plate thickness reduction rate of the end portion of the curve in the concave curved portion 261 was 25.4%, and a result was that tensile strain was concentrated on the concave curved portion 261 and stretch flange cracking was likely to occur.

**[0077]** On the other hand, in the first invention example, as illustrated in FIG. 17, the maximum value of the plate thickness reduction rate in the press-formed product 150 having the intermediate shape was 14.8%, and the plate thickness reduction rate could be reduced by providing the cutout portion 165 as compared with the conventional example and the comparative example. Further, in the first invention example, the maximum value of the plate thickness reduction rate in the press-formed product 250 having the target shape was 18.3%. The plate thickness reduction rate was lower than the maximum value of the plate thickness reduction rate in the press-formed product 250 having the target shape according to the conventional example and the press-formed product 250 having the target shape according to the comparative example.

**[0078]** Further, in the second invention example, as illustrated in FIG. 18, the maximum value of the plate thickness reduction rate in the press-formed product 150 having the intermediate shape was 13.9%, and the plate thickness reduction rate could be reduced by providing the cutout portion 165 as compared with the conventional example and the comparative example. Further, in the second invention example, the maximum value of the plate thickness reduction rate in the press-formed product 250 having the target shape was 18.8%. The plate thickness reduction rate was lower than the maximum value of the plate thickness reduction rate in the press-formed product 250 having the target shape according to the conventional example and the press-formed product 250 having the target shape according to the comparative example. Further, the plate thickness reduction rate at both ends of the concave curved portion 261 in the second invention example was 14.2% at the maximum, and the plate thickness reduction rate could be further reduced than the maximum value of 16.2% of the plate thickness reduction rate at both end portions of the concave curved portion 261 in the first invention example.

**[0079]** As described above, according to the press-forming method of the present invention, the radius of curvature $R_E$ of the end portion 161b of the curve of the concave curved portion 161 having the intermediate shape can be set with a condition that the radius of curvature $R_E$ is larger than the radius of curvature $R_0$ of the concave curved portion 261 having the target shape. Furthermore, by appropriately setting the radius of curvature $R_E$ of the end portion 161b of the curve, it is possible to suppress a decrease in plate thickness at both ends of the concave curved portion 261 having the target shape.

**[0080]** As described above, it was suggested that, according to the press-forming method of the present invention, it is possible to reduce stretch flange cracking at a concave curved portion in the process of press-forming a press-formed product having a target shape and having a concave curved portion.

## Industrial Applicability

**[0081]** The present invention can provide a press-forming method and a method of manufacturing a press-formed product capable of sufficiently suppressing stretch flange cracking of the press-formed product, the press-formed product having a top portion and a vertical wall portion and including a concave curved portion that is curved in a concave shape in a top view.

Reference Signs List

**[0082]**

1 INTERMEDIATE SHAPE FORMING TOOL OF PRESS FORMING
3 INTERMEDIATE SHAPE FORMING DIE
3a DIE SIDE INTERMEDIATE SHAPE CONCAVE CURVED PORTION FORMING PORTION
3b DIE SIDE INTERMEDIATE SHAPE LINEAR PORTION FORMING PORTION
5 INTERMEDIATE SHAPE FORMING PUNCH
5a PUNCH SIDE INTERMEDIATE SHAPE CONCAVE CURVED PORTION FORMING PORTION
5b PUNCH SIDE INTERMEDIATE SHAPE LINEAR PORTION FORMING PORTION
7 PAD
11 TARGET SHAPE FORMING TOOL OF PRESS FORMING
13 TARGET SHAPE FORMING DIE
13a DIE SIDE TARGET SHAPE CONCAVE CURVED PORTION FORMING PORTION
13b DIE SIDE TARGET SHAPE LINEAR PORTION FORMING PORTION
15 TARGET SHAPE FORMING PUNCH
15a PUNCH SIDE TARGET SHAPE CONCAVE CURVED PORTION FORMING PORTION
15b PUNCH SIDE TARGET SHAPE LINEAR PORTION FORMING PORTION
17 PAD
21 TOOL OF PRESS FORMING
23 DIE
23a DIE SIDE CONCAVE CURVED PORTION FORMING PORTION
25 PUNCH
25a PUNCH SIDE CONCAVE CURVED PORTION FORMING PORTION
27 PAD
31 INTERMEDIATE SHAPE FORMING TOOL OF PRESS FORMING
33 INTERMEDIATE SHAPE FORMING DIE
35 INTERMEDIATE SHAPE FORMING PUNCH
37 PAD
41 TARGET SHAPE FORMING TOOL OF PRESS FORMING
43 TARGET SHAPE FORMING DIE
45 TARGET SHAPE FORMING PUNCH
47 PAD
51 TOOL OF PRESS FORMING
53 DIE
55 PUNCH
57 PAD
100 BLANK
101 CONCAVE SHAPE
110 PRESS-FORMED PRODUCT
111 TOP PORTION
113 RIDGE PORTION
115 VERTICAL WALL PORTION
117 DIE SHOULDER PORTION
119 FLANGE PORTION
121 CONCAVE CURVED PORTION
121a CENTRAL PORTION OF CURVE
121b END PORTION OF CURVE
123 LINEAR PORTION
125 CUTOUT PORTION
127 CUTOUT PORTION
130 PRESS-FORMED PRODUCT
131 TOP PORTION
133 RIDGE PORTION
135 VERTICAL WALL PORTION
141 CONCAVE CURVED PORTION
141a CENTRAL PORTION OF CURVE
147 CUTOUT PORTION
150 PRESS-FORMED PRODUCT
153 RIDGE PORTION
155 VERTICAL WALL PORTION
157 DIE SHOULDER PORTION
159 FLANGE PORTION
161 CONCAVE CURVED PORTION
161a CENTRAL PORTION OF CURVE
161b END PORTION OF CURVE
163 LINEAR PORTION
165 CUTOUT PORTION
170 PRESS-FORMED PRODUCT
173 RIDGE PORTION
181 CONCAVE CURVED PORTION
181a CENTRAL PORTION OF CURVE
181b END PORTION OF CURVE
190 PRESS-FORMED PRODUCT
193 RIDGE PORTION
201 CONCAVE CURVED PORTION
201a CENTRAL PORTION OF CURVE
201b END PORTION OF CURVE
210 PRESS-FORMED PRODUCT
211 TOP PORTION
213 RIDGE PORTION
215 VERTICAL WALL PORTION
217 DIE SHOULDER PORTION
219 FLANGE PORTION
221 CONCAVE CURVED PORTION
221a CENTRAL PORTION OF CURVE
223 LINEAR PORTION
230 PRESS-FORMED PRODUCT
231 TOP PORTION
233 RIDGE PORTION
233a RIDGE PORTION
235 VERTICAL WALL PORTION
235a VERTICAL WALL PORTION
241 CONCAVE CURVED PORTION
243 LINEAR PORTION
250 PRESS-FORMED PRODUCT
251 TOP PORTION
253 RIDGE PORTION
253a RIDGE PORTION
255 VERTICAL WALL PORTION
255a VERTICAL WALL PORTION

257 DIE SHOULDER PORTION
257a DIE SHOULDER PORTION
259 FLANGE PORTION
259a FLANGE PORTION
261 CONCAVE CURVED PORTION
263 LINEAR PORTION

## Claims

**1.** A press-forming method of press-forming a press-formed product into a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, and a concave curved portion curved in a concave shape in a top view, the press-forming method comprising:

a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion of the target shape;
an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape having a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the flange portion and the vertical wall portion or at a part of the flange portion, the vertical wall portion, and the top portion in a central portion of the curve of the concave curved portion; and
a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape,
wherein the press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

**2.** A press-forming method of press-forming a press-formed product into a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, and a concave curved portion curved in a concave shape in a top view, the press-forming method comprising:

a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion;
an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the vertical wall portion and the top portion in a central portion of the curve of the concave curved portion; and
a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape,
wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

**3.** The press-forming method according to claim 1 or 2, wherein, in the intermediate shape forming step, a radius of curvature $R_E$ at an end portion of the curve of the concave curved portion having the intermediate shape is set to be larger than a radius of curvature $R_0$ at the concave curved portion having the target shape.

**4.** A method of manufacturing a press-formed product having a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, and a concave curved portion curved in a concave shape in a top view, the method comprising:

a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion of the target shape;
an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a flange portion continuous from the vertical wall portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the flange portion and the vertical wall portion or at a part of the flange portion, the vertical wall portion, and the top portion in a central portion of the curve of the concave curved portion; and
a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape,
wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

**5.** A method of manufacturing a press-formed product having a target shape, the target shape including a top portion, a vertical wall portion continuous from the top portion, and a concave curved portion curved

in a concave shape in a top view, the method comprising:

a blank forming step of forming a blank provided with a concave shape corresponding to a curve of the concave curved portion;
an intermediate shape forming step of press-forming the formed blank into a press-formed product having an intermediate shape, the intermediate shape including a top portion, a vertical wall portion continuous from the top portion, a concave curved portion curved in a concave shape in a top view, and a cutout portion located at a part of the vertical wall portion and the top portion in a central portion of the curve of the concave curved portion; and
a target shape forming step of press-forming the press-formed product having the intermediate shape into the target shape,
wherein press-forming is performed in the intermediate shape forming step such that a part of the concave shape provided in the blank becomes the cutout portion.

**6.** The method of manufacturing a press-formed product according to claim 4 or 5, wherein the press-forming is performed in the intermediate shape forming step such that a radius of curvature $R_E$ at an end portion of the curve of the concave curved portion having the intermediate shape is set to be larger than a radius of curvature $R_0$ at the concave curved portion having the target shape.

FIG.1

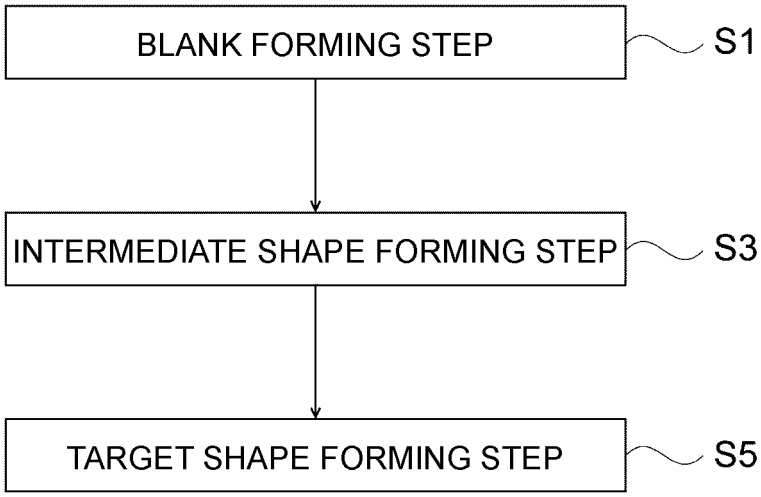

BLANK FORMING STEP
S1
INTERMEDIATE SHAPE FORMING STEP
S3
TARGET SHAPE FORMING STEP
S5

FIG.2

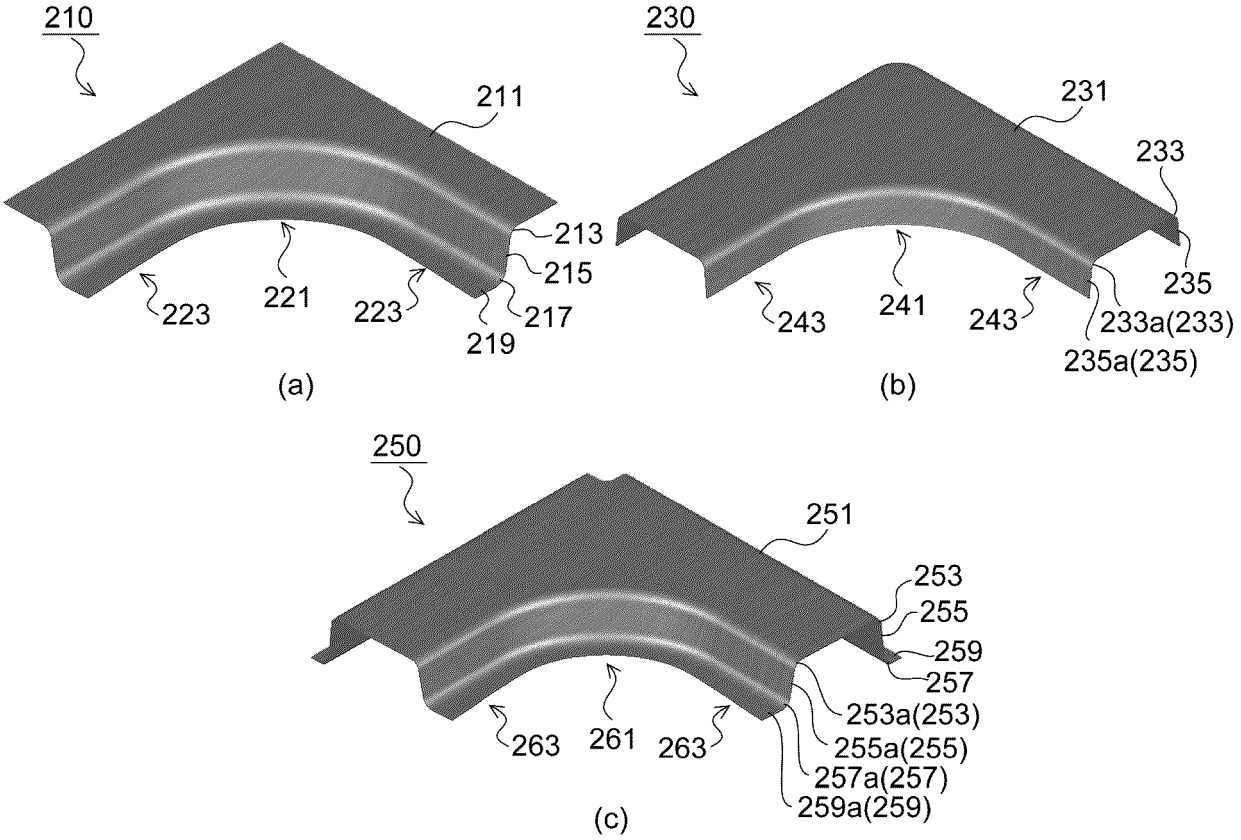

210
211
213
215
217
219
221
223
223
(a)
230
231
233
235
233a(233)
235a(235)
241
243
243
(b)
250
251
253
255
257
259
253a(253)
255a(255)
257a(257)
259a(259)
261
263
263
(c)

FIG.3

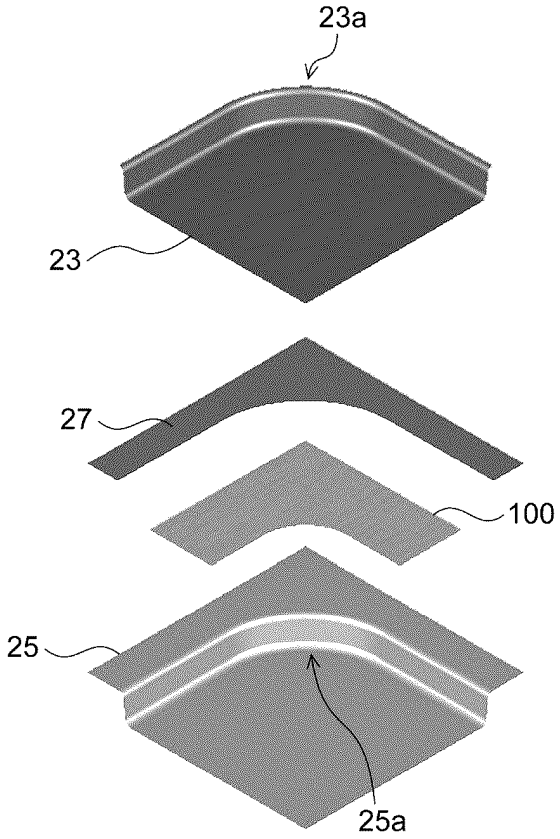

21
23a
23
27
100
25
25a

FIG.4

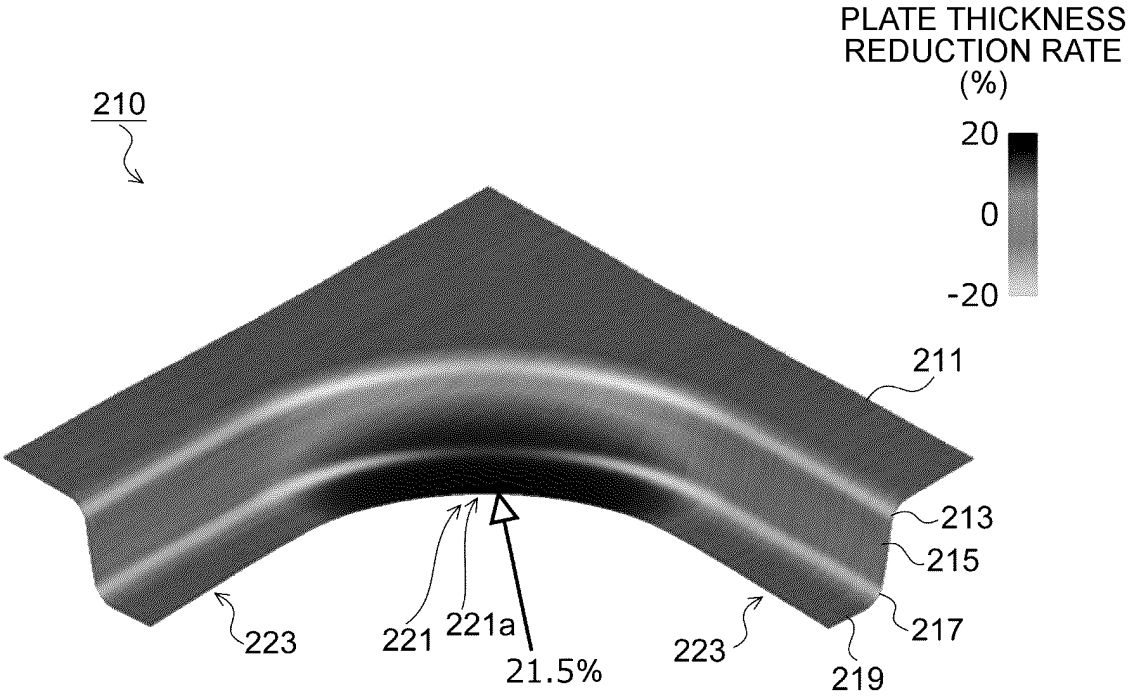
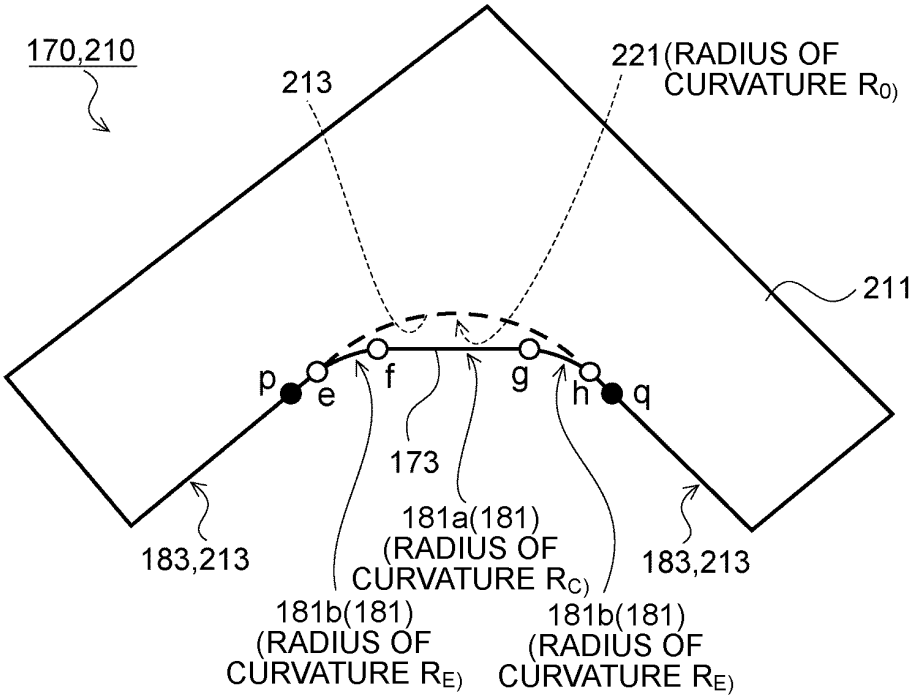


PLATE THICKNESS REDUCTION RATE (%)
20
0
-20
210
211
213
215
217
219
223
221
221a
21.5%
223

FIG.5




RIDGE LENGTH OF INTERMEDIATE SHAPE (CURVE efgh) < RIDGE LENGTH OF TARGET SHAPE (CURVE pq)
$R_0 > R_E$ AND $R_0 < R_C$

FIG.6

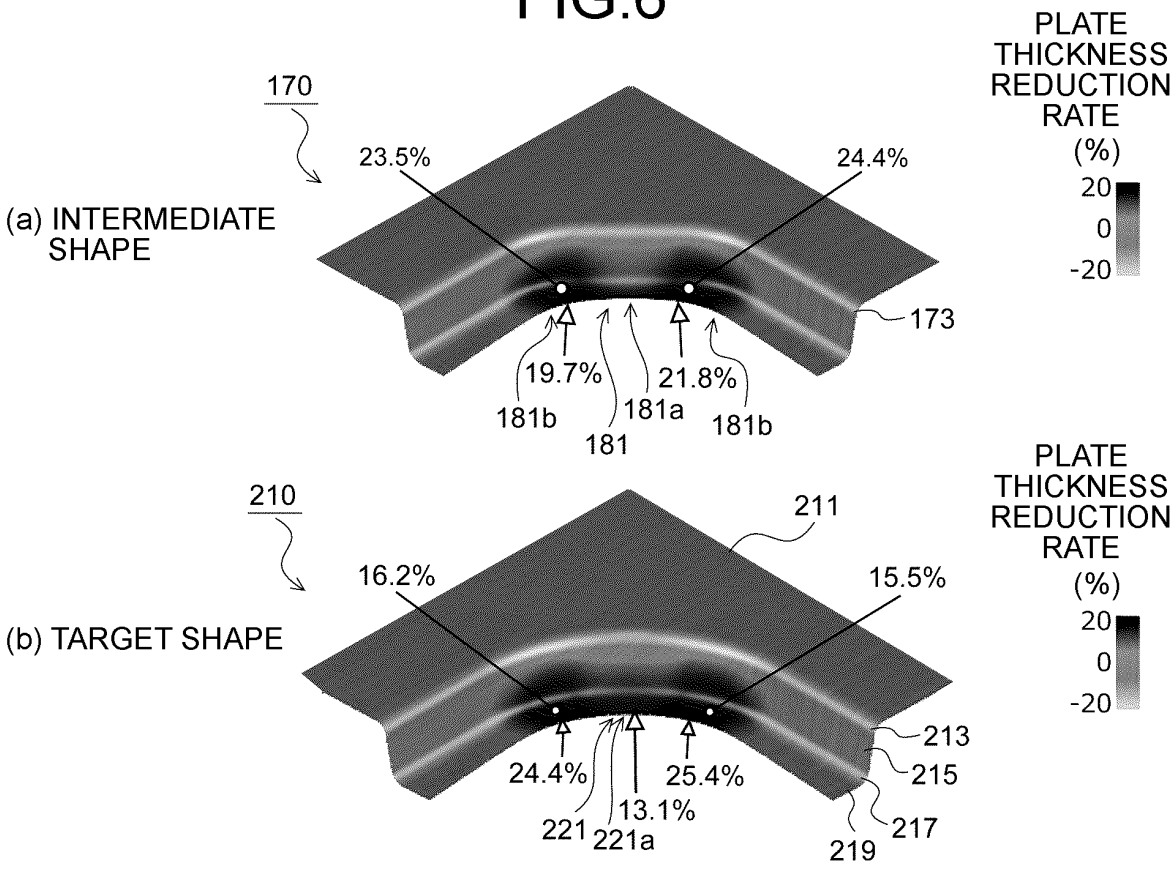


FIG.7

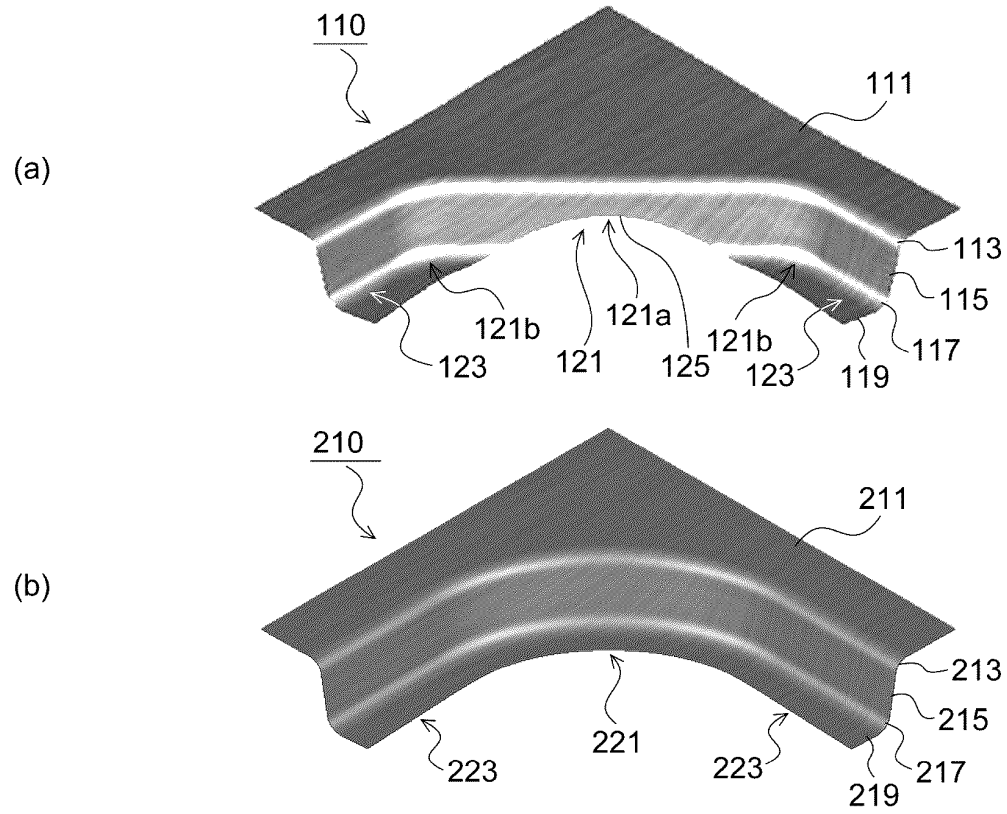
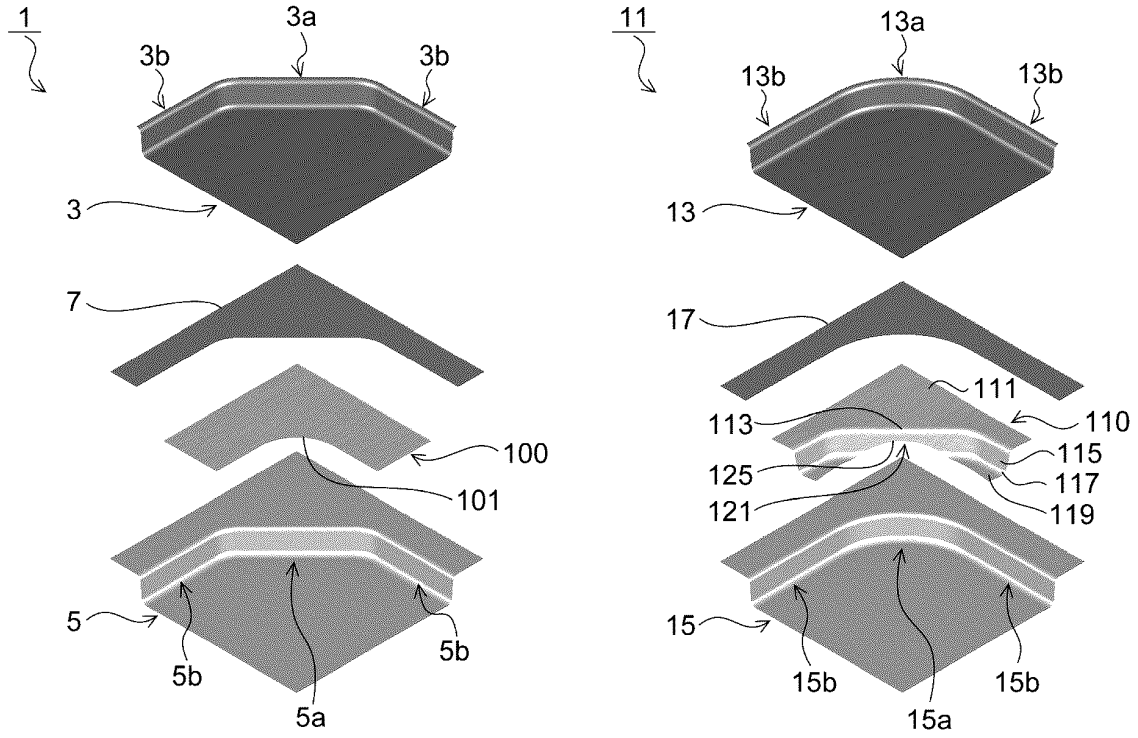



FIG.8




(a) INTERMEDIATE SHAPE FORMING STEP

(b) TARGET SHAPE FORMING STEP

FIG.9

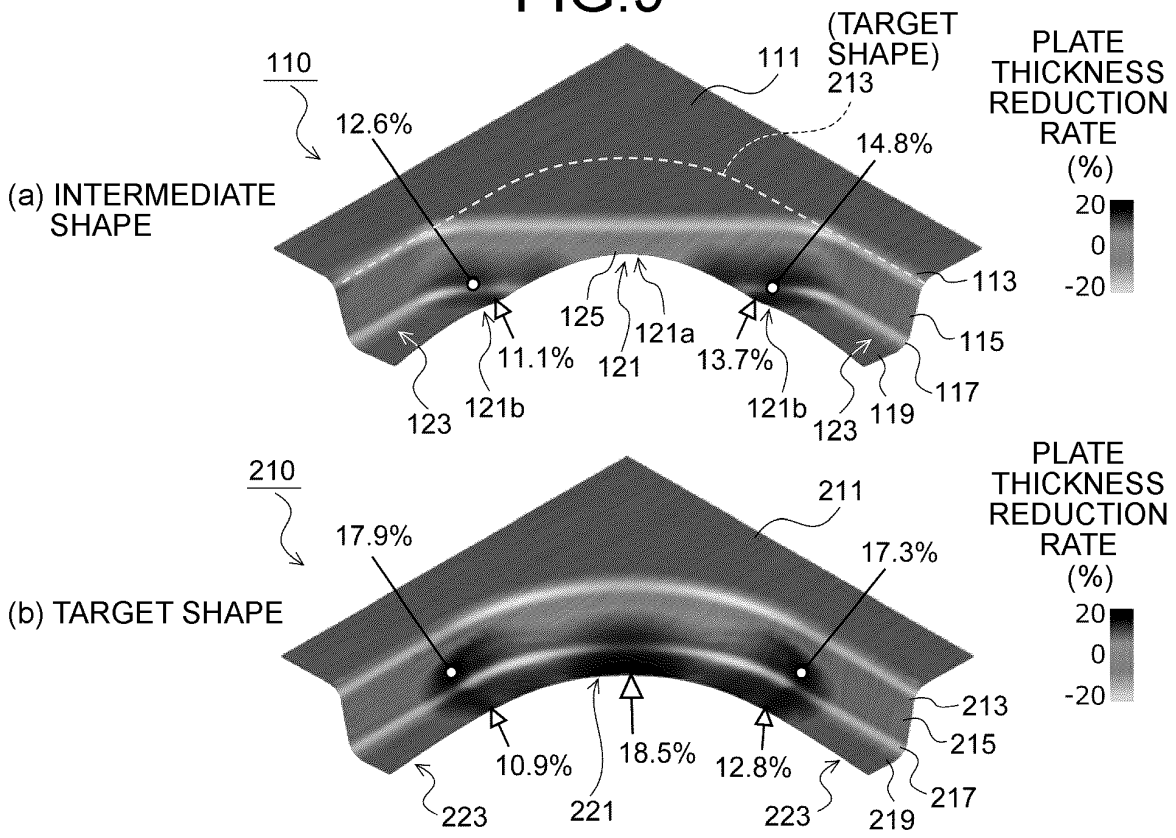
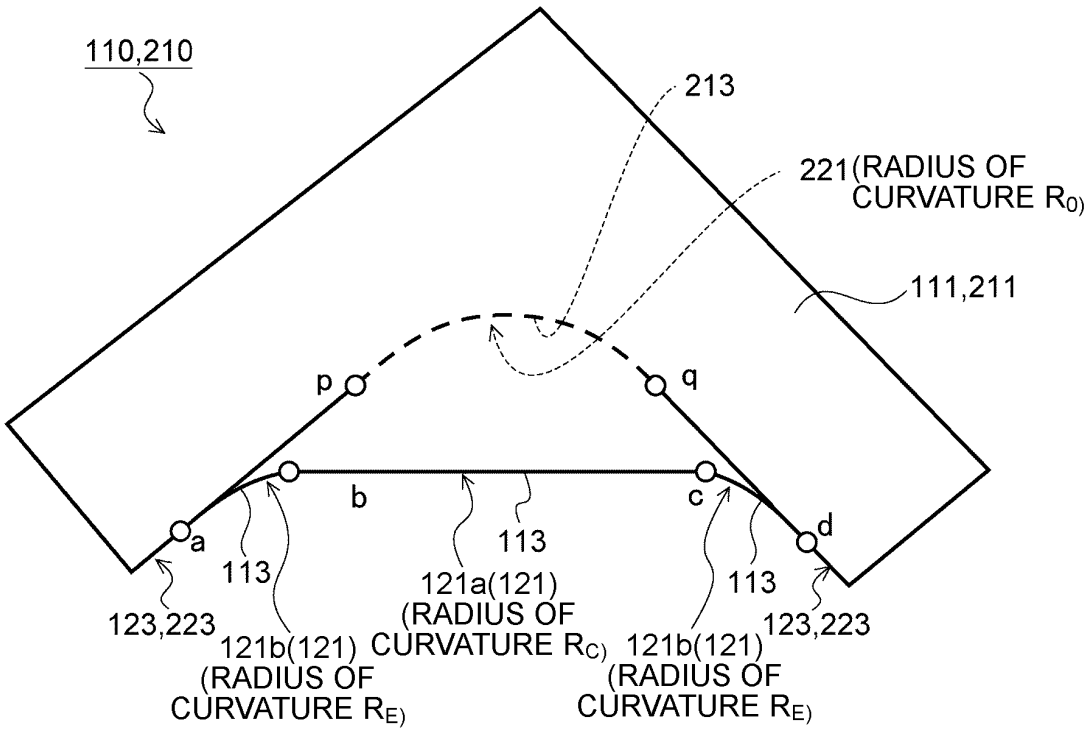
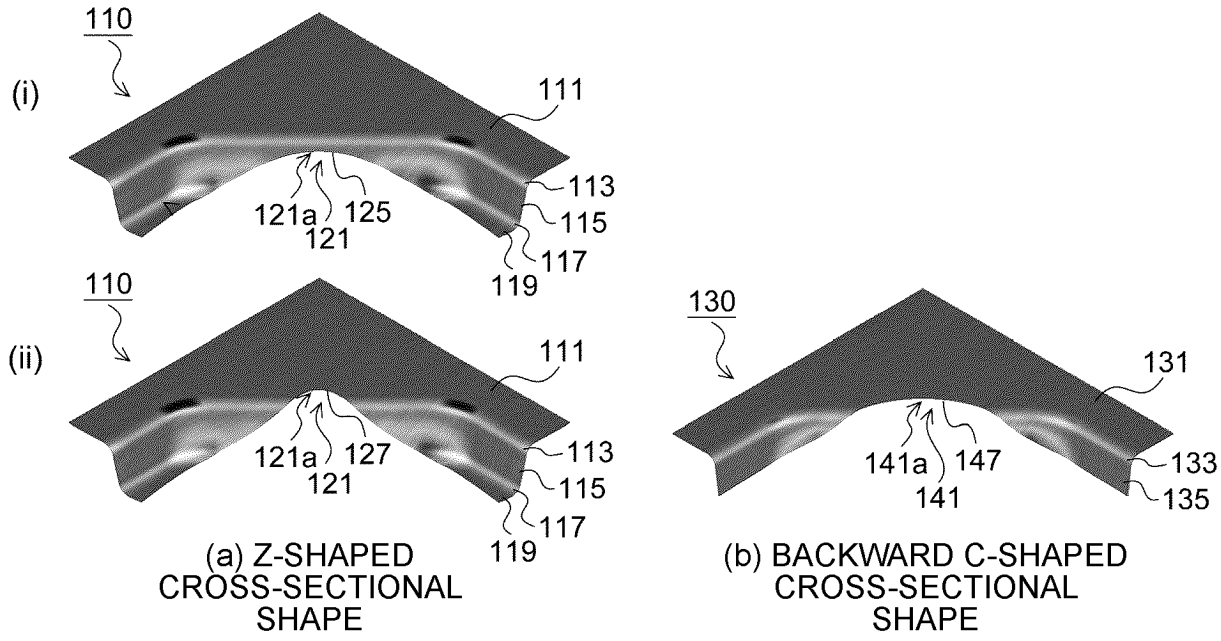



FIG.10




RIDGE LENGTH OF INTERMEDIATE SHAPE (CURVE abcd) > RIDGE LENGTH OF TARGET SHAPE (CURVE pq) (ANY OF $R_0<R_E$ OR $R_0>R_E$ IS POSSIBLE)

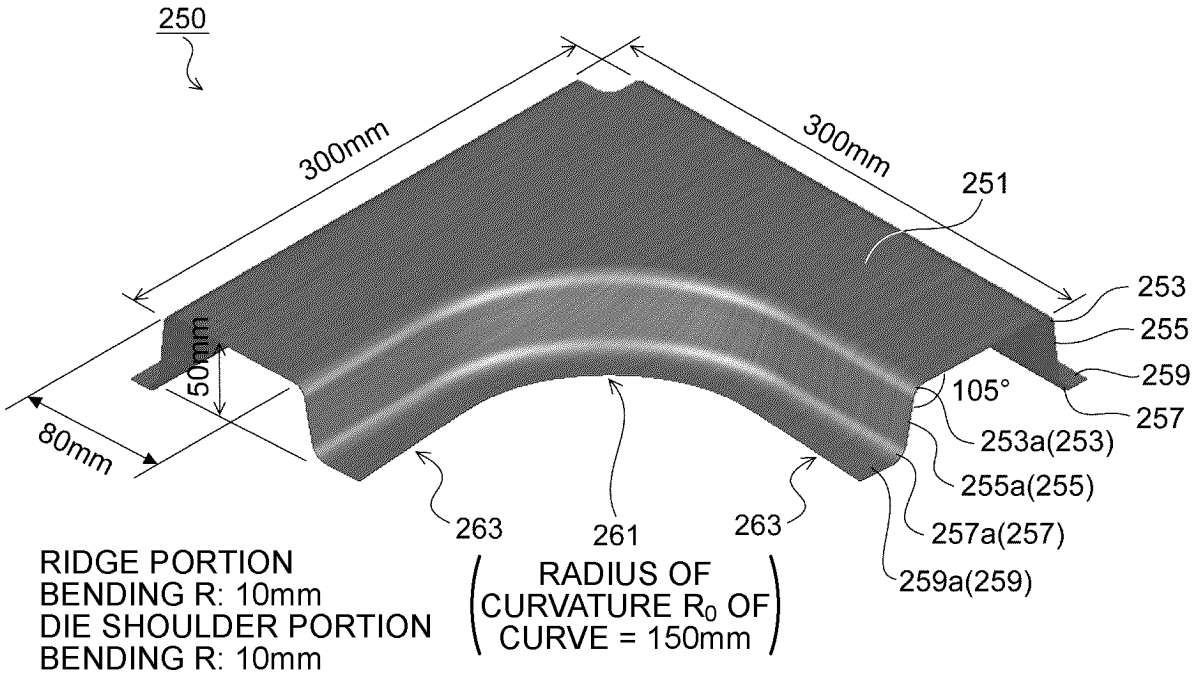
FIG.11




(a) Z-SHAPED CROSS-SECTIONAL SHAPE

(b) BACKWARD C-SHAPED CROSS-SECTIONAL SHAPE

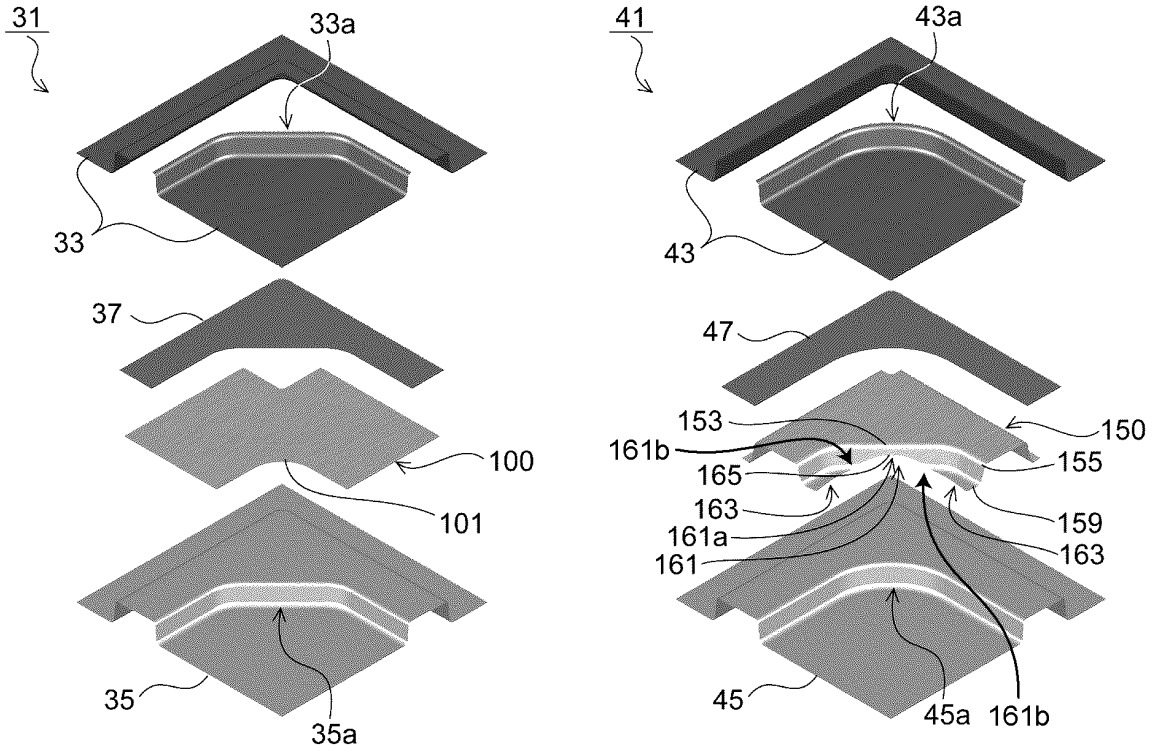
FIG.12




RIDGE PORTION
BENDING R: 10mm
DIE SHOULDER PORTION
BENDING R: 10mm

(RADIUS OF CURVATURE $R_0$ OF CURVE = 150mm)

FIG.13




(a) INTERMEDIATE SHAPE FORMING STEP

(b) TARGET SHAPE FORMING STEP

FIG.14

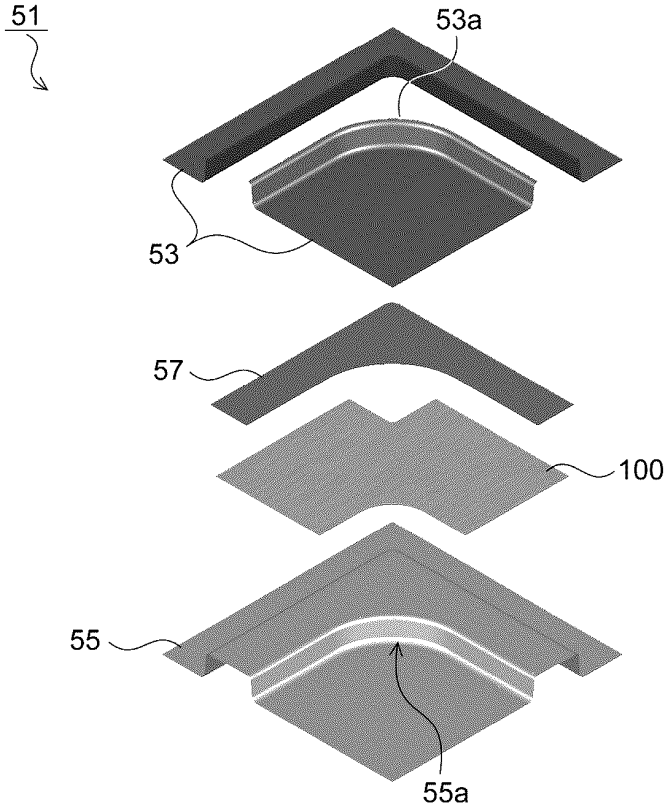


FIG.15

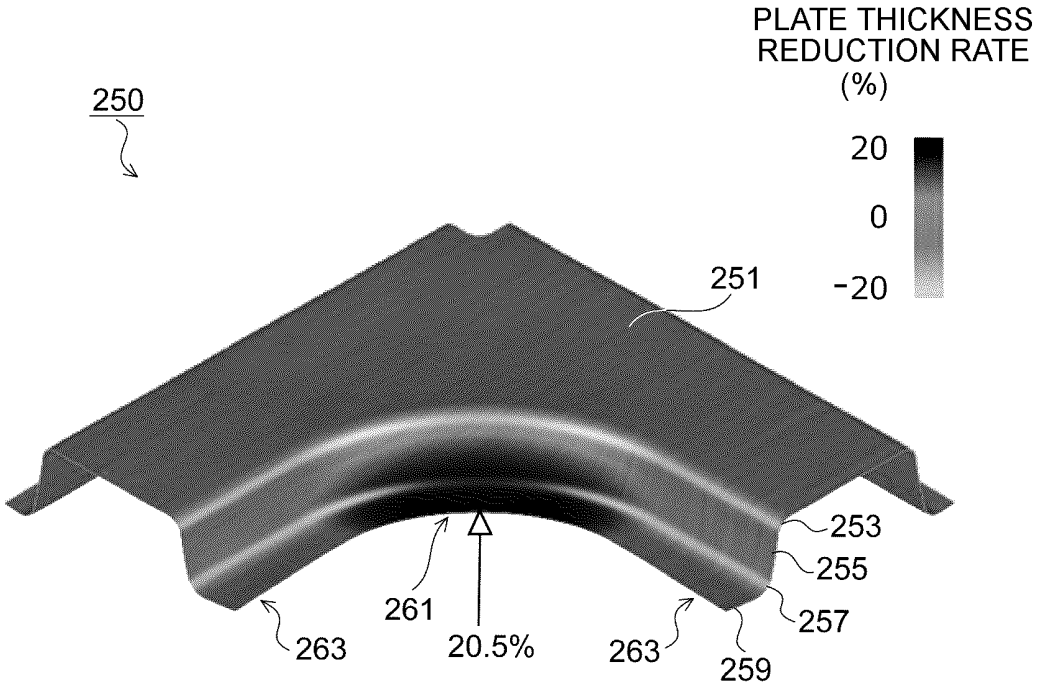


PLATE THICKNESS REDUCTION RATE (%)
20
0
-20
250
251
253
255
257
259
261
263
263
20.5%

FIG.16

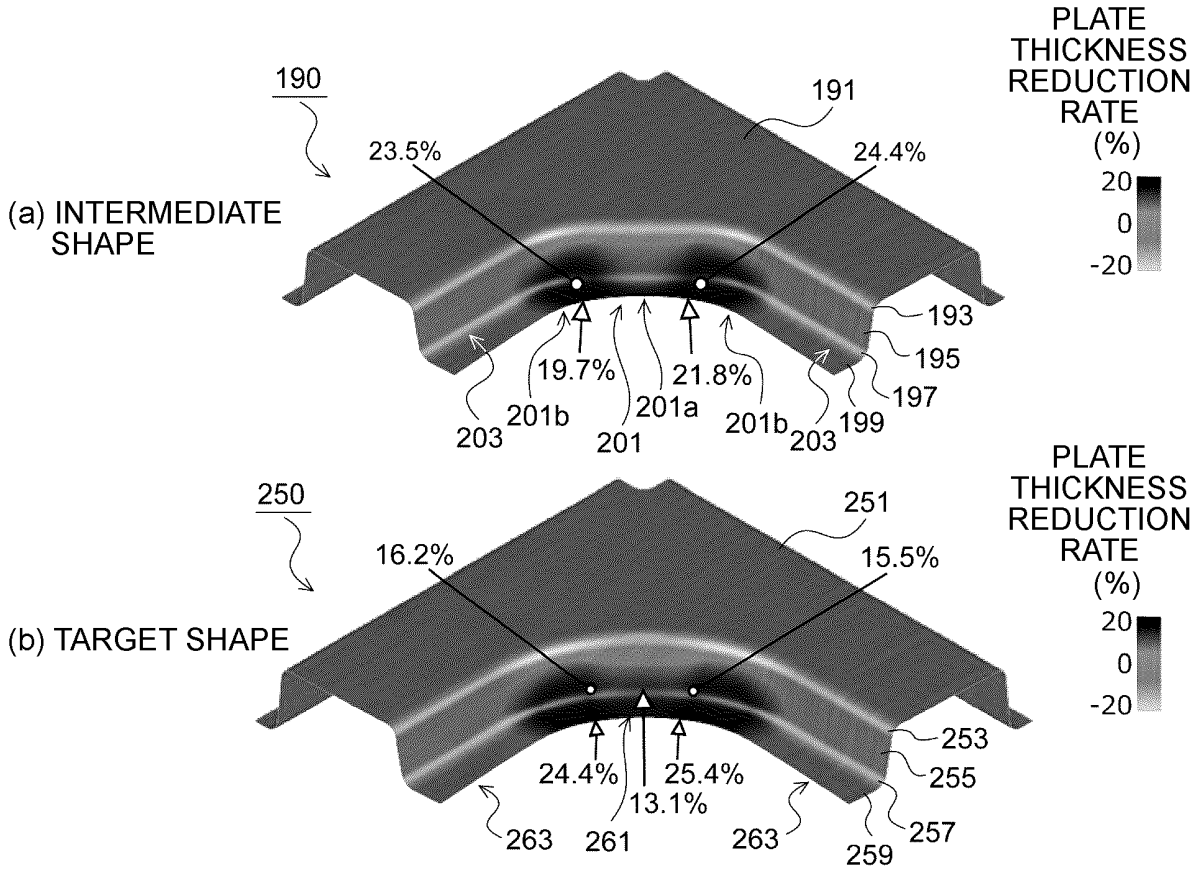

(a) INTERMEDIATE SHAPE
190
191
23.5%
24.4%
19.7%
21.8%
193
195
197
199
201
201a
201b
201b
203
203
PLATE THICKNESS REDUCTION RATE (%)
20
0
-20
(b) TARGET SHAPE
250
251
16.2%
15.5%
24.4%
25.4%
13.1%
253
255
257
259
261
263
263
PLATE THICKNESS REDUCTION RATE (%)
20
0
-20

FIG.17

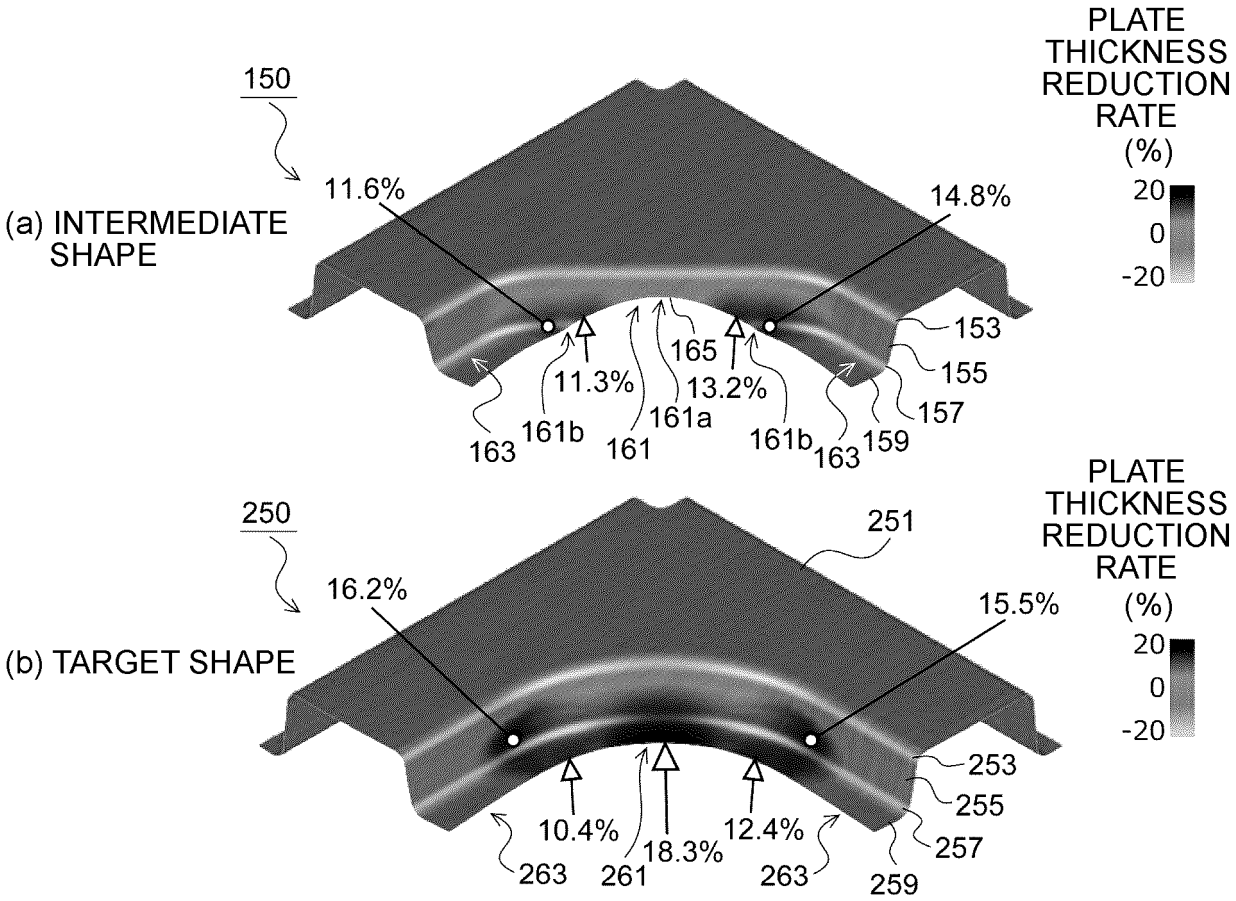
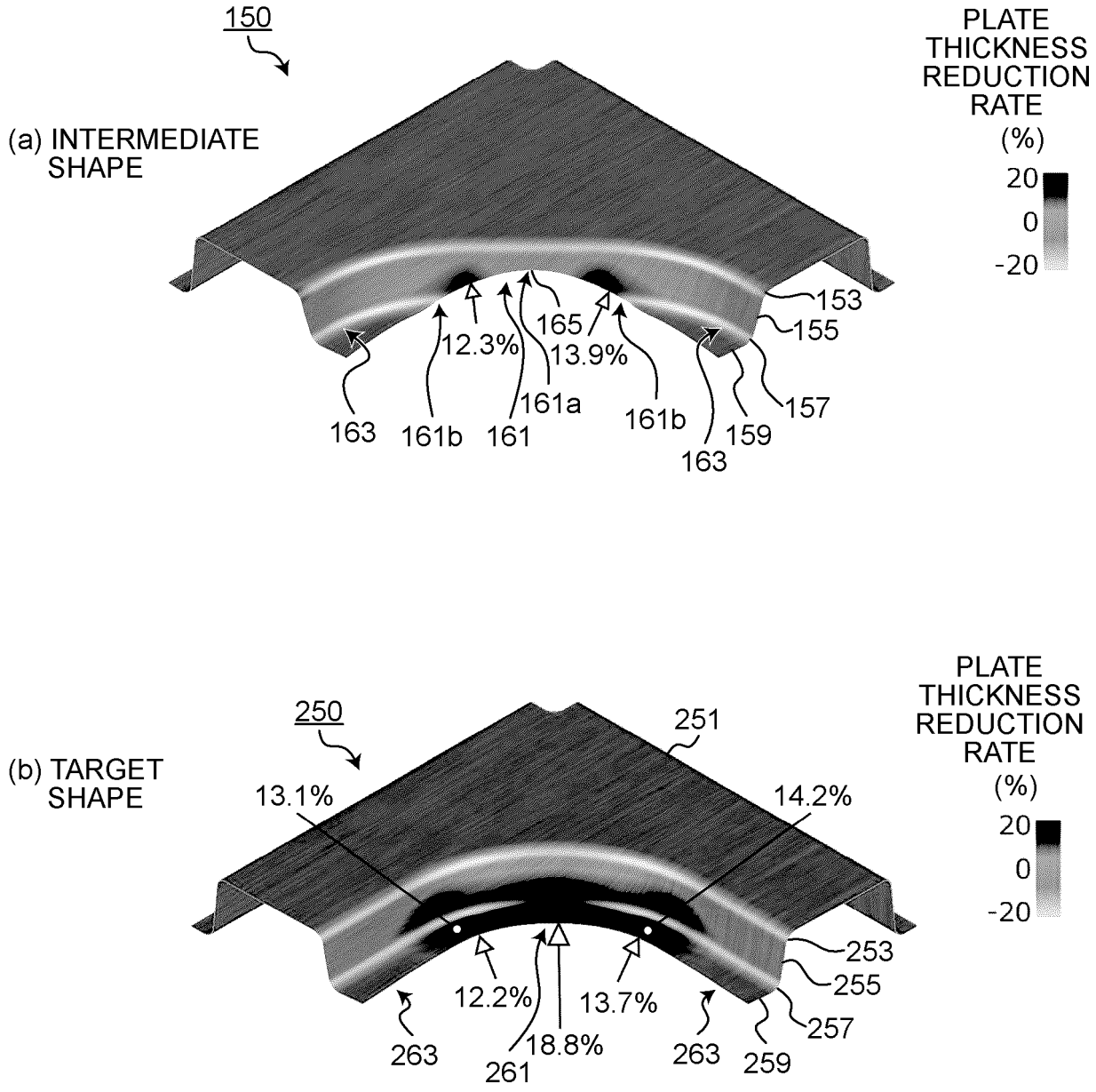

(a) INTERMEDIATE SHAPE
150
11.6%
14.8%
11.3%
13.2%
165
153
155
157
159
161
161a
161b
163
PLATE THICKNESS REDUCTION RATE (%)
20
0
-20
(b) TARGET SHAPE
250
16.2%
15.5%
10.4%
12.4%
18.3%
251
253
255
257
259
261
263
PLATE THICKNESS REDUCTION RATE (%)
20
0
-20

FIG.18


150
(a) INTERMEDIATE SHAPE
PLATE THICKNESS REDUCTION RATE (%)
20
0
-20
153
155
165
12.3%
13.9%
157
163
161b
161
161a
161b
159
163
250
(b) TARGET SHAPE
251
13.1%
14.2%
253
255
12.2%
13.7%
257
263
18.8%
263
259
261

## INTERNATIONAL SEARCH REPORT

International application No.
**PCT/JP2023/018764**

**A. CLASSIFICATION OF SUBJECT MATTER**

***B21D 22/26***(2006.01)i; ***B21D 24/00***(2006.01)i
FI: B21D22/26 C; B21D24/00 F; B21D24/00 H

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; B21D24/00

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

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

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

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | JP 2020-082143 A (DAIHATSU MOTOR CO LTD) 04 June 2020 (2020-06-04) paragraphs [0016]-[0028], fig. 1-4 | 1-6 |
| A | JP 2022-080353 A (JFE STEEL CORP) 30 May 2022 (2022-05-30) paragraphs [0017]-[0042], fig. 1-8 | 1-6 |
| A | WO 2014/185428 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 20 November 2014 (2014-11-20) entire text, all drawings | 1-6 |
| A | JP 2021-159951 A (NIPPON STEEL CORP) 11 October 2021 (2021-10-11) entire text, all drawings | 1-6 |
| A | JP 5168429 B2 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 21 March 2013 (2013-03-21) entire text, all drawings | 1-6 |

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| **11 July 2023** | **25 July 2023** |
| Name and mailing address of the ISA/JP<br>**Japan Patent Office (ISA/JP)**<br>**3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915**<br>**Japan** | Authorized officer<br><br>Telephone No. |

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**INTERNATIONAL SEARCH REPORT**
**Information on patent family members**

International application No.
**PCT/JP2023/018764**

| Patent document cited in search report | Publication date (day/month/year) | Patent family member(s) | Publication date (day/month/year) |
|---|---|---|---|
| JP 2020-082143 A | 04 June 2020 | (Family: none) | |
| JP 2022-080353 A | 30 May 2022 | (Family: none) | |
| WO 2014/185428 A1 | 20 November 2014 | US 2016/0082495 A1<br>entire text, all drawings<br>EP 2998043 A1<br>CA 2912041 A1<br>CN 105188982 A<br>KR 10-2016-0003770 A<br>MX 2015015496 A<br>KR 10-2018-0021228 A<br>BR 112015028362 A<br>TW 201505734 A | |
| JP 2021-159951 A | 11 October 2021 | (Family: none) | |
| JP 5168429 B2 | 21 March 2013 | US 2012/0297853 A1<br>entire text, all drawings<br>WO 2011/145679 A1<br>EP 2572811 A1<br>AU 2011255898 A1<br>TW 201206585 A<br>CA 2788845 A1<br>CN 102791396 A<br>MX 2012009036 A<br>KR 10-2012-0140236 A<br>RU 2012133251 A<br>ZA 201205651 B<br>BR 112012021712 A2<br>HU E045388 T2<br>ES 2741881 T3<br>AR 86415 A1 | |

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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


- JP 2021159951 A **[0007]**
- JP 5168429 B **[0007]**