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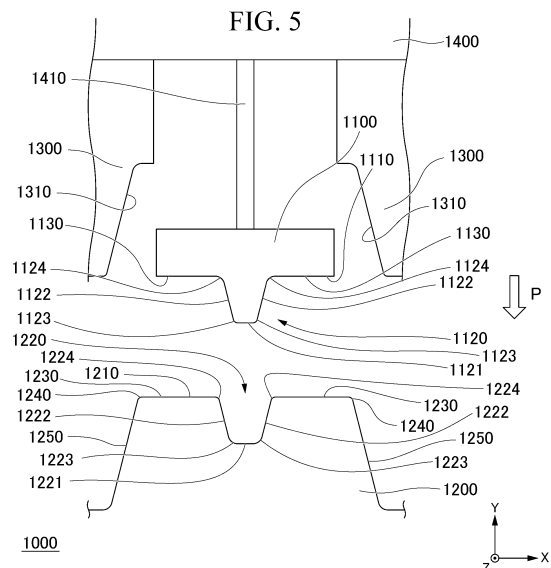
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(54) **HOT-PRESSING DEVICE, PRODUCTION METHOD FOR HOT-PRESSED MOLDED ARTICLE, AND HOT-PRESSED MOLDED ARTICLE**

(57) Provided is a hot press apparatus (1000) including a punch (1200), a die (1300), and a die pad (1100), in which a groove portion (1220) is provided in a top surface (1210) of the punch (1200), in which, in a cross section in a press direction (P), an angle between a wall surface of the groove portion (1220) and the press direction (P) is 2° to 8°, in which a refrigerant flow path is provided inside the punch (1200), in which the die (1300) and the die pad (1100) are disposed to face the punch (1200) in the press direction (P), the die pad (1100) is disposed facing the top surface (1210) of the punch (1200), and a protrusion (1120) is provided at a position on the die pad (1100) opposing the groove portion (1220) in the press direction (P), and the protrusion (1120) has an inverted shape of the groove portion (1220).



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Description

TECHNICAL FIELD

5 **[0001]** The present disclosure relates to a hot press apparatus, a method for manufacturing a hot press-formed product, and a hot press-formed product.

[0002] Priority is claimed on Japanese Patent Application No. 2022-085778, filed May 26, 2022, the content of which is incorporated herein by reference.

10 BACKGROUND ART

[0003] In the related art, as a frame member of an automobile, a member obtained by processing a sheet shaped member made of a metal into a predetermined cross-sectional shape has been used. In a case in which an impact from a collision is applied to a product having a frame member, the frame member is required to achieve a desired deformation mode and efficiently absorb the impact. For example, Patent Document 1 discloses a bumper reinforcement material that is provided with a small recessed portion and a large recessed portion surrounding the small recessed portion for the purpose of increasing a peak load or an energy absorption amount.

[0004] Such a frame member is required to be lightweight and have sufficient load capacity. Furthermore, in recent years, with the stricter collision safety standards and the stricter fuel efficiency regulations for a vehicle such as an automobile, there is a demand for a high-strength and lightweight member. In order to meet such a demand, progress is being made in the development of a lightweight frame member that employs so-called a high-strength material having high tensile strength.

[0005] Patent Document 2 discloses a technique for press-forming a sheet material into a hat-shaped product having an unevenness in its top surface. However, if a forming process of the unevenness in the top surface of the formed product and a forming process of a shoulder portion adjacent to the top surface are performed simultaneously, these forming processes interfere with each other, and thus it is difficult to perform the forming processes. In Patent Document 2, the forming process of the unevenness in the top surface of the formed product is performed in advance, and after the unevenness is restrained by a punch and a die pad, the shoulder of the formed product is formed by a punch and a die. In this way, the main point of Patent Document 2 is that the two forming processes are not performed simultaneously.

Citation List

Patent Document

35 **[0006]**

Patent Document 1: Japanese Patent No. 5329188

Patent Document 2: Japanese Unexamined Patent Application, First Publication No. 2020-075275

40 SUMMARY OF INVENTION

Technical Problem

[0007] In a case in which a hat-shaped product or groove-shaped member having a groove portion in its top surface is formed through hot press, if the method of Patent Document 2 is applied to the hot press, the hot press will be executed twice. In a case in which the forming process is performed through a single hot press, it is conceivable to form a groove portion in a heated sheet material using a die pad and a punch, and then form a shoulder using a punch and a die. In this case, however, two problems arise. Firstly, in a case in which the groove portion is formed via a spring as in Patent Document 2, the force of the spring is weak, and therefore the die pad cannot reach a bottom dead point of a forming process, and the groove portion cannot be formed into a desired shape (a shape that follows the groove portion at the top portion of the punch). Secondly, even if the die pushes the die pad to reach the bottom dead point of the forming process, a localized reduction in sheet thickness occurs in the groove portion of the formed product. Until the die reaches the bottom dead point of the forming process, a workpiece between the groove portion at the top portion of the punch and the die pad is not in uniform contact with the die, causing temperature variation in the workpiece. The reduction in sheet thickness occurs because a locally softened portion caused by the temperature variation in the workpiece is preferentially stretched when the die and die pad reach the bottom dead point of the forming process.

[0008] The present disclosure has been made in view of the above. An object of the present disclosure is to provide a hot press apparatus capable of suppressing a reduction in sheet thickness and necking at a recessed portion of a hot press-

formed product formed by a die pad, a method for manufacturing a hot press-formed product using the apparatus, and a hot press-formed product in which a reduction in sheet thickness and necking at a recessed portion of a press-formed product are suppressed.

Solution to Problem

[0009]

(1) A hot press apparatus according to one aspect of the present disclosure includes

a punch, a die, and a die pad,
in which a groove portion is provided in a top surface of the punch,
in which, in a cross section in a press direction, an angle between a wall surface of the groove portion and the press direction is 2° to 8° ,
in which a refrigerant flow path is provided inside the punch,
in which the die and the die pad are disposed to face the punch in the press direction,
the die pad is disposed facing the top surface of the punch, and
a protrusion is provided at a position on the die pad opposing the groove portion in the press direction, and the protrusion has an inverted shape of the groove portion.

(2) In the hot press apparatus of (1) above,

the die may have a step portion that comes into contact with the die pad in the press direction, and
the die pad may come into contact with the die in the press direction at a bottom dead point of a forming process.

(3) In the hot press apparatus of (1) or (2) above,

in the cross section, an angle between a straight line connecting an R end of a side surface portion side ridge portion of the wall surface and an R end of a bottom surface portion side ridge portion of the groove portion and the press direction may be 2° to 8° .

(4) A method for manufacturing a hot press-formed product according to one aspect of the present disclosure is a method for manufacturing a hot press-formed product using the hot press apparatus according to any one of (1) to (3) above, the method including:

arranging a blank between the die and the punch;
causing the blank to be sandwiched between the punch and the die pad; and
bringing the punch and the die close to each other in the press direction until the bottom dead point of the forming process.

(5) A hot press-formed product according to one aspect of the present disclosure is

a press-formed product that includes a first sheet portion having a recessed portion formed therein and a second sheet portion inclined with respect to the first sheet portion,
in which, in a cross-sectional view in a plane in which a cross-sectional line length of the recessed portion is the smallest among planes passing through a point at which a depth of the recessed portion is the largest, an angle between a side portion of the recessed portion and a direction perpendicular to a sheet surface of the first sheet portion is 2° to 8° , and
in which a sheet thickness at a portion of the recessed portion at which the sheet thickness is smallest is 60% or more of a sheet thickness at a portion of the first sheet portion excluding the recessed portion.

(6) In the hot press-formed product of (5) above,

in the cross-sectional view, an angle between a straight line connecting an R end of a side portion side ridge portion of the side portion and an R end of a bottom portion side ridge portion of the recessed portion and a direction perpendicular to the sheet surface of the first sheet portion may be 2° to 8° .

Advantageous Effects of Invention

[0010] According to the present disclosure, it is possible to provide a hot press apparatus capable of suppressing a reduction in sheet thickness and necking at a recessed portion of a hot press-formed product formed by a die pad, a

method for manufacturing a hot press-formed product using the apparatus, and a hot press-formed product in which a reduction in sheet thickness and necking at a recessed portion of a press-formed product are suppressed.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

[FIG. 1] A schematic perspective view of a hot press-formed product according to one embodiment of the present disclosure.

[FIG. 2] A schematic end view of a cut portion of the hot press-formed product of FIG. 1 viewed in a cross section in a direction along a Z coordinate axis.

[FIG. 3] An enlarged schematic end view of a cut portion of the vicinity of a recessed portion of the hot press-formed product of FIG. 2.

[FIG. 4] A schematic perspective view of a hot press apparatus according to one embodiment of the present disclosure.

[FIG. 5] A schematic end view of a cut portion of the hot press apparatus shown in FIG. 4 viewed in a cross section at cross section line A-A in a direction along a Z coordinate axis.

[FIG. 6] A schematic end view of a cut portion for explaining a hot press apparatus used in a method for manufacturing a hot press-formed product according to one embodiment of the present disclosure, showing a state in which a workpiece is placed thereon.

[FIG. 7] A schematic end view of the cut portion for explaining the hot press apparatus used in the method for manufacturing a hot press-formed product according to one embodiment of the present disclosure, showing a state in which the recessed portion is formed in the workpiece.

[FIG. 8] A schematic end view of the cut portion for explaining the hot press apparatus used in the method for manufacturing a hot press-formed product according to one embodiment of the present disclosure, showing a state in which press forming is completed.

[FIG. 9] A schematic end view of a cut portion for explaining a hot press apparatus used in a method for manufacturing a hot press-formed product according to another embodiment of the present disclosure.

[FIG. 10] A schematic end view of the cut portion for explaining the hot press apparatus used in the method for manufacturing a hot press-formed product according to another embodiment of the present disclosure, showing a state in which press forming is completed.

[FIG. 11] A schematic end view of a cut portion for explaining a hot press apparatus used in a method for manufacturing a hot press-formed product according to another embodiment of the present disclosure.

[FIG. 12] A schematic end view of a cut portion for explaining the recessed portion of the hot press-formed product according to one embodiment of the present disclosure.

[FIG. 13] A schematic end view of a cut portion of a hot press apparatus according to one embodiment of the present disclosure.

[FIG. 14] A schematic end view of a cut portion of a hot press-formed product according to one embodiment of the present disclosure.

[FIG. 15] A schematic end view of a cut portion for explaining a modification example of the recessed portion of the hot press-formed product according to one embodiment of the present disclosure, showing the vicinity of the recessed portion of the hot press-formed product.

[FIG. 16] A schematic end view of a cut portion for explaining a modification example of the recessed portion of the hot press-formed product according to one embodiment of the present disclosure, showing the vicinity of the recessed portion of the hot press-formed product.

[FIG. 17] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to the present disclosure.

[FIG. 18] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to the present disclosure.

[FIG. 19] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to the present disclosure.

[FIG. 20] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to the present disclosure.

[FIG. 21] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to the present disclosure.

[FIG. 22] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed product according to one embodiment of the present disclosure.

[FIG. 23] A schematic plan view for explaining a modification example of the recessed portion of the hot press-formed

product according to one embodiment of the present disclosure.

[FIG. 24] A graph showing experimental results of Example 1.

[FIG. 25] A graph showing experimental results of Example 2.

5 DESCRIPTION OF EMBODIMENTS

[0012] Hereinafter, embodiments of the present disclosure will be described with reference to examples, but it is obvious that the present disclosure is not limited to the examples which will be described below. In the following description, specific numerical values and materials may be given as examples, but other numerical values and materials may be applied as long as the effects of the present disclosure are obtained. In addition, the components of the following embodiments can be combined with each other.

[0013] First, a hot press-formed product 100 obtained by a hot press apparatus and a method for manufacturing a hot press-formed product according to the present embodiment will be described with reference to FIG. 1.

15 [Hot press-formed product]

[0014] FIG. 1 is a perspective view of the hot press-formed product 100 and is a view including a cut surface orthogonal to a longitudinal direction at the central position on the long hot press-formed product 100 in the longitudinal direction. This cut surface is also a cross section in a press direction P. As shown in FIG. 1, the hot press-formed product 100 of the present embodiment is the long hot press-formed product 100 and includes a first sheet portion 110 that extends in the longitudinal direction of the hot press-formed product 100, a second sheet portion 120 that extends in the longitudinal direction of the hot press-formed product 100 and is inclined with respect to the first sheet portion 110, and a ridge portion 130 that smoothly connects the first sheet portion 110 and the second sheet portion 120 and extends in the longitudinal direction of the hot press-formed product 100. The hot press-formed product 100 is a long member and has a longitudinal direction and a short direction orthogonal to the longitudinal direction. The longitudinal direction is a direction in which the hot press-formed product 100, which is a long member, extends. In FIG. 1, the longitudinal direction of the hot press-formed product 100 is parallel to a Z coordinate axis. An X coordinate axis and a Y coordinate axis in FIG. 1 form a plane including the short direction of the hot press-formed product 100. The X coordinate axis, the Y coordinate axis, and the Z coordinate axis in FIG. 1 are orthogonal to each other.

[0015] In the example of FIG. 1, a portion of the first sheet portion 110 excluding a recessed portion 140 has a generally flat sheet shape and extends in the longitudinal direction of the hot press-formed product 100. The portion of the first sheet portion 110 excluding the recessed portion 140 has a first sheet portion sheet surface 110a and a first sheet portion sheet surface 110b on a side opposite to the first sheet portion sheet surface 110a. When a direction parallel to the longitudinal direction of the hot press-formed product 100 is defined as a length direction of the first sheet portion 110, the first sheet portion 110 extends in the length direction of the first sheet portion 110.

[0016] The second sheet portion 120 is a portion in a substantially flat sheet shape and extends in the longitudinal direction of the hot press-formed product 100. The second sheet portion 120 has a second sheet portion sheet surface 120a and a second sheet portion sheet surface 120b on a side opposite to the second sheet portion sheet surface 120a. When a direction parallel to the longitudinal direction of the hot press-formed product 100 is defined as a length direction of the second sheet portion 120, the second sheet portion 120 extends in the length direction of the second sheet portion 120. When a direction orthogonal to the length direction of the second sheet portion 120 and a sheet thickness direction of the second sheet portion 120 is defined as a width direction of the second sheet portion 120, the second sheet portion 120 extends in the width direction of the second sheet portion 120. In the example of FIG. 1, the hot press-formed product 100 has a pair of second sheet portions 120.

[0017] The ridge portion 130 is a portion that smoothly connects the first sheet portion 110 and the second sheet portion 120 and extends in the longitudinal direction of the hot press-formed product 100. Since the second sheet portion 120 is inclined with respect to the first sheet portion 110, the ridge portion 130 connecting them has a curved shape that forms a curve in a view of a cross section orthogonal to the longitudinal direction of the hot press-formed product 100. The state in which the second sheet portion 120 is inclined with respect to the first sheet portion 110 means that the sheet surface of the first sheet portion 110 and the sheet surface of the second sheet portion 120 are not parallel. In addition, a direction parallel to the longitudinal direction of the hot press-formed product 100 is defined as a length direction of the ridge portion 130. The surface on the outer side of the bend of the ridge portion 130 is defined as a ridge outer surface 130a, and the surface on the inner side of the bend of the ridge portion 130 is defined as a ridge inner surface 130b. The first sheet portion sheet surface 110a and the second sheet portion sheet surface 120a are connected to the ridge outer surface 130a, and the first sheet portion sheet surface 110b and the second sheet portion sheet surface 120b are connected to the ridge inner surface 130b. One edge portion (a first sheet portion edge portion 110A) of the first sheet portion 110 extending in the longitudinal direction of the hot press-formed product 100 is connected to one edge portion (a ridge edge portion 130A) of the ridge portion 130 extending in the longitudinal direction of the hot press-formed product 100. One edge portion (a second sheet

portion edge portion 120A) of the second sheet portion 120 extending in the longitudinal direction of the hot press-formed product 100 is connected to the other edge portion (a ridge edge portion 130B) of the ridge portion 130 extending in the longitudinal direction. In the example of FIG. 1, the hot press-formed product 100 has a pair of ridge portions 130.

[0018] The first sheet portion 110 is provided with a recessed portion 140. When a direction parallel to the longitudinal direction of the hot press-formed product 100 is defined as a length direction of the recessed portion 140, the recessed portion 140 extends in the length direction of the recessed portion 140.

[0019] The recessed portion 140 may pass through the central position of the hot press-formed product 100 in the longitudinal direction and extend along the ridge portion 130. The central position on the hot press-formed product 100 in the longitudinal direction means a position that is within a range of 20% of a length of the hot press-formed product 100 in the longitudinal direction from the center position at which the length of the hot press-formed product 100 in the longitudinal direction is divided into two equal parts. The fact that the recessed portion 140 extends along the ridge portion 130 means that the recessed portion 140 is disposed to be substantially parallel to a part of the adjacent ridge portion 130.

[0020] In the second sheet portion 120, a flange portion may be formed on an edge portion that is not connected to the ridge portion 130 of edge portions extending in the longitudinal direction. The first sheet portion 110, the second sheet portion 120, or the flange portion may be provided with a hole, a notch, a welded part, or the like. In addition, the second sheet portion 120 or the flange portion may be provided with a bead.

[0021] FIG. 2 shows an end view of a cut portion of the hot press-formed product 100 viewed in a cross section at a plane orthogonal to the longitudinal direction of the hot press-formed product 100 in the longitudinal direction of the hot press-formed product 100 shown in FIG. 1. The recessed portion 140 is recessed in a direction perpendicular to the sheet surface of the first sheet portion 110 as will be described below. In the example of FIG. 2, the recessed portion 140 is recessed with respect to the first sheet portion 110 toward a side on which the second sheet portion 120 is located (a side of the first sheet portion sheet surface 110b).

[0022] In the example of FIG. 2, the recessed portion 140 has a bottom portion 141, a pair of side portions 142, a pair of bottom portion side ridge portions 143, and a pair of side portion side ridge portions 144. The bottom portion 141 of the recessed portion is connected at end portions thereof to the side portions 142 via the pair of bottom portion side ridge portions 143. Each side portion 142 is connected to the first sheet portion 110 via the side portion side ridge portion 144. The bottom portion 141, the side portion 142, the bottom portion side ridge portion 143, and the side portion side ridge portion 144 extend in the length direction of the recessed portion 140.

[0023] The bottom portion 141 of the recessed portion 140 has a bottom portion inner surface 141a located on an inner side of the recessed portion 140 (on a side of the side portion 142) and a bottom portion outer surface 141b on a side opposite to the bottom portion inner surface 141a. That is, the bottom portion inner surface 141a constitutes a part of the inner surface of the recessed portion 140.

[0024] FIG. 3 shows an enlarged view of the vicinity of the recessed portion 140 of the hot press-formed product 100 of FIG. 2. In a plane orthogonal to the longitudinal direction of the hot press-formed product 100, one of the boundaries between the first sheet portion 110 and the recessed portion 140 (the boundaries between the first sheet portion 110 and the side portion side ridge portion 144) is defined as a boundary gb1, and the other boundary is defined as a boundary gb2. Here, as shown in FIG. 3, on a plane orthogonal to the longitudinal direction of the hot press-formed product 100 in the longitudinal direction of the hot press-formed product 100, each of the boundary gb1 and the boundary gb2 is a point on the sheet surface on the outer side of the bend of the side portion side ridge portion 144. In other words, each of these boundaries is also an R end on the sheet surface on the outer side of the bend of the side portion side ridge portion 144.

[0025] In the example of the present embodiment, the recessed portion 140 is a portion of the first sheet portion 110 which is recessed toward the side on which the second sheet portion 120 is located (the side of the first sheet portion sheet surface 110b). The recessed portion 140 may be a portion of the first sheet portion 110 which is recessed toward a side opposite to the side on which the second sheet portion 120 is located (a side of the first sheet portion sheet surface 110a). That is, the recessed portion provided in the first sheet portion 110 may be recessed toward a side of the ridge outer surface 130a (the outside of the hot press-formed product 100) or a side of the ridge inner surface 130b (the inside of the hot press-formed product 100).

[0026] In the plane orthogonal to the longitudinal direction of the hot press-formed product 100, a distance between the boundary gb1 of the recessed portion and the boundary gb2 of the recessed portion is defined as a width w of the recessed portion 140. The width w of the recessed portion 140 does not need to be constant in the longitudinal direction of the hot press-formed product 100. The width w of the recessed portion 140 is preferably 10 mm to 52 mm in order to improve the compressive axial force performance in the direction along the Z coordinate axis or the moment bending performance around the direction along the X coordinate axis shown in FIG. 1 and the like. The width w of the recessed portion 140 is preferably smaller than a length of the recessed portion 140 in an extending direction.

[0027] In the direction in which the hot press-formed product 100, which is a long member, extends, a direction in which the boundaries gb1 at both end portions of the hot press-formed product 100 are connected is defined as the longitudinal direction.

[Press apparatus]

[0028] Next, a press apparatus (a hot press apparatus) used in the method for manufacturing a hot press-formed product according to the present embodiment will be described.

[0029] FIG. 4 shows an example of the press apparatus (the hot press apparatus) used in the method for manufacturing a hot press-formed product according to the present embodiment. The press apparatus 1000 shown in FIG. 4 includes a first die 1100, a second die 1200, and a third die 1300 as press dies. The first die 1100 and the second die 1200 are movable relative to each other in the press direction P. A workpiece (a blank) is sandwiched between the first die 1100 and the second die 1200. The third die 1300 is disposed adjacent to the first die 1100 in the direction along the X coordinate axis and is movable relative to the first die 1100 and the second die 1200. In the present embodiment, the third die 1300 is movable in the press direction P relative to the first die 1100 and the second die 1200. Further, a refrigerant flow path (not shown) is provided inside the second die 1200 of the press apparatus 1000. Here, the press direction P in the press apparatus 1000 is a negative direction on the Y coordinate axis. The X coordinate axis, the Y coordinate axis, and the Z coordinate axis in FIG. 4 are orthogonal to each other.

[0030] The first die 1100, the second die 1200, and the third die 1300 have a longitudinal direction in a direction along the Z coordinate axis. FIG. 5 shows a schematic end view of a cut portion of the press apparatus 1000 shown in FIG. 4 viewed in a cross section at cross section line A-A in a direction along the Z coordinate axis. Cross-sectional views of FIGS. 5 to 8 are views of cross sections in the press direction P.

[0031] The first die 1100 has a press surface 1110 and a protrusion 1120 provided on the press surface 1110. In the example of FIG. 5, the protrusion 1120 has a bottom surface portion 1121 and a pair of side surface portions 1122. The bottom surface portion 1121 is connected at end portions thereof to the side surface portions 1122 via a pair of bottom surface portion side ridge portions 1123. In the example of FIG. 5, the protrusion 1120 protrudes in the negative direction on the Y coordinate axis. Each of the side surface portions 1122 is connected to a holding surface portion 1130 of the press surface 1110 excluding the protrusion 1120 via a side surface portion side ridge portion 1124. The bottom surface portion 1121, the side surface portion 1122, the bottom surface portion side ridge portion 1123, and the side surface portion side ridge portion 1124 extend in a direction in which the protrusion 1120 extends, that is, in the direction along the Z coordinate axis in FIG. 4.

[0032] The second die 1200 has a press surface (a top surface) 1210 and a groove portion (a recessed surface portion) 1220 provided in the press surface 1210. That is, the second die 1200 has the groove portion 1220 in the top surface thereof. In the example of FIG. 5, the groove portion 1220 has a bottom surface portion 1221, a pair of side surface portions 1222, a pair of bottom surface portion side ridge portions 1223, and a pair of side surface portion side ridge portions 1224. The bottom surface portion 1221 is connected at end portions thereof to the side surface portions 1222 via the pair of bottom surface portion side ridge portions 1223. In the example of FIG. 5, the groove portion 1220 has a shape recessed in the negative direction on the Y coordinate axis. Each of the side surface portions 1222 is connected to a holding surface portion 1230 of the press surface 1210 excluding the groove portion 1220 via the side surface portion side ridge portion 1224. The bottom surface portion 1221, the side surface portion 1222, the bottom surface portion side ridge portion 1223, and the side surface portion side ridge portion 1224 have a constant length and extend in a direction in which the groove portion 1220 extends, that is, in the direction along the Z coordinate axis in FIG. 4. The second die 1200 further includes a side wall portion 1250 that is connected to the holding surface portion 1230 via a shoulder surface portion 1240. The shoulder surface portion 1240 is a portion that smoothly connects the holding surface portion 1230 and the side wall portion 1250, and the shoulder surface portion 1240 and the side wall portion 1250 extend in a direction in which the press surface 1210 extends, that is, in the direction along the Z coordinate axis in FIG. 4.

[0033] The protrusion 1120 of the first die 1100 and the groove portion 1220 of the second die 1200 have surface shapes corresponding to each other, and, when the workpiece is sandwiched between the first die 1100 and the second die 1200, the recessed portion 140 is formed in the workpiece. In other words, the protrusion 1120 has an inverted shape of the groove portion 1220. Furthermore, the holding surface portion 1130 of the first die 1100 and the holding surface portion 1230 of the second die 1200 are parallel to each other. In the present embodiment, the holding surface portion 1130 and the holding surface portion 1230 are perpendicular to the press direction P. The protrusion 1120 is provided at a position on the first die 1100 opposing the groove portion 1220 in the press direction P.

[0034] In a cross section in the press direction P, the wall surface of the groove portion 1220 has an angle of 2° to 8° with respect to the press direction P. More specifically, in a cross section in the press direction P, an angle between a straight line connecting an R end of the side surface portion side ridge portion 1224 located on a side of the side surface portion 1222 and an R end of the bottom surface portion side ridge portion 1223 located on a side of the side surface portion 1222 and the press direction P is 2° to 8° . The cross section in the press direction P is a plane in which a cross-sectional line length of the groove portion 1220 is the smallest among planes passing through a point on the bottom surface portion 1221 at which a depth of the groove portion 1220 of the second die 1200 is the largest in the entire groove portion 1220. The depth of the groove portion 1220 means a distance, on an imaginary plane that includes the shortest straight line connecting boundaries between the pair of side surface portion side ridge portions 1224 and the holding surface portion 1230

and on which the cross-sectional line length of the groove portion 1220 is the smallest when viewed in a cross section, from the straight line to the bottom surface portion 1221 in a direction orthogonal to the straight line connecting the boundaries. The cross-sectional line length of the groove portion 1220 can be measured by creating a 3D model on the basis of three-dimensional shape measurement of the second die 1200 and deriving the plane in which the cross-sectional line length is the smallest.

[0035] The radius of curvature of the bottom surface portion side ridge portion 1223 is 3 mm to 30 mm. The radius of curvature of the side surface portion side ridge portion 1224 is 3 mm to 30 mm. The radius of curvature of the side surface portion 1222 is greater than 30 mm, or the side surface portion 1222 is flat. Even if the side surface portion 1222 is curved within such a range of radius of curvature, the wall surface of the groove portion 1220 in the cross section described above can be approximated to a straight line, and the angle between the straight line connecting the R ends described above and the press direction P can be specified.

[0036] The third die 1300 has a press surface 1310. The press surface 1310 extends in a direction along the Z coordinate axis in FIG. 4. The first die 1100 and the third die 1300 are disposed to face the second die 1200 in the press direction P. The first die 1100 is disposed facing the top surface of the second die 1200.

[0037] In addition, the third die 1300 is connected to a slide plate 1400. In addition, the first die 1100 is connected to the slide plate 1400 via a support portion 1410 (a spring or a piston). As the slide plate 1400 moves, the third die 1300 moves. As the slide plate 1400 moves, the first die 1100 moves via the support portion 1410. The press apparatus 1000 may be provided with a drive unit (not shown) capable of driving the first die 1100, the second die 1200, and the third die 1300 independently of each other. In addition, any one of the first die 1100, the second die 1200, and the third die 1300 may be fixed to the press apparatus 1000.

[0038] Here, in the embodiment of the present application, the first die 1100 is defined as a die pad, the second die 1200 is defined as a punch, and the third die 1300 is defined as a die.

[Method for manufacturing hot press-formed product]

[0039] The method for manufacturing a hot press-formed product according to the present embodiment is a method for manufacturing a hot press-formed product in which a workpiece is hot-pressed to form a press-formed product including a first sheet portion having a recessed portion formed therein. In the method for manufacturing a hot press-formed product according to the present embodiment, first, the workpiece (the blank) 1 is placed between the first die 1100 and a second die 1200 as shown in FIG. 6. In the example of FIG. 6, the first die 1100 is positioned vertically above the second die 1200, and the workpiece 1 is placed on the holding surface portion 1230 of the second die 1200.

[0040] In the method for manufacturing a hot press-formed product according to the present embodiment, the temperature of the workpiece 1 at the start of press forming may be 600°C to 800°C. As a result, an effect that a component can be formed hot by the hot press apparatus described above while deformation resistance is low.

[0041] Next, the first die 1100 and the second die 1200 are moved relatively in the press direction P (downward in a vertical direction) to bring them close to each other. At this time, the third die 1300 may move together with the first die 1100, or the third die 1300 may not move. As a result, a portion of the workpiece 1 that corresponds to the first sheet portion 110 in the hot press-formed product 100 is sandwiched by the first die 1100 and the second die 1200.

[0042] Next, the first die 1100 is further moved in the press direction P from a state in which the protrusion 1120 of the first die 1100 is in contact with the workpiece 1. As a result, as shown in FIG. 7, the workpiece 1 is sandwiched by the first die 1100 and the second die 1200, and the recessed portion 140 is formed between the protrusion 1120 of the first die 1100 and the groove portion 1220 of the second die 1200.

[0043] In the method for manufacturing a hot press-formed product according to the present embodiment, when the recessed portion 140 is formed by the first die 1100 and the second die 1200, a pressing force may be 0.4 to 22.0 MPa. More preferably, the pressing force may be 0.4 to 4.4 MPa. This allows the workpiece to be formed while the deformation resistance is low, and further allows the forming load of the first die 1100 to be set to the minimum load force, resulting in reduced die costs.

[0044] Thereafter, the third die 1300 is further moved to the bottom dead point, and, as shown in FIG. 8, the workpiece 1 is sandwiched by the second die 1200 and the third die 1300, and the second sheet portion 120 is formed between the second die 1200 and the third die 1300, thereby completing the press forming. At this point, the first sheet portion 110, the second sheet portion 120, the ridge portion 130, and the recessed portion 140 are formed in the hot press-formed product 100. In addition, a flange portion may be formed between the second die 1200 and the third die 1300.

[0045] From the viewpoint of formability, the first die 1100 may reach the bottom dead point before the third die 1300 reaches the bottom dead point, or the first die 1100 may reach the bottom dead point at the same time that the third die 1300 reaches the bottom dead point.

[0046] FIG. 9 illustrates a hot press apparatus used in a method for manufacturing a hot press-formed product according to another embodiment of the present disclosure. FIG. 9 is a schematic end view of a cut portion of the press apparatus shown in FIG. 4 viewed in a cross section at cross section line A-A in a direction along the Z coordinate axis, similar to FIG.

5. End views of cut portions of FIGS. 9 to 11 are views of cross sections in the press direction P. The press apparatus 1000 shown in FIG. 9 has the same configuration as the press apparatus 1000 shown in FIG. 5 and the like, except that it is provided with a step portion 1320, and therefore a description thereof will be omitted here. That is, the configuration of the press apparatus 1000 according to the FIGS. 4 to 8 described above can be applied to the press apparatus 1000 shown in FIG. 9. The step portion 1320 may extend in a direction along the Z coordinate axis.

[0047] In the example of FIG. 9, two third dies 1300 are shown in an X coordinate axis direction. These two third dies 1300 may be connected to each other in the X coordinate axis direction.

[0048] FIG. 10 shows a state in which the workpiece is sandwiched by the dies and the third die 1300 is moved to the bottom dead point. As shown in FIG. 10, the workpiece is sandwiched by the second die 1200 and the third die 1300, and the second sheet portion 120 is formed between the second die 1200 and the third die 1300, thereby completing the press forming. At this point, the first sheet portion 110, the second sheet portion 120, the ridge portion 130, and the recessed portion 140 are formed in the hot press-formed product 100.

[0049] Since the third die 1300 includes the step portion 1320, the first die 1100 comes into contact with the third die 1300 in the press direction P at a bottom dead point of a forming process. As a result, the first die 1100 is pressed against the third die 1300, and thus it is possible to suppress necking even in a case in which the pressing force of the first die 1100 is insufficient. At this time, the support portion 1410 is deformed to be contracted in the press direction P.

[0050] In addition, another form of the press apparatus 1000 is shown in FIG. 11. The press apparatus 1000 in FIG. 11 is also a schematic end view of a cut portion of the press apparatus shown in FIG. 4 viewed in a cross section at cross section line A-A in a direction along the Z coordinate axis, similar to FIG. 5 and the like. In the press apparatus 1000 shown in FIG. 11, the third die 1300 is provided on only one side. In addition, the third die 1300 has the step portion 1320. The first die 1100 also has a press surface 1140 on a side opposite to the third die 1300 in the X axis direction. The press surface 1140 is provided to be connected to the press surface 1110 of the first die 1100. The press surface 1140 extends in a direction along the Z coordinate axis.

[0051] The press apparatus 1000 shown in FIG. 11 has the same configuration as the press apparatus 1000 shown in FIG. 9, except that the third die 1300 is provided on only one side, and therefore a description thereof will be omitted here. That is, the configuration of the press apparatus 1000 according to the FIG. 9 can be applied to the press apparatus 1000 shown in FIG. 11. The press apparatus 1000 in FIG. 11 has an advantage that an area for arranging a pressing mechanism of the third die 1300 on an upper side of the press apparatus 1000 can be increased, allowing for some likelihood in the press load design.

[0052] In the method for manufacturing a hot press-formed product according to the present embodiment, press forming may be performed such that a ratio of an area of the recessed portion 140 to an area of the first sheet portion 110 is 30% or more when viewed in a plane in a direction perpendicular to the sheet surface of the first sheet portion 110. The direction perpendicular to the sheet surface of the first sheet portion 110 means a direction, on an imaginary plane that includes the shortest straight line connecting the boundary gb1 and the boundary gb2 and on which a cross-sectional line length of the recessed portion 140 is the smallest when viewed in a cross section, orthogonal to the straight line connecting the boundary gb1 and the boundary gb2. The cross-sectional line length of the recessed portion 140 can be measured by creating a 3D model on the basis of three-dimensional shape measurement of the hot press-formed product 100 and deriving the plane in which the cross-sectional line length is the smallest. The three-dimensional shape measurement described in the present embodiment can be performed using a 3D scanner such as Atos (manufactured by GOM).

[0053] The definitions of the area of the first sheet portion 110 and the area of the recessed portion 140 will be described below.

[0054] In the method for manufacturing a hot press-formed product according to the present embodiment, press forming may be performed such that the maximum depth dmax in a depth d of the recessed portion 140 in the press direction P is 15 mm or more. The depth d of the recessed portion 140 means a depth in the press direction P. The press direction P is a direction perpendicular to the sheet surface of the first sheet portion 110. The maximum depth dmax means the maximum value of the depth d of the recessed portion 140 in the entire recessed portion 140. Since the maximum depth dmax is 15 mm or more, it is possible to obtain an effect of improving the compressive axial force performance in the direction along the Z coordinate axis or the moment bending performance around the direction along the X coordinate axis shown in FIG. 1 and the like. The depth of the recessed portion 140 means a distance from the straight line in the direction perpendicular to the sheet surface of the first sheet portion 110 described above to the bottom portion inner surface 141a.

[0055] More preferably, the maximum depth dmax is 20 mm or more in order to further improve the axial force or bending moment performance. More preferably, from the viewpoint of suppressing deterioration in productivity due to an increase in a press stroke caused by an increase in the stroke of the pad, the upper limit of the maximum depth dmax is preferably 50 mm.

[0056] In the method for manufacturing a hot press-formed product according to the present embodiment, when the recessed portion 140 is formed, pressing is performed such that, in a cross-sectional view in a plane (a cross section cut in the press direction) in which the cross-sectional line length of the recessed portion 140 is the smallest among planes passing through a point pd at which the depth d of the recessed portion 140 is the largest, an angle α between the side

portion 142 of the recessed portion 140 and the press direction P is 2° to 8° . More specifically, pressing is performed such that, in a plane in which the cross-sectional line length of the recessed portion 140 is the smallest among planes passing through the point pd at which the depth d of the recessed portion 140 is the largest, an angle between the straight line connecting the R end of the side portion side ridge portion 144 located on the side of the side portion 142 and the R end of the bottom portion side ridge portion 143 located on the side of the side portion 142 and the press direction P is 2° to 8° . The plane that passes through the point pd at which the depth d of the recessed portion 140 is the smallest and in which the cross-sectional line length of the recessed portion 140 is the smallest is parallel to the press direction P. The point pd at which the depth d of the recessed portion 140 is the largest is a point at which the depth d of the recessed portion 140 is the maximum depth dmax in the entire recessed portion 140.

[0057] The radius of curvature of the bottom portion side ridge portion 143 is 3 mm to 30 mm. The radius of curvature of the side portion side ridge portion 144 is 3 mm to 30 mm. The radius of curvature of the side portion 142 is greater than 30 mm, or the side portion 142 is flat. Even if the side portion 142 is curved within such a range of radius of curvature, the side portion 142 in the cross section described above can be approximated to a straight line, and the angle between the straight line connecting the R ends described above and the press direction P can be specified.

[0058] FIG. 12 shows an end view of a cut portion in a plane in which the cross-sectional line length of the recessed portion 140 is the smallest among planes passing through the point pd at which the depth d of the recessed portion 140 is the largest, viewed in a cross section. FIG. 12 shows the hot press-formed product 100 placed on the press apparatus 1000 after the completion of press forming and is an enlarged view of the vicinity of the recessed portion 140 of the hot press-formed product 100. As shown in FIG. 12, the cross-sectional line length of the recessed portion 140 means a line length along the inner surface of recessed portion 140 from the boundary gb1 to the boundary gb2 in a plane including the shortest straight line connecting the boundary gb1 and the boundary gb2. A cross section that defines a curve C that corresponds to the shape of the recessed portion 140 is a plane in which the cross-sectional line length of the recessed portion 140 is the smallest among planes passing through the point pd.

[0059] The curve C corresponds to the shape of the inner surface of the recessed portion 140 in this cross section. The curve C has a point ip1 and a point ip2, which are one end points of the side portion 142, between the boundary gb1 or the boundary gb2 and the point pd. The point ip1 and the point ip2 are also the R ends of the side portion side ridge portion 144. In this cross section, pressing is performed such that the angle α between the side portion 142 of the recessed portion 140 and the press direction P is 2° to 8° , and therefore the recessed portion 140 that is formed by the first die 1100 can be processed to a forming height closer to the bottom dead point, and a reduction in sheet thickness and necking at the recessed portion can be suppressed. Since the angle α is 2° or more, there is an effect that the die can be easily released after press forming. Furthermore, since the angle α is 8° or less, a portion of the workpiece 1 that does not come into contact with the first die 1100 or the second die 1200 during forming with the first die 1100 can be reduced, and a portion at which cooling does not progress can be reduced. In a case in which a portion at which cooling does not progress is small, the reduction in sheet thickness of the workpiece 1 during forming does not occur locally and does not lead to necking, and therefore there is an effect capable of forming a component without excessive reduction in sheet thickness or necking.

[0060] As illustrated in FIG. 12, in a case in which the side portion 142 of the recessed portion 140 is flat, the inclination of the side portion 142 coincides with the inclination of a tangent line ti1 or a tangent line ti2. In addition, the inclination of the tangent line ti1 or the inclination of the tangent line ti2 coincides with the inclination of the straight line connecting the R end of the side portion side ridge portion 144 located on a side of the side portion 142 and the R end of the bottom portion side ridge portion 143 located on a side of the side portion 142. In the examples of FIG. 12 and the like, the side portions 142 are drawn to have the same inclination with respect to the press direction P, but the two side portions 142 may have different angles with respect to the press direction P as long as the angle requirements with respect to the press direction P are satisfied.

[0061] In the hot press-formed product 100 obtained by the manufacturing method described above, the ratio of the area of the recessed portion 140 to the area of the first sheet portion 110 may be 30% or more when viewed in a plane in a direction perpendicular to the sheet surface of the first sheet portion 110. The area of the first sheet portion 110 is an area of a portion including the recessed portion 140 and excluding the second sheet portion 120 and the ridge portion 130 between the first sheet portion 110 and the second sheet portion 120.

[0062] The area of the recessed portion 140 is an area from the boundary gb1 to the boundary gb2 when viewed in a plane in a direction perpendicular to the sheet surface of the first sheet portion 110. Since the area of the recessed portion 140 with respect to the area of the first sheet portion 110 is 30% or more when viewed in a plane in a direction perpendicular to the sheet surface of the first sheet portion 110, it is possible to obtain an effect of improving the compressive axial force performance in the direction along the Z coordinate axis or the moment bending performance around the direction along the X coordinate axis shown in FIG. 1 and the like. More preferably, the area of the recessed portion 140 with respect to the area of the first sheet portion 110 is 50% or more in order to further improve the axial force or bending moment performance.

[0063] The area of the first sheet portion 110 is defined as an area of the range surrounded by the boundary between the ridge portion 130 and the first sheet portion 110 and the end portions of the first sheet portion 110 in the longitudinal direction in a plan view in a direction perpendicular to the sheet surface of the first sheet portion 110. The boundary between

the first sheet portion 110 and the ridge portion 130 can be specified by creating a 3D model on the basis of three-dimensional shape measurement of the hot press-formed product 100 and detecting the boundary between the first sheet portion 110 and the ridge portion 130 from this 3D model. Similarly, the area of the recessed portion 140 is defined as an area of the range on a side of the recessed portion 140 surrounded by the boundary between the side portion side ridge portion 144 and the first sheet portion 110. The boundary between the first sheet portion 110 and the side portion side ridge portion 144 can also be specified by creating a 3D model on the basis of three-dimensional shape measurement of the hot press-formed product 100 and detecting the boundary between the first sheet portion 110 and the side portion side ridge portion 144 from this 3D model.

[0064] In the hot press-formed product 100 according to the present embodiment, the maximum depth $d_{\max}$ of the recessed portion 140 in a direction perpendicular to the sheet surface of the first sheet portion 110 may be 15 mm or more. Since the maximum depth $d_{\max}$ is 15 mm or more, it is possible to obtain an effect of improving the compressive axial force performance in the direction along the Z coordinate axis or the moment bending performance around the direction along the X coordinate axis shown in FIG. 1 and the like. More preferably, the maximum depth $d_{\max}$ is 20 mm or more in order to further improve the axial force or bending moment performance.

[0065] The depth d of the recessed portion 140 means a distance, on an imaginary plane that includes the shortest straight line connecting the boundary $gb1$ and the boundary $gb2$ and on which a cross-sectional line length of the recessed portion 140 is the smallest when viewed in a cross section, from the straight line to the bottom portion inner surface 141a in a direction orthogonal to the straight line connecting the boundary $gb1$ and the boundary $gb2$.

[0066] In the hot press-formed product 100 obtained by the manufacturing method described above, in a cross-sectional view in a plane that passes through a point pd at which the depth d of the recessed portion 140 is the largest and in which the cross-sectional line length of the recessed portion 140 is the smallest, an angle between the side portion 142 of the recessed portion 140 and a direction perpendicular to the sheet surface of the first sheet portion 110 is 2° to 8° .

[0067] In addition, the sheet thickness at a portion of the recessed portion 140 at which the sheet thickness is smallest is 60% or more of the sheet thickness at a portion of the first sheet portion 110 excluding the recessed portion 140. Here, the sheet thickness of the portion of the first sheet portion 110 excluding the recessed portion 140 is defined as an average value of sheet thicknesses of any three points at a portion of the first sheet portion 110 excluding the recessed portion 140. In addition, the plane that passes through the point pd at which the depth d of the recessed portion 140 is the smallest and in which the cross-sectional line length of the recessed portion 140 is the smallest is orthogonal to the sheet surface of the first sheet portion 110. According to the manufacturing method described above, the reduction in sheet thickness at the recessed portion can be suppressed, and therefore, in the hot press-formed product 100, the sheet thickness of the portion at which the sheet thickness is the smallest in the recessed portion 140 can be made 60% or more of the sheet thickness of the portion of the first sheet portion 110 excluding the recessed portion 140.

[0068] In the hot press-formed product 100 according to the present embodiment, deformation occurs when a load of a certain level or more is applied in a direction orthogonal to the longitudinal direction of the hot press-formed product 100 or in the longitudinal direction of the hot press-formed product 100. At this time, a tensile force or a compressive force is applied in a direction orthogonal to the extending direction of the recessed portion 140. In the hot press-formed product 100 of the present embodiment, the sheet thickness of the portion at which the sheet thickness is smallest in the recessed portion 140 is 60% or more of the sheet thickness of the portion of the first sheet portion 110 excluding the recessed portion 140, thereby improving the axial force or bending moment performance of a member generated by the recessed portion 140.

[0069] The sheet thicknesses of the first sheet portion 110 and the recessed portion 140 are measured by creating a 3D model on the basis of three-dimensional shape measurement of the hot press-formed product 100 and detecting the sheet thickness from this 3D model as described above.

[0070] In the hot press-formed product according to the present embodiment, an average sheet thickness $t1$ of the first sheet portion 110 may be 0.8 to 2.6 mm. The sheet thickness of the workpiece 1 is measured at three or more portions from the 3D model, and the arithmetic average value of the sheet thickness measurement values at these portions is defined as the average sheet thickness $t1$ of the workpiece 1. The average sheet thickness $t1$ of the first sheet portion 110 is determined by the following method. In a plane orthogonal to the longitudinal direction of the hot press-formed product 100 at the central position of the hot press-formed product 100 in the longitudinal direction, the sheet thickness at any position on the first sheet portion 110 excluding the recessed portion 140 is measured at three or more portions from the 3D model. The arithmetic average value of the sheet thickness measurement values at these portions is defined as the average sheet thickness $t1$.

[0071] In the method for manufacturing a hot press-formed product according to the present embodiment, an average sheet thickness t of the workpiece 1 may be 0.8 to 2.6 mm. The sheet thickness of the workpiece 1 is measured at three or more portions from the 3D model, and the arithmetic average value of the sheet thickness measurement values at these portions is defined as the average sheet thickness t of the workpiece 1.

[0072] In the protrusion 1120 of the first die 1100 used in the method for manufacturing a hot press-formed product according to the present embodiment, the maximum distance in the press direction from the press surface 1110 to the

protrusion 1120 may be 15 mm or more. In the first die 1100 used in the method for manufacturing a hot press-formed product according to the present embodiment, the press direction intersects with the press surface 1110. Here, the maximum distance in the press direction from the press surface 1110 to the protrusion 1120 means the maximum distance in the press direction from the holding surface portion 1130 to the protrusion 1120.

[0073] In addition, in a cross-sectional view in a plane that passes through a point at which the distance from the press surface 1110 to the protrusion 1120 of the first die 1100 is the largest and in which the cross-sectional line length of the protrusion 1120 is the shortest, the side surface portion 1222 of the groove portion 1220 of the second die 1200 has an angle of 2° to 8° with respect to the press direction on a curve corresponding to the surface shape of the protrusion 1120.

[0074] The press die or press apparatus used in the method for manufacturing a hot press-formed product according to the present disclosure is not limited to the configurations described above, and various modifications can be applied as long as it is configured to perform the press forming described above. For example, as one embodiment, a press apparatus 2000 may further include a fourth die 2400 as shown in FIG. 13. FIG. 13 is a schematic end view of a cut portion of the press apparatus 2000 viewed in a cross section in a direction along a longitudinal direction of a first die 2100, similar to FIG. 5. The configurations of a first die 2100, a second die 2200, and a third die 2300 are as described above, and the fourth die 2400 processes the second sheet portion 120 and the flange portion connected to the second sheet portion 120 while clamping them together with the third die 2300 during press forming. Since the fourth die 2400 is further provided, there is an effect of suppressing the occurrence of wrinkles in the flange portion. In addition, the third die 2300 is connected to a slide plate 1400. In addition, the first die 2100 is connected to the slide plate 1400 via a support portion 1410 (a spring or a piston).

[0075] In the hot press-formed product 100 according to the present disclosure, as one embodiment, as illustrated in Figure 14, in a cross-sectional view of a hot press-formed product 200 in the longitudinal direction, a recessed portion 250 shallower than a recessed portion 240 may be further provided in a first sheet portion 210. As a result, there is an effect of improving the compressive axial force performance in the direction along the Z coordinate axis or the moment bending performance around the direction along the X coordinate axis shown in FIG. 1 and the like.

[0076] In the above embodiment, the hot press-formed product 100 having two second sheet portions 120 is used as an example for explanation, but the hot press-formed product according to the present disclosure may also have the second sheet portion 120 on only one side of the first sheet portion 110.

[0077] In addition, in the above embodiment, the hot press-formed product 100 having the second sheet portion 120 connected to the first sheet portion 110 via the ridge portion 130 has been described, but the hot press-formed product according to the present disclosure does not need to have the second sheet portion or the ridge portion. That is, even in the case of the hot press-formed product 100 constituted by the first sheet portion 110 provided with the recessed portion 140, it is possible to obtain the effect of the present disclosure that a reduction in sheet thickness and necking at the recessed portion 140 are suppressed.

[0078] The hot press-formed product 100 according to the above embodiment is preferably a long member. That is, when viewed in a plane in a direction perpendicular to the sheet surface of first sheet portion 110, it is preferable that the size of first sheet portion 110 in the longitudinal direction be greater than the size thereof in the short direction. Furthermore, the size of the first sheet portion 110 in the longitudinal direction may be the same as the size thereof in the short direction. The recessed portion 140 may be provided along the longitudinal direction of the first sheet portion 110, or a part of the recessed portion 140 may be provided along the short direction of the first sheet portion 110. Alternatively, a part of the recessed portion 140 may extend in a direction intersecting with the longitudinal direction or the short direction of the first sheet portion 110.

[0079] The hot press-formed product 100 according to the above embodiment has a tensile strength of 1470 MPa or more. Since the tensile strength of the hot press-formed product 100 is set to 1470 MPa or more, a certain yield stress can be ensured, and distortion can be suppressed. The tensile strength of the hot press-formed product 100 is more preferably 2000 MPa or more in order to have a higher yield stress. The tensile strength of the hot press-formed product 100 is determined as follows. Specifically, a sample of a size conforming to either the JIS No. 5 tensile test, the JIS No. 13B tensile test, or the JIS No. 14B tensile test is obtained from the first sheet portion 110 or the second sheet portion 120 of the hot press-formed product 100, and the tensile strength of this sample is measured using a universal testing machine or a hydraulic servo type strength testing machine in accordance with a method conforming to JIS Z 2241, and this tensile strength is regarded as the tensile strength of the hot press-formed product 100. In a case in which it is not possible to obtain a test piece as specified by JIS, a micro tensile test piece may be used as the sample. In the micro tensile test, the width or sheet thickness of a parallel portion is preferably 0.2 to 2.0 mm, and a test piece shape formed such that a uniform load is applied within the parallel portion of the tensile test is preferable. The test piece is preferably machined by wire cut electric discharge machining. As the micro tensile test piece, for example, the test piece in the Journal of the Japan Welding Society, Vol. 75 (2006), No. 6, pp. 461-465 (https://www.jstage.jst.go.jp/article/jjws175/6/75_6_461/_pdf/-char/ja) can be used.

[0080] It is more preferable that the hot press-formed product 100 according to the above embodiment have a length in the longitudinal direction of 700 to 1700 mm, and it is more preferable that a length of the first sheet portion 110 in the width direction (a length from the first sheet portion edge portion 110A to the other edge portion) be 30 to 200 mm. Moreover, in

the hot press-formed product 100 according to the above embodiment, it is more preferable that a length of the second sheet portion 120 in the width direction be 30 to 200 mm.

[0081] In the hot press-formed product according to the above embodiment, the recessed portion may have a V-shaped cross-sectional shape including a curve in part, as shown in FIG. 15, or a cross-sectional shape including a curve, as shown in FIG. 16.

[0082] In addition, as illustrated in FIG. 15, a recessed portion 340 of a hot press-formed product 300 may have a bottom portion 341 of which a cross section includes a curve and a pair of side portions 342. The bottom portion 341 is connected to the side portion 342, and each side portion 342 is connected to a first sheet portion 310 via a side portion side ridge portion 344. The first sheet portion 310 has a first sheet portion sheet surface 310a and a first sheet portion sheet surface 310b on a side opposite to the first sheet portion sheet surface 310a. The bottom portion 341 has a bottom portion inner surface 341a located on an inner side of the recessed portion 340 and a bottom portion outer surface 341b on a side opposite to the bottom portion inner surface. In a plane orthogonal to the longitudinal direction of the hot press-formed product 300, one of the boundaries between the first sheet portion 310 and the recessed portion 340 (the boundaries between the first sheet portion 310 and the side portion side ridge portion 344) is defined as a boundary gb1, and the other boundary is defined as a boundary gb2. On a plane orthogonal to the longitudinal direction of the hot press-formed product 300, each of the boundary gb1 and the boundary gb2 is a point on the sheet surface on the outer side of the bend of the side portion side ridge portion 344. In the plane orthogonal to the longitudinal direction of the hot press-formed product 300, a distance between the boundary gb1 and the boundary gb2 is defined as a width of the recessed portion 340. In the case of the shape shown in FIG. 15, the definition of the curve corresponding to the shape of the recessed portion is the same as that in the above embodiment.

[0083] In the example of FIG. 16, a recessed portion 440 does not have flat side portions as illustrated in FIG. 3, but rather includes a curve that corresponds to the shape of the inner surface of the recessed portion 440. The curve includes a curved portion 441 and a curved portion 442, and an intersection point of the curved portion 441 and the curved portion 442 is a point ip.

[0084] The shape of the recessed portion of the press-formed product according to the present disclosure in a plan view of the first sheet portion is not particularly limited. FIGS. 17 to 23 show modification examples of the recessed portion provided in the first sheet portion. FIGS. 17 to 23 schematically show only the shape of the recessed portion provided in the first sheet portion.

[0085] The press-formed product according to the above embodiment is preferably used as a hot press-formed product for a vehicle, such as a front bumper reinforcement, a rear bumper reinforcement, a side sill outer, a side sill inner, a door impact beam, a front side member, and a rear side member.

Examples

(Example 1)

[0086] In Example 1, a three-point bending test was performed in a simulation on the hot press-formed product having three recessed portions as shown in FIG. 14. The sheet thickness of a workpiece was set to 1.2 mm, and the tensile strength of the workpiece was set to a 2000 MPa class. As the conditions for the simulation of the three-point bending test, three-point bending in which the center of a member was pressed down statically was performed, and the sheet thickness of the central recessed portion of the member was set to a sheet thickness obtained by the forming simulation. In the present example, the span of a receiving jig for the three-point bending was set to 1000 mm.

[0087] The area ratio of the recessed portions was set to 40%, the maximum depth was set to 15 mm, and the width was set to 35 mm. The angle between the side portion of the recessed portions and the press direction during press forming was changed as shown in Table 1. In addition, the sheet thickness reduction rate at the recessed portion and the component performance (the yield strength) were investigated. The results are shown in Table 1. Here, on the basis of an arithmetic average t_a of sheet thicknesses of any three points at a portion of the first sheet portion excluding the recessed portion, and a sheet thickness t_{min} of a portion of which the sheet thickness is the smallest in the recessed portion, $(t_a - t_{min})/t_a$ is defined as the sheet thickness reduction rate at the recessed portion. The sheet thickness reduction rate at the recessed portion can be calculated by dividing the sheet thickness reduced at a portion of the recessed portion at which the sheet thickness is reduced the most by the sheet thickness of the first sheet portion in the simulation. The yield strength of the member for evaluating the member performance was calculated from the simulation results of the three-point bending test. Here, the yield strength is a value obtained by dividing a load, which an impactor pressing down in the three-point bending test receives from the test piece, by a weight, and this is used to evaluate the component performance. In addition, in Table 1, the load is a load that the impactor receives from the test piece, and the weight is a weight of the hot press-formed product.

[Table 1]

Angle of side portion of recessed portion with respect to press direction (°)	Sheet thickness reduction rate of recessed portion (%)	Load (kN)	Weight (kg)	Component performance (kN/kg)	Component performance determination
0	27.26	28.79	3.62	7.957	C
3	28.35	28.87	3.62	7.971	B
5	30.99	28.88	3.62	7.976	B
8	39.46	28.78	3.62	7.961	B
10	42.68	28.71	3.61	7.951	C
12	43.39	28.59	3.61	7.926	C

[0088] In addition, FIG. 24 shows the results of this simulation. According to FIG. 24, it was confirmed that the sheet thickness reduction rate can be suppressed by setting the angle of the side portion of the recessed portion to 8° or less with respect to the press direction. It was also found that, when the angle of the side portion of the recessed portion is in the range of 2° to 8° with respect to the press direction, a high component performance of 7.96 kN/kg or more, which is a target component performance, can be achieved. It was also found that, when the angle of the side portion of the recessed portion is 2° or more with respect to the press direction, the press-formed product can be easily released from the die. On the basis of these results, components of which overall component performance determination was good were rated as B (Good), and the others were rated as C (Bad). In the press-formed products of Examples 1 to 3, the angle between the side portion of the recessed portion and the direction perpendicular to the sheet surface of the first sheet portion was the same as the angle between the side portion of the recessed portion and the press direction. In Examples 1 to 3, the angle of the side portion of the recessed portion with respect to the press direction is defined as in the above embodiment.

(Example 2)

[0089] In Example 2, a three-point bending test was performed in a simulation on the hot press-formed product having one recessed portion as shown in FIG. 1. The sheet thickness of a workpiece was set to 2.01 mm, and the tensile strength of the workpiece was set to a 2000 MPa class. As the conditions for the simulation of the three-point bending test, three-point bending in which the center of a member was pressed down statically was performed, and the sheet thickness of the central recessed portion of the member was set to a sheet thickness obtained by the forming simulation. In the present example, the span of a receiving jig for the three-point bending was set to 1000 mm.

[0090] The area ratio of the recessed portions was set to 35%, the maximum depth was set to 20 mm, and the width was set to 35 mm. The angle between the side portion of the recessed portions and the press direction during press forming was changed as shown in Table 2, and the sheet thickness reduction rate at the recessed portion and the component performance (the yield strength) were investigated. The results are shown in Table 2. Here, the definitions and calculation methods of the sheet thickness reduction rate at the recessed portion and the component performance are the same as those in Example 1. In addition, the definitions of the load and the like in Table 2 are the same as those in Table 1.

[Table 2]

Angle of side portion of recessed portion with respect to press direction (°)	Sheet thickness reduction rate of recessed portion (%)	Load (kN)	Weight (kg)	Component performance (kN/kg)	Component performance determination
0	28.98	58.81	7.85	7.492	C
2	30.54	58.95	7.85	7.510	B
5	37.98	59.02	7.85	7.518	B
8	38.54	59.00	7.85	7.516	B
10	41.21	58.75	7.84	7.494	C
12	45.44	58.49	7.83	7.470	C

[0091] In addition, FIG. 25 shows the results of this simulation. According to FIG. 25, it was confirmed that the sheet thickness reduction rate can be suppressed by setting the angle of the side portion of the recessed portion to 8° or less with respect to the press direction. It was also found that, when the angle of the side portion of the recessed portion is in the range of 2° to 8° with respect to the press direction, high component performance of 7.50 kN/kg or more, which is a target component performance, can be achieved. It was also found that, when the angle of the side portion of the recessed portion is 2° or more with respect to the press direction, the press-formed product can be easily released from the die. On the basis of these results, components of which overall component performance determination was good were rated as B (good), and the others were rated as C (bad).

(Example 3)

[0092] As shown in Table 3, the sheet thickness of the workpiece, the number of recessed portions, the tensile strength of the workpiece, and the pad pressure during forming (the pressing force of the first die) were changed, the three-point bending test of the test piece was performed in a simulation, and an overall evaluation was performed from the member yield strength performance and the die cost. As the cross-sectional dimensions, the height of the second sheet portion was set to 65 mm, the width of the first sheet portion was set to 100 mm, the width of the recessed portion was set to 40 mm, and the depth of the recessed portion was set to 23 mm. The angle of the side portion of the recessed portion was set to 5° with respect to the press direction. In a case in which the number of recessed portions of the first sheet portion was one, the recessed portion was disposed at the center in the width direction, and in a case in which the number of recessed portions of the first sheet portion was two, a shallow groove having a depth of 8 mm was provided between the recessed portion at the center in the width direction and the second sheet portion. The results are shown in Table 3. In the present example, the span of a receiving jig for the three-point bending was set to 1300 mm.

[Table 3]

No.	Sheet thickness of workpiece (mm)	The number of recessed portions (piece)	Tensile strength of workpiece (MPa)	Pad pressure (MPa)	Member yield strength performance evaluation (kN/kg)	Die cost	Overall evaluation
1	2.0	1	1470	22.0	6.594	B	B
2	1.8	1	1470	22.0	6.911	B	A
3	2.0	2	1470	22.0	7.034	B	A
4	2.0	1	2000	22.0	7.201	B	A
5	2.0	1	1470	4.4	6.511	A	A

[0093] In Table 3, in the evaluation criteria for the die cost, conditions with a pad pressure of 10.0 MPa or less were rated as A (very good), and conditions with a pad pressure of more than 10.0 MPa and 50.0 MPa or less were rated as B (good). Further, in the overall evaluation, members with a member yield strength performance evaluation result of 6.6 kN/kg or more and a die cost corresponding to condition B, or members with a member yield strength performance evaluation result of less than 6.6 kN/kg but a die cost corresponding to condition A were rated as A (very good), and members with a member yield strength performance evaluation result of less than 6.6 kN/kg and a die cost corresponding to condition B were rated as B (good).

INDUSTRIAL APPLICABILITY

[0094] According to the present disclosure, it is possible to provide a hot press apparatus capable of suppressing a reduction in sheet thickness and necking at a recessed portion of a hot press-formed product formed by a die pad, a method for manufacturing a hot press-formed product using the apparatus, and a hot press-formed product in which a reduction in sheet thickness and necking at a recessed portion of a press-formed product are suppressed, and therefore it is very useful in industry.

REFERENCE SIGNS LIST

[0095]

100 Hot press-formed product
 110 First sheet portion
 120 Second sheet portion
 130 Ridge portion
 140 Recessed portion
 141 Bottom portion
 142 Side portion
 143 Bottom portion side ridge portion
 144 Side portion side ridge portion
 1000 Press apparatus
 1100 First die (die pad)
 1200 Second die (punch)
 1300 Third die (die)

Claims

1. A hot press apparatus comprising a punch, a die, and a die pad,

wherein a groove portion is provided in a top surface of the punch,
 wherein, in a cross section in a press direction, an angle between a wall surface of the groove portion and the press direction is 2° to 8° ,
 wherein a refrigerant flow path is provided inside the punch,
 wherein the die and the die pad are disposed to face the punch in the press direction,
 the die pad is disposed facing the top surface of the punch, and
 a protrusion is provided at a position on the die pad opposing the groove portion in the press direction, and the protrusion has an inverted shape of the groove portion.

2. The hot press apparatus according to claim 1,

wherein the die has a step portion that comes into contact with the die pad in the press direction, and
 wherein the die pad comes into contact with the die in the press direction at a bottom dead point of a forming process.

3. The hot press apparatus according to claim 1, wherein, in the cross section, an angle between a straight line connecting an R end of a side surface portion side ridge portion of the wall surface and an R end of a bottom surface portion side ridge portion of the groove portion and the press direction is 2° to 8° .

4. A method for manufacturing a hot press-formed product using the hot press apparatus according to any one of claims 1 to 3, the method comprising:

arranging a blank between the die and the punch;
 causing the blank to be sandwiched between the punch and the die pad; and
 bringing the punch and the die close to each other in the press direction until the bottom dead point of the forming process.

5. A hot press-formed product that includes a first sheet portion having a recessed portion formed therein and a second sheet portion inclined with respect to the first sheet portion,

wherein, in a cross-sectional view in a plane in which a cross-sectional line length of the recessed portion is the smallest among planes passing through a point at which a depth of the recessed portion is the largest, an angle between a side portion of the recessed portion and a direction perpendicular to a sheet surface of the first sheet portion is 2° to 8° , and
 wherein a sheet thickness at a portion of the recessed portion at which the sheet thickness is smallest is 60% or more of a sheet thickness at a portion of the first sheet portion excluding the recessed portion.

6. The hot press-formed product according to claim 5, wherein, in the cross-sectional view, an angle between a straight line connecting an R end of a side portion side ridge portion of the side portion and an R end of a bottom portion side

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ridge portion of the recessed portion and a direction perpendicular to the sheet surface of the first sheet portion is 2° to 8° .

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FIG. 1

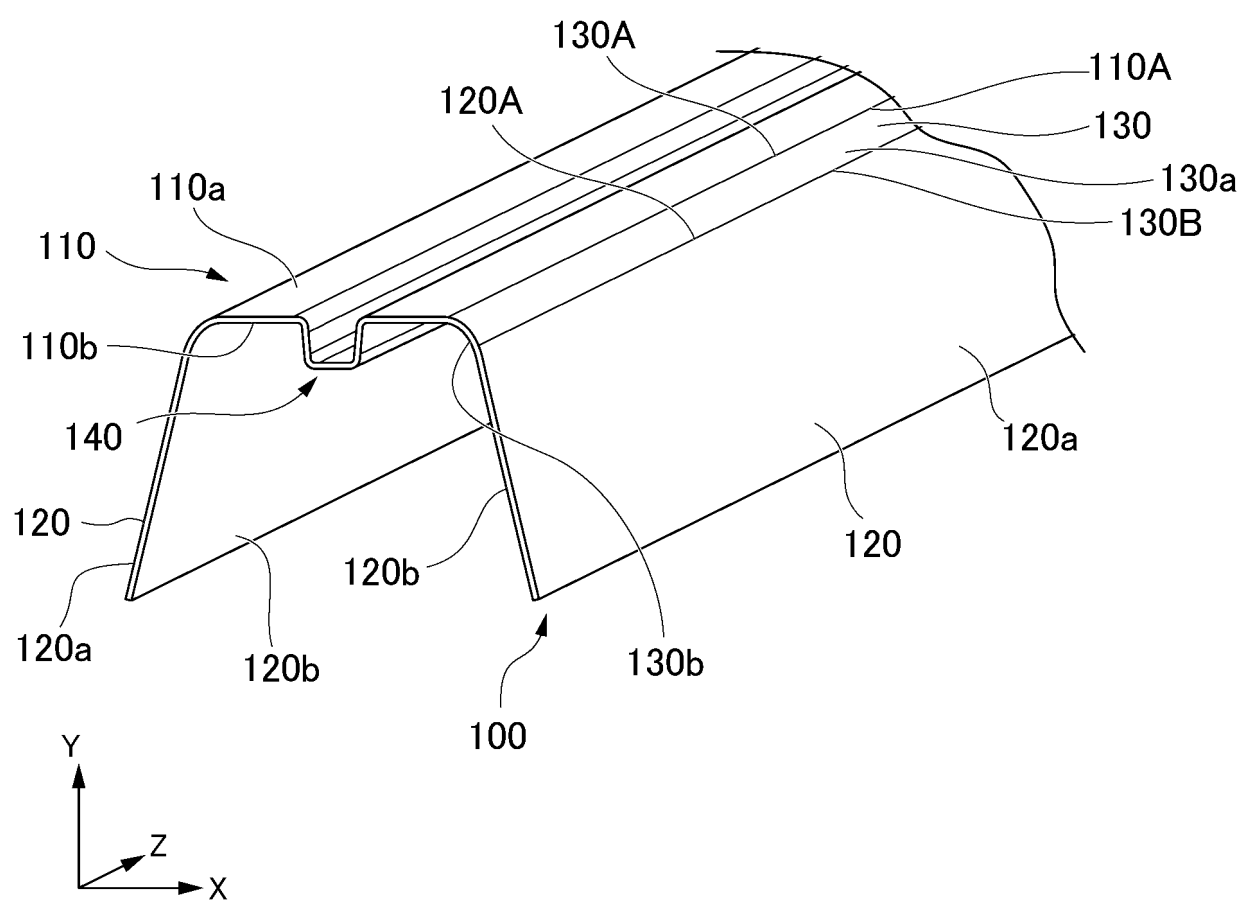


FIG. 2

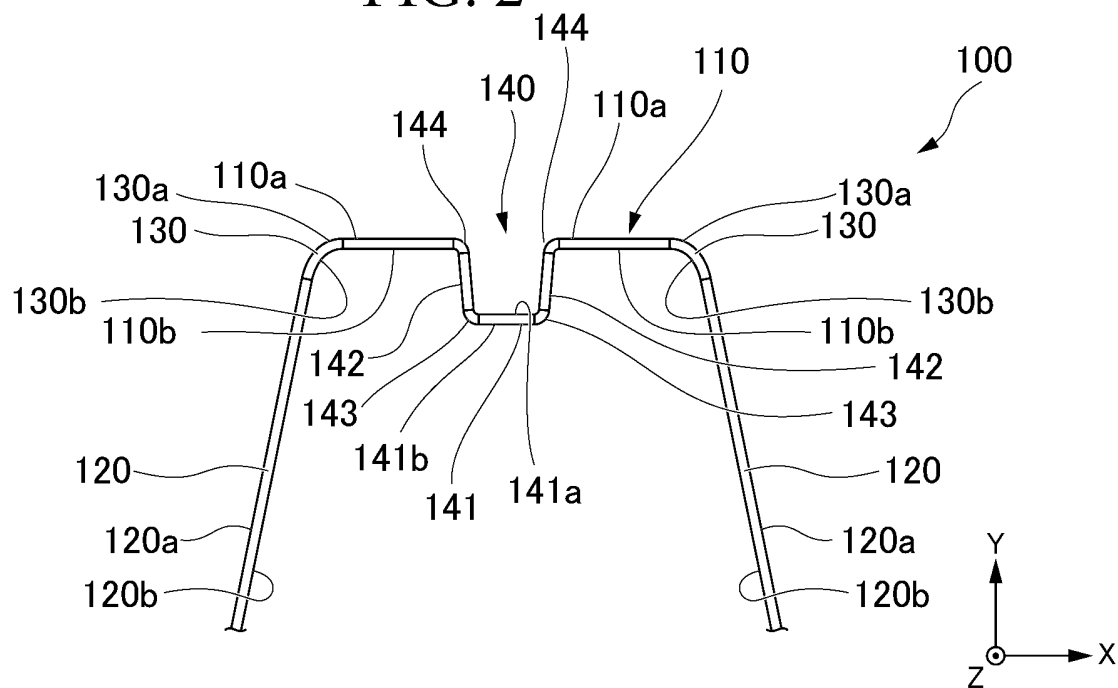


FIG. 3

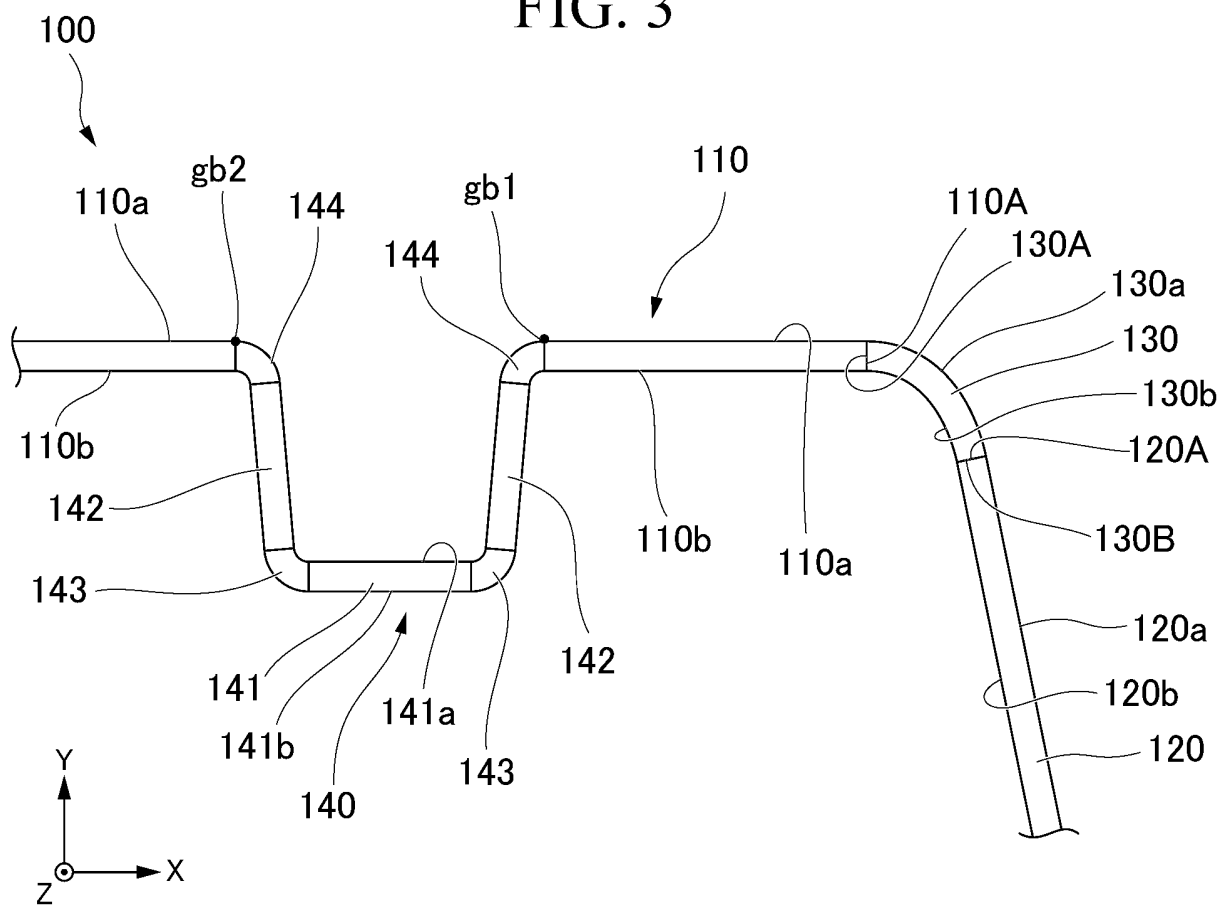


FIG. 4

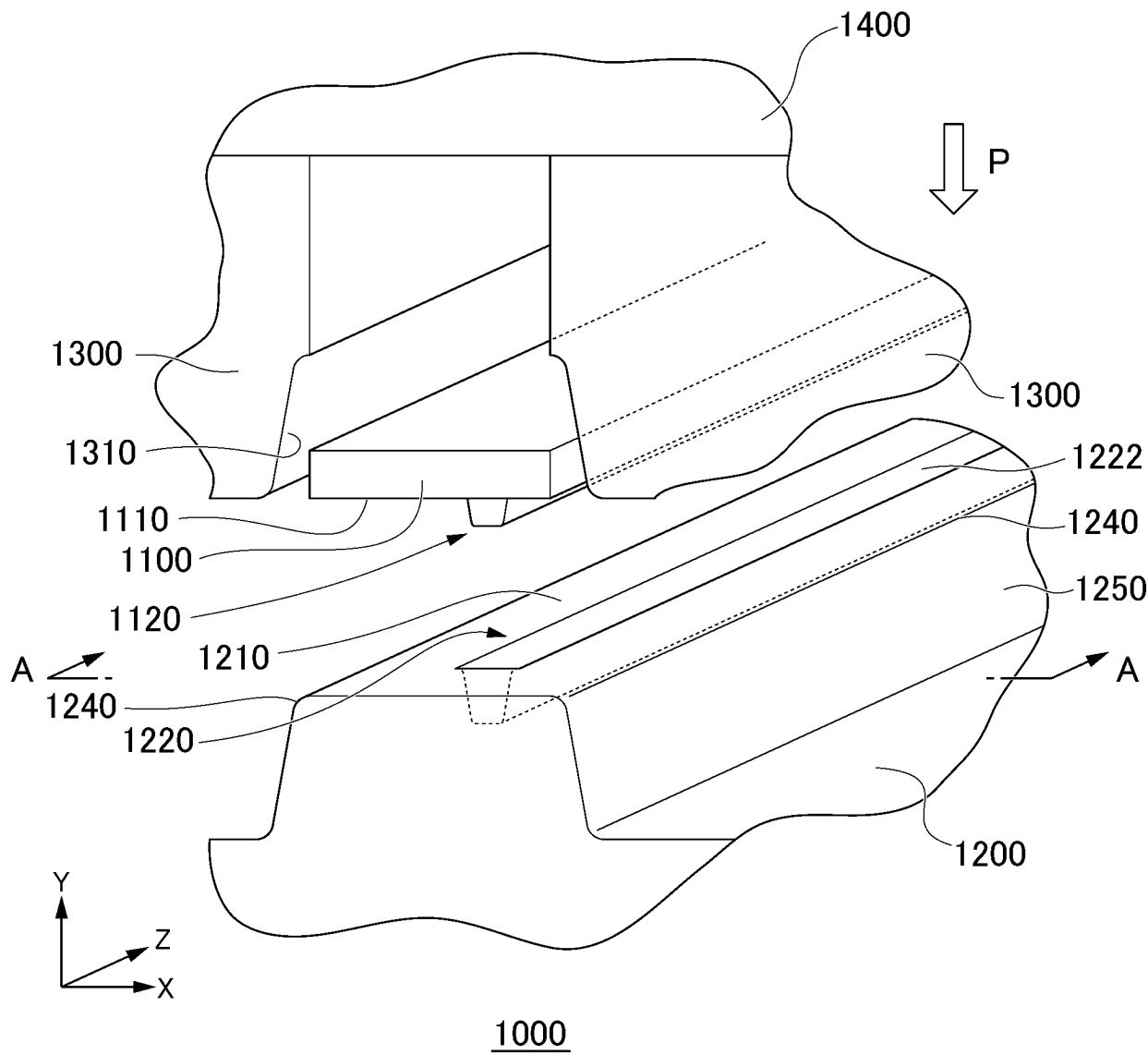


FIG. 5

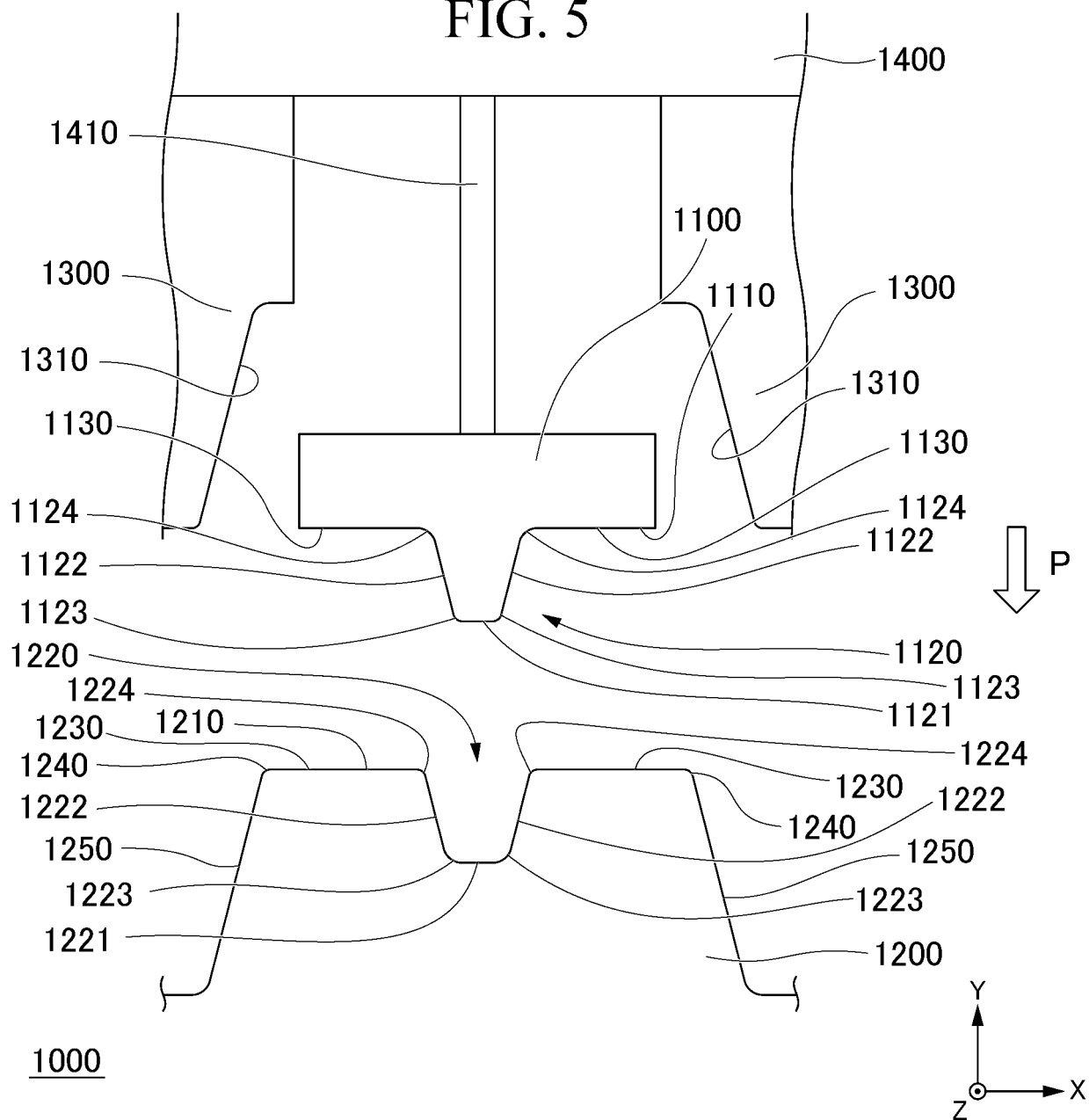


FIG. 6

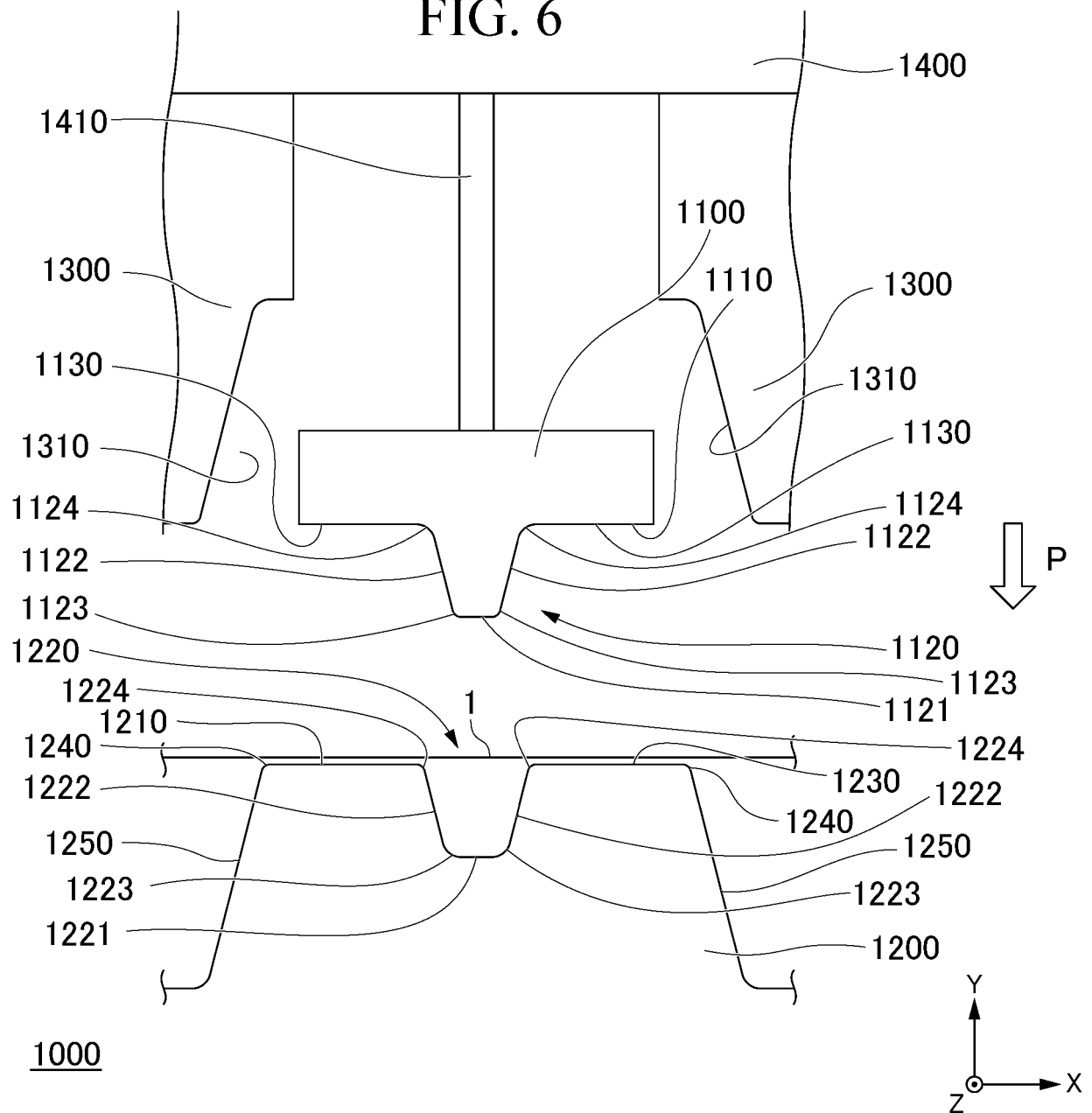


FIG. 7

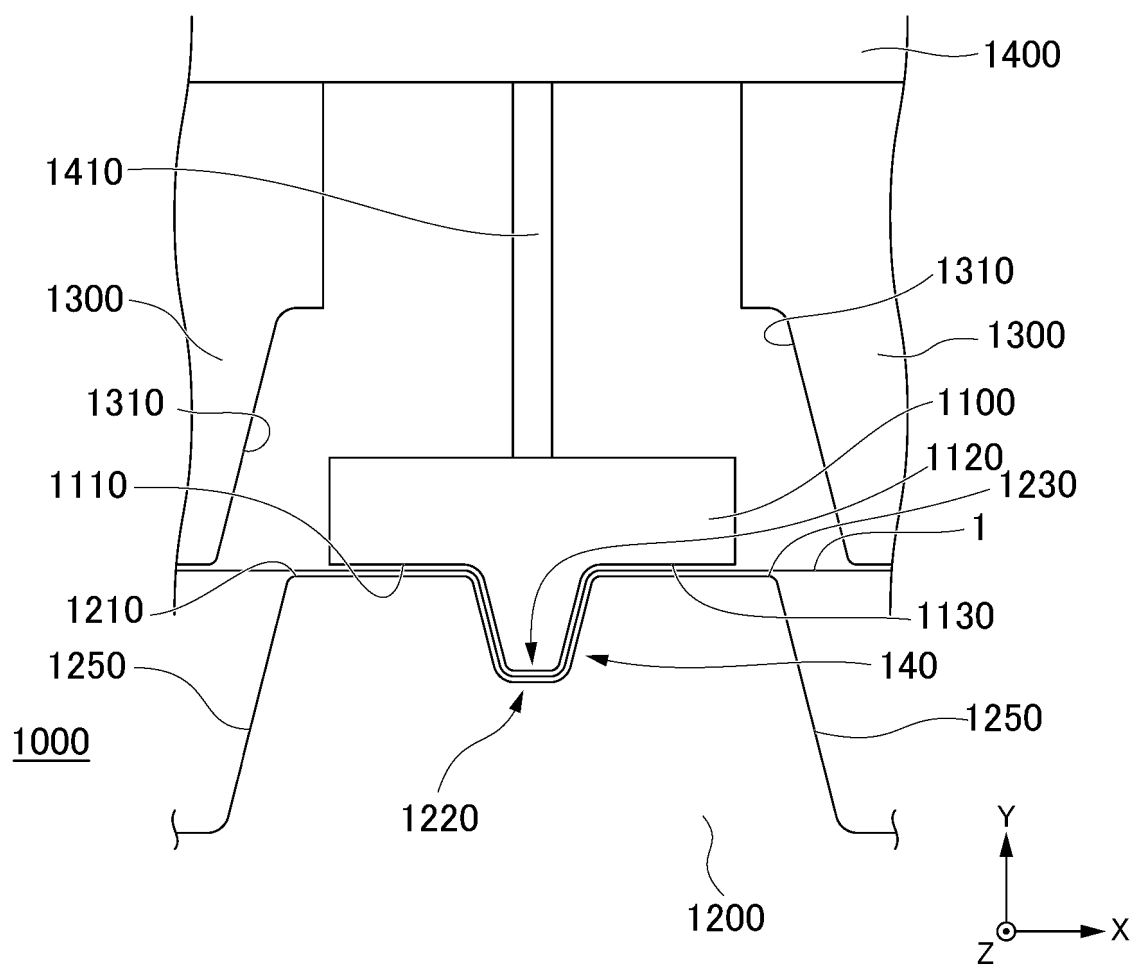


FIG. 8

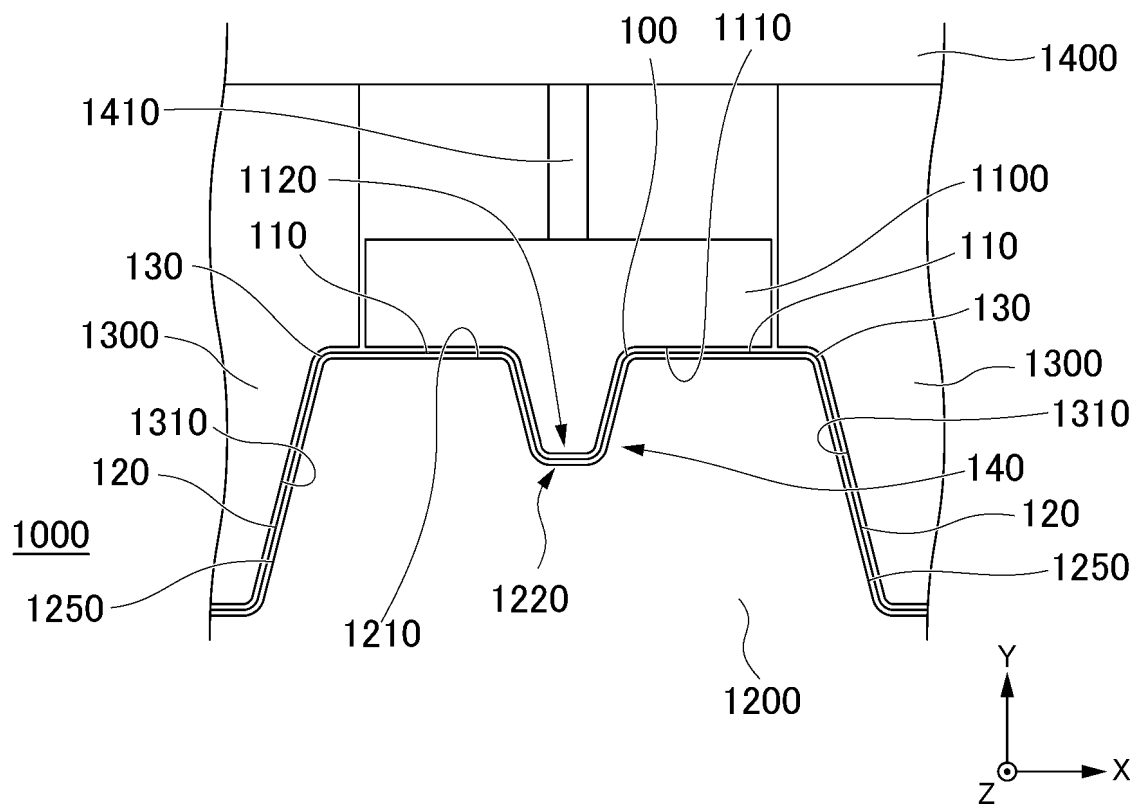


FIG. 9

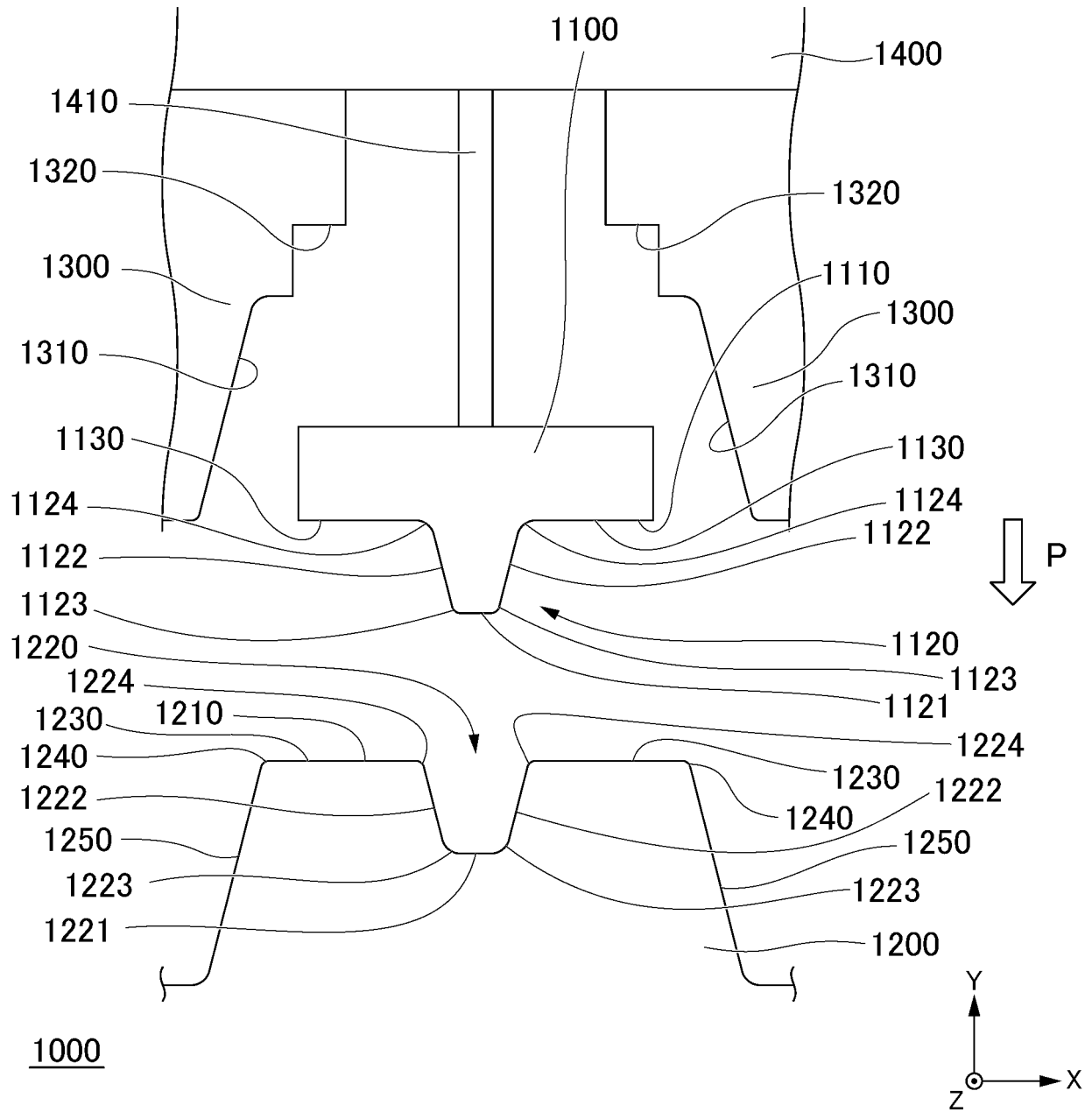


FIG. 10

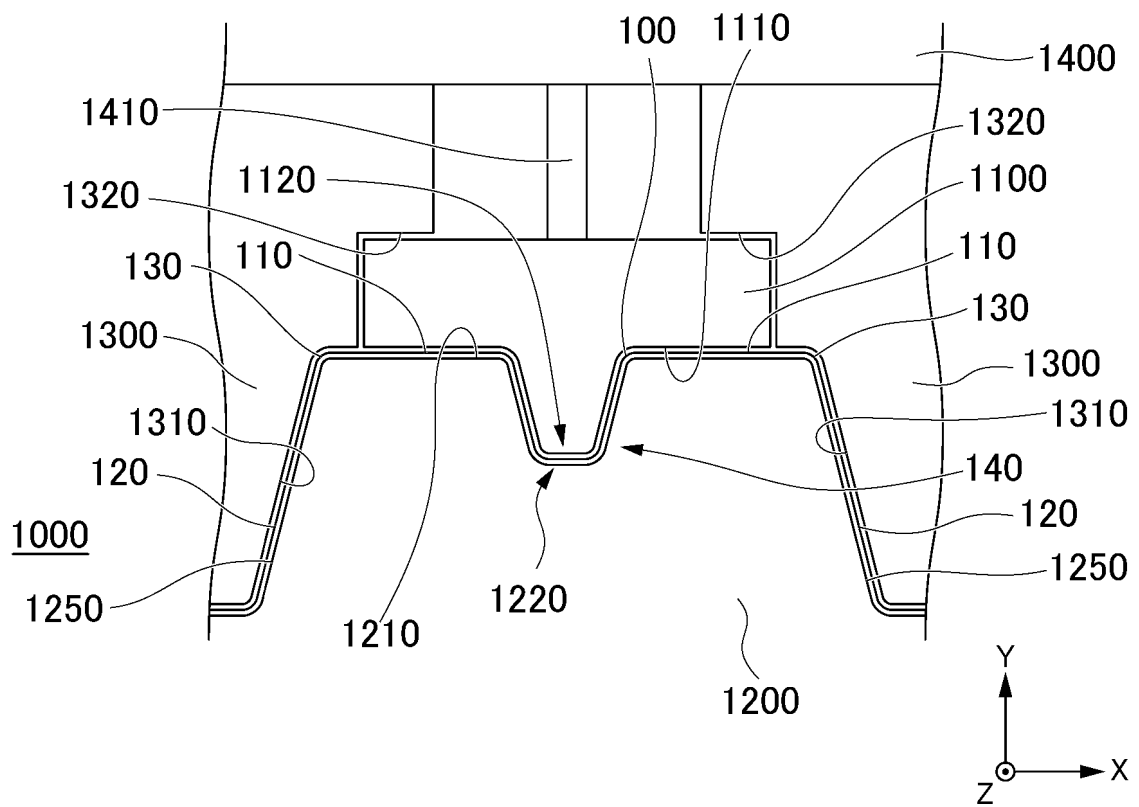


FIG. 11

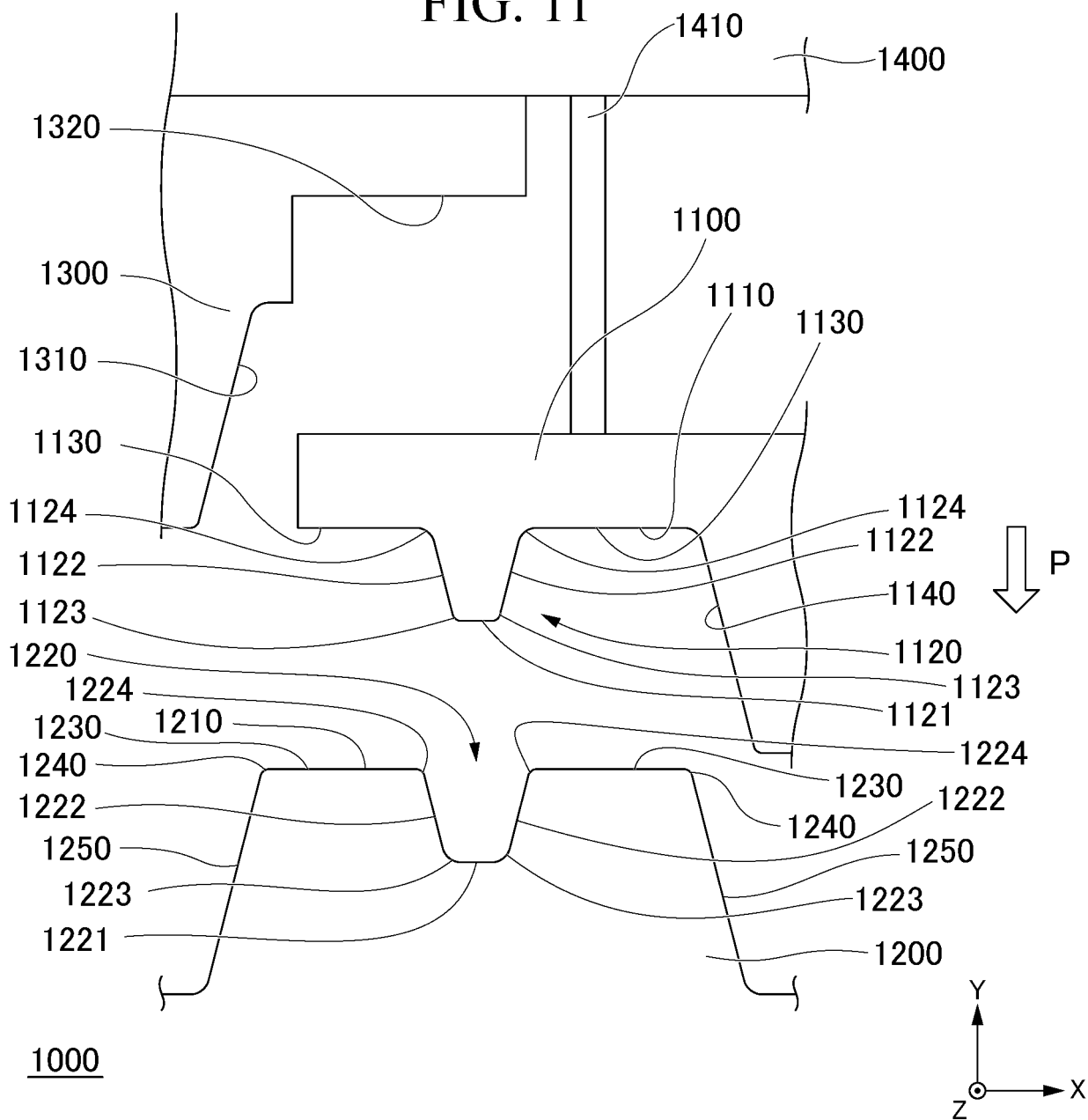


FIG. 12

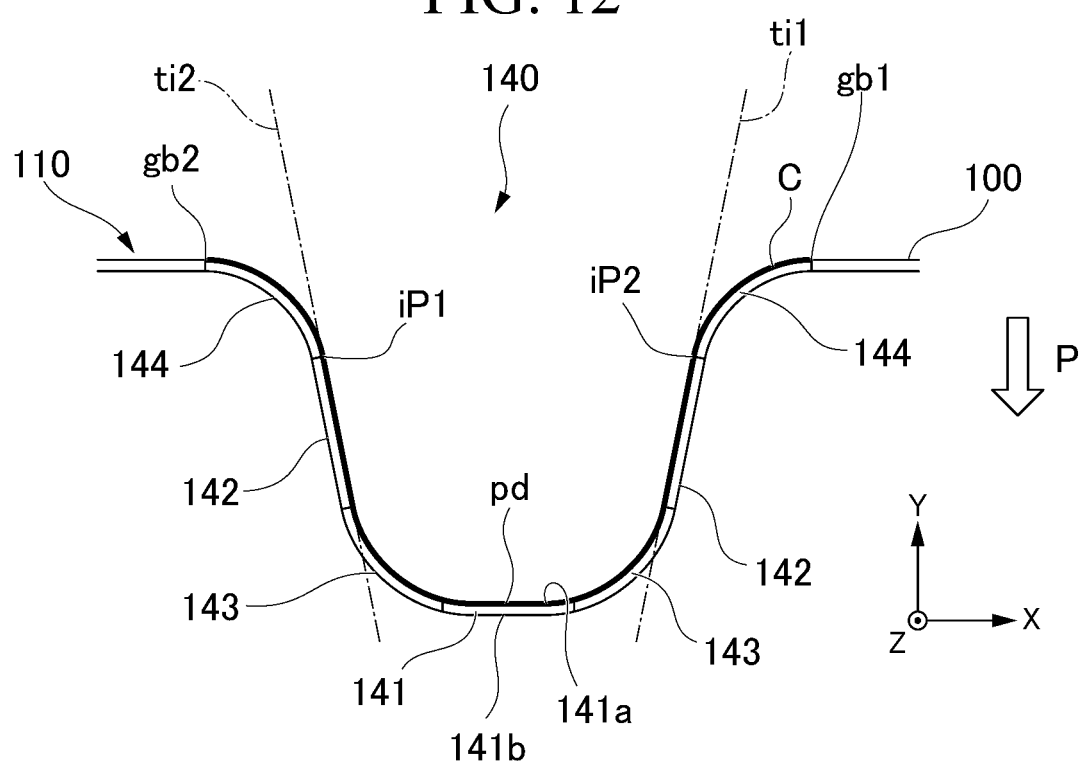


FIG. 13

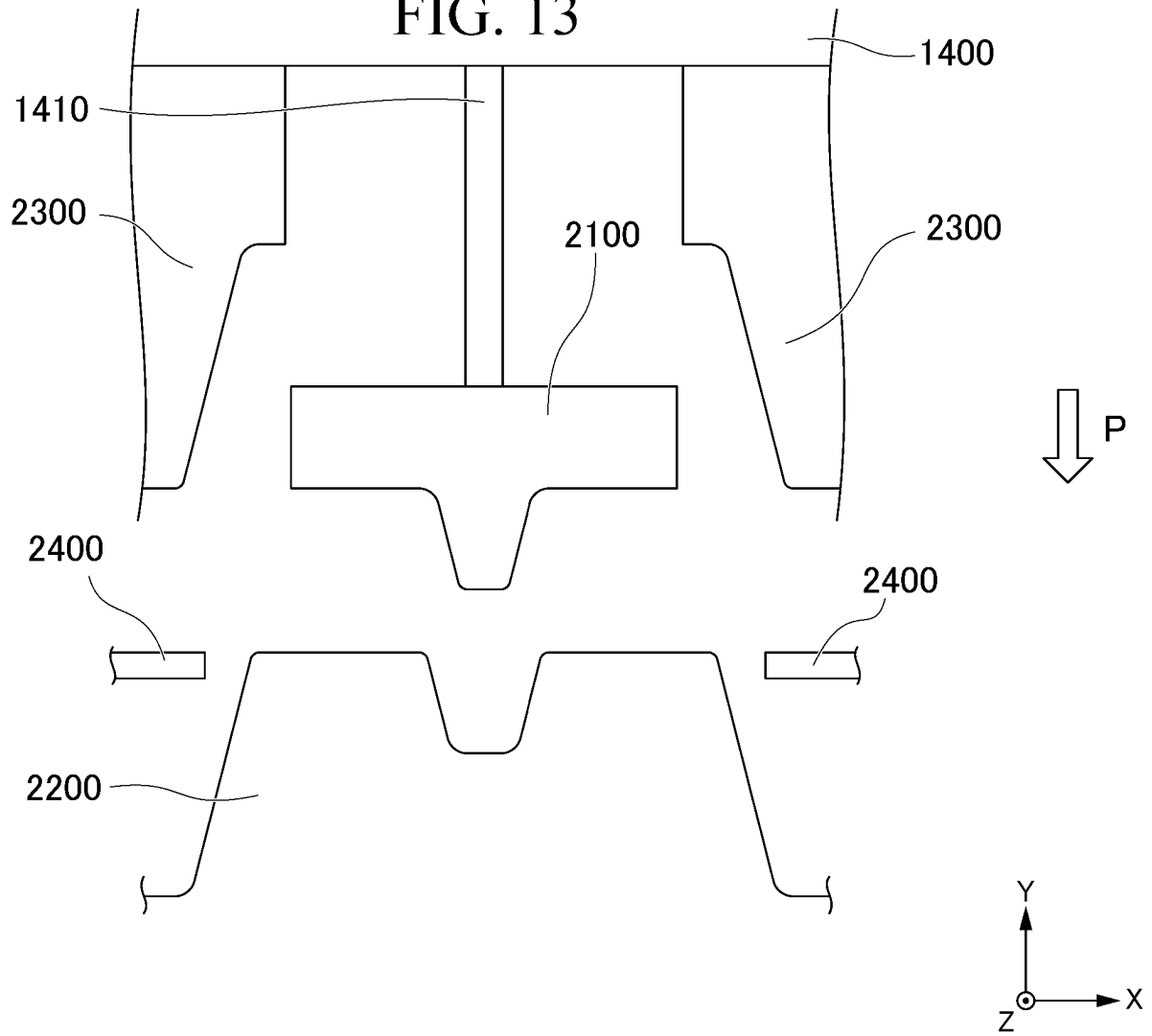


FIG. 14

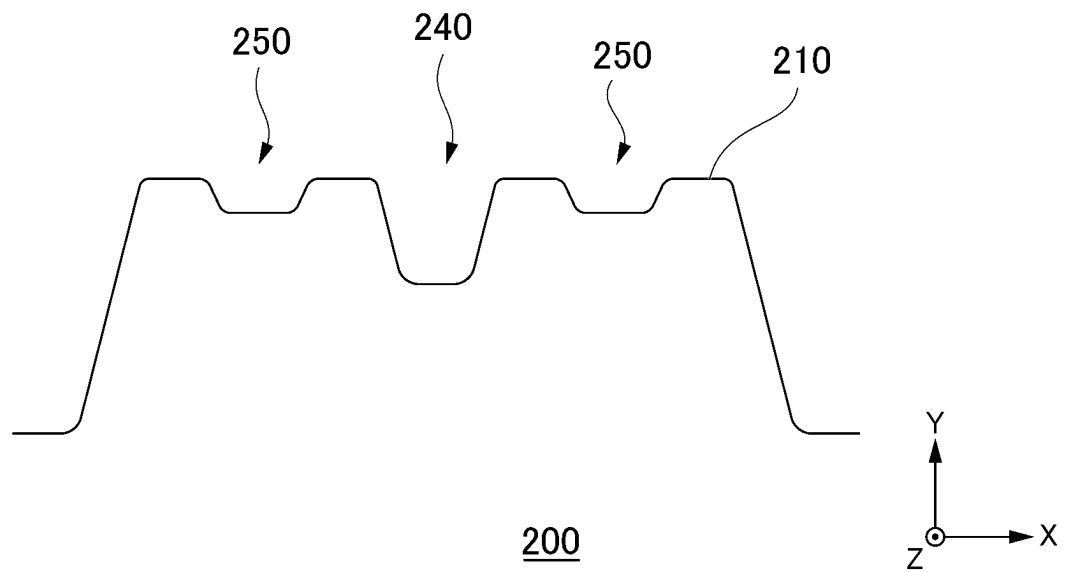


FIG. 15

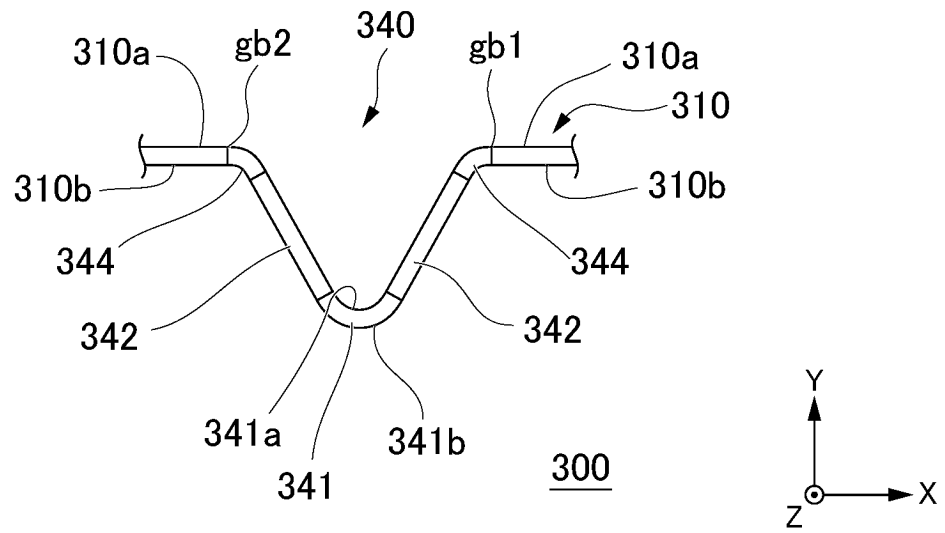


FIG. 16

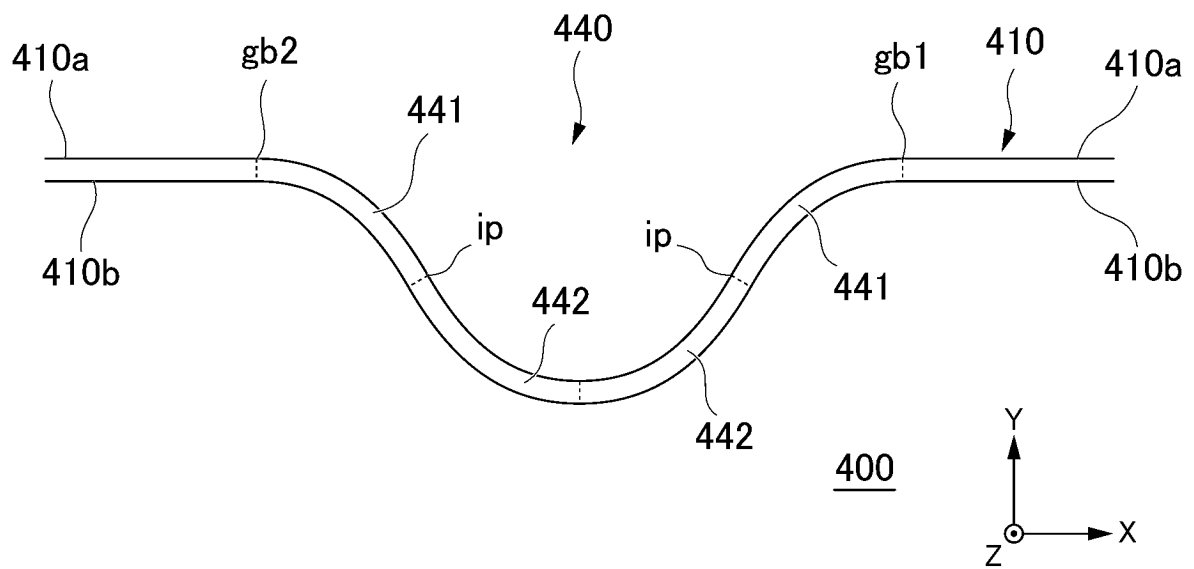


FIG. 17

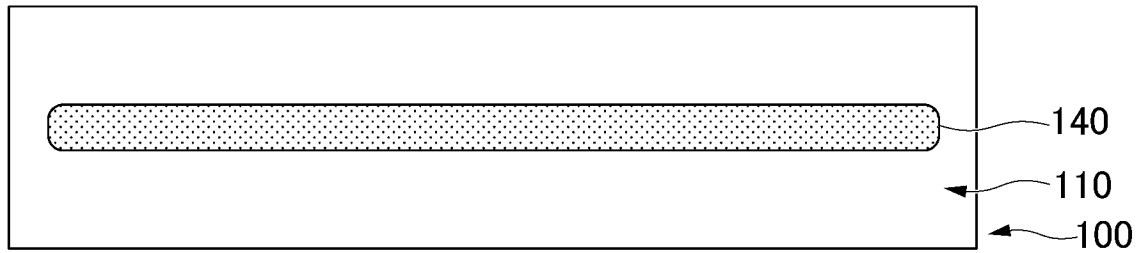


FIG. 18

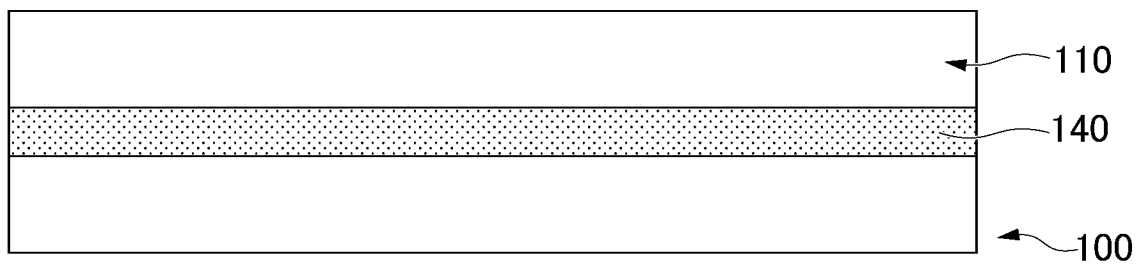


FIG. 19

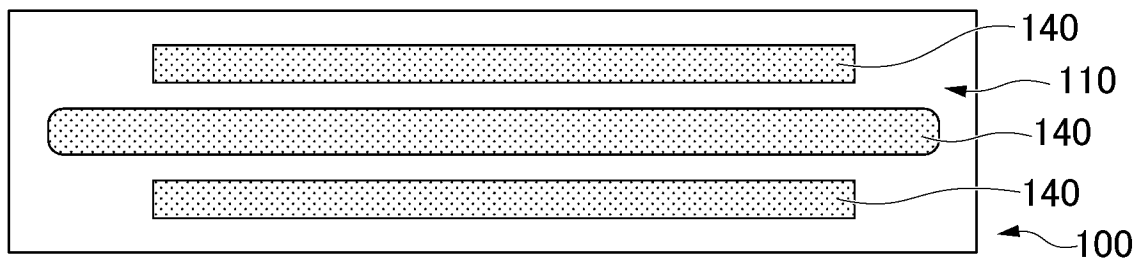


FIG. 20

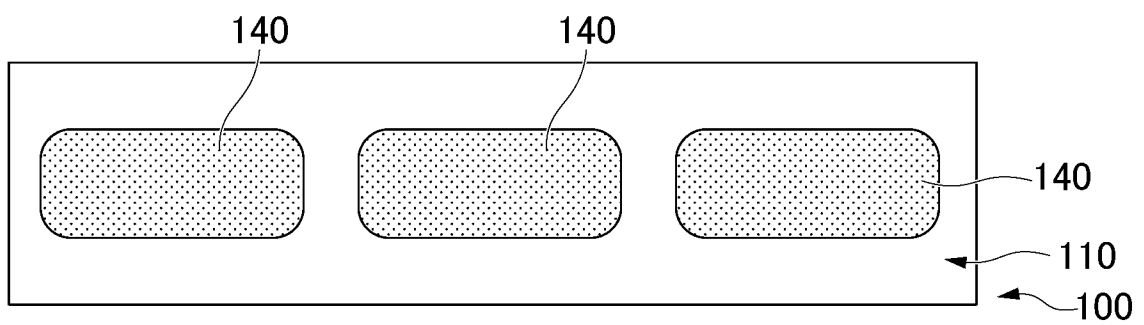


FIG. 21

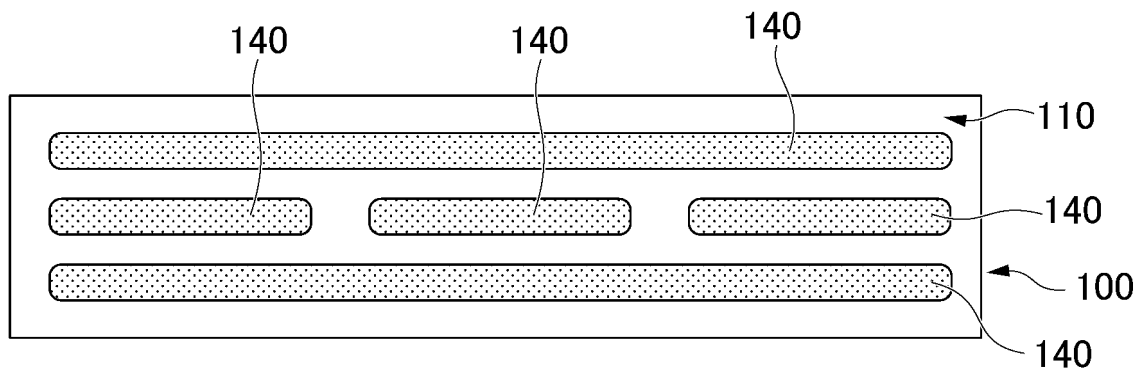


FIG. 22

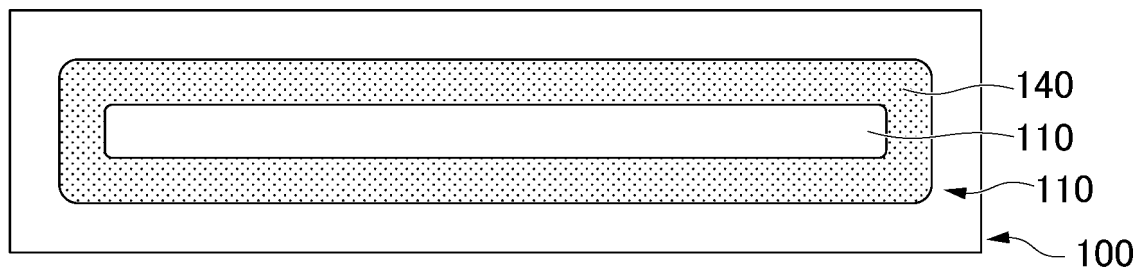


FIG. 23

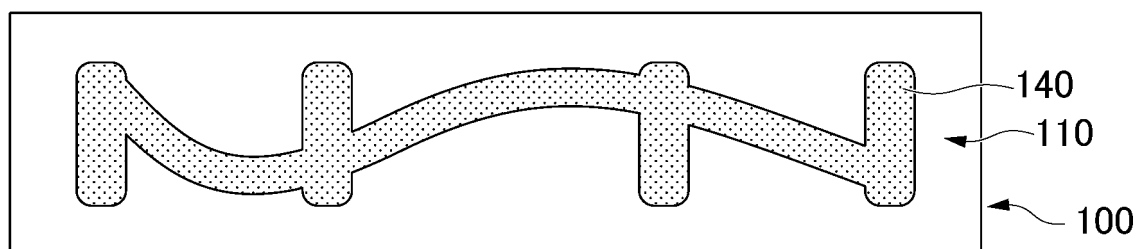


FIG. 24

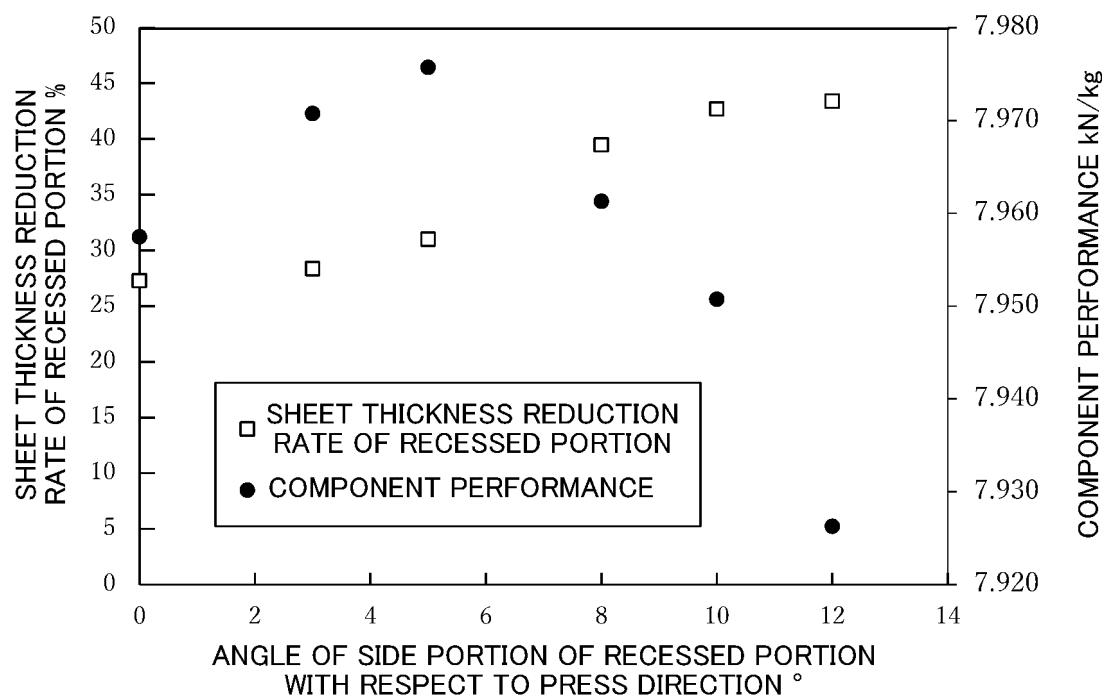
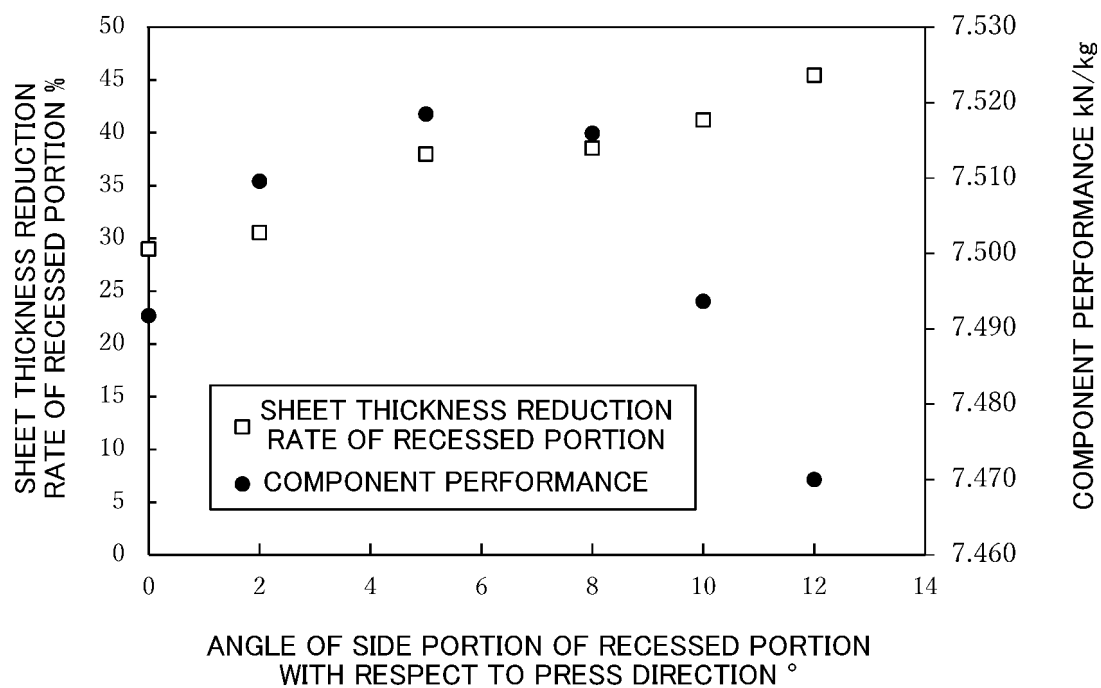


FIG. 25



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/019628

A. CLASSIFICATION OF SUBJECT MATTER

B21D 22/20(2006.01)i; **B21D 22/26**(2006.01)i; **B21D 24/00**(2006.01)i
 FI: B21D22/20 H; B21D24/00 M; B21D24/00 H; B21D22/26 D

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D22/20; B21D22/26; B21D24/00

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2021/215391 A1 (TOYOTA TEKKO KK) 28 October 2021 (2021-10-28)	1-6
A	WO 2020/111061 A1 (NIPPON STEEL CORPORATION) 04 June 2020 (2020-06-04)	1-6
A	JP 59-56927 A (NISSAN JIDOSHA KK) 02 April 1984 (1984-04-02)	1-6
A	JP 6985989 B2 (KOBE STEEL LTD) 22 December 2021 (2021-12-22)	1-6

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

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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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	

Date of the actual completion of the international search

12 June 2023

Date of mailing of the international search report

27 June 2023

Name and mailing address of the ISA/JP

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

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/019628

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2021/215391	A1	28 October 2021	(Family: none)			
WO	2020/111061	A1	04 June 2020	CN	113165299	A	
JP	59-56927	A	02 April 1984	(Family: none)			
JP	6985989	B2	22 December 2021	US	2021/0229156	A1	
				EP	3815807	A1	
				CN	112313020	A	

REFERENCES CITED IN THE DESCRIPTION

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