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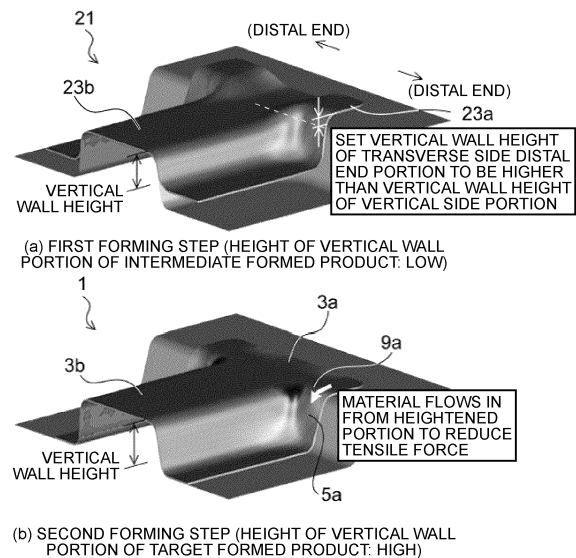
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(54) **METHOD FOR MANUFACTURING PRESS-MOLDED ARTICLE**

(57) A method for manufacturing a press-formed product according to the present invention is a method for manufacturing a press-formed product including at least a top plate portion, a vertical wall portion, and a ridge portion which is a connection portion between the top plate portion and the vertical wall portion, the method including: a first forming step of press-forming a metal sheet blank into an intermediate formed product including an intermediate top plate portion, an intermediate vertical wall portion, and an intermediate ridge portion connecting the intermediate top plate portion and the intermediate vertical wall portion, the intermediate formed product including a convex portion having a height higher than a reference height of a top plate surface at one position or a plurality of positions of the intermediate top plate portion including the intermediate ridge portion; and a second forming step of press-forming the intermediate formed product into the press-formed product.

FIG. 1



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Description

Field

5 **[0001]** The present invention relates to a method for manufacturing a press-formed product including at least a top plate portion, a vertical wall portion, and a ridge portion which is a connection portion between the top plate portion and the vertical wall portion.

Background

10 **[0002]** Under the recent carbon dioxide emission regulations, it is also necessary to reduce the weight of the vehicle body as the improvement of the collision safety of the vehicle body progresses due to the tightening of the collision safety standard of automobiles. Therefore, in order to achieve both collision safety performance and weight reduction of the vehicle body, metal sheets having higher strength than the conventional metal sheets are being adopted in the vehicle
15 body. Ultra-high-tensile steel sheets of 1.5 GPa class or more have been applied in close proximity. However, since a metal sheet having high strength is generally poor in ductility, when a press-formed product is manufactured as a vehicle body component, cracking is likely to occur from an end portion in the process of press-forming.

[0003] Conventionally, methods for preventing cracks in press-formed articles have been adopted. For example, Patent Literature 1 discloses a method for preventing a crack generated at a connection portion between a wall portion continuous
20 from a connection side portion and a flange portion continuous from the wall portion when press-forming a T-shaped component having a T-shaped top plate portion in which a vertical side portion and a transverse side portion are connected by the connection side portion. In addition, Patent Literature 2 discloses a method for preventing a crack due to stretch flange forming of a press-formed product including a flat plate portion having a recessed outer peripheral edge portion in which a part of an outer peripheral edge is recessed inward and a flange portion bent along the recessed outer peripheral
25 edge portion.

Citation List

Patent Literature

30 **[0004]**

- Patent Literature 1: JP 2019-13952 A
- Patent Literature 2: JP 2016-104492 A

35 Summary

Technical Problem

40 **[0005]** In the method disclosed in Patent Literature 1, first, in a first forming step, an intermediate-shape component having a convex shape portion formed on the vertical side portion side of the connecting side portion in the top plate portion and a curved R portion obtained by raising a bottom R portion connecting the wall portion and the flange portion continuous from the connecting side portion upward is formed. Then, in the second forming step, the convex shape portion and the curved R portion of the intermediate-shape component are crushed to form a T-shaped component having a target shape.
45 As a result, the material is allowed to flow into the wall portion continuous with the connection side portion, and the crack generated at the connection portion between the wall portion and the flange portion can be prevented.

[0006] In addition, in the method disclosed in Patent Literature 2, plastic deformation is applied to a portion corresponding to the flat plate portion in the blank material, and the material is drawn into the portion subjected to the plastic deformation, so that the material is drawn to the portion corresponding to the bent portion of the flange portion, and an
50 excess portion is applied to the portion corresponding to the bent portion. Then, the blank material applied with the excess is bend-processed to form a press-formed product having a flange portion. As a result, the formability of the bent portion in the flange portion of the press-formed product is not deteriorated, and the occurrence of stretch flange cracking can be effectively suppressed.

[0007] As described above, the methods disclosed in Patent Literature 1 and Patent Literature 2 prevent cracking of a
55 portion subjected to stretch flange deformation in a press-formed product. Meanwhile, for example, in a press-formed product having a top plate portion having a substantially T-shape or a substantially L-shape in a top view and having a transverse side portion and a vertical side portion, there has been a case where a crack occurs at an end portion on a distal end side of the transverse side portion in a ridge portion connecting the vertical wall portion and the transverse side portion,

unlike a crack caused by stretch flange deformation. However, in the methods disclosed in Patent Literature 1 and Patent Literature 2 described above, it is not possible to suppress cracking at the end portion of the ridge portion connecting the vertical wall portion and the transverse side portion of the press-formed product having such a top plate portion having a substantially T-shape or a substantially L-shape.

5 **[0008]** In addition, also in press-forming of a press-formed product including a top plate portion, a vertical wall portion continuous with the top plate portion via a ridge portion, and a vertical flange portion continuous with the vertical wall portion, it has been difficult to suppress a crack generated at an end portion of the ridge portion.

10 **[0009]** Further, in press-forming of a press-formed product including a top plate portion and a vertical wall portion continuous with the top plate portion via a ridge portion, in which the top plate portion or a part thereof is curved in a top view, and the vertical wall portion is continuous inside the curve of the top plate portion, it is also difficult to suppress a crack generated at an end portion of the ridge portion.

15 **[0010]** The present invention has been made in view of the above problems, and an object of the present invention is to provide a method for manufacturing a press-formed product which includes a top plate portion and a vertical wall portion continuous with the top plate portion via a ridge portion while suppressing occurrence of cracking during press-forming.

Solution to Problem

20 **[0011]** To solve the above-described problem and achieve the objection, (1) a method according to the present invention for manufacturing a press-formed product including at least a top plate portion, a vertical wall portion, and a ridge portion which is a connection portion between the top plate portion and the vertical wall portion, includes: a first forming step of press-forming a metal sheet blank into an intermediate formed product including an intermediate top plate portion, an intermediate vertical wall portion, and an intermediate ridge portion connecting the intermediate top plate portion and the intermediate vertical wall portion, the intermediate formed product including a convex portion having a height higher than a reference height of a top plate surface at one position or a plurality of positions of the intermediate top plate portion including the intermediate ridge portion; and a second forming step of press-forming the intermediate formed product into the press-formed product.

30 (2) In the above-described method for manufacturing the press-formed product according to the invention (1), in a shape of the press-formed product, the top plate portion includes a transverse side portion, a vertical side portion, and a connection R portion where the transverse side portion and the vertical side portion are connected to each other, the top plate portion having a substantially T-shape or a substantially L-shape in a top view, the press-formed product including: the ridge portion connected to the top plate portion from the transverse side portion of the top plate portion to the connection R portion and the vertical side portion; the vertical wall portion continuous from the transverse side portion of the top plate portion to the connection R portion and the vertical side portion via the ridge portion; and a bottom flange portion continuous from the vertical wall portion, in the first forming step, the intermediate top plate portion includes an intermediate transverse side portion, an intermediate vertical side portion, and an intermediate connection R portion where the intermediate transverse side portion and the intermediate vertical side portion are connected to each other, the intermediate top plate portion having a substantially T-shape or a substantially L-shape in a top view, and press-forming is performed to obtain the intermediate formed product in which a height of the intermediate vertical side portion of the intermediate top plate portion is lower than a height of the vertical side portion in a target product shape, and further, in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion higher than the height of the vertical side portion at an end portion of the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion of the intermediate formed product and/or the intermediate connection R portion of the intermediate top plate portion including the intermediate ridge portion of the intermediate formed product.

35 (3) In the above-described method for manufacturing the press-formed product according to the invention (2), in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion whose height gradually increases toward a distal end side of the intermediate transverse side portion on the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion.

40 (4) In the above-described method for manufacturing the press-formed product according to the invention (2), in the first forming step, press-forming is performed to obtain the intermediate formed product including the convex portion having a constant height to a distal end side of the intermediate transverse side portion on the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion.

45 (5) In the above-described method for manufacturing the press-formed product according to the invention (2), in the first forming step, the convex portion is formed on the intermediate connection R portion including the intermediate ridge portion, and press-forming is further performed to obtain the intermediate formed product having the intermediate transverse side portion of the intermediate top plate portion having a height corresponding to the height of the convex portion of the intermediate connection R portion.

[0012] In the above-described method for manufacturing the press-formed product according to the invention (1), in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion higher than a reference height of the top plate surface at one position or a plurality of positions of the intermediate top plate portion including an end portion of the intermediate ridge portion.

[0013] In the above-described method for manufacturing the press-formed product according to the invention (6), the press-formed product includes a vertical flange portion continuous with the vertical wall portion, and in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion at an end portion of the intermediate top plate portion including the intermediate ridge portion on a vertical flange portion side in the press-formed product.

[0014] In the above-described method for manufacturing the press-formed product according to the invention (6), the press-formed product includes the vertical wall portion in which the top plate portion or a part of the top plate portion is curved in a top view, and the vertical wall portion is continuous with an inner side of a curve of the top plate portion, and in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion on the intermediate top plate portion including the end portion of the intermediate ridge portion.

Advantageous Effects of Invention

[0015] In the present invention, it is possible to manufacture a press-formed product having a top plate portion and a vertical wall portion continuous with the top plate portion via a ridge portion while suppressing occurrence of cracking during press-forming. In particular, in a press-formed product having a top plate portion having a substantially T-shape or a substantially L-shape in a top view and having a transverse side portion and a vertical side portion, it is possible to suppress cracking of the ridge portion on the distal end side of the transverse side portion. Further, in a press-formed product including a top plate portion, a vertical wall portion continuous with the top plate portion via a ridge portion, and a vertical flange portion continuous with the vertical wall portion, it is possible to suppress cracking of the end portion of the ridge portion close to the vertical flange side. Further, in a press-formed product including a top plate portion and a vertical wall portion continuous with the top plate portion via a ridge portion, in which the top plate portion or a part thereof is curved in a top view, and the vertical wall portion includes a vertical wall portion continuous inside the curve of the top plate portion, it is possible to suppress cracking of an end portion of the ridge portion.

Brief Description of Drawings

[0016]

FIG. 1 is a diagram for explaining an example in which a ridge portion on a transverse side distal end side and an entire top plate transverse side portion are made higher as convex portions in a method for manufacturing a press-formed product according to a first embodiment of the present invention, and illustrating a first forming step of press-forming the top plate vertical side portion into a press-formed product having an intermediate shape in which a vertical wall height is lower than a target shape, a second forming step of press-forming the top plate vertical side portion into a press-formed product having a vertical wall height of the target shape, and a reason why it is possible to suppress a crack at an end portion of the transverse side ridge portion of the press-formed product having the target shape ((a) first forming step and (b) second forming step).

FIG. 2 is a diagram for explaining an example in which the convex portion is only the connection R portion in the method for manufacturing the press-formed product according to the first embodiment of the present invention, and illustrating a first forming step of press-forming the top plate vertical side portion into a press-formed product having an intermediate shape in which a vertical wall height is lower than a target shape, a second forming step of press-forming the top plate vertical side portion into a press-formed product having a vertical wall height of the target shape, and a reason why it is possible to suppress cracking at the end portion of the transverse side ridge portion of the press-formed product having the target shape ((a) first forming step and (b) second forming step).

FIG. 3 is a diagram illustrating an example of a case where a roundness of a distal end of a top plate transverse side portion of a press-formed product provided with a top plate portion having a substantially T-shape in a top view, which is a target to be manufactured in the present invention, is small.

FIG. 4 is a diagram illustrating an example of a case where a roundness of a distal end of a top plate transverse side portion of a press-formed product provided with a top plate portion having a substantially T-shape in a top view, which is a target to be manufactured in the present invention, is large.

FIG. 5 is a diagram illustrating an example of a press-formed product including a top plate portion having a substantially L-shape in a top view, which is a target to be manufactured in the present invention.

FIG. 6 is a diagram for explaining a conventional manufacturing method of press-forming a press-formed product having a substantially T-shape in a top view in two steps ((a) first forming step and (b) second forming step).

FIG. 7 is a contour diagram illustrating a result of obtaining a sheet thickness change rate at a forming bottom dead center of each of an intermediate shape and a target shape of a substantially T-shaped press-formed product press-formed by two conventional steps ((a) intermediate shape and (b) target shape).

FIG. 8 is a diagram for explaining a portion where a crack occurs in a press-formed product including a top plate portion having a substantially T-shape press-formed by a conventional manufacturing method and a reason therefor.

FIG. 9 is a diagram illustrating an example of a punch used for press-forming of a press-formed product having an intermediate shape in which a convex portion is formed on a top plate portion in a first forming step in the method for manufacturing a press-formed product according to the first embodiment of the present invention, and is a diagram illustrating a specific example of a punch in which a "convex portion" having a uniform height is formed on a ridge portion continuous from a position where a transverse side portion of the top plate portion extends, and the punch is formed into an intermediate formed product having a top plate transverse side portion having a height corresponding to the height of the convex portion.

FIG. 10 is a diagram illustrating an example of a punch used for press-forming of a press-formed product having an intermediate shape in which a convex portion is formed on a top plate portion in a first forming step in the method for manufacturing a press-formed product according to the first embodiment of the present invention, and is a diagram illustrating a specific example of a punch in which a "convex portion" is formed on a ridge portion continuous from a position where the transverse side portion of the top plate portion extends so as to gradually increase in height toward a distal end portion of the ridge portion, and the punch is formed into an intermediate formed product having a top plate transverse side portion having a height corresponding to a height of the convex portion.

FIG. 11 is a diagram illustrating an example of a punch used for press-forming of a press-formed product having an intermediate shape in which a convex portion is formed on a top plate portion in a first forming step in the method for manufacturing a press-formed product according to the first embodiment of the present invention, and is a diagram illustrating a specific example of a punch in which a "convex portion" is formed on a joining R portion of the top plate portion.

FIG. 12 is a contour diagram illustrating a result of obtaining a sheet thickness change rate at a forming bottom dead center for each of an intermediate shape and a target shape of a substantially T-shaped press-formed product press-formed by a method for manufacturing a press-formed product using a punch illustrated in FIG. 10 (a) according to the first embodiment of the present invention ((a) intermediate shape and (b) target shape).

FIG. 13 is a contour diagram illustrating a result of obtaining a sheet thickness change rate at a forming bottom dead center for each of an intermediate shape and a target shape of a substantially T-shaped press-formed product press-formed in two conventional steps in a case where a product target shape is FIG. 4 ((a) intermediate shape and (b) target shape).

FIG. 14 is a contour diagram illustrating a result of obtaining a sheet thickness change rate at a forming bottom dead center of each of an intermediate shape and a target shape of a substantially T-shaped press-formed product press-formed by a method for manufacturing a press-formed product using a punch (convex portion) illustrated in FIG. 11 (a) according to the first embodiment of the present invention ((a) intermediate shape and (b) target shape).

FIG. 15 is a contour diagram illustrating a result of obtaining a sheet thickness change rate at a forming bottom dead center for each of an intermediate shape and a target shape of a substantially T-shaped press-formed product press-formed by a method for manufacturing a press-formed product using a punch (convex portion + height Up of transverse side portion) illustrated in FIG. 11 (b) according to the first embodiment of the present invention ((a) intermediate shape and (b) target shape).

FIG. 16 is a diagram illustrating a result of a sheet thickness change rate obtained for each of an intermediate shape and a target shape of a press-formed product having a top plate portion of a substantially L-shape press-formed by a conventional method ((a) intermediate shape and (b) target shape).

FIG. 17 is a diagram illustrating a result of a sheet thickness change rate obtained for each of an intermediate shape and a target shape of a press-formed product having a substantially L-shaped top plate portion press-formed by the method according to the first embodiment of the present invention ((a) intermediate shape and (b) target shape).

FIG. 18 is an explanatory diagram of a method for manufacturing a press-formed product according to a second embodiment of the present invention.

FIG. 19 is an explanatory diagram of an intermediate punch used in the method for manufacturing a press-formed product according to the second embodiment of the present invention.

FIG. 20 is an explanatory diagram of an intermediate formed product according to the second embodiment of the present invention.

FIG. 21 is a diagram for explaining a sheet thickness decrease rate of the press-formed product formed according to the second embodiment of the present invention.

FIG. 22 is an explanatory diagram of another aspect of the intermediate punch according to the second embodiment of the present invention.

FIG. 23 is an explanatory diagram of a press-formed product having a target shape according to the second

embodiment of the present invention.

FIG. 24 is an explanatory diagram of a conventional method of press-forming the press-formed product illustrated in FIG. 23 in one step.

5 FIG. 25 is an explanatory diagram of a sheet thickness decrease rate when press-forming is performed by the conventional method illustrated in FIG. 24.

FIG. 26 is an explanatory diagram of a method for manufacturing a press-formed product according to a third embodiment of the present invention.

FIG. 27 is an explanatory diagram of an intermediate punch used in the method for manufacturing a press-formed product according to the third embodiment of the present invention.

10 FIG. 28 is an explanatory diagram of an intermediate formed product according to the third embodiment of the present invention.

FIG. 29 is a diagram for explaining a sheet thickness decrease rate of the press-formed product formed according to the third embodiment of the present invention.

15 FIG. 30 is an explanatory diagram of a press-formed product having a target shape according to the third embodiment of the present invention.

FIG. 31 is an explanatory diagram of a conventional method of press-forming the press-formed product illustrated in FIG. 30 in one step.

FIG. 32 is an explanatory diagram of a sheet thickness decrease rate when press-forming is performed by the conventional method illustrated in FIG. 31.

20 FIG. 33 is an explanatory diagram for explaining a mechanism in which a crack occurs in a press-formed product press-formed by the conventional method illustrated in FIG. 31.

FIG. 34 is a diagram for explaining an inclination angle of a transverse side portion distal end side in the press-formed product having the intermediate shape in Example 1.

25 FIG. 35 is a diagram for explaining a height increment for uniformly heightening a portion on the transverse side portion distal end side in the press-formed product having the intermediate shape in Example 1.

Description of Embodiments

(First Embodiment)

30 **[0017]** Hereinafter, prior to the description of the method for manufacturing a press-formed product according to a first embodiment of the present invention, a press-formed product targeted in the present invention and occurrence of cracking in the press-formed product will be described. Note that the same or similar components are denoted by the same reference signs, and redundant description will be omitted.

35 <Press-Formed Product Targeted in Present Invention>

[0018] FIG. 3 illustrates a press-formed product 1 including a top plate portion 3, a vertical wall portion 5, and a bottom flange portion 7 as an example of a press-formed product to be manufactured in the present invention.

40 **[0019]** As illustrated in FIG. 3, the top plate portion 3 has a substantially T-shape in a top view including a transverse side portion 3a and a vertical side portion 3b. Further, the top plate portion 3 has an arc-shaped connection R portion 3c from the transverse side portion 3a to the vertical side portion 3b.

45 **[0020]** As illustrated in FIG. 3, the vertical wall portion 5 is continuous from the transverse side portion 3a to the vertical side portion 3b of the top plate portion 3 via a ridge portion 9. Then, the vertical wall portion 5 includes a transverse side vertical wall portion 5a continuous from the transverse side portion 3a via a transverse side ridge portion 9a, and a vertical side vertical wall portion 5b continuous from the vertical side portion 3b via a vertical side ridge portion 9b. Further, the vertical wall portion 5 includes a connection R-side vertical wall portion 5c that is continuous from the connection R portion 3c via a connection R-side ridge portion 9c and connects the transverse side vertical wall portion 5a and the vertical side vertical wall portion 5b.

50 **[0021]** As illustrated in FIG. 3, the bottom flange portion 7 is continuous from the vertical wall portion 5, and is formed continuously from each of the transverse side vertical wall portion 5a, the vertical side vertical wall portion 5b, and the connection R-side vertical wall portion 5c.

[0022] Conventionally, such a press-formed product 1 has been press-formed in two steps of a first forming step and a second forming step as illustrated in FIG. 6.

55 **[0023]** First, in the first forming step, as illustrated in FIG. 6 (a), a blank 11, which is a metal sheet, is sandwiched between a punch 13 and a pad 15, and a die 17 is relatively moved to the punch 13 side to press-form a press-formed product 21 (see FIG. 6 (b)) having an intermediate shape having a lower vertical wall height than the target shape. Here, a top plate portion 23 of the press-formed product 21 having the intermediate shape is press-formed into the same shape as the top plate

portion 3 (see FIG. 3) of the press-formed product 1 having the target shape.

[0024] Then, in the subsequent second forming step, as illustrated in FIG. 6 (b), the top plate portion 23 of the press-formed product 21 having the intermediate shape is sandwiched between a punch 31 and a pad 33, and a die 35 is relatively moved to the punch 31 side to press-form the press-formed product 1 having the target shape with the vertical wall height higher than that of the intermediate shape.

[0025] However, when the press-formed product 21 having the intermediate shape is press-formed into the press-formed product 1 having the target shape (FIG. 3) in the second forming step, there has been a case where a crack is generated at an end portion of the transverse side ridge portion 9a connecting the transverse side portion 3a and the transverse side vertical wall portion 5a. Note that the end portion of the transverse side ridge portion 9a refers to a portion on the distal end side of the transverse side ridge portion 9a in the direction in which the transverse side portion 3a extends.

[0026] In order to identify the cause of the occurrence of a crack at the end portion of the transverse side ridge portion 9a of the press-formed product 1 including the top plate portion 3 having such a substantially T-shape, analysis (FEM analysis) by a finite element method was performed for each step of press-forming the press-formed product 1 having the target shape in two steps as illustrated in FIG. 6.

[0027] FIG. 7 illustrates the sheet thickness change rate at the forming bottom dead center of the press-formed product 21 having the intermediate shape and the press-formed product 1 having the target shape obtained by FEM analysis for each of the first forming step and the second forming step. Note that the results illustrated in FIG. 7 illustrate a case where a steel sheet having a sheet thickness of 1.2 mm and a tensile strength of 780 MPa class was used as the blank 11, the vertical wall height of the press-formed product 21 in the intermediate shape was 20 mm, and the vertical wall height of the press-formed product 1 in the target shape was 30 mm. In addition, the sheet thickness change rate illustrated in FIG. 7 is a value obtained by dividing a difference between the sheet thickness of each part of the press-formed product 21 having the intermediate shape or the press-formed product 1 and the sheet thickness of the metal sheet as the blank 11 by the sheet thickness of the blank 11. In the present specification and the drawings, in a case where the sheet thickness change rate is a positive value, it is referred to as a sheet thickness increase rate, and in a case where the sheet thickness change rate is a negative value, it is referred to as a sheet thickness decrease rate. As the absolute value of the sheet thickness decrease rate is larger, cracking is more likely to occur.

[0028] FIG. 7 (a) illustrates the sheet thickness change rate at the forming bottom dead center of the press-formed product 21 having the intermediate shape press-formed in the first forming step illustrated in FIG. 6 (a), and the sheet thickness decrease rate at the end portion of a transverse side ridge portion 29a was -4.7%. FIG. 7 (b) illustrates the sheet thickness change rate at the forming bottom dead center of the press-formed product 1 having the target shape press-formed in the second forming step illustrated in FIG. 6 (b), and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a was -16.9%. As described above, the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape is large, and as a result, the sheet thickness greatly decreases at the end portion of the transverse side ridge portion 9a in the second forming step, and cracking is likely to occur.

[0029] The reason why the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape is large will be described with reference to FIG. 8. Conventionally, as described above, the press-formed product 21 having the intermediate shape in which the vertical wall height is lower than the target shape is press-formed in the first forming step, and the press-formed product 21 having the intermediate shape is press-formed into the press-formed product 1 having the vertical wall height of the target shape in the subsequent second forming step. In this case, in the second forming step, as illustrated in FIG. 8, the transverse side ridge portion 29a is stretched, and a large tensile force acts on the transverse side ridge portion 9a. As a result, the large tensile force increases the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape as illustrated in FIG. 7 (b) described above, leading to occurrence of cracking.

[0030] Therefore, the inventor has intensively studied a method of reducing the tensile force acting on the transverse side ridge portion 9a in the process of press-forming the press-formed product 1 having the target shape in two steps. As a result, as illustrated in FIGS. 1 and 2, the inventors have conceived that, in the first forming step, FIG. 1: the vertical wall height of the distal end portion of a transverse side portion 23a in the top plate portion 23 of the press-formed product 21 having the intermediate shape is formed higher than the vertical wall height of a vertical side portion 23b, and FIG. 2: a convex portion 23d lifted upward is formed in a region including a connection R portion 23c and extending from the transverse side portion 23a to the vertical side portion 23b in the top plate portion 23 of the press-formed product 21 having the intermediate shape. Referring to FIG. 2, when the connection R portion 23c to be the top plate portion having the target shape is formed by crushing the convex portion 23d lifted upward in the subsequent second forming step, the material flows from the convex portion 23d lifted upward to the distal end portion side of the transverse side ridge portion 9a. As a result, it has been found that the tensile force generated at the transverse side ridge portion 9a can be reduced, and cracking at the end portion of the transverse side ridge portion 9a can be suppressed. The present invention has been made based on the above examination results, and specific configurations thereof are as follows.

<Method for Manufacturing Press-Formed Product>

[0031] In the method for manufacturing the press-formed product according to the first embodiment, the press-formed product 1 illustrated in FIG. 2 described above is press-formed into an intermediate shape in which the vertical wall height of the vertical side portion of the top plate portion is lower than the target shape in the first forming step, and press-formed into the vertical wall height of the target shape in the subsequent second forming step.

[0032] Then, in the method for manufacturing the press-formed product according to the first embodiment, as illustrated in FIG. 1 (a), in the first forming step, the top plate portion 23 of the press-formed product 21 having the intermediate shape is formed so that the vertical wall height of the transverse side portion 23a includes a "convex portion" that is higher than the vertical wall height of the vertical side portion. Note that, in the first forming step, as exemplified in FIGS. 9 and 10, it is sufficient that the portion of the top plate portion 23 where the transverse side portion 23a is formed may be press-formed into the press-formed product 21 having the intermediate shape using a punch 71 including a region higher than the portion where the vertical side portion 23b is formed. Alternatively, in the method for manufacturing the press-formed product according to the first embodiment, as illustrated in FIG. 2 (a), in the first forming step, the convex portion 23d having a height higher than the peripheral height (the reference height of the top plate surface) is formed in a region extending from the transverse side portion 23a including the connection R portion 23c to the vertical side portion 23b. Here, the convex portion 23d is formed so as to be higher than the vertical side portion 23b of the top plate portion 23 having the intermediate shape. Note that, in the first forming step, as exemplified in FIG. 11 (a), it is sufficient that the press-formed product 21 having the intermediate shape is press-formed using the punch 71 in which a convex portion forming portion 73d is provided in a region extending from a transverse side forming portion 73a including a connection R forming portion 73c of a top plate forming portion 73 to a vertical side forming portion 73b. In addition, in the first forming step, as exemplified in FIG. 11 (b), it is also possible to press-form the press-formed product 21 having the intermediate shape using a punch 61 in which a region extending from a convex portion forming portion 63d of the top plate forming portion to a transverse side distal end side forming portion 63a1 becomes a convex portion forming portion.

[0033] Further, in the method for manufacturing the press-formed product according to the first embodiment, in the subsequent second forming step, the intermediate formed product formed in the first forming step is press-formed into the top plate portion 3 having a target shape.

<Reason Why Occurrence of Cracking Can Be Suppressed>

[0034] The reason why the occurrence of cracking at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape can be suppressed by the method for manufacturing the press-formed product according to the first embodiment will be described with reference to FIGS. 1 and 2.

[0035] In the first embodiment, as described above, in the first forming step, press-forming is performed on the press-formed product 21 having the intermediate shape including the "convex portion" in which the height of the transverse side portion 23a of the top plate portion 23 having the intermediate shape is higher than the height of the vertical side portion 23b (FIG. 1 (a)). Alternatively, in the first forming step, the press-formed product 21 having the intermediate shape in which the convex portion 23d having a height higher than that of the vertical side portion 23b of the top plate portion 23 having the intermediate shape is formed on the top plate portion 23 is press-formed (FIG. 2 (a)).

[0036] When the press-formed product 21 having such an intermediate shape is press-formed into the press-formed product 1 having a target shape in the second forming step, as illustrated in FIGS. 1 (b) and 2 (b), the material flows from the portion having a high height in the intermediate shape to the transverse side ridge portion 9a. As a result, it is possible to reduce the tensile force generated at the transverse side ridge portion 9a of the press-formed product 1 having the target shape. As a result, a decrease in the sheet thickness at the end portion of the transverse side ridge portion 9a is reduced, and cracking can be suppressed.

<Aspects of Transverse Side Portion>

[0037] In the above description, as illustrated in FIG. 1 (a), in the first forming step, the portion on the distal end side in the direction in which the transverse side portion 23a of the press-formed product 21 having the intermediate shape extends is made uniformly high. As an aspect thereof, those illustrated in FIGS. 9 (a) and 9 (b) can be exemplified. FIG. 9 (a) is a schematic diagram of a punch (mold) for uniformly forming a portion of the top plate forming portion 73 on the distal end side of the transverse side forming portion 73a higher than the boundary line between the region obtained by extending the vertical side forming portion 73b toward the transverse side forming portion 73a and the transverse side forming portion 73a. FIG. 9 (b) is a schematic diagram of a punch (mold) that uniformly and highly forms a portion of the top plate forming portion 73 from the boundary line between the region obtained by extending the vertical side forming portion 73b toward the transverse side forming portion 73a and the transverse side forming portion 73a to the distal end. As described above, the range in which the portion on the distal end side of the transverse side forming portion 73a is uniformly increased is not

particularly limited. However, from the viewpoint of suppressing wrinkles in the vicinity of the connection R portion 3c in the second forming step, it is preferable to make the portion on the distal end side higher than the boundary line with the region where the vertical side forming portion 73b is extended in the transverse side forming portion 73a having the intermediate shape. Therefore, only the portion on the distal end side of the transverse side forming portion 73a may be made uniformly higher than that in FIG. 9 (a) (not illustrated).

[0038] In addition, in the first forming step, in a case where the portion on the distal end side of the transverse side portion 23a is made uniformly high, the increment in height of the portion on the distal end side is preferably 0.05 or more and 0.5 or less in ratio to the vertical wall height of a transverse side vertical wall portion 25a of the press-formed product 21 having the intermediate shape. In a case where the increment of the height on the distal end side of the transverse side portion 23a is smaller than 0.05, the height of the transverse side portion 23a (see FIG. 8) is insufficient, and only the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape slightly decreases, and it may be difficult to prevent cracking. In addition, in a case where the increment of the height on the distal end side of the transverse side portion 23a is larger than 0.5, the vertical wall height at the distal end of the transverse side portion 23a becomes too high in the first forming step, so that the transverse side ridge portion 29a is stretched to increase the absolute value of the sheet thickness decrease rate, and the risk of occurrence of cracking in the first forming step may increase.

[0039] Furthermore, in the present invention, in the first forming step, as exemplified in FIG. 10, the transverse side forming portion 73a having the intermediate shape may be inclined so as to gradually increase toward the distal end side in the extending direction.

[0040] FIG. 12 illustrates a result of obtaining the sheet thickness change rate for each of the press-formed product 21 having the intermediate shape and the press-formed product 1 having the target shape in the first forming step with the press-formed product 21 having the intermediate shape having the transverse side portion 23a in which the distal end side is inclined so as to be gradually increased. The results illustrated in FIG. 12 illustrate that a steel sheet having a sheet thickness of 1.2 mm and a tensile strength of 780 MPa class was used as the blank 11. Further, the vertical wall height of the intermediate shape is set to 20 mm, the vertical wall height of the target shape is set to 30 mm, and in the press-formed product 21 of the intermediate shape, the inclination angle of the distal end side of the transverse side portion 23a is set to 15.4°, and the height increment at the distal end is set to 5.5 mm.

[0041] As illustrated in FIG. 12 (a), in the press-formed product 21 having the intermediate shape, the sheet thickness decrease rate of the distal end portion of the transverse side ridge portion 29a was -9.1%, and the absolute value thereof was increased as compared with the conventional method (-4.7%) illustrated in FIG. 7 (a) described above. However, as illustrated in FIG. 12 (b), in the press-formed product 1 having the target shape, the sheet thickness decrease rate of the distal end portion of the transverse side ridge portion 9a was -11.9%, and the absolute value thereof was smaller than that in the conventional method (-16.9%) illustrated in FIG. 7 (b) described above. This result illustrates that even in a case where the distal end side of the transverse side portion 23a is inclined in the press-formed product 21 having the intermediate shape, it is possible to suppress cracking at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape.

[0042] Note that, as a specific aspect of inclining the distal end side of the transverse side portion 23a of the intermediate shape, those illustrated in FIGS. 10 (a) and 10 (b) can be exemplified. FIG. 10 (a) is obtained by setting a boundary line between a region obtained by extending the vertical side forming portion 73b of the top plate forming portion 73 toward the transverse side forming portion 73a and the transverse side forming portion 73a as a starting point, and inclining the transverse side forming portion 73a so as to gradually increase toward the distal end in the direction in which the transverse side forming portion 73a extends. FIG. 10 (b) is obtained by setting an extension region side of the vertical side forming portion 73b as a starting point with respect to a boundary line between a region obtained by extending the vertical side forming portion 73b toward the transverse side forming portion 73a and the transverse side forming portion 73a, and inclining the transverse side forming portion 73a so as to gradually increase toward the distal end in the direction in which the transverse side forming portion 73a extends.

[0043] As described above, the start position for inclining the portion on the distal end side of the transverse side forming portion 73a is not particularly limited, and may be inclined from the distal end side with respect to the boundary line between the region obtained by extending the vertical side forming portion 73b and the transverse side forming portion 73a (not illustrated).

[0044] In addition, as illustrated in FIGS. 10 (a) and 10 (b), in a case where the distal end side of the transverse side forming portion 73a is inclined in the press-formed product 21 having the intermediate shape, the inclination angle based on the transverse side portion 3a of the target shape is preferably 3 degrees or more and 25 degrees or less.

[0045] In a case where the inclination angle is smaller than 3 degrees, the absolute value of the sheet thickness decrease rate of the transverse side ridge portion 9a in the press-formed product 1 having the target shape only slightly decreases, and it may be difficult to prevent cracking. In addition, in a case where the inclination angle is larger than 25 degrees, in the first forming step (see FIG. 12 (a)), the transverse side ridge portion 29a between the transverse side portion 23a and the transverse side vertical wall portion 25a is stretched to increase the absolute value of the sheet

thickness decrease rate, and the risk of occurrence of cracking in the first forming step may increase.

[0046] Note that FIGS. 9 (a) and 9 (b) and FIGS. 10 (a) and 10 (b) illustrate specific shapes of punches (molds) for forming the transverse side portions 23a of the press-formed product 21 having an intermediate shape, but the present invention is not limited to these shapes. A shape other than the transverse side forming portion 73a illustrated in FIGS. 9 and 10 may be adopted as long as the punch (mold) is a punch in which the height of the portion on the distal end side of the transverse side portion in the top plate portion of the intermediate shape is formed higher than the portion of the vertical side portion in the top plate portion of the intermediate shape.

[0047] For example, in the first forming step, the height of the region obtained by extending the vertical side portion in the transverse side portion of the intermediate shape may be made higher than the height of the vertical side portion of the intermediate shape.

[0048] The above description is directed to the press-formed product 1 having the top plate portion 3 having a substantially T-shape in a top view. However, as illustrated in FIG. 5, the present invention may be a press-formed product 41 including a top plate portion 43 having a transverse side portion 43a and a vertical side portion 43b and having a substantially L-shape in a top view, a vertical wall portion 45, and a bottom flange portion 47.

[0049] As illustrated in FIG. 16, the press-formed product 41 having the substantially L-shaped top plate portion 43 has also been conventionally manufactured by press-forming into an intermediate shape having a low vertical wall height in the first forming step and press-forming into a vertical wall height of a target shape in the subsequent second forming step. Therefore, similarly to the press-formed product 1 having the top plate portion 3 having the substantially T-shape, a transverse side vertical wall portion 55a of a press-formed product 51 having the intermediate shape in FIG. 16 (a) is stretched in the vertical wall height direction in the second forming step in FIG. 16 (b). As a result, a large tensile force acts on a transverse side vertical wall portion 45a and a transverse side ridge portion 49a of the target shape. As a result, due to this large tensile force, the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 49a increases (17.7%), leading to occurrence of cracking.

[0050] As illustrated in FIG. 17 (a), in the first forming step, the portion on the distal end side of a transverse side portion 53a is made higher so that the portion on the distal end side of the transverse side portion 53a in the top plate portion is made higher than the portion on the vertical side portion. In the subsequent second forming step, the portion on the distal end side of the transverse side portion 53a of the intermediate shape is set to the height of the target shape.

[0051] As a result, similarly to the case of manufacturing the press-formed product 1 having the substantially T-shaped top plate portion 3 described above, the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 49a of the target shape can be decreased (-12.6%), and cracking can be suppressed.

[0052] Note that, in the press-formed product 51 having the intermediate shape illustrated in FIG. 17 (a), the height of the portion of the top plate portion on the distal end side of the transverse side portion 53a is made uniformly higher than the portion of the top plate portion on the distal end side of a vertical side portion 53b. However, even in a case where the press-formed product 41 having a substantially L-shape is manufactured, the transverse side portion 53a of the intermediate shape may have a portion on the distal end side of the transverse side portion 53a inclined such that the transverse side portion 53a gradually increases toward the distal end in the direction in which the transverse side portion 53a is connected to and extends from the vertical wall portion.

[0053] Next, FEM analysis was performed for each step of press-forming the press-formed product 1 having the target shape in the first forming step and the second forming step to verify that the decrease in sheet thickness at the end portion of the transverse side ridge portion 9a was reduced by performing intermediate forming using the punch shape illustrated in FIG. 11.

[0054] FIG. 14 illustrates the results of obtaining the sheet thickness change rate at the forming bottom dead center of the press-formed product 21 having the intermediate shape and the press-formed product 1 having the target shape by FEM analysis for the first forming step and the second forming step according to the first embodiment. Note that the results illustrated in FIG. 14 illustrate a case where a steel sheet of 780 MPa class is used as the blank 11, the vertical wall height of the press-formed product 21 having the intermediate shape is 20 mm, and the vertical wall height of the press-formed product 1 having the target shape is 30 mm. In addition, the sheet thickness change rate is a value obtained by dividing a difference between the sheet thickness of each part of the press-formed product 1 or the press-formed product 21 having the intermediate shape and the sheet thickness of the metal sheet as the blank 11 by the sheet thickness of the blank 11.

[0055] In the press-formed product 21 having the intermediate shape, as illustrated in FIG. 14 (a), the sheet thickness decrease rate at the end portion of the transverse side ridge portion 29a was -1.8%. The absolute value of the sheet thickness decrease rate is slightly increased as compared with the sheet thickness decrease rate (= -1.2%, see FIG. 13 (a)) of the press-formed product 21 having the intermediate shape press-formed by the conventional method.

[0056] On the other hand, the sheet thickness decrease rate of the press-formed product 1 having the target shape press-formed in the second forming step illustrated in FIG. 14 (b) was -8.1%. The absolute value of this value decreases as compared with the sheet thickness decrease rate (= -11.0%, see FIG. 13 (b)) at the end portion of the transverse side ridge portion 9a of the press-formed product 1 press-formed by the conventional method. As a result, it can be seen that cracking can be suppressed at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target

shape.

[0057] As described above, in the method for manufacturing the press-formed product according to the first embodiment, the top plate portion 3 having a target shape is formed by crushing the convex portion 23d in the second forming step. As a result, it is possible to reduce the tensile force generated at the transverse side ridge portion 9a continuous from the transverse side portion 3a in the top plate portion 3 having the target shape and to suppress the cracking at the end portion of the transverse side ridge portion 9a.

[0058] Note that the height increment of the convex portion 23d formed on the top plate portion 23 having the intermediate shape in the first forming step (the height to the vertex of the convex portion 23d with respect to the vertical side portion 23b of the top plate portion 23 having the intermediate shape) is preferably 5% to 50% with respect to the width of the transverse side vertical wall portion 25a.

[0059] In a case where the height increment of the convex portion 23d is less than 5%, the material flow to the transverse side ridge portion 9a due to crushing of the convex portion 23d in the second forming step is insufficient, and cracking may not be sufficiently suppressed. In addition, in a case where the height increment of the convex portion 23d exceeds 50%, the material flow to the transverse side ridge portion 9a due to crushing of the convex portion 23d in the second forming step becomes excessive, and although cracking can be suppressed, the material may be excessive and wrinkles may be generated, which may be a problem.

[0060] The present invention may have a shape other than the convex portion 23d illustrated in FIG. 2 (a) as long as the convex portion is formed in the connection R portion connecting the transverse side portion to the vertical side portion in the top plate portion of the intermediate shape.

[0061] In addition, as another aspect of the first embodiment, in the first forming step, the press-formed product 21 having the intermediate shape illustrated in FIG. 15 (a) may be press-formed. Here, in the press-formed product 21 having the intermediate shape, the convex portion 23d is formed on the top plate portion 23, and a portion 23a1 on the distal end side of the transverse side portion 23a is higher than the vertical side portion 23b of the top plate portion 23 having the intermediate shape. In this case, in the first forming step, for example, in addition to the convex portion forming portion 63d as illustrated in FIG. 11 (b), it is sufficient that the punch 61 having the transverse side distal end side forming portion 63a1 for forming the portion 23a1 having the intermediate shape uniformly higher than the vertical side portion 23b is used. Then, in the subsequent second forming step, the convex portion 23d is crushed, and the portion 23a1 having the intermediate shape is set to the height of the target shape.

[0062] FIG. 15 (a) is a diagram illustrating a result of obtaining the sheet thickness change rate at the forming bottom dead center of the press-formed product 51 having the intermediate shape according to another aspect of the first embodiment by FEM analysis. FIG. 15 (b) is a diagram illustrating a result of obtaining the sheet thickness change rate at the forming bottom dead center of the press-formed product 1 having the target shape according to another aspect of the first embodiment by FEM analysis. Note that the results illustrated in FIG. 15 illustrate a case where a steel sheet of 780 MPa class is used as the blank 11, the vertical wall height of the press-formed product 51 having the intermediate shape is 20 mm, and the vertical wall height of the press-formed product 1 having the target shape is 30 mm. In addition, the sheet thickness change rate illustrated in FIG. 15 is a value obtained by dividing a difference between the sheet thickness of each part of the press-formed product 51 having the intermediate shape or the press-formed product 1 and the sheet thickness of the metal sheet as the blank 11 by the sheet thickness of the blank 11.

[0063] In the press-formed product 51 having the intermediate shape, as illustrated in FIG. 15 (a), the sheet thickness decrease rate at the end portion of the transverse side ridge portion 29a was -2.5%. The absolute value of the sheet thickness decrease rate is increased as compared with the sheet thickness decrease rate (= -1.2%) (see FIG. 13 (a)) of the press-formed product 51 having the intermediate shape press-formed by the conventional method.

[0064] On the other hand, when the press-formed product 51 having the intermediate shape illustrated in FIG. 15 (a) was press-formed into the press-formed product 1 having the target shape in the second forming step, as illustrated in FIG. 15 (b), the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a was -4.7%. The absolute value of this value greatly decreases as compared with the sheet thickness decrease rate (= -11.0%, see FIG. 13 (b)) by the conventional method. Furthermore, the absolute value is smaller than the sheet thickness decrease rate (= -8.1%, FIG. 14 (b)) at which only the convex portion 23d is formed. Accordingly, in the first forming step, the convex portion 23d is formed on the press-formed product 51 having the intermediate shape, and the portion 23a1 on the distal end side of the transverse side portion 23a is increased, so that the decrease in the sheet thickness at the end portion of the transverse side ridge portion 9a can be further suppressed, which is preferable.

[0065] Note that, in a case where the portion 23a1 on the distal end side of the transverse side portion 23a is made higher when the press-formed product 21 having the intermediate shape is press-formed, the height increment is preferably equal to or less than the height increment of the convex portion 23d. By making the convex portion 23d higher than the portion 23a1, it is possible to crush the convex portion 23d in the process of press-forming to a target shape to generate a material flow to the transverse side ridge portion 9a.

[0066] Further, in the press-formed product 21 having the intermediate shape illustrated in FIG. 15, the height is set higher from the extension region side of the vertical side portion 23b than the boundary line between the region obtained by

extending the vertical side portion 23b toward the transverse side portion 23a and the transverse side portion 23a, and the portion 23a1 from the boundary line to the distal end side of the transverse side portion 23a is uniformly set higher.

[0067] However, in the present invention, except that the convex portion 23d is made higher than or equal to the portion 23a1, a form and a range in which the portion on the distal end side of the transverse side portion is made higher in the press-formed product having the intermediate shape press-formed in the first forming step are not particularly limited.

[0068] Further, as illustrated in FIGS. 5 and 16 (b) as an example, the present invention may be the press-formed product 41 including the top plate portion 43 having the transverse side portion 43a and the vertical side portion 43b and having a substantially L-shape in a top view, the vertical wall portion 45, and the bottom flange portion 47.

[0069] Conventionally, when the press-formed product 41 having the top plate portion 43 having a substantially L-shape is press-formed into an intermediate shape having a low vertical wall height in the first forming step and press-formed into a vertical wall height having a target shape in the subsequent second forming step, cracks are likely to occur at the end portions of the transverse side ridge portions 49a.

[0070] Therefore, in the present invention, similarly to the substantially T-shaped press-formed product 1 described above, in the first forming step, a convex portion higher than the height (reference height of the top plate surface) of the vertical side portion 53b of a top plate portion 53 having the intermediate shape is formed at the connection R portion connecting the transverse side portion and the vertical side portion of the top plate portion. Then, in the subsequent second forming step, the convex portion is crushed to form a top plate portion having a target shape.

[0071] As a result, even in a case where the press-formed product 41 having the top plate portion 43 having a substantially L-shape is manufactured, it is possible to reduce a decrease in sheet thickness at the end portion of the transverse side ridge portion 49a of the target shape and to suppress cracking. Further, in the first forming step, the convex portion may be formed on the top plate portion of the intermediate shape, and the portion on the distal end side of the transverse side portion may be made higher than the vertical side portion of the top plate portion of the intermediate shape.

[0072] According to such a method for manufacturing the press-formed product according to the first embodiment, even in a case where a high-strength steel sheet is used, it is possible to suppress cracking at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape. Therefore, the press-formed product 1 manufactured using the high-tensile steel sheet by the method for manufacturing the press-formed product according to the first embodiment can be manufactured as a vehicle body component.

(Second Embodiment)

[0073] A target shape of the press-formed product targeted in the second embodiment will be described with reference to FIG. 23. A press-formed product 101 includes a top plate portion 103, a top plate flange portion 105 extending from one longitudinal end of the top plate portion 103, and a vertical wall portion 109 continuous from the top plate portion 103 via a ridge portion 107. In addition, a vertical flange portion 111 bent outward toward one end side in the longitudinal direction of the vertical wall portion 109 and a horizontal flange portion 113 bent outward toward a lower end of the vertical wall portion 109 are provided.

[0074] The background of the invention according to the second embodiment will be described by taking the press-formed product 101 as an example. FIG. 24 is an explanatory diagram of a conventional manufacturing method for press-forming the press-formed product 101 illustrated in FIG. 23 in one step.

[0075] A blank 115 to be formed into the press-formed product 101 illustrated in FIG. 23 is made of a metal sheet, and as illustrated in FIG. 24, has a substantially rectangular overall shape, and has a top plate flange corresponding portion 117 formed on one end side and a vertical flange corresponding portions 119 formed on both sides with the top plate flange corresponding portion 117 interposed therebetween.

[0076] In addition, a mold 121 used in the conventional method for manufacturing the press-formed product 101 includes a punch 123, a pad 125 for pressing the blank 115, and a die 127 for forming the top plate portion 103, the vertical wall portion 109, the horizontal flange portion 113, and the vertical flange portion 111 in cooperation with the punch 123. The punch 123 includes a top plate forming surface portion 129 that mainly forms the top plate portion 103. Then, the top plate includes a top plate transverse side forming surface portion 168 which forms the transverse side of the top plate forming surface portion 129, a punch-side vertical wall forming surface portion 131 which forms the vertical wall portion 109 continuously to the vertical side, and a punch-side horizontal flange forming surface portion 133 which forms the flange portion continuously to the punch-side vertical wall forming surface portion 131. Further, a punch-side vertical flange forming surface portion 135 for forming the vertical flange portion 111 is provided continuously to the transverse side of the top plate forming surface portion 129.

[0077] The pad 125 has a shape corresponding to the top plate forming surface portion 129 of the punch 123. The die 127 includes a pair of right and left, and includes a die-side vertical wall forming surface portion 137, a die-side horizontal flange forming surface portion 139, and a die-side vertical flange forming surface portion 141.

[0078] In the conventional method for manufacturing the press-formed product 101, the blank 115 is sandwiched between the pad 125 and the punch 123, the die 127 is moved relative to the punch 123, the top plate portion 103, the

vertical wall portion 109, and the horizontal flange portion 113 are press-formed, and the vertical flange portion 111 is laterally bent to be press-formed into a target shape. With respect to such a conventional method for manufacturing the press-formed product 101, press-forming analysis was performed by the finite element method (FEM) in the case of using a metal sheet having a tensile strength of 1.5 GPa class, and the sheet thickness decrease rate of the press-formed product 101 after forming was determined.

[0079] FIG. 25 is a contour display of the sheet thickness decrease rate at the forming bottom dead center, and the sheet thickness decrease rate is larger at a portion having a lighter color. In the following description, the sheet thickness decrease rate is represented by a value (ratio) obtained by dividing a difference between the sheet thickness of the metal sheet as the blank 115 and the sheet thickness of each part after press-forming by the sheet thickness of the metal sheet as the blank 115. When the value of the sheet thickness decrease rate increases, cracking is likely to occur. As illustrated in the partially enlarged view of FIG. 25, the sheet thickness decrease rate is 8.9% at the end portion of the ridge portion 107 on the side where the vertical flange portion 111 is formed (hereinafter, simply "an end portion 142 of the ridge portion 107"), which indicates that the sheet thickness decrease rate is the largest and cracking is likely to occur.

[0080] The reason why the sheet thickness decrease rate of the end portion 142 of the ridge portion 107 is increased will be described with reference to FIG. 25. Arrows in FIG. 25 indicate tensile forces generated in the forming process. When the vertical wall portion 109 is formed via the ridge portion 107, a tensile force as indicated by an arrow (i) in FIG. 25 acts on the plate surface of the ridge portion 107. In addition, when the vertical flange portion 111 is laterally bent, a tensile force indicated by an arrow (ii) is further applied to the end portion 142 of the ridge portion 107. As described above, since both the tensile force at the time of forming the vertical wall portion 109 and the tensile force at the time of lateral bending of the vertical flange portion 111 act on the end portion 142 of the ridge portion 107, the sheet thickness decrease rate increases and cracking is likely to occur.

[0081] Therefore, the inventor has studied a method of reducing the tensile force acting on the end portion 142 of the ridge portion 107. As a result, in a case where the press-formed product 101 having the target shape illustrated in FIG. 23 is press-formed, the press-forming is performed in two steps of the first forming step and the second forming step, a convex portion having a height higher than the peripheral height (the reference height of the top plate surface) is formed at an end portion of the ridge portion of the intermediate formed product formed in the first forming step on a side close to the intermediate vertical flange portion, and the convex portion is crushed to the height of the target formed product in the second forming step. As a result, it has been found that the tensile force of the end portion 142 of the ridge portion 107 can be reduced, and wrinkles do not occur in the top plate portion 103 and the vertical wall portion 109. The present invention is based on such findings, and a method for manufacturing the press-formed product 101 according to the second embodiment will be described with reference to FIG. 18.

[0082] The method for manufacturing the press-formed product 101 according to the second embodiment includes a first forming step (FIG. 18 (a)) and a second forming step (FIG. 18 (b)). The first forming step is a step of press-forming an intermediate formed product 149 (see FIG. 20 (a)) having an intermediate top plate portion 143, an intermediate vertical wall portion 145 continuous with the intermediate top plate portion 143 via an intermediate ridge portion 144, and a convex portion 147 higher than the peripheral height (reference height of the top plate surface) formed at the end portion 142 of the intermediate ridge portion 144 on the side close to an intermediate vertical flange portion 153. In addition, the intermediate formed product 149 includes an intermediate horizontal flange portion 151 and the intermediate vertical flange portion 153. The second forming step is a step of press-forming the intermediate formed product 149 into the press-formed product 101 having the target shape. Hereinafter, each step will be described in detail.

<First Forming Step>

[0083] In the first forming step, as illustrated in FIG. 18 (a), the blank 115 is press-formed by an intermediate punch 155, an intermediate pad 157, and an intermediate die 159 to manufacture the intermediate formed product 149 illustrated in FIG. 20. The blank 115 is similar to that illustrated in FIG. 24. As illustrated in FIGS. 18 and 19, the intermediate punch 155 includes an intermediate top plate forming surface portion 161 having a T-shape including a vertical side and a transverse side in plan view, a punch-side intermediate vertical wall forming surface portion 163 for forming the intermediate vertical wall portion 145, a punch-side intermediate horizontal flange forming surface portion 165 for forming the intermediate horizontal flange portion 151, and a punch-side intermediate vertical flange forming surface portion 167 for forming the intermediate vertical flange portion 153.

[0084] A convex portion forming portions 169 for forming the convex portions 147 are formed on both sides in the width direction of the end portion of the intermediate top plate forming surface portion 161. In the intermediate punch 155 illustrated in FIG. 19, the convex portion forming portion 169 extends toward the top plate flange portion 105 (see FIG. 20), and the overall height of the intermediate top plate forming surface portion 161 is increased. The punch-side intermediate vertical wall forming surface portion 163 has an inclination angle smaller than that of the conventional punch-side vertical wall forming surface portion 131 illustrated in FIG. 24. In addition, the angle formed by the punch-side intermediate horizontal flange forming surface portion 165 and the punch-side intermediate vertical wall forming surface portion 163 is

set to be the same angle as the angle formed by the vertical wall portion 109 having the target shape and the horizontal flange portion 113 having the target shape.

[0085] The intermediate pad 157 in FIG. 18 has a shape corresponding to the intermediate top plate forming surface portion 161 of the intermediate punch 155. The intermediate die 159 includes a die-side intermediate vertical wall forming surface portion 171 having a shape corresponding to the punch-side intermediate vertical wall forming surface portion 163, and a die-side intermediate horizontal flange forming surface portion 173 having a shape corresponding to the punch-side intermediate horizontal flange forming surface portion 165. In addition, a die-side intermediate vertical flange forming surface portion 175 having a shape corresponding to the punch-side intermediate vertical flange forming surface portion 167 is provided.

[0086] The intermediate formed product 149 illustrated in FIG. 20 (a) is manufactured by the intermediate punch 155, the intermediate pad 157, and the intermediate die 159. As described above, the intermediate formed product 149 includes the intermediate top plate portion 143, the intermediate vertical wall portion 145, the top plate flange portion 105, the intermediate horizontal flange portion 151, and the intermediate vertical flange portion 153. In addition, the convex portion 147 is formed at an end portion 146 of the intermediate ridge portion 144 in the intermediate formed product 149.

[0087] FIG. 20 (b) illustrates an A-A cross section of the intermediate formed product 149 in FIG. 20 (a) in comparison with the press-formed product 1 having a target shape (FIG. 21) (two-dot chain line). As illustrated in FIG. 20 (b), the convex portion 147 is formed at the end portion of the ridge portion of the intermediate formed product 149, so that the end portion 146 of the intermediate ridge portion 144 swells, and the bending radius of the top plate portion 103 and the vertical wall portion 109 is made larger than the target shape, whereby the tensile force when bending the top plate portion 103 and the vertical wall portion 109 in the first forming step can be reduced. As illustrated in FIG. 20 (a), the sheet thickness decrease rate of the end portion 146 of the intermediate ridge portion 144 is 2.8%, which is smaller than 8.9% of the conventional press-formed product 101 illustrated in FIG. 25.

<Second Forming Step>

[0088] The second forming step is a step of press-forming the intermediate formed product 149 into the press-formed product 101 having the target shape. The punch 123, the pad 125, and the die 127 used in the second forming step have the same shapes as those of the conventional punch 123, the pad 125, and the die 127 illustrated in FIG. 24.

[0089] In the second forming step, the convex portion 147 of the end portion 146 of the intermediate ridge portion 144 illustrated in FIG. 20 is crushed into the target shape, so that a material flow toward the end portion 146 of the intermediate ridge portion 144 is generated to reduce the tensile force, and the end portion 142 of the ridge portion 107 of the press-formed product 101 having the target shape illustrated in FIG. 23 can be prevented from cracking. In addition, since the convex portion 147 is applied to the end portion 146 of the intermediate ridge portion 144 and not to the entire region, an excessive material flow does not occur in the second forming step, and wrinkles do not occur in the top plate portion 103 and the vertical wall portion 109 of the press-formed product 101 having the target shape.

[0090] FIG. 21 illustrates the press-formed product 101 formed in the second forming step. As illustrated in FIG. 21, the sheet thickness decrease rate of the end portion 142 of the ridge portion 107 in the press-formed product 101 formed by the second forming step through the first forming step was 4.1%. As described above, as compared with the sheet thickness decrease rate of 8.9% (see FIG. 25) of the end portion 142 of the conventional ridge portion 107 illustrated in FIG. 25, it can be seen that the sheet thickness decrease rate is reduced in the present invention, and cracking can be prevented.

[0091] Note that the shape of the intermediate punch 155 in the first forming step is not limited to that illustrated in FIG. 19, and may be, for example, that illustrated in FIGS. 22 (a) and 22 (b). In FIG. 22 (a), the convex portion forming portion 169 is formed only on both sides in the width direction of the end portion of the intermediate top plate forming surface portion 161, and in FIG. 22 (b), the convex portion forming portion 169 extends to the top plate transverse side forming surface portion 168, but the other region of the transverse side of the top plate transverse side forming surface portion 168 is not high.

[0092] Further, the press-formed product 101 having the target shape of the second embodiment includes the vertical flange portion 111, but the press-formed product having the target shape of the present invention includes a press-formed product not including the vertical flange.

(Third Embodiment)

[0093] A target shape of the press-formed product targeted in the third embodiment will be described with reference to FIG. 30. A press-formed product 177 includes a top plate portion 179 having a curved portion in a top view and a vertical wall portion 183 continuous from a part of the inner side of the curve of the top plate portion 179 via a ridge portion 181, and an end portion 185 of the ridge portion 181 has an R shape.

[0094] The background of the invention according to the third embodiment will be described by taking the press-formed product 177 as an example. FIG. 31 is an explanatory diagram of a conventional method for manufacturing the press-

formed product 177 in which the press-formed product 177 illustrated in FIG. 30 is press-formed in one step.

[0095] A blank 187 to be formed into the press-formed product 177 is made of a metal sheet, and as illustrated in FIG. 31, a top plate corresponding portion 189 formed in the top plate portion 179 is curved in an arc shape. Then, on the inner side of the curve of the top plate corresponding portion 189, a vertical wall corresponding portion 191 is formed at a portion that enters the inner side in the longitudinal direction from both ends of the top plate corresponding portion 189. In addition, an end portion 193 of the vertical wall corresponding portion 191 is formed in an R shape.

[0096] In the conventional method for manufacturing the press-formed product 177, the blank 187 is sandwiched between a pad 199 of a mold 195 and a punch 197, a die 201 is moved relative to the punch 197, and the top plate portion 179 and the vertical wall portion 183 are press-formed to obtain a target shape. With respect to such a conventional method for manufacturing the press-formed product 177, the press-forming analysis was performed by the finite element method (FEM) for the case where a metal sheet having a tensile strength of 980 MPa class was used for the blank 187, and the sheet thickness decrease rate was determined for the press-formed product 177 after forming.

[0097] FIG. 32 is a contour display of the sheet thickness decrease rate at the forming bottom dead center, and the sheet thickness decrease rate is larger at a portion having a lighter color. As illustrated in FIG. 32, the sheet thickness decrease rate of the end portion 185 of the ridge portion 181 is 10.8%, and it can be seen that the sheet thickness decrease rate is the largest and cracking is likely to occur.

[0098] The reason why the sheet thickness decrease rate of the end portion 185 of the ridge portion 181 is increased will be described with reference to FIG. 33. Arrows in FIG. 33 indicate tensile forces generated in the forming process. When the vertical wall portion 183 is formed via the ridge portion 181, a tensile force as indicated by an arrow (iii) in FIG. 33 acts on the plate surface of the ridge portion 181. In addition, as indicated by an arrow (iv), a tensile force is generated at the end portion 185 of the ridge portion by drawing the vertical wall portion 183 inward. In addition, the end portion 185 of the ridge portion has a notch shape, and as indicated by an arrow (v), a large tensile force acts due to concentration of the tensile force, the sheet thickness decrease rate increases, and cracking easily occurs.

[0099] Therefore, the inventor has studied a method of reducing the tensile force acting on the end portion 185 of the ridge portion. As a result, press-forming was performed in two steps of the first forming step and the second forming step. Then, a convex portion higher than the peripheral height (the reference height of the top plate surface) is applied to the end portion of the ridge portion of the intermediate formed product formed in the first forming step, and the convex portion is crushed to the height of the target formed product in the second forming step. As a result, it has been found that the tensile force of the end portion 185 of the ridge portion 181 can be reduced, and wrinkles do not occur in the top plate portion 179 and the vertical wall portion 183. The present invention is based on such findings, and a method for manufacturing the press-formed product 177 according to the third embodiment will be described with reference to FIG. 26.

[0100] The method for manufacturing the press-formed product 177 according to the third embodiment includes a first forming step (FIG. 26 (a)) and a second forming step (FIG. 26 (b)). The first forming step is a step of press-forming an intermediate formed product 211 (see FIG. 28) having an intermediate top plate portion 203, an intermediate vertical wall portion 207 continuous with the intermediate top plate portion 203 via an intermediate ridge portion 205, and a convex portion 209 higher than the peripheral height (reference height of the top plate surface) formed at an end portion 206 of the intermediate ridge portion 205. In addition, the second forming step is a step of press-forming the intermediate formed product 211 into the press-formed product 177 (FIG. 29). Hereinafter, each step will be described in detail.

<First Forming Step>

[0101] In the first forming step, as illustrated in FIG. 26 (a), the blank 187 is press-formed by an intermediate punch 213, an intermediate pad 215, and an intermediate die 217 to manufacture the intermediate formed product 211 illustrated in FIG. 28. The blank 187 is similar to that illustrated in FIG. 31. As illustrated in FIGS. 26 (a) and 27 schematically illustrating the intermediate punch 213 in FIG. 26 (a), the intermediate punch 213 includes an intermediate top plate forming surface portion 219 and a punch-side intermediate vertical wall forming surface portion 221 for forming the intermediate ridge portion 205.

[0102] Punch-side convex portion forming portions 223 for forming the convex portions 209 are formed on both sides in the width direction of the end portion of the intermediate top plate forming surface portion 219. The punch illustrated in FIGS. 26 (a) and 27 is disposed such that the position of the central portion of the punch-side convex portion forming portion 223 overlaps with the end portion 206 of the intermediate ridge portion 205.

[0103] The intermediate pad 215 has a shape corresponding to the intermediate top plate forming surface portion 219 of the intermediate punch 213. The intermediate die 217 includes a die-side intermediate vertical wall forming surface portion 225 having a shape corresponding to the punch-side intermediate vertical wall forming surface portion 221 and a die-side convex portion forming portion 226 having a shape corresponding to the punch-side convex portion forming portion 223.

[0104] FIG. 28 (b) illustrates a cross section taken along line B-B in FIG. 28 (a) in comparison with a cross section of a target press-formed product shape (two-dot chain line). As illustrated in FIG. 28 (b), the convex portion 209 is formed at the end portion of the ridge portion of the intermediate formed product 211, so that the end portion 206 of the intermediate ridge

portion 205 swells, and the bending radius of the intermediate top plate portion 203 and the intermediate vertical wall portion 207 is made larger than the target shape, whereby the tensile force when bending the intermediate top plate portion 203 and the intermediate vertical wall portion 207 in the first forming step can be reduced. As illustrated in FIG. 28 (a), the sheet thickness decrease rate of the end portion 206 of the intermediate ridge portion 205 is 5.5%, which is smaller than 10.8% of the conventional press-formed product 177 illustrated in FIG. 32.

<Second Forming Step>

[0105] The second forming step is a step of press-forming the intermediate formed product 211 into the press-formed product 177 having the target shape. The punch 197, the pad 199, and the die 201 used in the second forming step have the same shapes as those of the conventional punch 197, the pad 199, and the die 201 illustrated in FIG. 31.

[0106] In the second forming step, the convex portion 209 of the end portion 206 of the intermediate ridge portion 205 in FIG. 28 is crushed into the target shape, so that a material flow toward the end portion 206 of the intermediate ridge portion 205 is generated to reduce the tensile force, and the end portion 185 of the ridge portion 181 of the press-formed product 177 having the target shape can be prevented from cracking. In addition, since the convex portion 209 is applied to the end portion 206 of the intermediate ridge portion 205 and not to the entire region, an excessive material flow does not occur, and wrinkles do not occur in the top plate portion 179 and the vertical wall portion 183 of the press-formed product 177 having the target shape.

[0107] FIG. 29 illustrates the press-formed product 177 formed in the second forming step. As illustrated in FIG. 29, the sheet thickness decrease rate of the end portion 185 of the ridge portion 181 in the press-formed product 177 formed by the second forming step through the first forming step was 7.0%. As described above, it can be seen that the sheet thickness decrease rate of the end portion 185 of the ridge portion 181 greatly decreases as compared with the sheet thickness decrease rate of 10.8% (see FIG. 32) when press-forming is performed in the conventional one step, and cracking can be prevented.

[0108] Note that the shape of the intermediate punch 213 in the first forming step is not limited to that illustrated in FIG. 27 (a), and may be, for example, that illustrated in FIG. 27 (b). In the configuration illustrated in FIG. 27 (a), the punch-side convex portion forming portion 223 is disposed such that the position of the top of the punch-side convex portion forming portion extends to the outside of the end portion 206 of the intermediate ridge portion 205, and in the configuration illustrated in FIG. 27 (b), the punch-side convex portion forming portion 223 extends to the end of the intermediate top plate forming surface portion 219 along the ridge portion.

[0109] In addition, the curvature of the curve of the ridge portions 181 of the top plate portion 179 and the vertical wall portion 183 in FIG. 29 is not necessarily constant, and a part thereof may be a straight line. In addition, the intermediate vertical wall portion 207 of the intermediate formed product 211 does not necessarily have to have the same angle as the angle of the target shape, and may have a smaller inclination than the angle of the target shape or no inclination.

[Examples]

[0110] Since analysis for verifying the effects of the present invention has been performed, this will be described below.

(Example 1)

[0111] In Example 1, the press-formed product 1 including the top plate portion 3 having a substantially T-shape illustrated in FIG. 3 and the press-formed product 41 including the top plate portion 43 having a substantially L-shape illustrated in FIG. 5 were used. Then, each of the press-formed product 1 and the press-formed product 41 was manufactured by the first forming step and the second forming step of the method for manufacturing the press-formed product according to the first embodiment described above.

[0112] In the analysis, a steel sheet having a sheet thickness of 1.2 mm and a tensile strength of 780 MPa class was used as a blank as a metal sheet. Then, FEM analysis was performed for each of the first forming step and the second forming step, and the effect of suppressing the occurrence of cracking at the end portions of the transverse side ridge portion 9a (press-formed product 1 having a substantially T-shape) and the transverse side ridge portion 49a (press-formed product 41 having a substantially L-shape) in the target shape was examined. Here, the effect of suppressing the occurrence of cracking was evaluated by the sheet thickness decrease rate. Note that, as described above, the sheet thickness decrease rate is a negative value of the sheet thickness change rate obtained by dividing the difference between the sheet thickness of each part of the press-formed product having the intermediate shape or the target shape and the sheet thickness of the metal sheet as the blank by the sheet thickness of the blank.

[0113] In Example 1, in the first forming step, the invention example was such that the height of the portion on the distal end side of the transverse side portion 23a in the top plate portion having the intermediate shape was set to be higher than the height of the portion of the vertical side portion in the top plate portion having the intermediate shape. Then, in the

invention example, in the first forming step, the transverse side forming portion in the top plate forming portion formed into the intermediate shape had the shape illustrated in FIGS. 34 and 35. In FIG. 34, the distal end side of the transverse side portion of the top plate portion of the intermediate shape is inclined so as to gradually increase toward the distal end in the direction in which the transverse side portion extends. Here, the press-formed product having an intermediate shape in which the distal end side of the transverse side portion is inclined was changed to various inclination angles.

[0114] On the other hand, in FIG. 35, the transverse side portion of the top plate portion having the intermediate shape is uniformly raised at a portion on the distal end side in the direction in which the transverse side portion extends. Further, in the intermediate shape in which the distal end side of the transverse side portion was made uniformly high, the convex portion 23d lifted upward from the transverse side portion to the vertical side portion was formed so as to straddle the connection R portion having a substantially T-shape or a substantially L-shape. Here, for the intermediate shape in which the distal end side of the transverse side portion was made uniformly high, the height increment of the portion on the distal end side of the transverse side portion was variously changed, and the height of the convex portion 23d was set to be the same as the height of the portion on the distal end side of the transverse side portion.

[0115] Further, in Example 1, as a comparison target, as illustrated in FIG. 7 (a) or FIG. 16 (a) described above, a case where the heights of the portions of the top plate portions 23 and 53 of the press-formed articles 21 and 51 having the intermediate shapes on the distal end sides of the transverse side portions 23a and 53a are set to the heights of the top plate portions 3 and 43 having the target shapes was taken as a conventional example. Then, also in the conventional example, similarly to the invention example, FEM analysis was performed for each of the first forming step and the second forming step, and the sheet thickness decrease rate was obtained for each of the press-formed articles having the intermediate shape and the target shape at the forming bottom dead center.

[0116] Table 1 illustrates the results of the inclination angle of the portion on the distal end side of the transverse side portion 23a or the portion on the distal end side of the transverse side portion 53a in the top plate portion of the intermediate shape and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the press-formed product having the target shape or the transverse side ridge portion 49a of the press-formed product 41. Note that the sheet thickness decrease rate decreases as the absolute value of the value increases.

Table 1

No.	Inclination angle of portion on distal end side of transverse side portion (degrees)	Sheet thickness decrease rate of end portion of transverse side ridge portion of press-formed product having target shape (%)		Notes
		T-shape	L-shape	
1	0	-16.9	-17.7	Conventional example
2	3.8	-15.2	-15.5	Invention example
3	6.3	-14.0	-14.4	Invention example
4	8.8	-13.1	-14.0	Invention example
5	12.5	-12.2	-14.4	Invention example
6	15.4	-11.9	-14.1	Invention example
7	18.3	-10.6	-13.8	Invention example
8	21.1	-10.7	-15.4	Invention example
9	23.7	-11.1	-14.2	Invention example

[0117] In the conventional example of No. 1, the inclination of the portion on the distal end side of the transverse side portion 23a (substantially T-shaped) or the distal end side of the transverse side portion 53a (substantially L-shaped) in the top plate portion having the intermediate shape is set to 0°. In No. 1, the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a (substantially T-shaped) of the target shape is -16.9%, and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 49a (substantially L-shaped) is -17.7%. These absolute values are large, and cracking is considered to occur.

[0118] On the other hand, in Nos. 2 to 9, the inclination angle of the portion on the distal end side of the transverse side portion 23a or the distal end side of the transverse side portion 53a in the top plate portion having the intermediate shape is

set to 3.8° to 23.7°. It can be seen that the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a or the transverse side ridge portion 49a of the target shape in Nos. 2 to 9 decreases as compared with the conventional example (-17.7%). In particular, in No. 7 in which the inclination angle was 18.3°, the sheet thickness decrease rate was -10.6%, and the absolute value thereof significantly decreased, which was favorable.

[0119] Table 2 illustrates the height of the portion on the distal end side of the transverse side portion 23a or the distal end side of the transverse side portion 53a in the top plate portion of the intermediate shape, and the results of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a or the transverse side ridge portion 49a of the press-formed product of the target shape.

Table 2

No.	Height increment of portion on distal end side of transverse side portion (mm)	Sheet thickness decrease rate of end portion of transverse side ridge portion of press-formed product having target shape (%)		Notes
		T-shape	L-shape	
1	0	-16.9	-17.7	Conventional example
11	3	-15.1	-14.6	Invention example
12	5	-13.1	-13.5	Invention example
13	7	-11.8	-12.6	Invention example
14	10	-12.0	-12.1	Invention example
15	15	-11.0	-12.7	Invention example
16	20	-10.8	-12.3	Invention example
17	25	-8.0	-7.4	Invention example

[0120] In the conventional example of No. 1, the height increment on the distal end side of the transverse side portion 23a (substantially T-shaped) or the distal end side of the transverse side portion 53a (substantially L-shaped) in the top plate portion having the intermediate shape is set to 0 mm. In No. 1, the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a (substantially T-shaped) of the target shape is -16.9%, and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 49a (substantially L-shaped) is -17.7%. These absolute values are large, and cracking is considered to occur.

[0121] On the other hand, in Nos. 11 to 17, the height increment of the portion on the distal end side of the transverse side portion 23a (substantially T-shape) or the distal end side of the transverse side portion 53a (substantially L-shape) in the top plate portion having the intermediate shape is set to 3 mm to 25 mm. It can be seen that the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a (substantially T-shape) or the transverse side ridge portion 49a (substantially L-shape) of the target shape in Nos. 11 to 17 decreases as compared with the conventional example. In particular, in No. 17 in which the height increment was 25 mm, the sheet thickness decrease rate was -8.0%, and the absolute value thereof significantly decreased, which was favorable.

[0122] As described above, according to the method of the present invention, it has been illustrated that when a press-formed product including a top plate portion having a substantially T-shape or a substantially L-shape is manufactured by press-forming in two steps, cracking at the end portion of the transverse side ridge portion can be suppressed.

(Example 2)

[0123] In Example 2, the press-formed product 1 including the top plate portion 3 having a substantially T-shape with the dimensions illustrated in FIG. 4 is subjected to the press-forming by the first forming step and the second forming step of the method for manufacturing the press-formed product according to the first embodiment described above.

[0124] A steel sheet having a sheet thickness of 1.2 mm and a tensile strength of 780 MPa class was used as a blank. Then, the FEM analysis of the first forming step and the second forming step was performed, and the effect of suppressing the occurrence of cracking at the end portion of the transverse side ridge portion 9a of the target shape was examined. Here, the effect of suppressing the occurrence of cracking was evaluated by the sheet thickness decrease rate of the press-formed product having a target shape obtained by FEM analysis. Note that, as described above, the sheet thickness

decrease rate is a negative value of the sheet thickness change rate obtained by dividing the difference between the sheet thickness of each part of the press-formed product having the intermediate shape or the target shape and the sheet thickness of the metal sheet as the blank by the sheet thickness of the blank.

[0125] In the invention example, in the first forming step, the press-formed product 21 having the intermediate shape (FIG. 2 (a)) or the press-formed product 51 having the intermediate shape (FIG. 15 (a)) was press-formed using the punch 71 illustrated in FIG. 11 (a) or the punch 61 illustrated in FIG. 11 (b) described above.

[0126] The height increment of the convex portion 23d was variously changed by changing the height of the convex portion forming portion 73d of the punch 71 illustrated in FIG. 11 (a).

[0127] In addition, the height of the convex portion forming portion 63d of the punch 61 illustrated in FIG. 11 (b) and the height of the transverse side distal end side forming portion 63a1 were made equal to each other, and the height increment in the convex portion 23d was variously changed.

[0128] In addition, as a comparison, as illustrated in FIG. 13 described above, a case where no convex portion is formed on the connection R portion 23c of the top plate portion 23 of the press-formed product 21 having the intermediate shape was taken as a conventional example. Then, in the conventional example, similarly to the invention example, FEM analysis was performed for the first forming step and the second forming step, and the sheet thickness decrease rate was obtained for the press-formed product 1 having the target shape at the forming bottom dead center. Note that, in the present example, cracking occurs when the absolute value of the sheet thickness decrease rate exceeds 10% by actual press-forming and press-forming analysis in advance.

[0129] Table 3 illustrates the results of the height increment at the convex portion 23d of the press-formed product 21 having the intermediate shape illustrated in FIG. 2 (a) or FIG. 13 (a) and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape. Note that the sheet thickness decreases as the absolute value of the sheet thickness decrease rate increases.

Table 3

No.	Height increment in bulging convex portion (mm)	Sheet thickness decrease rate in end portion of transverse side ridge portion of press-formed product having target shape (%)	Notes
21	0	-11.0	Conventional example
22	3	-10.0	Invention example
23	5	-9.4	Invention example
24	7	-9.0	Invention example
25	10	-8.1	Invention example

[0130] In the conventional example of No. 21, the height increment of the convex portion is set to 0 mm without forming the convex portion on the press-formed product 21 having the intermediate shape. In No. 21, the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape was - 11.0%, and the absolute value was large, so that cracking occurred.

[0131] On the other hand, in the invention examples No. 22 to No. 25, the convex portion 23d is formed on the top plate portion 23 having the intermediate shape, and the height increment thereof is set to 3 mm to 10 mm. It can be seen that the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape in Nos. 22 to 25 decreased as compared with the conventional example (-11.0%). In particular, in No. 25 in which the height increment was 10 mm, the sheet thickness decrease rate was -8.1%, and the absolute value greatly decreased.

[0132] Table 4 illustrates the results of the height increment at the portion 23a1 on the distal end side of the convex portion 23d and the transverse side portion 23a of the press-formed product 21 having the intermediate shape illustrated in FIG. 15 or 13 and the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the press-formed product 1 having the target shape. Note that, similarly to Table 3, the sheet thickness decreases as the absolute value of the sheet thickness decrease rate increases.

Table 4

No.	Height increment in bulging convex portion and portion on distal end side of transverse side portion (mm)	Sheet thickness decrease rate in end portion of transverse side ridge portion of press-formed product having target shape (%)	Notes
21	0	-11.0	Conventional example

(continued)

No.	Height increment in bulging convex portion and portion on distal end side of transverse side portion (mm)	Sheet thickness decrease rate in end portion of transverse side ridge portion of press-formed product having target shape (%)	Notes
31	3	-9.6	Invention example
32	5	-7.7	Invention example
33	7	-6.2	Invention example
34	10	-4.7	Invention example

[0133] In the conventional example of No. 21, similarly to Table 3 described above, the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape was -11.0%, and the absolute value was large, so that cracking occurred.

[0134] On the other hand, in the invention examples No. 31 to No. 34, the height increment in the portion 23a1 on the distal end side of the convex portion 23d and the transverse side portion 23a of the intermediate shape is set to 3 mm to 10 mm. It can be seen that the absolute value of the sheet thickness decrease rate at the end portion of the transverse side ridge portion 9a of the target shape in Nos. 31 to 34 decreases as compared with the conventional example. In particular, No. 34 in which the height increment was 10 mm had a favorable sheet thickness decrease rate of -4.7%.

[0135] As described above, according to the method of the present invention, it has been illustrated that when a press-formed product including a top plate portion having a substantially T-shape is manufactured by press-forming in two steps, it is possible to suppress cracking at the end portion of the transverse side ridge portion.

(Example 3)

[0136] In Example 3, a 1.5 GPa class material having a thickness of 1.2 mm was used as the metal sheet of the blank 115, and the press-formed product 101 having the target dimension illustrated in FIG. 23 was press-formed by the method of the present invention, the comparative method, and the conventional method.

[0137] In the method of the present invention, the height h of the convex portion forming portion 169 of the intermediate punch 155 was changed using the intermediate punch 155 illustrated in FIG. 19 in the first forming step, so that the intermediate formed product 149 in which the height increment Δh of the end portion 146 of the intermediate ridge portion 144 illustrated in FIG. 20 was changed was press-formed, and then the target press-formed product 101 illustrated in FIG. 23 was press-formed in the second forming step. The comparison method is a method for manufacturing a press-formed product in which the convex portion 147 is not formed in the first step although press-forming is performed in two steps. In the conventional method, as illustrated in FIG. 24, press-forming was performed in one step.

[0138] The sheet thickness decrease rate of the end portion 142 (see FIG. 23) of the ridge portion 107 was obtained by FEM analysis. The sheet thickness decrease rate is a value (ratio) obtained by dividing a difference between the sheet thickness of the metal sheet as the blank and the sheet thickness of each part of the formed product by the sheet thickness of the metal sheet as the blank 115. Table 5 illustrates the ridge portion end portion height increment Δh and the maximum sheet thickness decrease rate of the target press-formed product 101. Note that it is to be noted that actual press-forming and press-forming analysis in advance illustrate that cracking occurs in the target press-formed product 101 of Example 3 when the maximum sheet thickness decrease rate is 7.0% or more.

Table 5

No.	Ridge portion end portion height increment Δh (mm)	Number of steps	Maximum sheet thickness decrease rate of target press-formed product (%)	Notes
41	0.0	1	8.9	Conventional example
42	0.0	2	7.2	Comparative example
43	0.5	2	4.2	Invention example
44	1.0	2	3.9	Invention example
45	1.5	2	4.1	Invention example
46	2.0	2	4.2	Invention example

(continued)

No.	Ridge portion end portion height increment Δh (mm)	Number of steps	Maximum sheet thickness decrease rate of target press-formed product (%)	Notes
47	3.0	2	4.6	Invention example
48	5.0	2	4.5	Invention example
49	7.0	2	5.2	Invention example
50	9.0	2	6.0	Invention example

[0139] In the conventional example in which press-forming was performed in one step of No. 41, the height increment Δh at the end portion of the ridge portion was 0, the maximum sheet thickness decrease rate was as large as 8.9%, and cracking occurred. In addition, the comparative example of No. 42 was press-formed in two steps, but the height increment Δh at the end portion of the ridge portion was 0, the maximum sheet thickness decrease rate was as large as 7.2%, and cracking occurred. On the other hand, in Nos. 43 to 50, it was found that the maximum sheet thickness decrease rate was reduced, and cracking was suppressed. In particular, No. 44 had a maximum sheet thickness decrease rate of 3.9%, which was less than half, which was significantly favorable.

(Example 4)

[0140] In Example 4, a 980 MPa class material having a thickness of 1.4 mm was used as a blank metal sheet, and press-forming was performed on the press-formed product 177 having a target dimension illustrated in FIG. 30 by the method of the present invention, the comparative method, and the conventional method. In the method of the present invention, the height H of the punch-side convex portion forming portion 223 of the intermediate punch 213 was changed using the intermediate punch 213 illustrated in FIG. 27 (a) in the first forming step, so that the intermediate formed product 211 in which the height increment ΔH of the end portion 206 of the intermediate ridge portion 205 illustrated in FIG. 28 (a) was changed was press-formed, and then the target press-formed product 177 illustrated in FIG. 30 was press-formed in the second forming step. The comparison method is a method for manufacturing the press-formed product 101 in which the convex portion 209 is not formed in the first step although the press-forming is performed in two steps. In the conventional method, as illustrated in FIG. 31, press-forming was performed in one step.

[0141] The sheet thickness decrease rate of the end portion 185 (see FIG. 30) of the ridge portion 181 was obtained by FEM analysis. Table 6 illustrates the ridge portion end portion height increment ΔH and the maximum sheet thickness decrease rate of the target press-formed product 177. Note that it is to be noted that actual press-forming and press-forming analysis in advance illustrate that cracking occurs in the target press-formed product 229 of Example 4 when the maximum sheet thickness decrease rate is 10.5% or more.

Table 6

No.	Ridge portion end portion height increment ΔH (mm)	Number of steps	Maximum sheet thickness decrease rate of target press-formed product (%)	Notes
51	0.0	1	10.8	Conventional example
52	0.0	2	10.5	Comparative example
53	1.0	2	10.3	Invention example
54	2.0	2	9.9	Invention example
55	3.0	2	8.9	Invention example
56	5.0	2	7.0	Invention example
57	7.0	2	5.4	Invention example
58	9.0	2	4.6	Invention example
59	11.0	2	5.3	Invention example

[0142] In the conventional example in which press-forming was performed in one step of No. 51, the height increment ΔH at the end portion of the ridge portion was 0, the maximum sheet thickness decrease rate was as large as 10.8%, and

5 cracking occurred. In addition, the comparative example of No. 52 was press-formed in two steps, but the height increment ΔH at the end portion of the ridge portion was 0, the maximum sheet thickness decrease rate was as large as 10.5%, and cracking occurred. On the other hand, in Nos. 53 to 59, it was found that the maximum sheet thickness decrease rate was reduced, and cracking was suppressed. In particular, No. 58 had a maximum sheet thickness decrease rate of 4.6%, which was less than half, which was significantly favorable.

Industrial Applicability

10 **[0143]** The present invention can provide a method for manufacturing a press-formed product capable of suppressing occurrence of cracking when a press-formed product including a top plate portion having a substantially T-shape or a substantially L-shape is manufactured by press-forming.

Reference Signs List

15 **[0144]**

- 1 PRESS-FORMED PRODUCT
- 3 TOP PLATE PORTION
- 3a TRANSVERSE SIDE PORTION
- 20 3b VERTICAL SIDE PORTION
- 3c CONNECTION R PORTION
- 5 VERTICAL WALL PORTION
- 5a TRANSVERSE SIDE VERTICAL WALL PORTION
- 5b VERTICAL SIDE VERTICAL WALL PORTION
- 25 5c CONNECTION R-SIDE VERTICAL WALL PORTION
- 7 BOTTOM FLANGE PORTION
- 9 RIDGE PORTION
- 9a TRANSVERSE SIDE RIDGE PORTION
- 9b VERTICAL SIDE RIDGE PORTION
- 30 9c CONNECTION R-SIDE RIDGE PORTION
- 11 BLANK
- 13 PUNCH
- 15 PAD
- 17 DIE
- 35 21 PRESS-FORMED PRODUCT HAVING INTERMEDIATE SHAPE
- 23 TOP PLATE PORTION
- 23a TRANSVERSE SIDE PORTION
- 23a1 PORTION ON DISTAL END SIDE
- 23b VERTICAL SIDE PORTION
- 40 23c CONNECTION R PORTION
- 23d CONVEX PORTION
- 25a TRANSVERSE SIDE VERTICAL WALL PORTION
- 29a TRANSVERSE SIDE RIDGE PORTION
- 31 PUNCH
- 45 33 PAD
- 35 DIE
- 41 PRESS-FORMED PRODUCT (SUBSTANTIALLY L-SHAPED)
- 43 TOP PLATE PORTION
- 43a TRANSVERSE SIDE PORTION
- 50 43b VERTICAL SIDE PORTION
- 45 VERTICAL WALL PORTION
- 45a TRANSVERSE SIDE VERTICAL WALL PORTION
- 47 BOTTOM FLANGE PORTION
- 49a TRANSVERSE SIDE RIDGE PORTION
- 55 51 PRESS-FORMED PRODUCT HAVING INTERMEDIATE SHAPE (SUBSTANTIALLY L-SHAPED)
- 53 TOP PLATE PORTION
- 53a TRANSVERSE SIDE PORTION
- 53b VERTICAL SIDE PORTION

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55a TRANSVERSE SIDE VERTICAL WALL PORTION
61 PUNCH
63a1 TRANSVERSE SIDE DISTAL END SIDE FORMING PORTION
63b VERTICAL SIDE FORMING PORTION
5 63d CONVEX PORTION FORMING PORTION
71 PUNCH
73 TOP PLATE FORMING PORTION
73a TRANSVERSE SIDE FORMING PORTION
73b VERTICAL SIDE FORMING PORTION
10 73c CONNECTION R FORMING PORTION
73d CONVEX PORTION FORMING PORTION
101 PRESS-FORMED PRODUCT
103 TOP PLATE PORTION
105 TOP PLATE FLANGE PORTION
15 107 RIDGE PORTION
109 VERTICAL WALL PORTION
111 VERTICAL FLANGE PORTION
113 HORIZONTAL FLANGE PORTION
115 BLANK
20 117 TOP PLATE FLANGE CORRESPONDING PORTION
119 VERTICAL FLANGE CORRESPONDING PORTION
121 MOLD
123 PUNCH
125 PAD
25 127 DIE
129 TOP PLATE FORMING SURFACE PORTION
131 PUNCH-SIDE VERTICAL WALL FORMING SURFACE PORTION
133 PUNCH-SIDE HORIZONTAL FLANGE FORMING SURFACE PORTION
135 PUNCH-SIDE VERTICAL FLANGE FORMING SURFACE PORTION
30 137 DIE-SIDE VERTICAL WALL FORMING SURFACE PORTION
139 DIE-SIDE HORIZONTAL FLANGE FORMING SURFACE PORTION
141 DIE-SIDE VERTICAL FLANGE FORMING SURFACE PORTION
142 END PORTION OF RIDGE PORTION
143 INTERMEDIATE TOP PLATE PORTION
35 144 INTERMEDIATE RIDGE PORTION
145 INTERMEDIATE VERTICAL WALL PORTION
146 END PORTION OF INTERMEDIATE RIDGE PORTION
147 CONVEX PORTION
149 INTERMEDIATE FORMED PRODUCT
40 151 INTERMEDIATE HORIZONTAL FLANGE PORTION
153 INTERMEDIATE VERTICAL FLANGE PORTION
155 INTERMEDIATE PUNCH
157 INTERMEDIATE PAD
159 INTERMEDIATE DIE
45 161 INTERMEDIATE TOP PLATE FORMING SURFACE PORTION
163 PUNCH-SIDE INTERMEDIATE VERTICAL WALL FORMING SURFACE PORTION
165 PUNCH-SIDE INTERMEDIATE HORIZONTAL FLANGE FORMING SURFACE PORTION
167 PUNCH-SIDE INTERMEDIATE VERTICAL FLANGE FORMING SURFACE PORTION
168 TOP PLATE TRANSVERSE SIDE FORMING SURFACE PORTION
50 169 CONVEX PORTION FORMING PORTION
171 DIE-SIDE INTERMEDIATE VERTICAL WALL FORMING SURFACE PORTION
173 DIE-SIDE INTERMEDIATE HORIZONTAL FLANGE FORMING SURFACE PORTION
175 DIE-SIDE INTERMEDIATE VERTICAL FLANGE FORMING SURFACE PORTION
177 PRESS-FORMED PRODUCT
55 179 TOP PLATE PORTION
181 RIDGE PORTION
183 VERTICAL WALL PORTION
185 END PORTION OF RIDGE PORTION

187 BLANK
189 TOP PLATE CORRESPONDING PORTION
191 VERTICAL WALL CORRESPONDING PORTION
193 END PORTION OF VERTICAL WALL CORRESPONDING PORTION
5 195 MOLD
197 PUNCH
199 PAD
201 DIE
203 INTERMEDIATE TOP PLATE PORTION
10 205 INTERMEDIATE RIDGE PORTION
206 END PORTION OF INTERMEDIATE RIDGE PORTION
207 INTERMEDIATE VERTICAL WALL PORTION
209 CONVEX PORTION
211 INTERMEDIATE FORMED PRODUCT
15 213 INTERMEDIATE PUNCH
215 INTERMEDIATE PAD
217 INTERMEDIATE DIE
219 INTERMEDIATE TOP PLATE FORMING SURFACE PORTION
221 PUNCH-SIDE INTERMEDIATE VERTICAL WALL FORMING SURFACE PORTION
20 223 PUNCH-SIDE CONVEX PORTION FORMING PORTION
225 DIE-SIDE INTERMEDIATE VERTICAL WALL FORMING SURFACE PORTION
226 DIE-SIDE CONVEX PORTION FORMING PORTION
229 PRESS-FORMED PRODUCT

25
Claims

30 1. A method for manufacturing a press-formed product including at least a top plate portion, a vertical wall portion, and a ridge portion which is a connection portion between the top plate portion and the vertical wall portion, the method comprising:

35 a first forming step of press-forming a metal sheet blank into an intermediate formed product including an intermediate top plate portion, an intermediate vertical wall portion, and an intermediate ridge portion connecting the intermediate top plate portion and the intermediate vertical wall portion, the intermediate formed product including a convex portion having a height higher than a reference height of a top plate surface at one position or a plurality of positions of the intermediate top plate portion including the intermediate ridge portion; and a second forming step of press-forming the intermediate formed product into the press-formed product.

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

45 in a shape of the press-formed product, the top plate portion includes a transverse side portion, a vertical side portion, and a connection R portion where the transverse side portion and the vertical side portion are connected to each other, the top plate portion having a substantially T-shape or a substantially L-shape in a top view, the press-formed product including:

50 the ridge portion connected to the top plate portion from the transverse side portion of the top plate portion to the connection R portion and the vertical side portion;
the vertical wall portion continuous from the transverse side portion of the top plate portion to the connection R portion and the vertical side portion via the ridge portion; and
a bottom flange portion continuous from the vertical wall portion,

in the first forming step,

55 the intermediate top plate portion includes an intermediate transverse side portion, an intermediate vertical side portion, and an intermediate connection R portion where the intermediate transverse side portion and the intermediate vertical side portion are connected to each other, the intermediate top plate portion having a substantially T-shape or a substantially L-shape in a top view, and press-forming is performed to obtain the intermediate formed product in which a height of the intermediate

vertical side portion of the intermediate top plate portion is lower than a height of the vertical side portion in a target product shape, and

further, in the first forming step,

press-forming is performed to obtain the intermediate formed product having the convex portion higher than the height of the vertical side portion at an end portion of the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion of the intermediate formed product and/or the intermediate connection R portion of the intermediate top plate portion including the intermediate ridge portion of the intermediate formed product.

3. The method for manufacturing the press-formed product according to claim 2, wherein in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion whose height gradually increases toward a distal end side of the intermediate transverse side portion on the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion.

4. The method for manufacturing the press-formed product according to claim 2, wherein in the first forming step, press-forming is performed to obtain the intermediate formed product including the convex portion having a constant height to a distal end side of the intermediate transverse side portion on the intermediate transverse side portion of the intermediate top plate portion including the intermediate ridge portion.

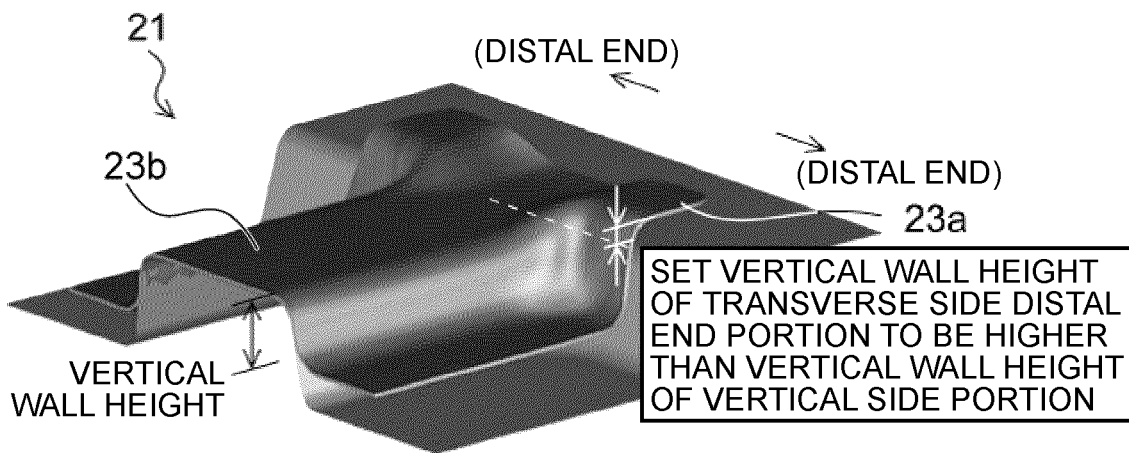
5. The method for manufacturing the press-formed product according to claim 2, wherein in the first forming step, the convex portion is formed on the intermediate connection R portion including the intermediate ridge portion, and press-forming is further performed to obtain the intermediate formed product having the intermediate transverse side portion of the intermediate top plate portion having a height corresponding to the height of the convex portion of the intermediate connection R portion.

6. The method for manufacturing the press-formed product according to claim 1, wherein in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion higher than a reference height of the top plate surface at one position or a plurality of positions of the intermediate top plate portion including an end portion of the intermediate ridge portion.

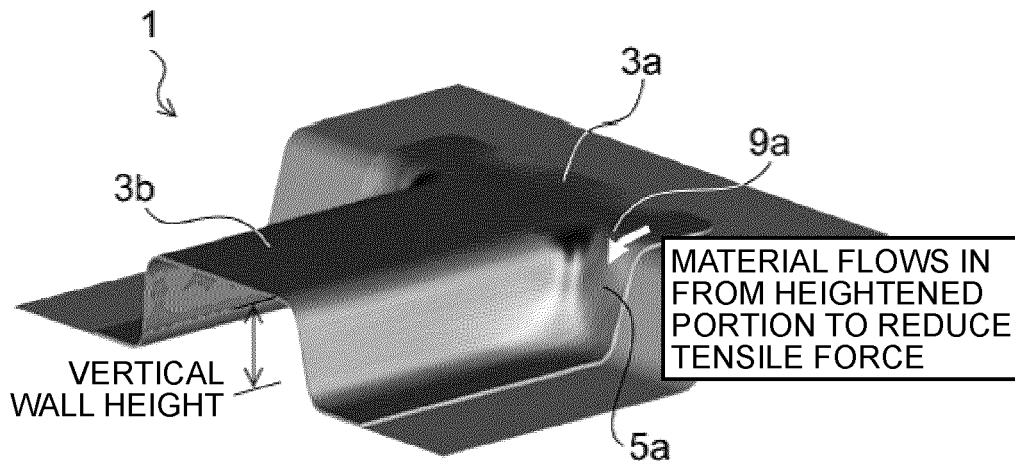
7. The method for manufacturing the press-formed product according to claim 6, wherein the press-formed product includes a vertical flange portion continuous with the vertical wall portion, and in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion at an end portion of the intermediate top plate portion including the intermediate ridge portion on a vertical flange portion side in the press-formed product.

8. The method for manufacturing the press-formed product according to claim 6, wherein the press-formed product includes the vertical wall portion in which the top plate portion or a part of the top plate portion is curved in a top view, and the vertical wall portion is continuous with an inner side of a curve of the top plate portion, and in the first forming step, press-forming is performed to obtain the intermediate formed product having the convex portion on the intermediate top plate portion including the end portion of the intermediate ridge portion.

FIG.1

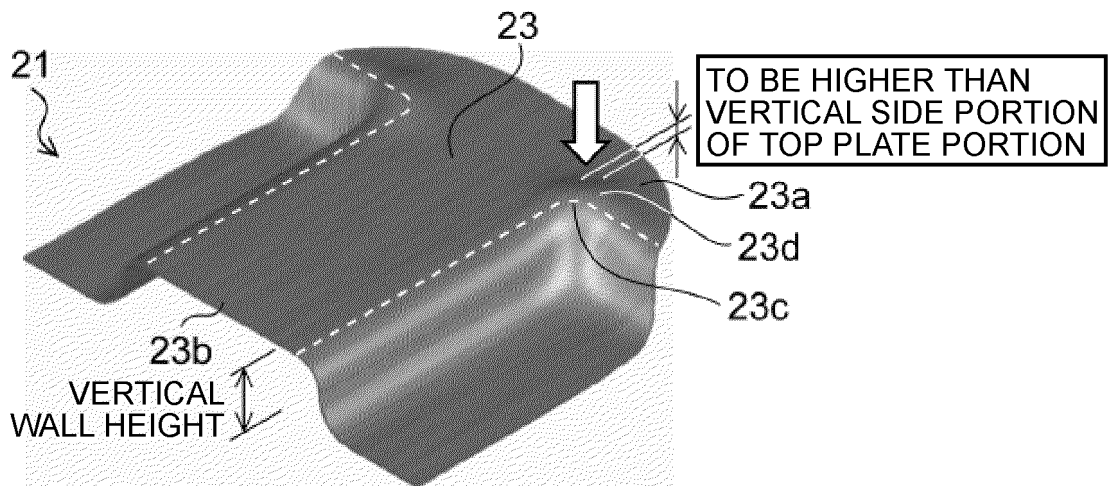


(a) FIRST FORMING STEP (HEIGHT OF VERTICAL WALL PORTION OF INTERMEDIATE FORMED PRODUCT: LOW)

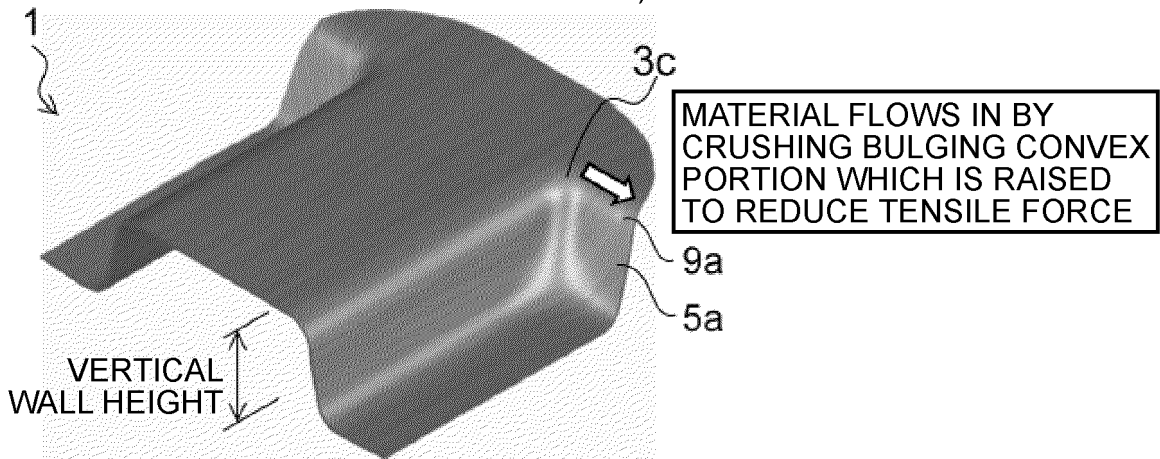


(b) SECOND FORMING STEP (HEIGHT OF VERTICAL WALL PORTION OF TARGET FORMED PRODUCT: HIGH)

FIG.2



(a) FIRST FORMING STEP (VERTICAL WALL HEIGHT OF INTERMEDIATE SHAPE: LOW)



(b) SECOND FORMING STEP (VERTICAL WALL HEIGHT OF TARGET SHAPE: HIGH)

FIG.3

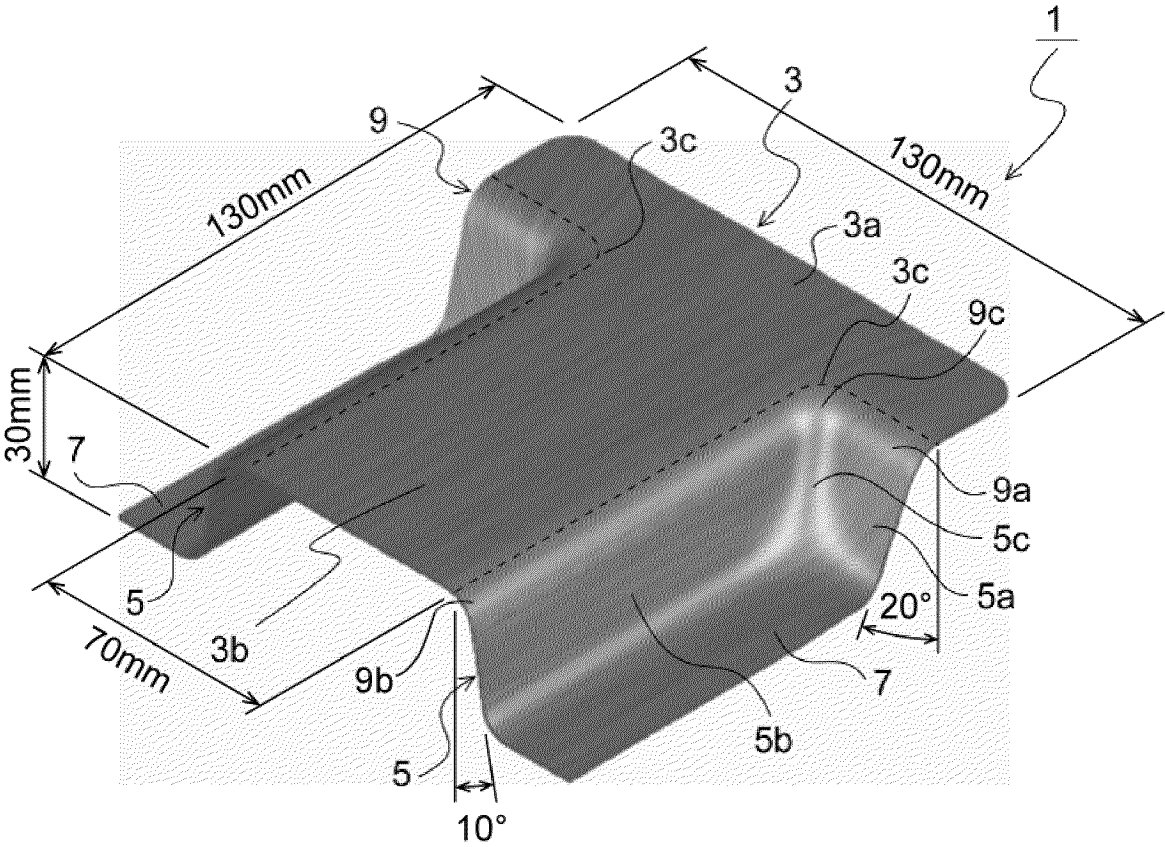


FIG.4

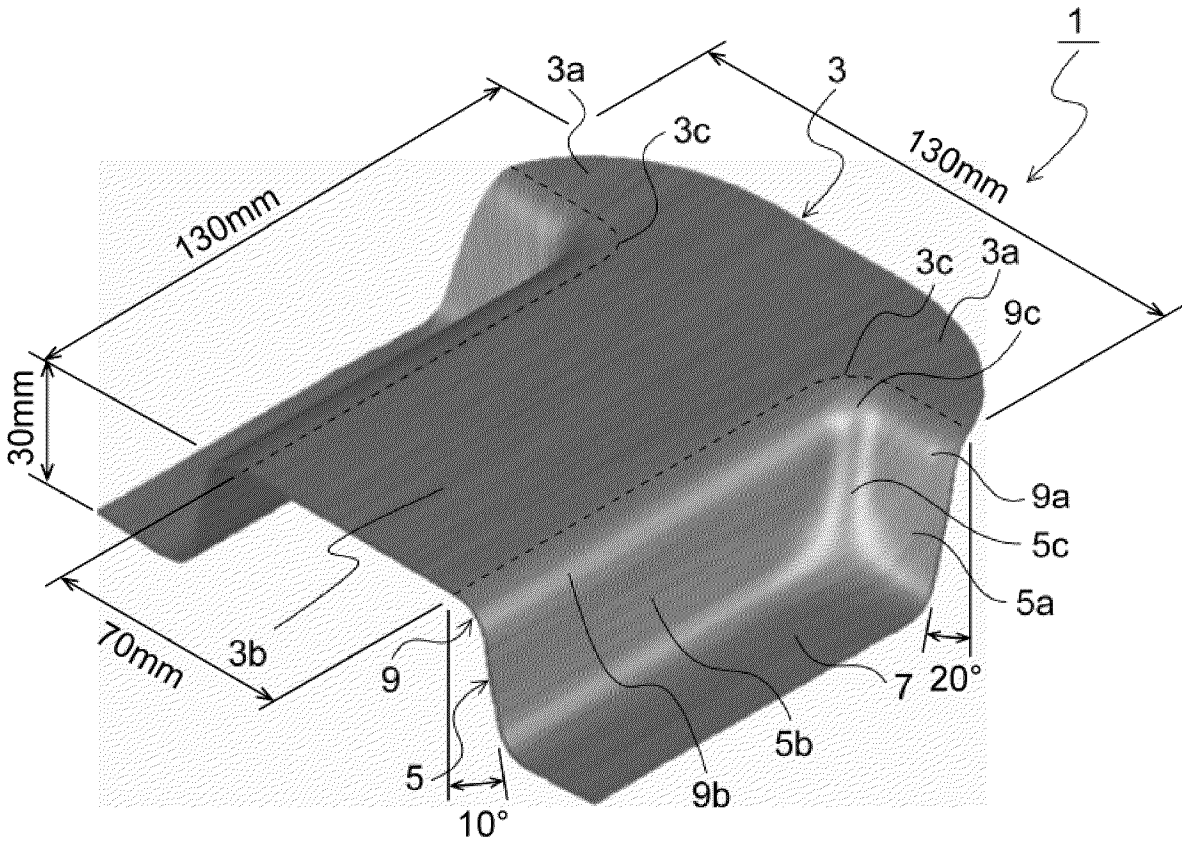


FIG.5

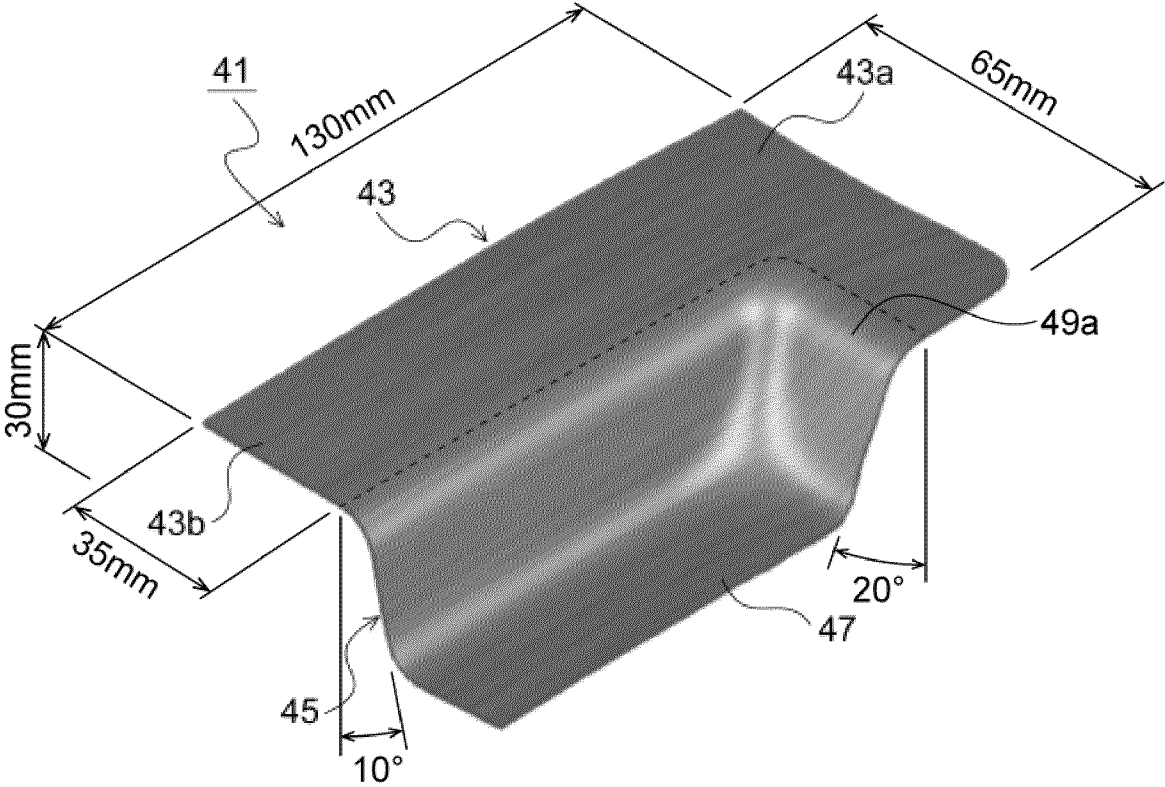
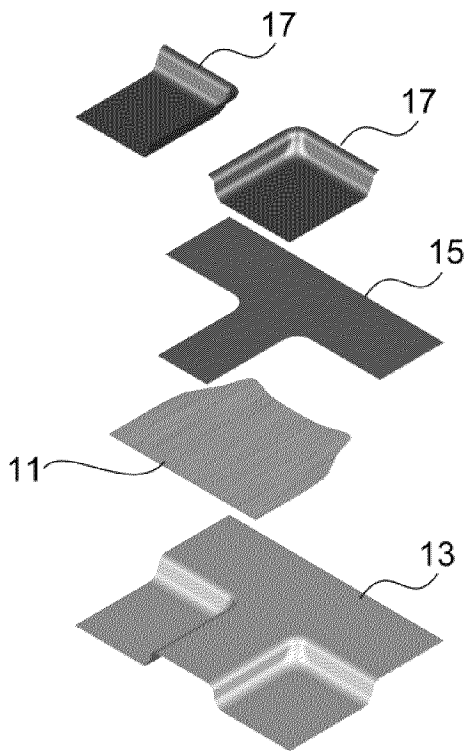
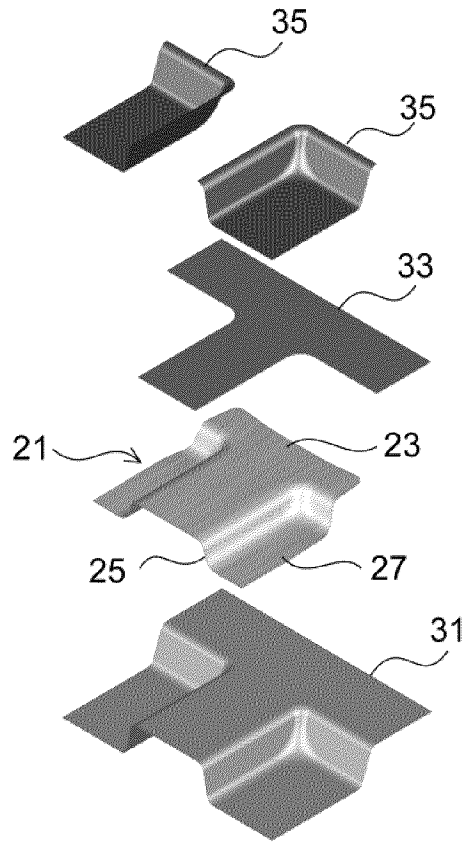


FIG.6

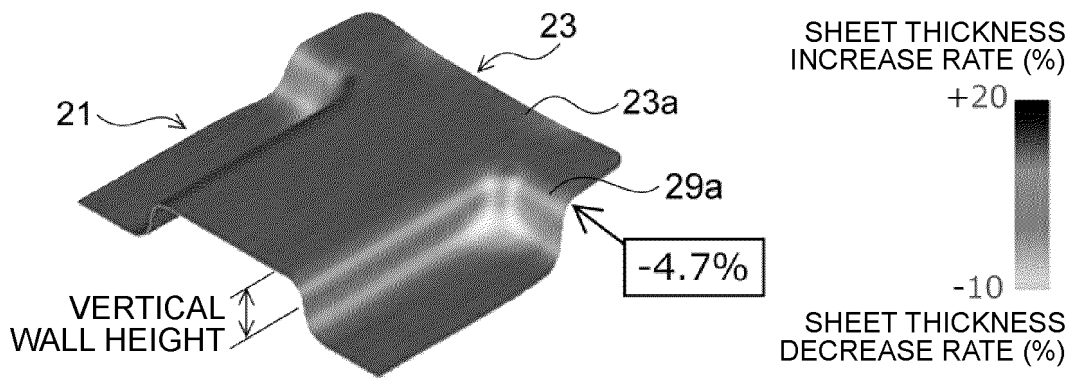


(a) FIRST FORMING STEP
(VERTICAL WALL HEIGHT OF
INTERMEDIATE SHAPE: LOW)

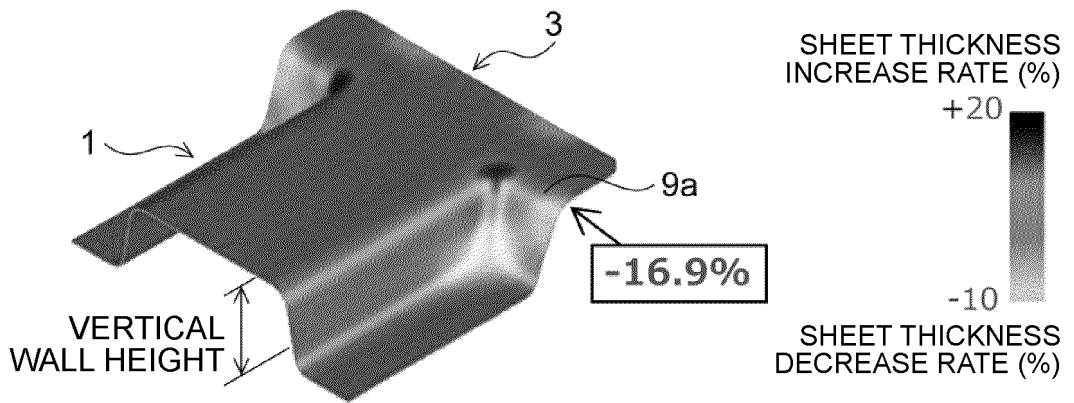


(b) SECOND FORMING STEP
(VERTICAL WALL HEIGHT OF
TARGET SHAPE: HIGH)

FIG.7

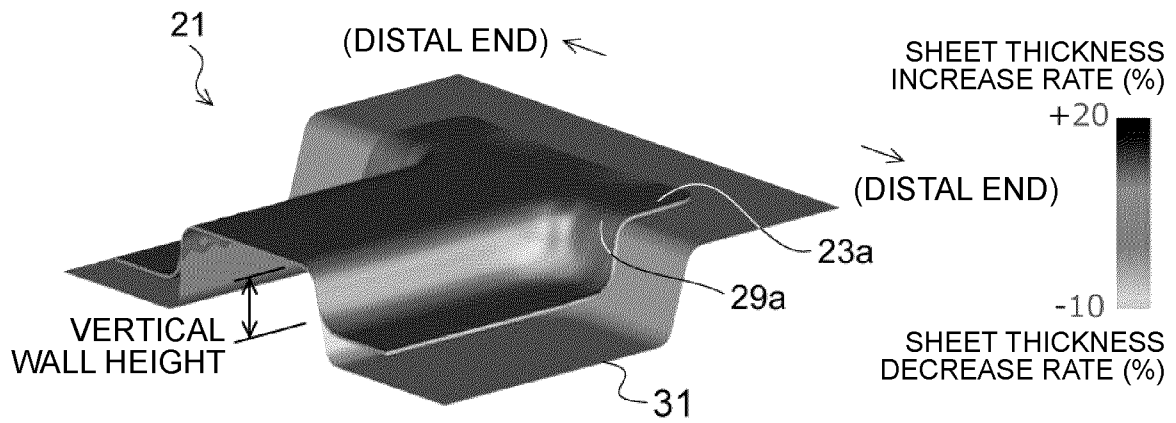


(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)

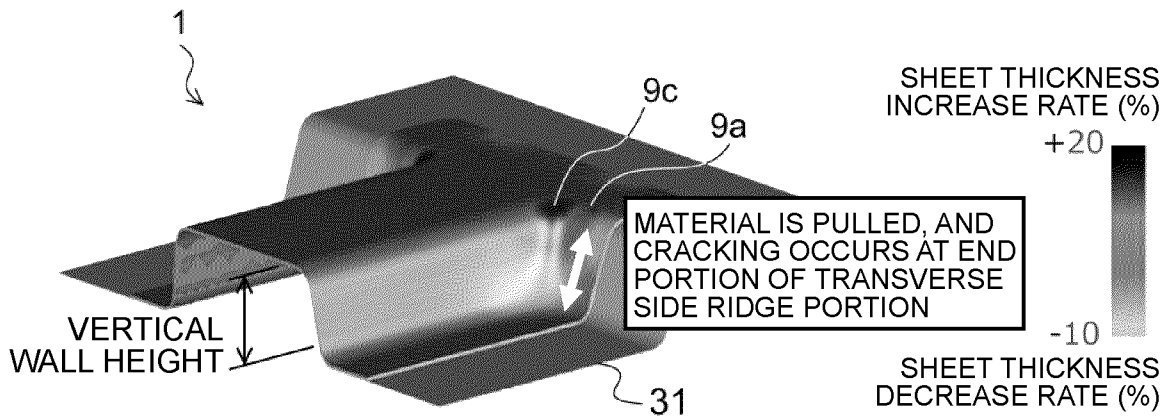


(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

FIG.8

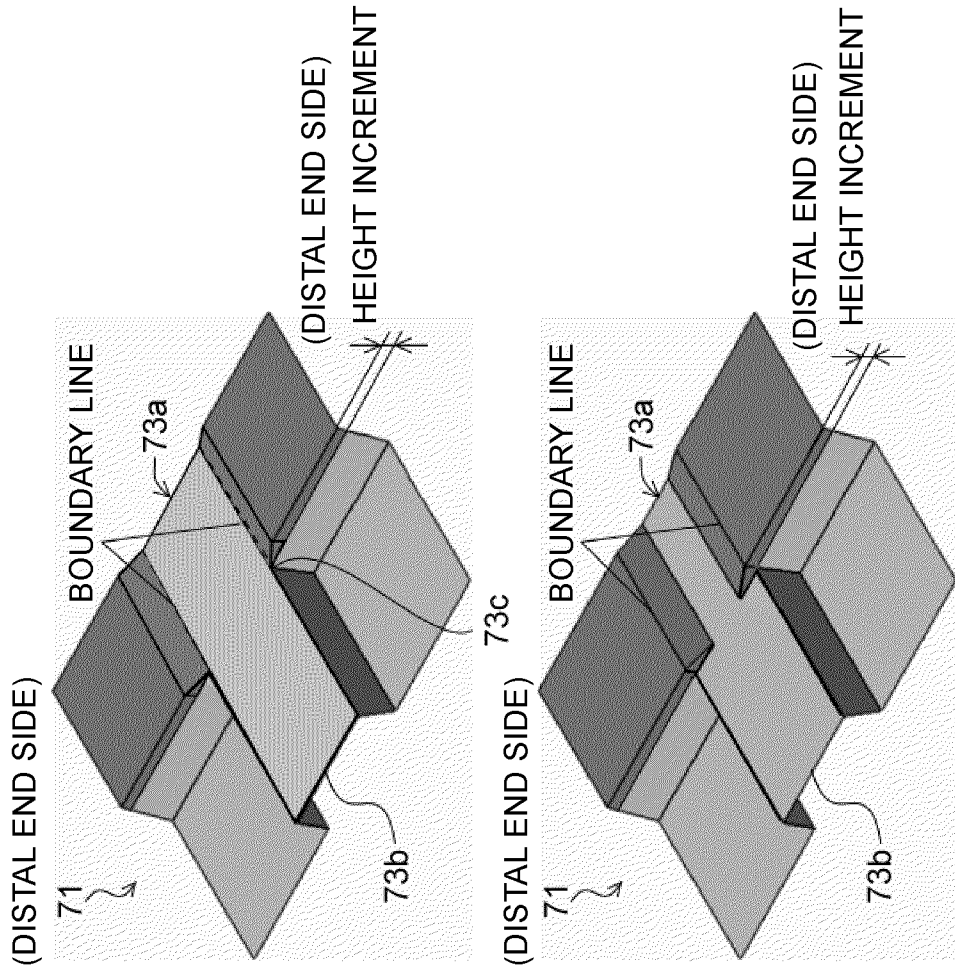


(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)



(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

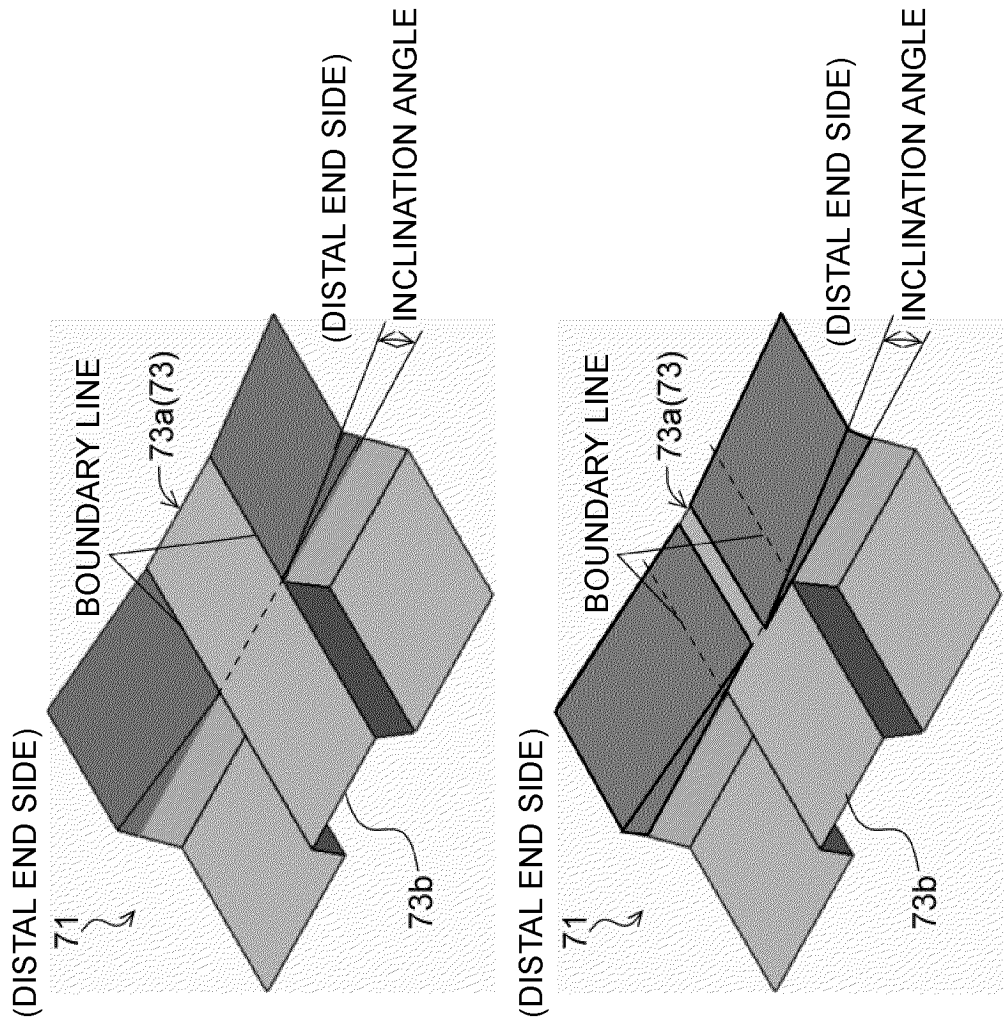
FIG.9



(a) EXAMPLE IN WHICH HEIGHT IS INCREASED FROM BOUNDARY LINE BETWEEN REGION OBTAINED BY EXTENDING VERTICAL SIDE PORTION TO TRANSVERSE SIDE PORTION AND TRANSVERSE SIDE PORTION TOWARD DISTAL END, AND PORTION ON DISTAL END SIDE IS UNIFORMLY RAISED

(b) EXAMPLE IN WHICH HEIGHT IS INCREASED FROM EXTENSION REGION SIDE OF BOUNDARY LINE EXTENDING VERTICAL SIDE PORTION TO TRANSVERSE SIDE PORTION SIDE AND TRANSVERSE SIDE PORTION, AND HEIGHT IS UNIFORMLY INCREASED FROM EXTENSION REGION TO DISTAL END SIDE

FIG.10



(a) EXAMPLE OF INCLINING FROM BOUNDARY LINE BETWEEN REGION OBTAINED BY EXTENDING VERTICAL SIDE PORTION TO TRANSVERSE SIDE PORTION SIDE AND TRANSVERSE SIDE PORTION TOWARD DISTAL END

(b) EXAMPLE OF INCLINING FROM EXTENSION REGION SIDE OF BOUNDARY LINE BETWEEN REGION OBTAINED BY EXTENDING VERTICAL SIDE PORTION TO TRANSVERSE SIDE PORTION SIDE AND TRANSVERSE SIDE PORTION TOWARD DISTAL END

FIG. 11

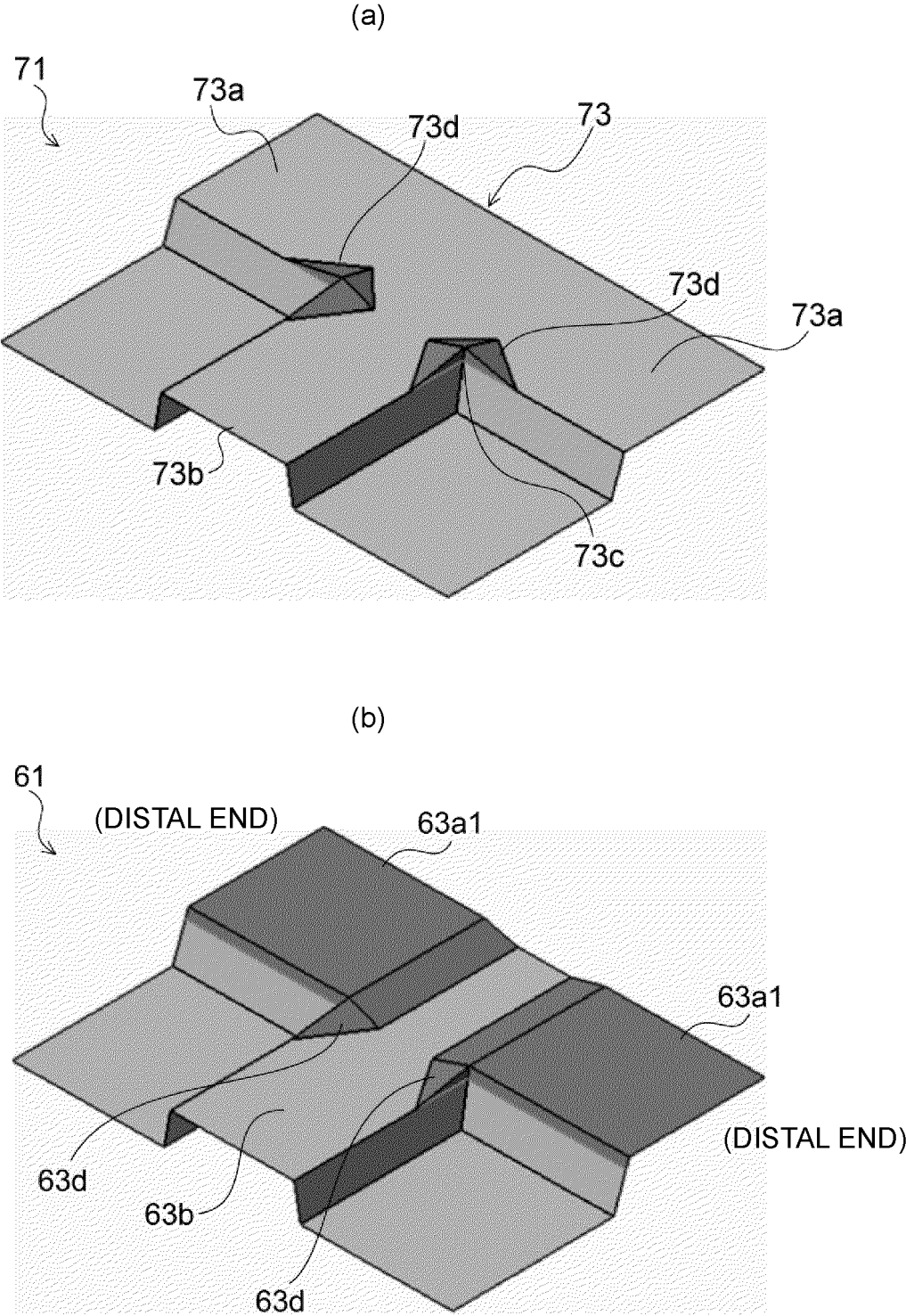
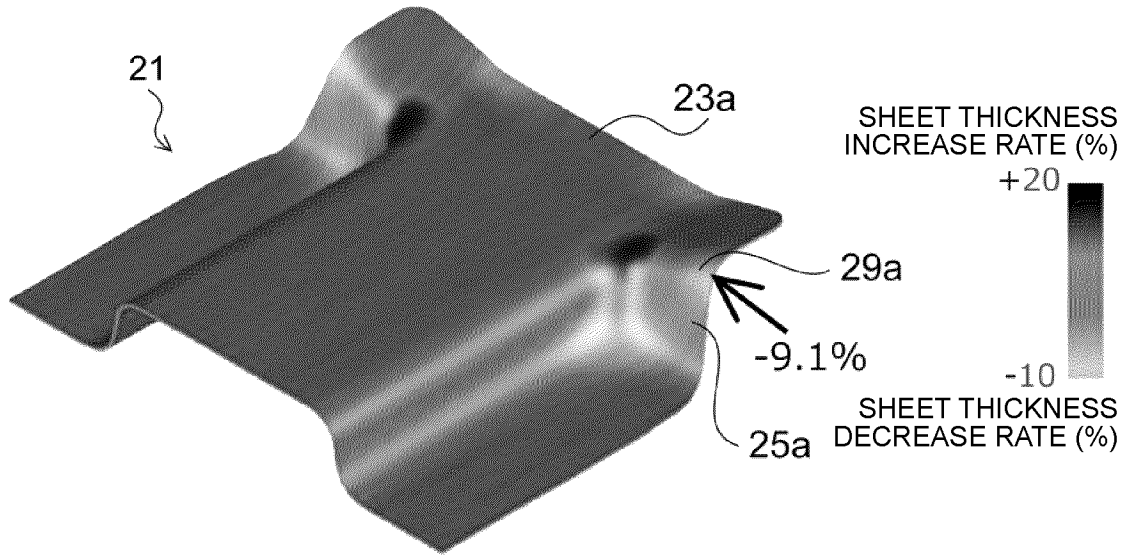
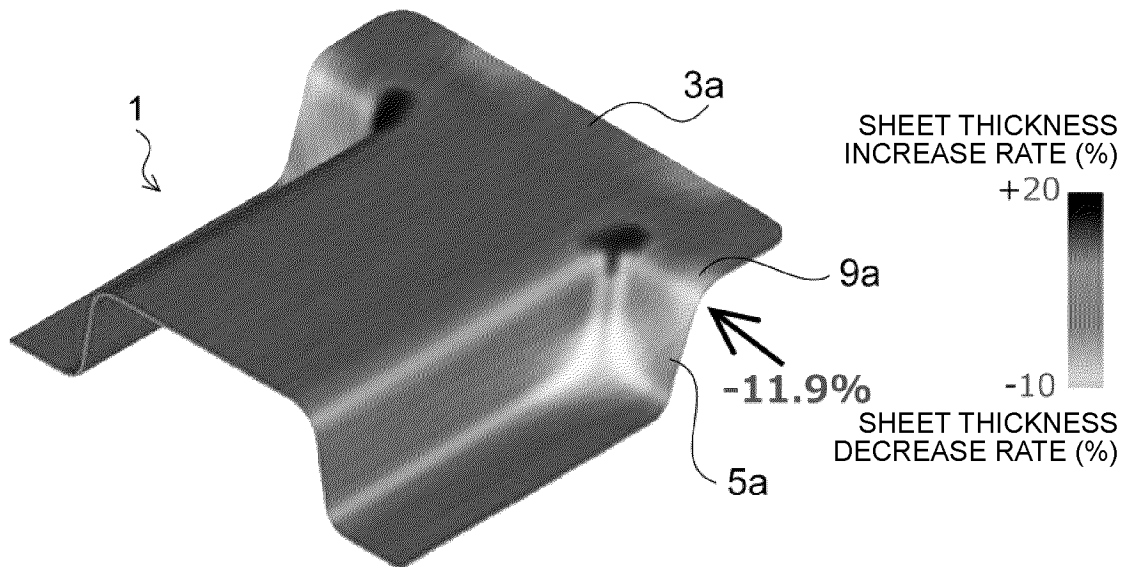


FIG.12

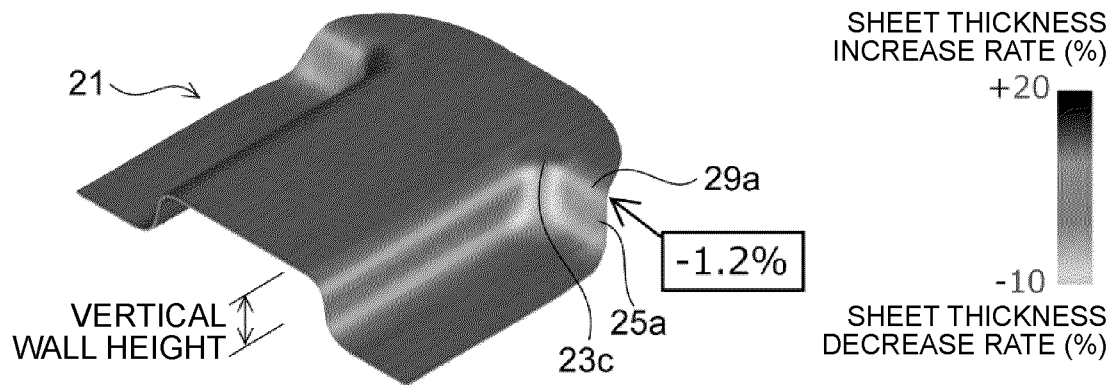


(a) INTERMEDIATE SHAPE

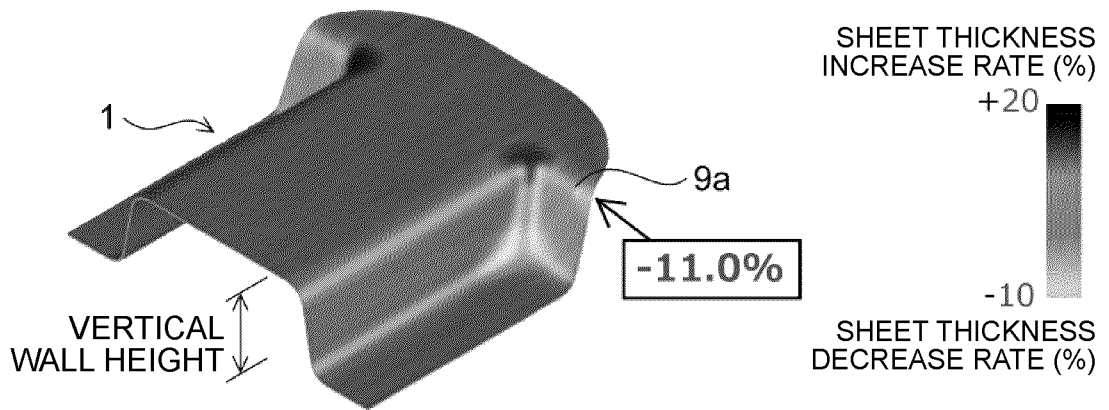


(b) TARGET SHAPE

FIG.13

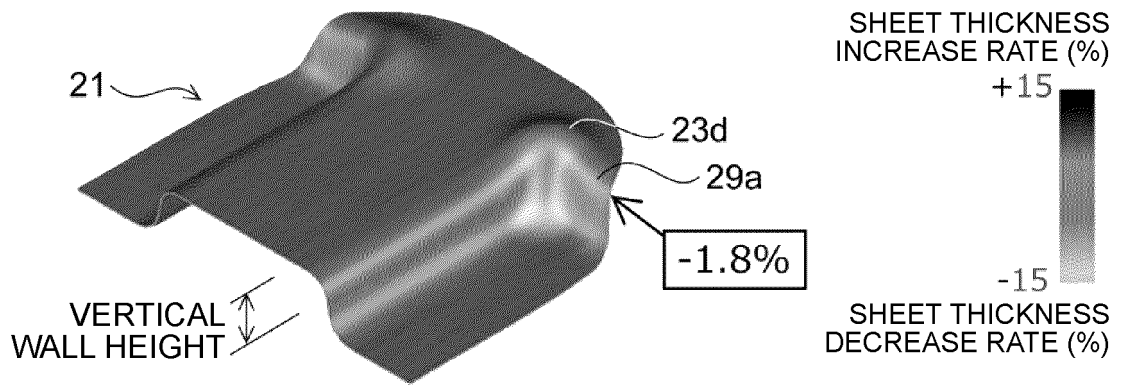


(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)

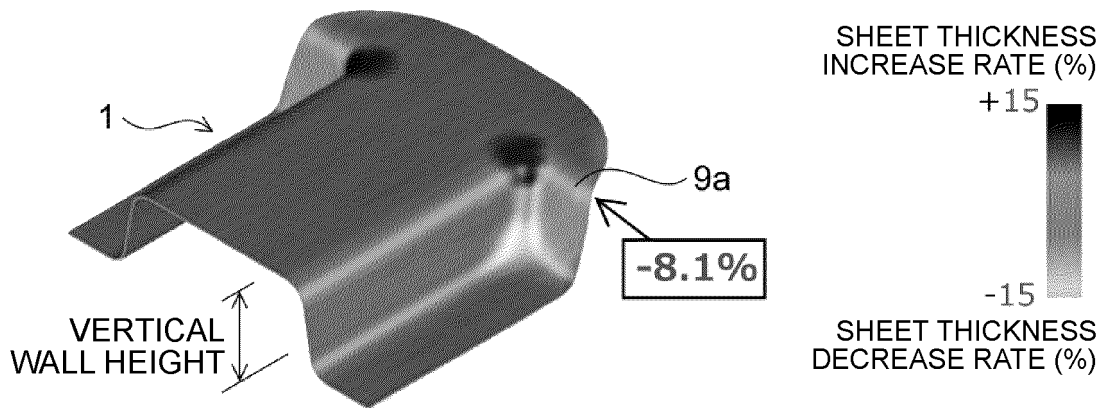


(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

FIG.14

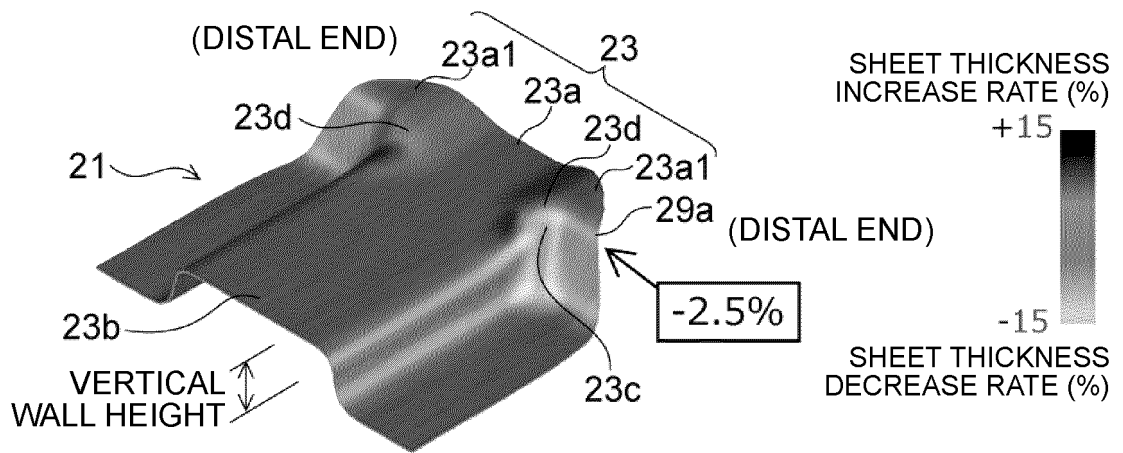


(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)

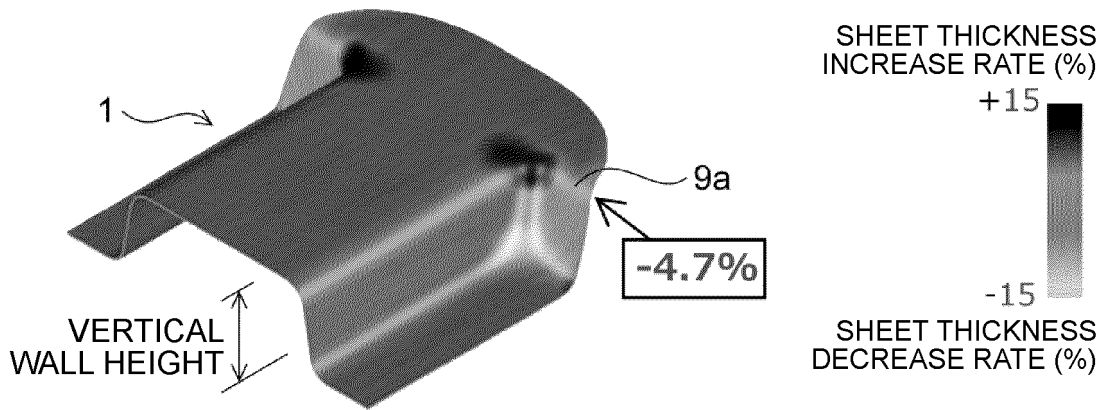


(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

FIG.15

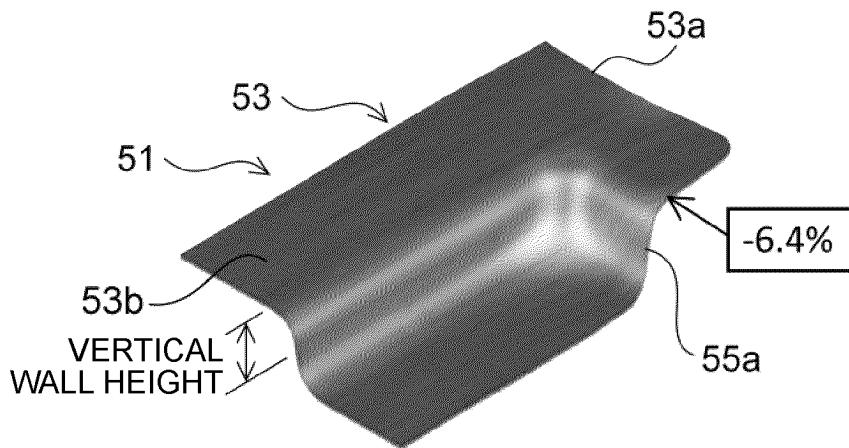


(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)

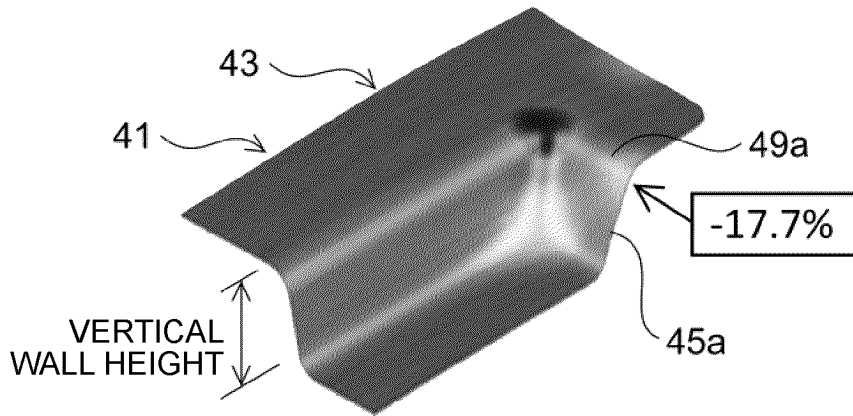
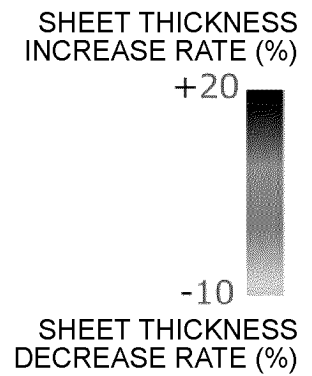


(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

FIG.16



(a) FIRST FORMING STEP
(VERTICAL WALL HEIGHT OF INTERMEDIATE SHAPE: LOW)



(b) SECOND FORMING STEP
(VERTICAL WALL HEIGHT OF TARGET SHAPE: HIGH)

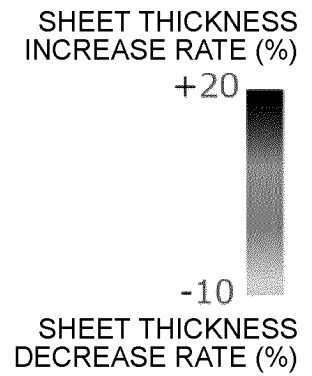
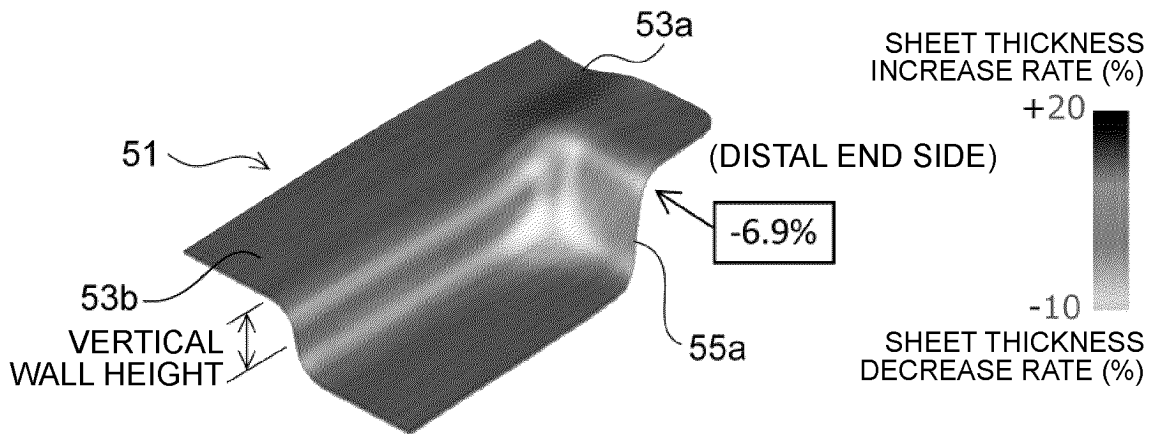
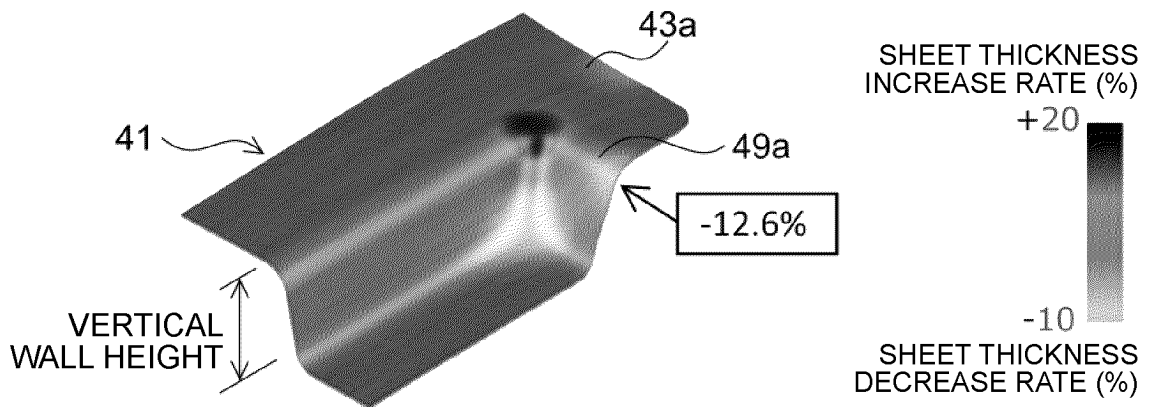


FIG.17



(a) INTERMEDIATE SHAPE (VERTICAL WALL HEIGHT: LOW)



(b) TARGET SHAPE (VERTICAL WALL HEIGHT: HIGH)

FIG. 18

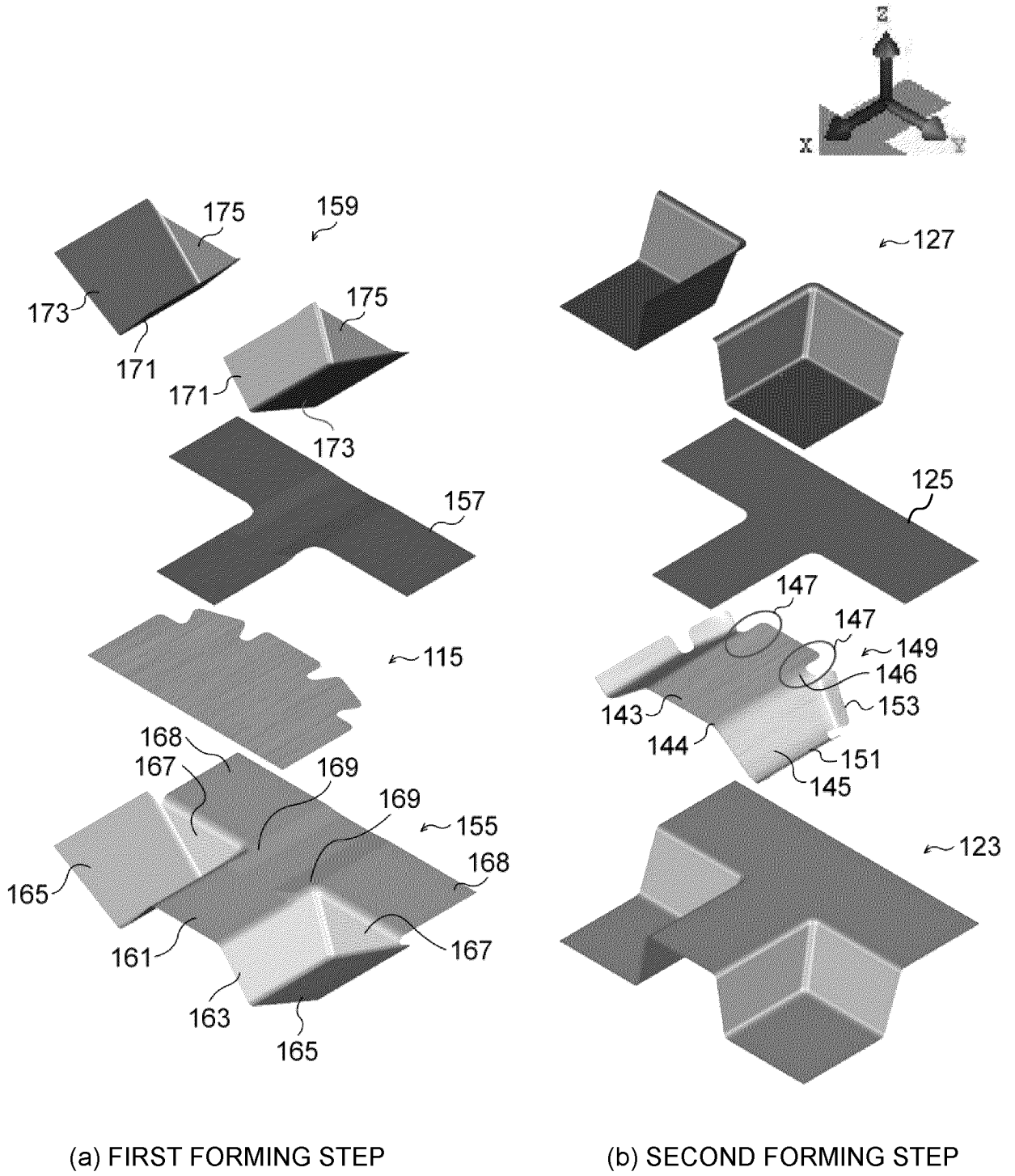


FIG.19

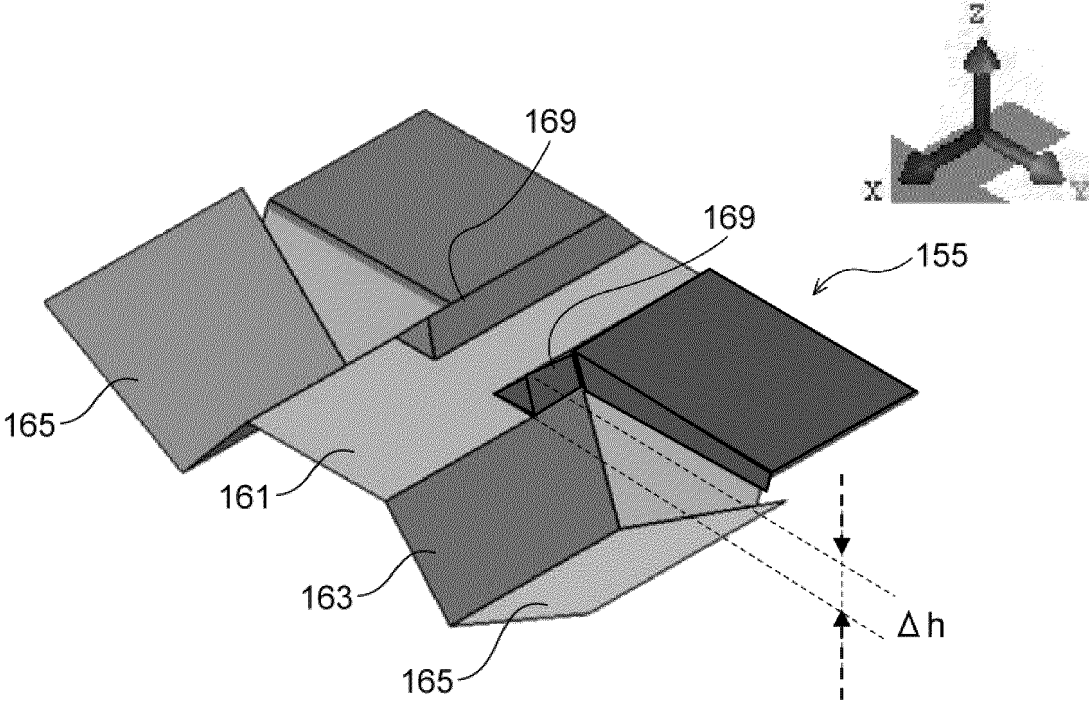
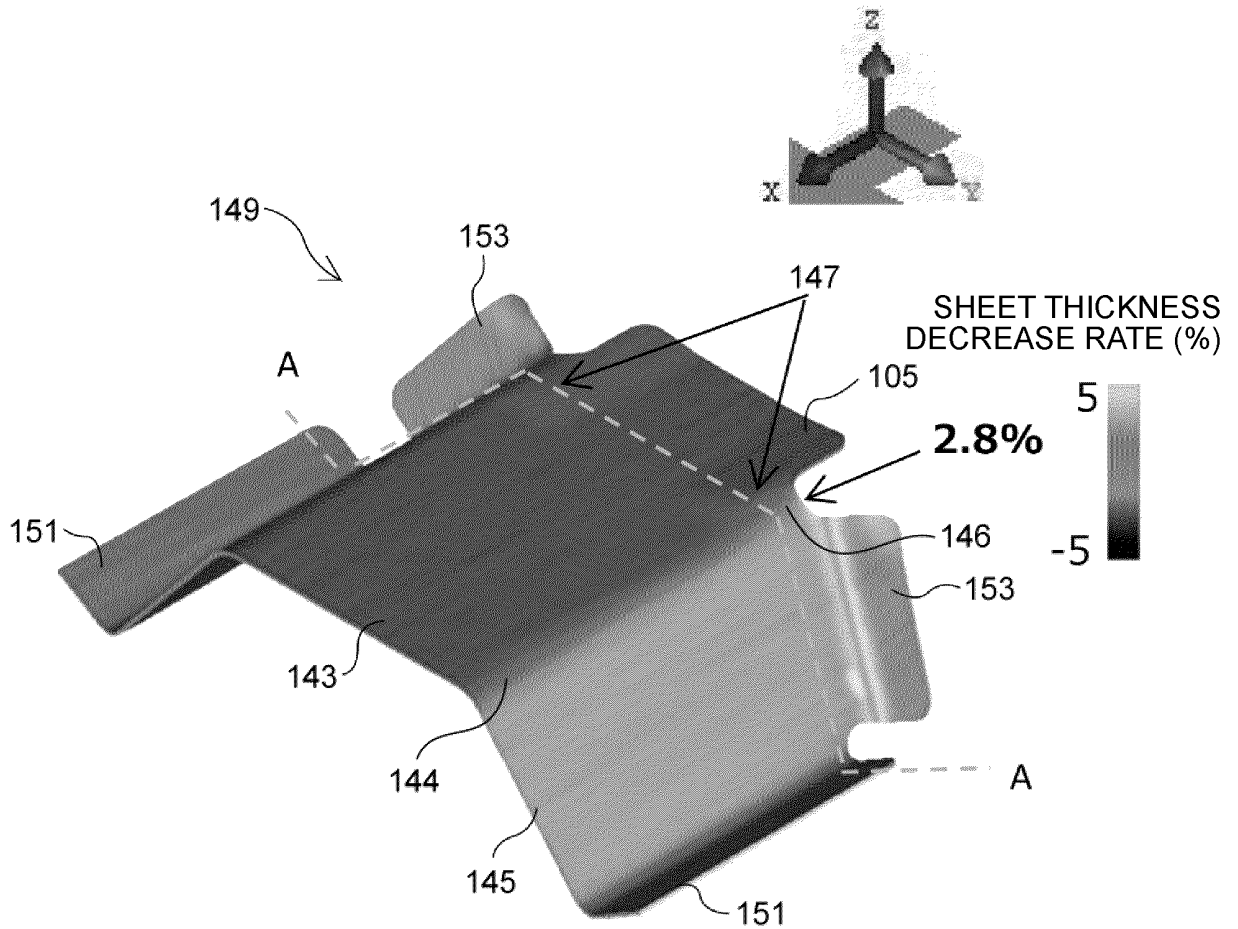
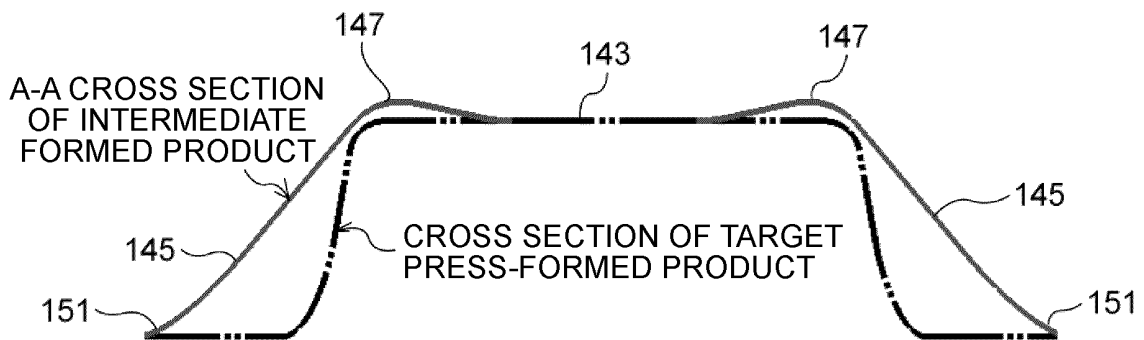


FIG.20



(a)



(b)

FIG.21

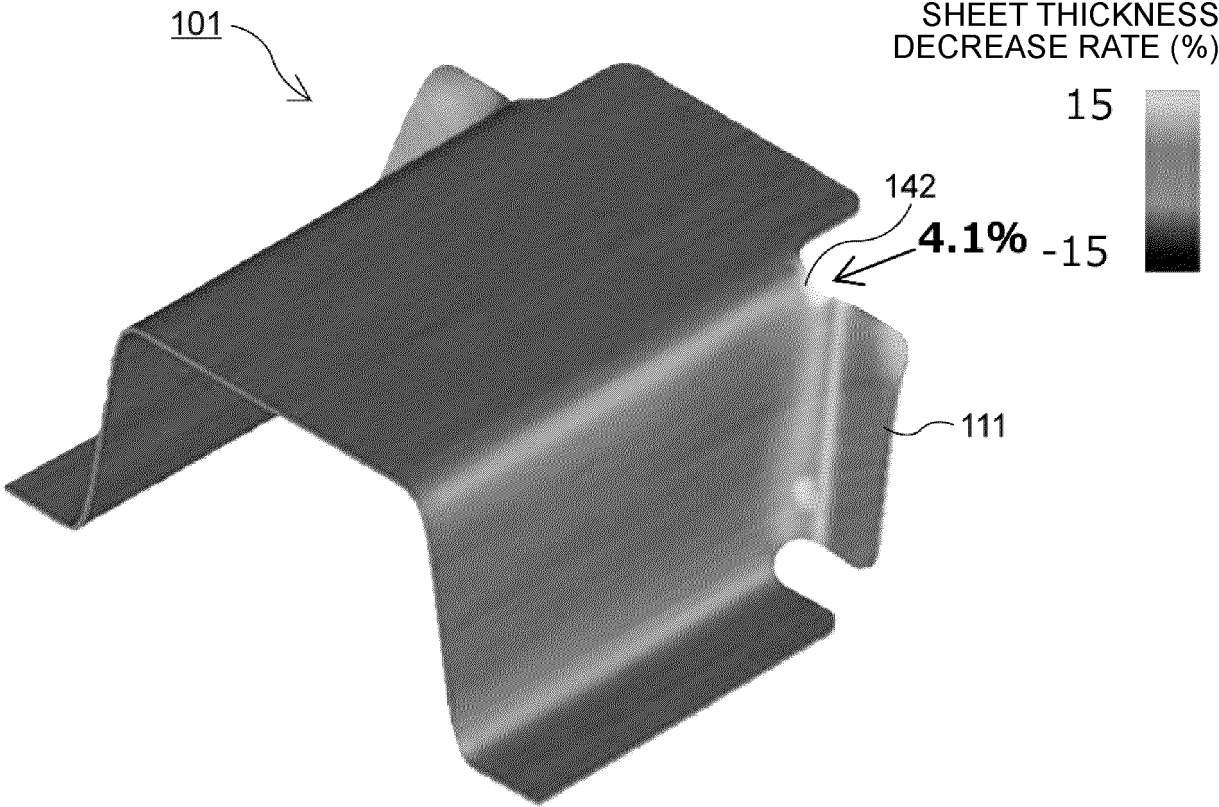


FIG.22

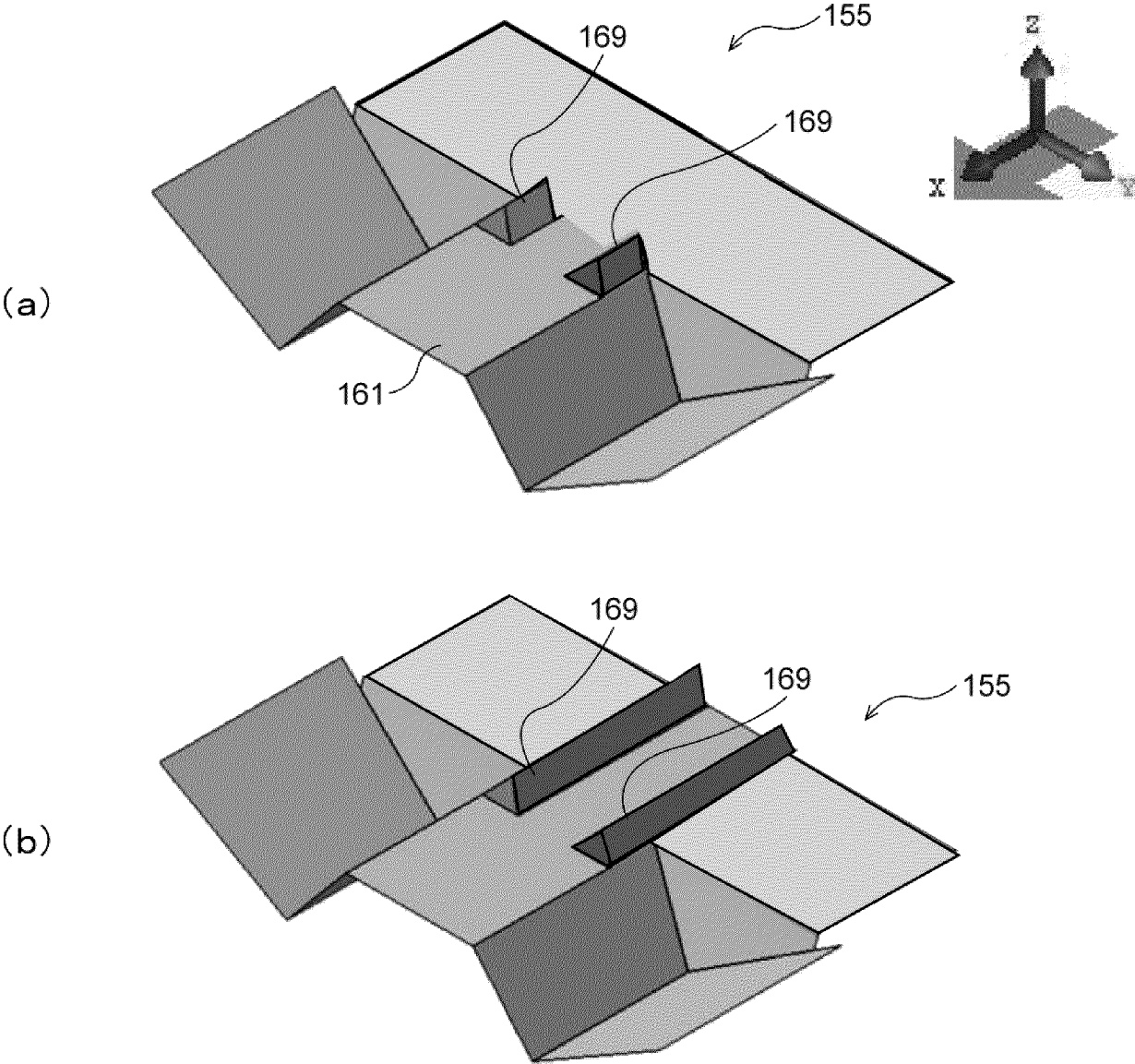


FIG.24

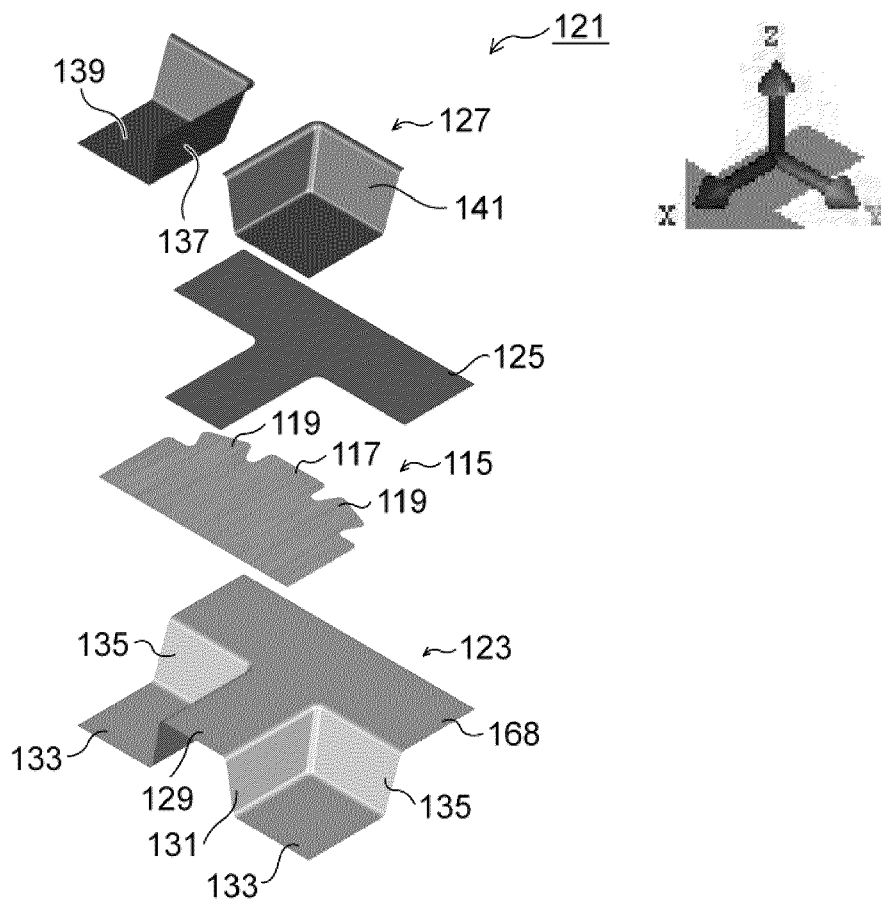


FIG.25

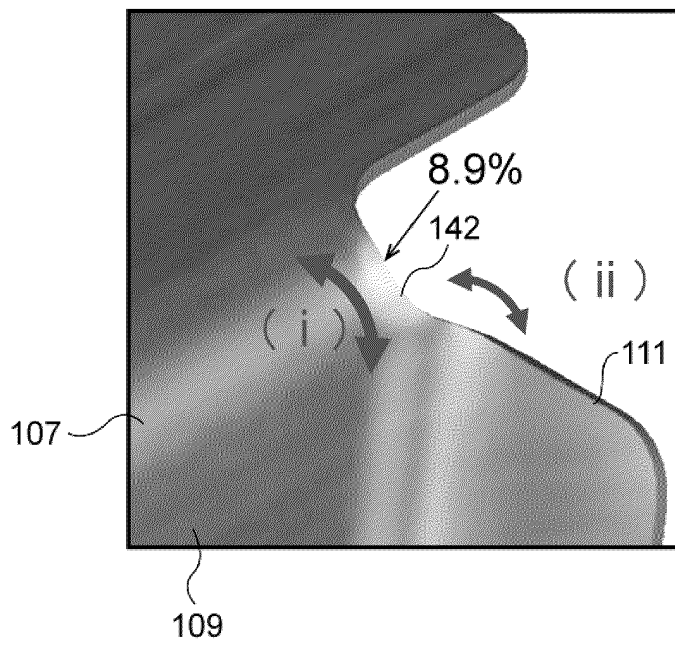
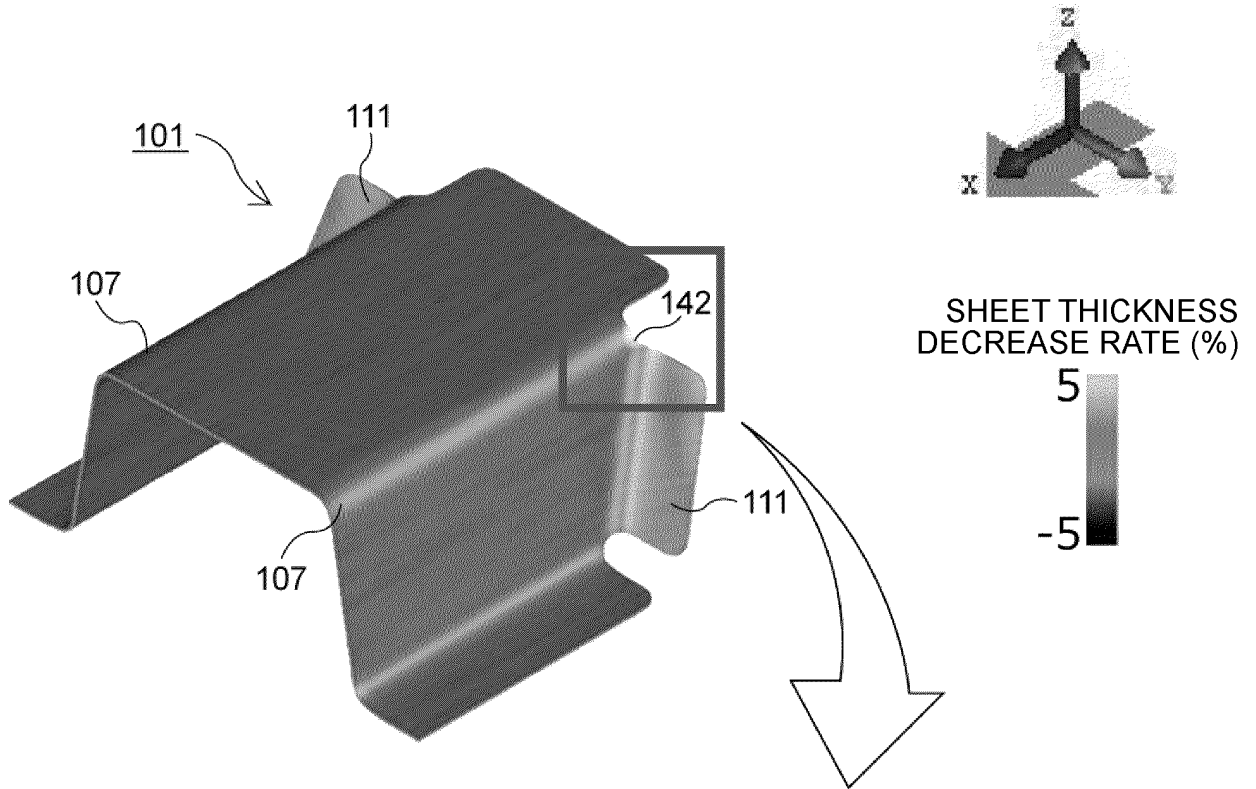
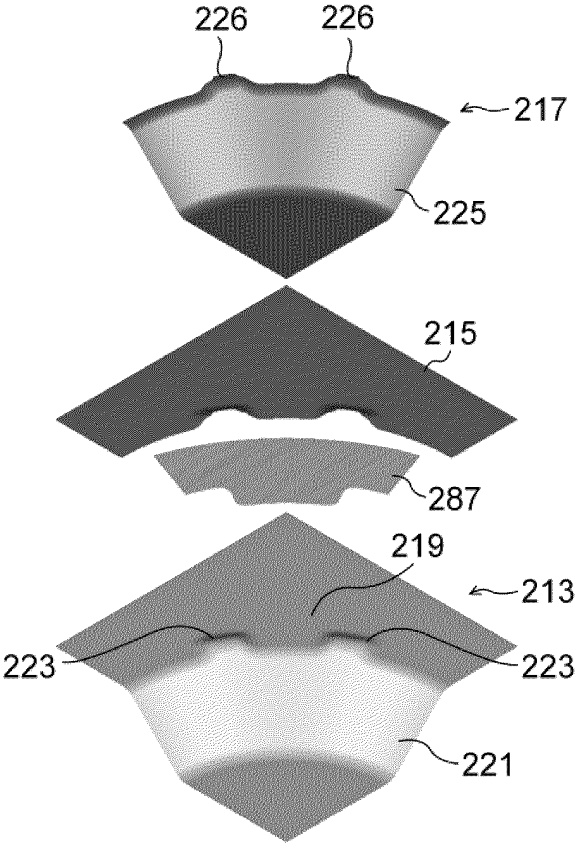
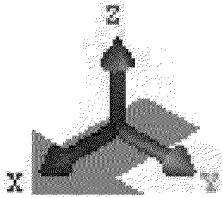
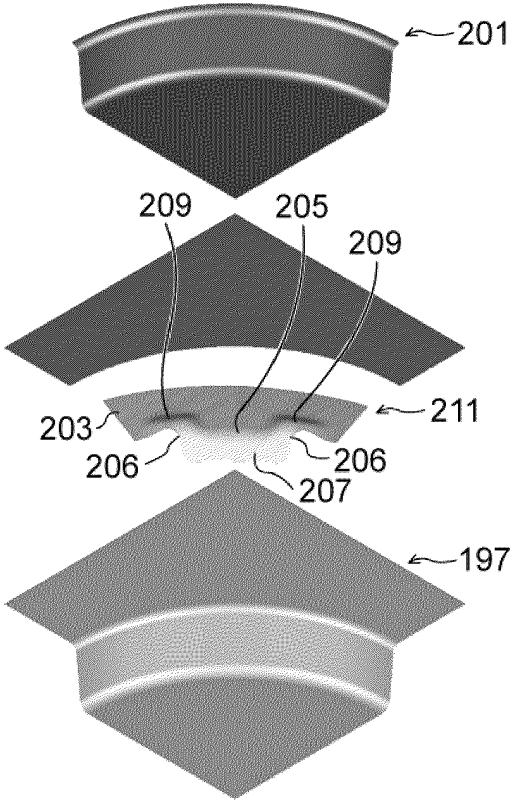


FIG.26



(a) FIRST FORMING STEP



(b) SECOND FORMING STEP

FIG.27

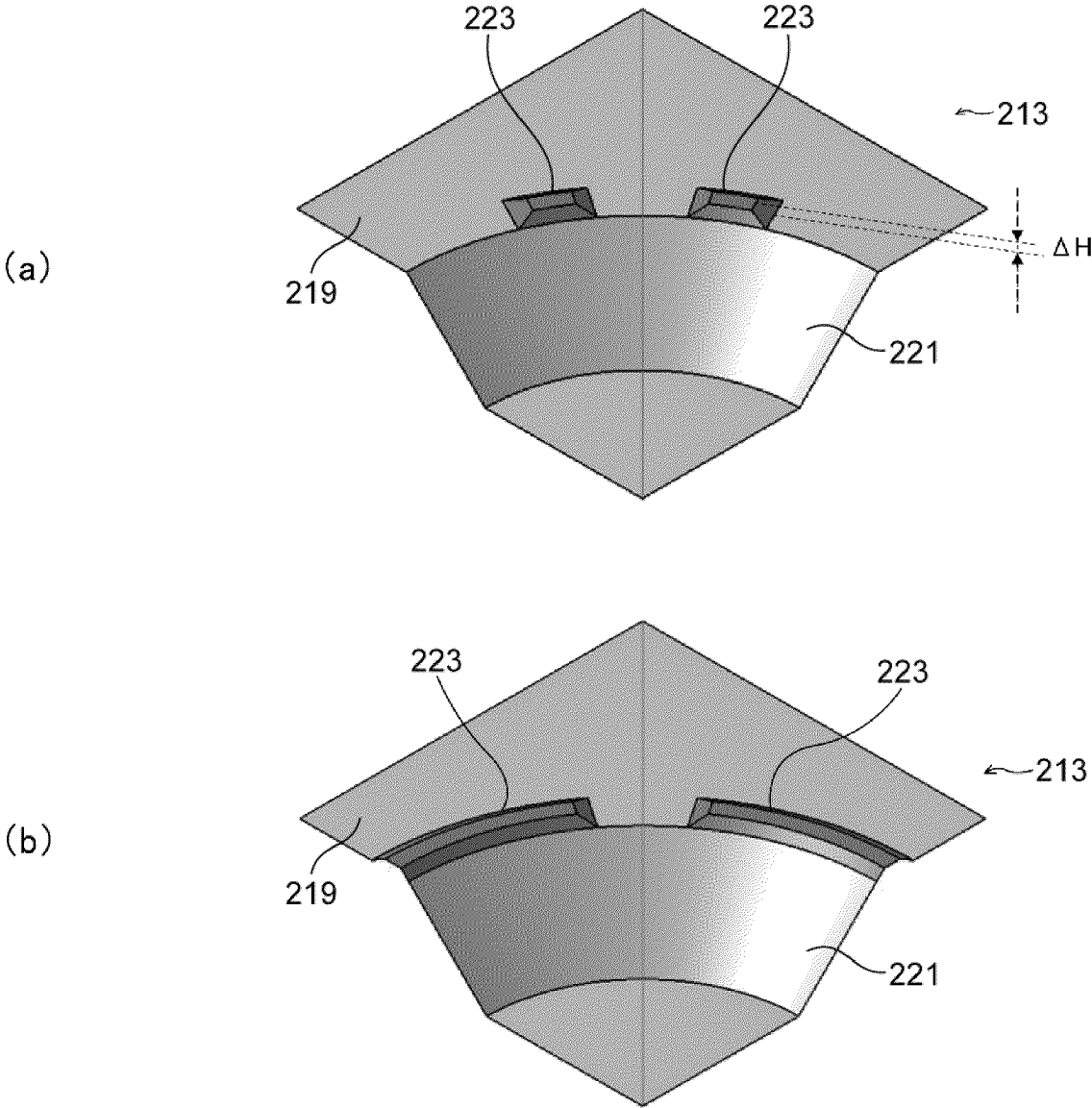
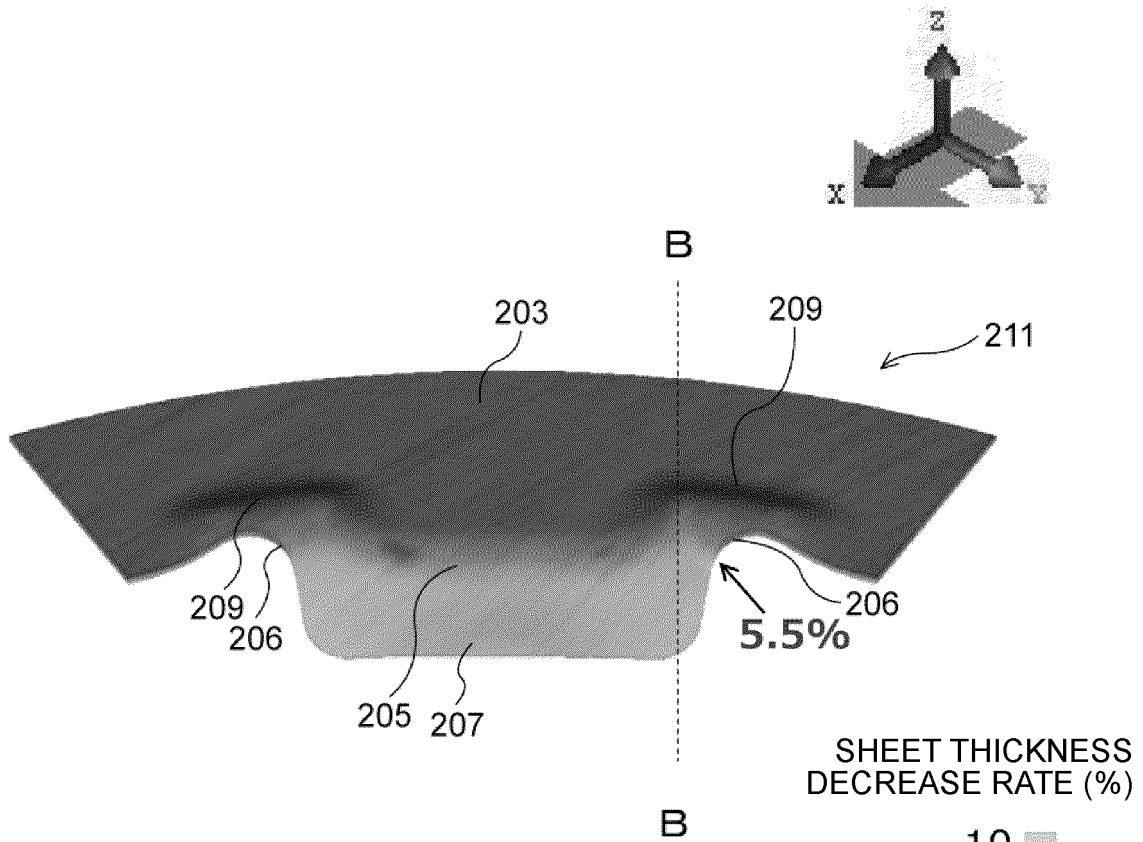
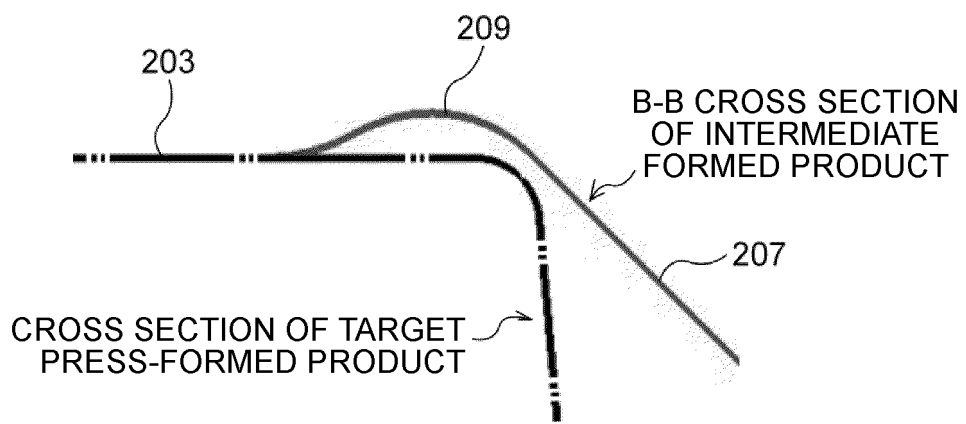
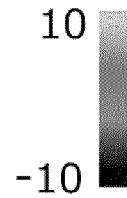


FIG.28



(a)

SHEET THICKNESS DECREASE RATE (%)



(b)

FIG.29

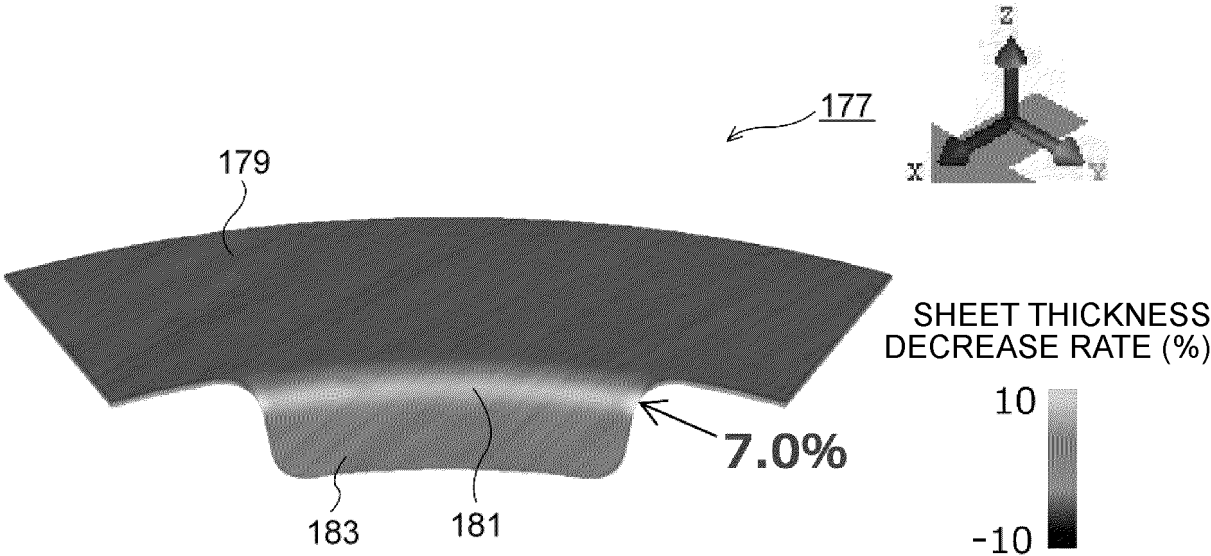


FIG.30

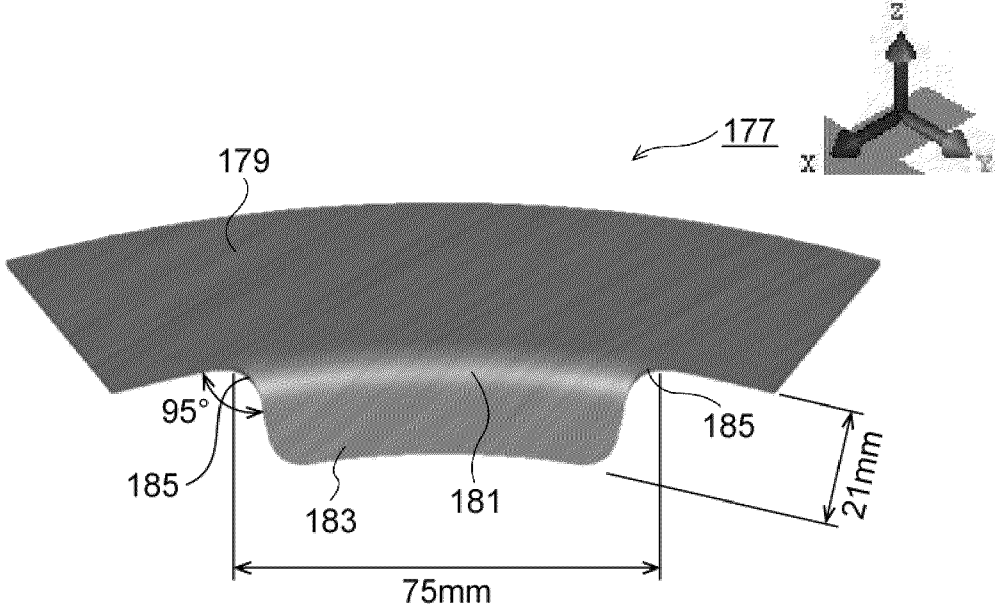


FIG.31

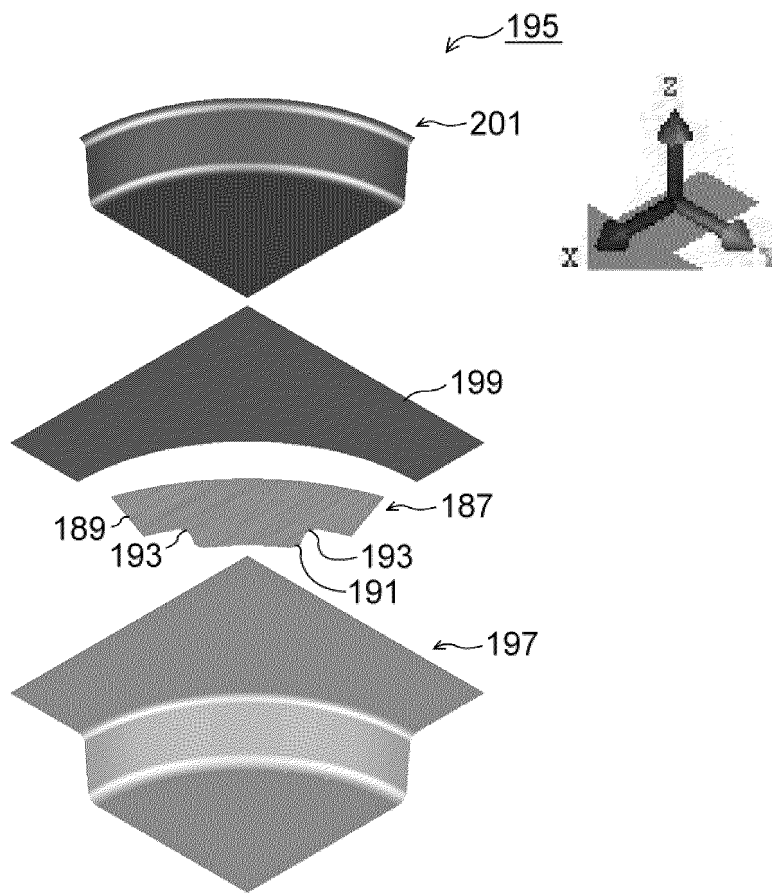


FIG.32

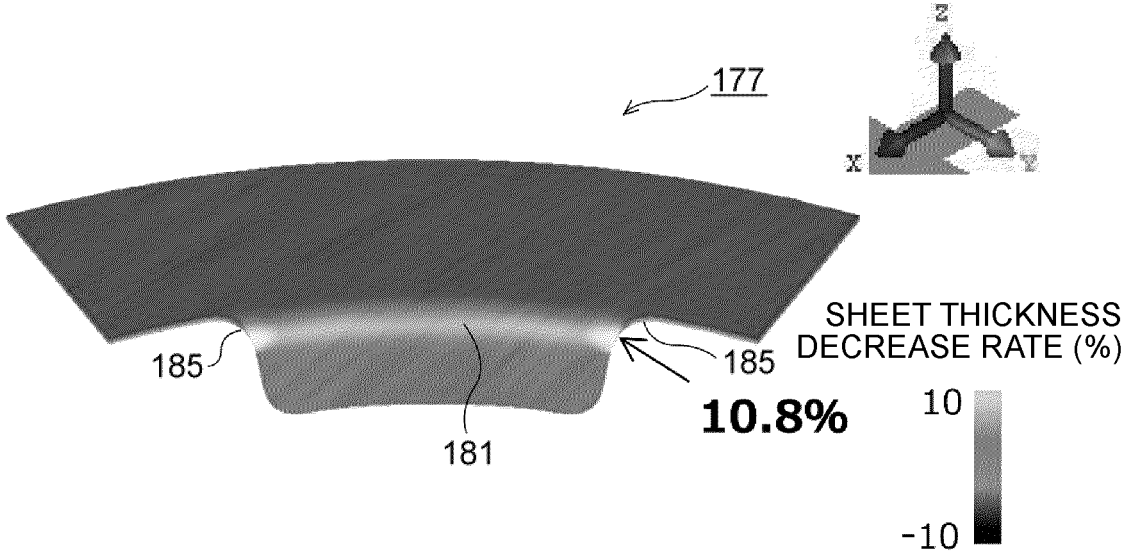


FIG.33

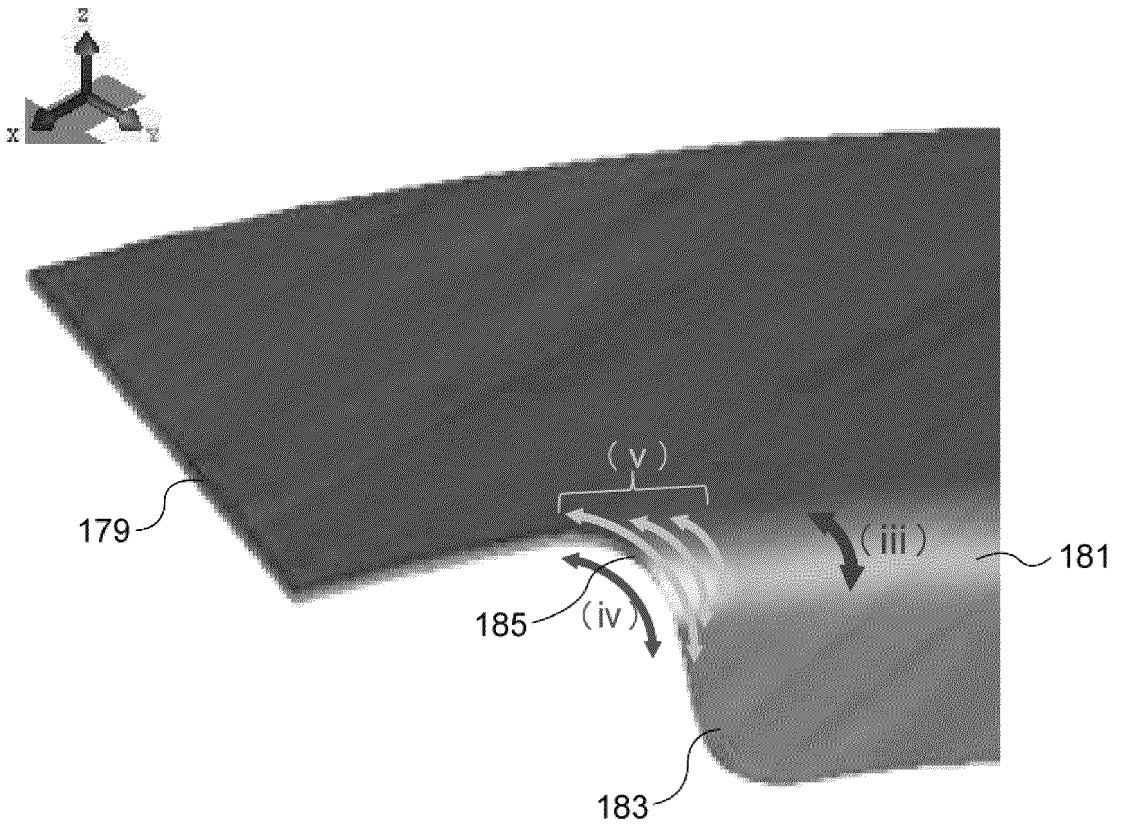


FIG.34

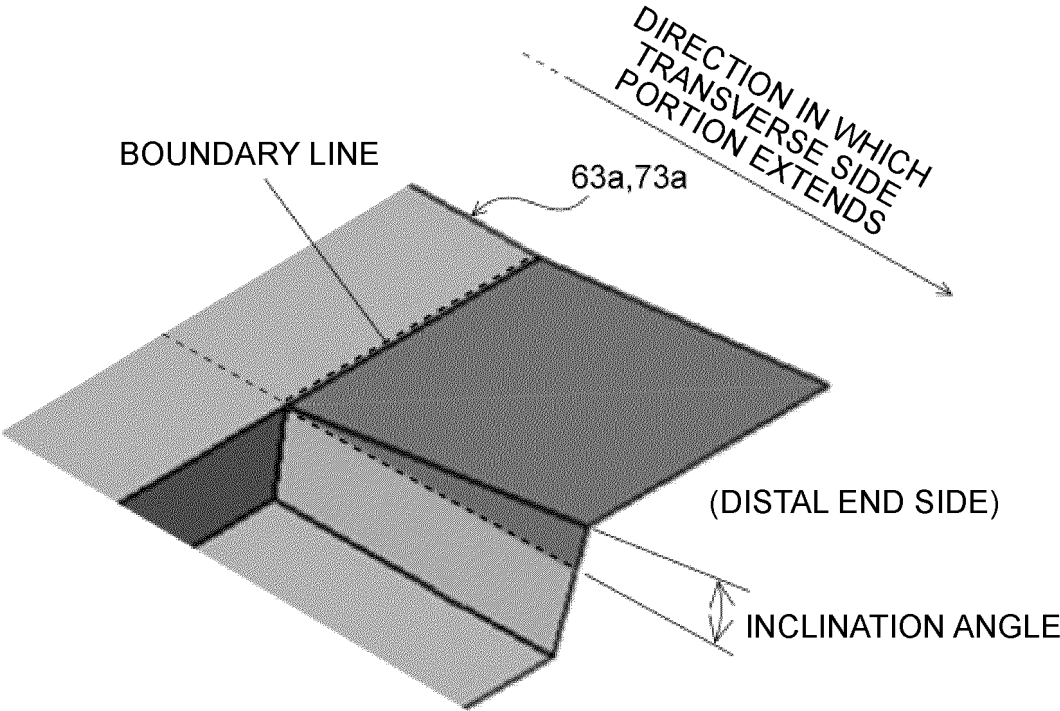
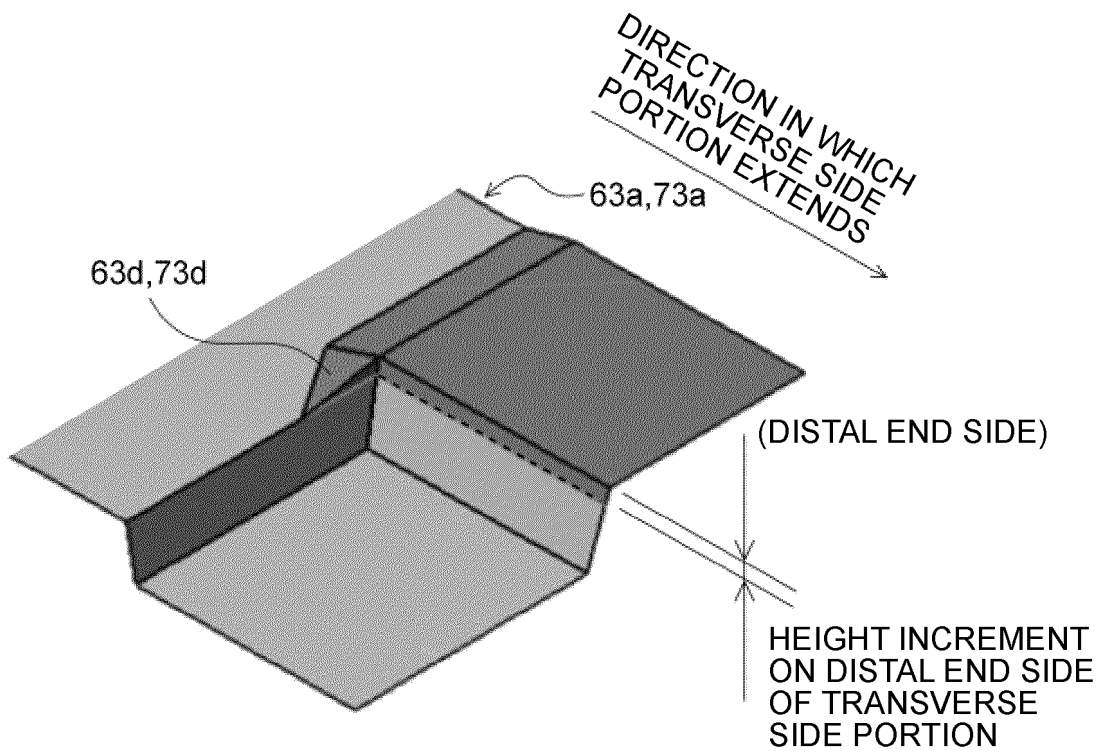


FIG.35



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/035138

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

FI: B21D22/26 C; B21D22/26 D

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

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D22/26

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

15

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)

20

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2021-176646 A (JFE STEEL CORP.) 11 November 2021 (2021-11-11) paragraphs [0014]-[0034], fig. 5	1, 6, 8
Y		7
A		2-5
Y	WO 2015/174353 A1 (NIPPON STEEL & SUMITOMO METAL CORP.) 19 November 2015 (2015-11-19) paragraphs [0023]-[0042], fig. 2, 3	7
A		1-6, 8
A	JP 2007-29966 A (TOPRE CORP.) 08 February 2007 (2007-02-08) entire text, all drawings	1-8
A	WO 2018/225832 A1 (NIPPON STEEL & SUMITOMO METAL CORP.) 13 December 2018 (2018-12-13) entire text, all drawings	1-8

40

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

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“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	

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Date of the actual completion of the international search

01 December 2023

Date of mailing of the international search report

12 December 2023

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Name and mailing address of the ISA/JP

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Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/035138

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Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2021-176646 A	11 November 2021	(Family: none)	
WO 2015/174353 A1	19 November 2015	US 2017/0151597 A1 paragraphs [0049]-[0069], fig. 2, 3 EP 3144078 A1 CA 2948791 A1 KR 10-2016-0145130 A CN 106457341 A MX 2016014730 A RU 2016144269 A KR 10-2018-0136583 A BR 112016026553 A	
JP 2007-29966 A	08 February 2007	(Family: none)	
WO 2018/225832 A1	13 December 2018	US 2020/0101514 A1 entire text, all drawings EP 3636362 A1 CN 110709181 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2019013952 A [0004]
- JP 2016104492 A [0004]