(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 219 037 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
02.08.2023 Bulletin 2023/31

(21) Application number: **21897392.3**

(22) Date of filing: **30.06.2021**

(51) International Patent Classification (IPC):
B21D 22/20 *(2006.01)* ***B21D 22/26*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
B21D 22/20; B21D 22/26

(86) International application number:
PCT/JP2021/024791

(87) International publication number:
WO 2022/113412 (02.06.2022 Gazette 2022/22)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **25.11.2020 JP 2020194883**

(71) Applicant: **JFE Steel Corporation**
Tokyo 100-0011 (JP)

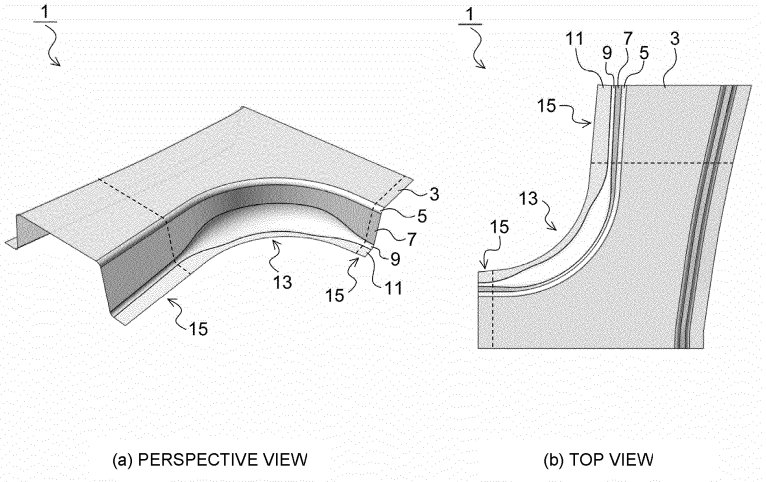
(72) Inventors:
- **FUJII, Yusuke**
  Tokyo 100-0011 (JP)
- **URABE, Masaki**
  Tokyo 100-0011 (JP)

(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

(54) PRESS FORMING METHOD

(57) A press forming method according to the present invention is to perform press forming of a press forming part 1 that includes a top portion 3, a side wall portion 7 continuous from the top portion 3 via a punch shoulder 5, and a flange portion 11 continuous from the side wall portion 7 via a die shoulder 9, the press forming part having a curved portion 13 curved in a recessed manner in a top view, the press forming method including: making a bending radius of the die shoulder 9 in the curved portion 13 increased from an end side toward a middle portion of the curve.

FIG.1



(a) PERSPECTIVE VIEW (b) TOP VIEW

EP 4 219 037 A1

Description

Field

[0001] The present invention relates to a press forming method, and more specifically relates to a press forming method of a press forming part including a top portion, a side wall portion continuous from the top portion via a punch shoulder, and a flange portion continuous from the side wall portion via a die shoulder, the press forming part having a curved portion curved in a recessed manner in a top view.

Background

[0002] Press forming is a manufacturing method capable of manufacturing metal parts at a low cost in a short time, and is used for manufacturing of many automotive parts. In recent years, in order to achieve both improvement in collision safety of an automobile and weight reduction of an automotive body, a metal sheet having higher strength is used for automotive parts. Main problems in press forming of a high-strength metal sheet include generation of a fracture due to a decrease in ductility and generation of wrinkles due to an increase in yield strength.

[0003] For example, in press forming of bringing a press forming part 101 in which a side wall portion 107 is curved in a recessed manner in a top view as illustrated in FIG. 7 into a target shape, a flange portion 111 in a curved portion 113 is pulled in a circumferential direction and a fracture is likely to be generated. In addition, when a shrink deformation in the circumferential direction is generated as reaction force in a top portion 103 and a punch shoulder 105 in the curved portion 113, wrinkles are likely to be generated. This deformation is called stretch flange deformation. Thus, it is important to control generation of the fracture and wrinkles in such a stretch flange deformation in press forming of the press forming part 101 curved in the recessed manner.

[0004] Several technologies of controlling a fracture and wrinkles of a press forming part curved in a recessed manner in a top view have been proposed to date. For example, Patent Literature 1 discloses a press forming method of press forming, from a sheet metal blank, an L-shaped part including a top portion and a side wall portion that is connected to the top portion via a bent portion having a portion curved in an arc shape and that has a flange portion on an opposite side of the bent portion. According to the press forming method, a portion of the sheet metal blank which portion corresponds to the top portion is pressed by a pad, an end of a portion of the sheet metal blank which portion corresponds to an L-shaped lower portion of the L-shaped part is allowed to slide (movement in a plane), and the side wall portion and the flange portion are formed by pulling of the portion corresponding to the L-shaped lower portion toward a side of the side wall portion, whereby it is possible to control generation of the fracture in the flange portion and generation of the wrinkles in the top portion.

[0005] In addition, Patent Literature 2 discloses a press forming method of press forming a part that has a hat-shaped or U-shaped cross section shape, and has a curved portion curved in a longitudinal direction and straight side portions connected to both ends of the curved portion. According to the press forming method, it is assumed that it is possible to control generation of the fracture due to the stretch flange deformation by causing a material movement that relaxes a tensile deformation in a circumferential direction which deformation is generated in a flange portion of the curved portion.

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Patent No. 5168429
Patent Literature 2: Japanese Patent No. 6028956 Summary

Technical Problem

[0007] In the technology disclosed in Patent Literature 1, as illustrated in FIG. 8, a moving direction of a material of a blank (metal sheet) flowing out from the top portion 103 to a side of the flange portion 111 does not coincide with a direction in which the material is pulled by the stretch flange deformation (dotted line in the circumferential direction in the flange portion 111). When the material movement of the blank is resolved into vectors in two directions as illustrated in FIG. 9, although a movement from an end side of the curved portion 113 toward a middle portion (solid black arrow in the drawing) is effective for controlling the fracture of the flange portion 111 due to the stretch flange deformation, a movement from the top portion 103 toward the side wall portion 107 (broken black arrow in the drawing) does not contribute to the controlling of the stretch flange deformation. Furthermore, even when the material moves toward the

middle portion of the curved portion 113, a material movement in the vicinity of the middle portion of the curved portion 113 (white arrow in the drawing) may induce wrinkles in the vicinity of the top portion 103 and the punch shoulder 105.

[0008] In addition, the technology disclosed in Patent Literature 1 is to control wrinkles of a top portion by pressurizing a portion corresponding to the top portion in a sheet metal blank with a pad. However, a high-strength steel sheet requires an increase in a pad load for pressurizing the wrinkles. Thus, there is a concern that a pressure generator such as a gas cylinder installed in a tool of press forming becomes huge. As a result, there are a problem that there is a case where a space for installing the pad cannot be secured in the tool of press forming, and a problem of an increase in a cost due to an increase in a size of the tool of press forming. Furthermore, in a case where the technology of Patent Literature 1 is applied to press forming of the press forming part 101 illustrated in FIG. 7, since a punch shoulder 105 cannot be pressurized with a pad, wrinkles at the punch shoulder 105 cannot be controlled.

[0009] In addition, the technology disclosed in Patent Literature 2 is to control wrinkles by moving a material of a top surface of a curved portion in a direction of becoming away from a flange, in which a stretch flange deformation is generated, by deep drawing. However, application to a part shape in which such a material movement cannot be performed, or a part manufactured by crash forming is not possible.

[0010] Furthermore, in both Patent Literature 1 and Patent Literature 2, for example, in a press forming part in which it is necessary to give a bead shape to a top portion 103 in a curved portion 113, there is a case where a material of a portion corresponding to a top portion 103 in a curved portion 113 illustrated in FIG. 9 cannot be moved to a flange portion 111 where a stretch flange deformation is generated. This makes it difficult to control the wrinkles and is a problem.

[0011] The present invention has been made to solve the above-described problems, and an object thereof is to provide a press forming method capable of controlling, in a press forming part that has a top portion, a side wall portion, and a flange portion and that is curved in a recessed manner in a top view, a fracture in the flange portion in which a stretch flange deformation is generated, and wrinkles of the top portion on a side of the flange portion and a punch shoulder.

Solution to Problem

[0012] To solve the problem and achieve the object, a press forming method according to the present invention is the press forming method of press forming a press forming part that includes a top portion, a side wall portion continuous from the top portion via a punch shoulder, and a flange portion continuous from the side wall portion via a die shoulder, the press forming part having a curved portion curved in a recessed manner in a top view. The press forming method includes: making a bending radius of the die shoulder in the curved portion increased from an end side toward a middle portion of the curve.

[0013] Moreover, in the press forming method according to the present invention, a minimum bending radius of the die shoulder is made smaller than a bending radius of the punch shoulder.

[0014] Moreover, in the press forming method according to the present invention, a portion of shape that restrains rotational motion, which restrains a rotational motion of a blank in a press forming process, is formed on the top portion on the end side of the curve.

[0015] Moreover, in the press forming method according to the present invention, a flange width of the flange portion in the curved portion is larger in the middle portion than on the end side of the curve.

[0016] Moreover, in the press forming method according to the present invention, a blank used for the press forming of the press forming part is a metal sheet having tensile strength of a 440 MPa-grade to a 1600 MPa-grade.

[0017] Moreover, the press forming method according to the present invention further performs, with a press forming part press formed by the press forming method according to the present invention being a pre-formed part, press forming of the pre-formed part into a target shape. The press forming method includes: making, in the pre-formed part, a bending radius of the die shoulder in the middle portion of the curved portion larger than the target shape.

Advantageous Effects of Invention

[0018] In the present invention, in press forming of a press forming part including a top portion, a side wall portion continuous from the top portion via a punch shoulder, and a flange portion continuous from the side wall portion via a die shoulder, and having a curved portion curved in a recessed manner in a top view, when a bending radius of the die shoulder in the curved portion is increased from an end side toward a middle portion of the curve, a material can be moved from the top portion on the end side of the curve toward the flange portion in the middle portion of the curve. Thus, it is possible to control a fracture in the flange portion in the curved portion and to control wrinkles in the top portion on a side of the flange portion and the punch shoulder in the curved portion.

Brief Description of Drawings

[0019]

FIG. 1 is a view illustrating an example of a press forming part to be formed in a press forming method according to an embodiment of the present invention ((a) perspective view, and (b) top view).

FIG. 2 is a view for describing a reason why a fracture and wrinkles can be controlled by the press forming method according to the embodiment of the present invention ((a) top view, (b) cross-sectional view of an end side of a curve, and (c) a cross-sectional view of a middle portion of the curve).

FIG. 3 is a view illustrating an example of a press forming part which is to be formed in the press forming method according to the embodiment of the present invention, and in which a bent shape that restrains a rotational motion of a blank in a horizontal plane parallel to a top portion is formed in the top portion on an end side of a curved portion.

FIG. 4 is a view illustrating an example of a press forming part which is to be formed in the press forming method according to the embodiment of the present invention, and in which a bead shape that restrains a rotational motion of the blank in the horizontal plane parallel to the top portion is formed in the top portion on the end side of the curved portion.

FIG. 5 is a view illustrating an example of a press forming part which is to be formed in the press forming method according to the embodiment of the present invention and in which a flange width of the flange portion in the middle portion of the curve is increased.

FIG. 6 is a view for describing a reason why a fracture can be controlled in the press forming part in which the flange width of the flange portion in the middle portion of the curve is increased by the press forming method according to the embodiment of the present invention.

FIG. 7 is a view for describing a fracture and wrinkles generated in press forming of a press forming part having a portion curved in a recessed manner in a top view.

FIG. 8 is a view for describing a mechanism in which the fracture and wrinkles are generated in a process of press forming the press forming part curved in the recessed manner in the top view.

FIG. 9 is a view for describing a material movement in the press forming of the press forming part curved in the recessed manner in the top view.

Description of Embodiments

[0020] A press forming method according to an embodiment of the present invention will be described below with reference to FIG. 1 to FIG. 6.

[0021] As illustrated in FIG. 1 as an example, the press forming method according to the present embodiment is to perform press forming of a press forming part 1 that includes a top portion 3, a side wall portion 7 continuous from the top portion 3 via a punch shoulder 5, and a flange portion 11 continuous from the side wall portion 7 via a die shoulder 9, and that has a curved portion 13 curved in a recessed manner in a top view and straight portions 15 extending linearly from both ends of the curve in the curved portion 13 (broken line in FIG. 1), a bending radius of the die shoulder 9 in the curved portion 13 being increased from end sides toward a middle portion of the curve.

[0022] A reason why both a fracture of the flange portion 11 and wrinkles of the top portion 3 and the punch shoulder 5 in the curved portion 13 of the press forming part 1 can be controlled in the press forming method according to the present embodiment will be described with reference to FIG. 2 in which a movement of a material in the press forming process is schematically illustrated. Note that broken lines in FIG. 2 indicate both ends of the curve (boundaries between the curved portion 13 and the straight portions 15).

[0023] The die shoulder 9 is increased from the end sides toward the middle portion of the curve in such a manner that a bending radius Rd,2 (FIG. 2(c)) in the middle portion of the curve (B-B' cross section) is larger than a bending radius Rd,1 (FIG. 2(b)) on the end sides of the curve (A-A' cross section). Thus, at the die shoulder 9 in the middle portion of the curved portion 13, since the material can be easily moved in the press forming process, a stretch flange deformation is generated in a wide range, and a strain is dispersed (black broken line arrow in FIG. 2(a)).

[0024] On the other hand, since the bending radius of the die shoulder 9 is smaller on the end sides of the curve than in the middle portion of the curve, in a process of press forming the end sides of the curve by using a punch and a die, a material deformed by an abutment on the die shoulder of the die is less likely to move on the die shoulder, whereby force of pulling the material from the top portion 3 toward the side of the flange portion 11 is increased. At the same time, the material is pulled from the end sides toward the middle portion of the curve in a process of press forming the middle portion of the curve. Thus, it is possible to increase the material movement from the top portion 3 and the punch shoulder 5 on the end sides of the curve toward the flange portion 11 in the middle portion of the curve (solid black arrow in FIG. 2(a)).

[0025] As described above, the stretch flange deformation is generated in a wide range in the middle portion of the curve, the strain is dispersed, and the material movement from the end sides of the curve toward the flange portion 11 is increased, whereby the fracture of the flange portion 11 can be controlled.

[0026] Furthermore, since the bending radius of the die shoulder 9 in the middle portion of the curve is large, the large material movement toward the middle of the curve in the top portion 3 in the vicinity of the middle portion of the curve

(white arrow in FIG. 2 (a)) becomes small, and generation of wrinkles can be controlled in the top portion 3 on a side of the flange portion 11 and the punch shoulder 5 in the middle portion of the curve.

[0027] From the above, in the press forming method according to the present embodiment, both the fracture of the flange portion 11 and the wrinkles of the top portion 3 and the punch shoulder 5 in the curved portion 13 of the press forming part 1 can be controlled.

[0028] Note that in the press forming method according to the present embodiment, the minimum bending radius of the die shoulder 9 is preferably smaller than a bending radius of the punch shoulder 5.

[0029] Here, the minimum bending radius of the die shoulder 9 is the smallest bending radius of the die shoulder 9 in the curved portion 13. In the press forming part 1, as illustrated in FIG. 2, since the bending radius of the die shoulder 9 is increased from the end sides toward the middle portion of the curve, the minimum bending radius of the die shoulder 9 is the bending radius Rd,1 at the ends of the curve.

[0030] As described above, by making the minimum bending radius (= Rd,1) of the die shoulder 9 smaller than the bending radius (= Rp) of the punch shoulder 5, it is possible to restrain the material movement in the die shoulder 9 in the press forming process, and to strongly pull the material by that amount from the side of the top portion 3 to the side of the flange portion 11 in the press forming process. As a result, it is possible to further control the fracture of the flange portion 11 and the wrinkles of the top portion 3 and the punch shoulder 5 in the curved portion.

[0031] In the above description, the bending radius of the die shoulder 9 is changed as illustrated in FIG. 1. However, in the press forming method according to the present invention, as in a press forming part 21 illustrated as an example in FIG. 3, in addition to a bending radius of a die shoulder 29 being increased from end sides toward a middle portion of a curve, a portion 37 of shape that restrains rotational motion, which restrains a rotational motion of a blank in a horizontal plane parallel to a top portion 23 in a press forming process, may be formed on the top portion 23 on an end side of a curved portion 33 and in a straight portion 35.

[0032] The portion 37 of shape that restrains rotational motion has a bent shape formed between a side wall portion 39 continuous on an opposite side of a side wall portion 27 of the straight portion 35 and the top portion 23.

[0033] As described above, by forming the portion 37 of shape that restrains rotational motion in the press forming process, it is possible to move the material from the top portion 23 on the end side of the curve and in the straight portion 35 to a flange portion 31 in the middle portion of the curve via the die shoulder 29 while controlling the rotational motion of the blank in the horizontal plane parallel to the top portion 23 in the press forming process, and to sufficiently control wrinkles of the top portion 23 and the punch shoulder 25 in the curved portion 33.

[0034] Note that in the present invention, the portion 37 of shape that restrains rotational motion does not necessarily have the shape illustrated in FIG. 3, and may have any shape as long as the rotational motion of the blank in the horizontal plane parallel to the top portion 23 can be restrained in the press forming process, for example, as a bead-shaped portion 43 of shape that restrains rotational motion formed on a top portion 23 of a press forming part 41 illustrated as an example in FIG. 4. Then, the bead shape formed on the top portion 23 is not limited to a recessed shape such as that of the portion 43 of shape that restrains rotational motion, and may be a protrusive shape.

[0035] In addition, the portion 37 of shape that restrains rotational motion illustrated in FIG. 3 and the portion 43 of shape that restrains rotational motion illustrated in FIG. 4 are formed from the end of the curved portion 33 to the straight portion 35. However, with respect to a position and a range in which the portion of shape that restrains rotational motion is formed, forming in a portion corresponding to only the end of the curved portion 33 or a portion corresponding to only the straight portion 35 is not excluded.

[0036] Furthermore, in the press forming method according to the present invention, in addition to the bending radius of the die shoulder described above, a flange width of a flange portion 61 in a middle portion of a curved portion 63 may be increased compared to those on end sides of the curve as in a press forming part 51 illustrated as an example in FIG. 5.

[0037] Effects acquired by press forming of the press forming part 51 illustrated in FIG. 5 are as follows. For example, as illustrated in FIG. 6(a), the press forming part 1 described above is acquired by press forming using a blank 71 having a shape that becomes a shape of the press forming part 1 when press formed. In this case, a flange equivalent portion 73 in the blank 71 becomes the flange portion 11 of the press forming part 1 (FIG. 1).

[0038] On the other hand, as illustrated in FIG. 6(b), the press forming part 51 illustrated in FIG. 5 is press formed by utilization of a blank 75 in which an excess material (hatched region in the drawing) of a flange equivalent portion 77 corresponding to the flange portion 61 is increased.

[0039] When the press forming part 51 is press formed by utilization of such a blank 75, since a material of the flange portion 61 in the curved portion 63 is less likely to stretch, a material insufficient for forming the flange portion 61 is pulled from a side of a top portion 53 via a punch shoulder 55 and a side wall portion 57. As a result, a material toward a middle portion of the curve in the curved portion 63 increases, and a fracture of the flange portion 61 can be further controlled.

[0040] As in the press forming part 51 illustrated in FIG. 5, in a case where the flange width of the flange portion 61 in the curved portion 63 is made larger in the middle portion than on the end sides of the curve, the maximum flange width in the middle portion of the curve is preferably 1.1 to 1.5 times as large as the flange width on the end sides.

[0041] When the flange width in the middle portion of the curve is less than 1.1 times as large, force of pulling the

material from the top portion 53 toward a side of the flange portion 61 in the press forming process does not increase much. In addition, when the flange width in the middle portion of the curve is made larger than 1.5 times, the flange width of the flange portion 61 is too large and becomes an obstacle when being joined to another part. Thus, it is necessary to cut off the flange portion 61 in a subsequent step in such a manner that the flange width becomes narrow, the number of work processes increases, and a yield rate decreases.

[0042] Note that in the press forming method according to the embodiment of the present invention, for example, as illustrated in FIG. 1, the press forming part 1 having the straight portions 15 extending from both ends of the curve of the curved portion 13 is an object to be formed. However, in the present invention, a press forming part having only a curved portion or a press forming part having a straight portion extending from only one end of a curve may be press formed, and presence or absence of the straight portion does not matter.

[0043] In addition, although being increased from both end sides of the curve toward the middle portion in the above description, a bending radius of a die shoulder may be increased from any one end side of a curve toward a middle portion.

[0044] In the above description, examples of specific aspects of the present invention are described on the basis of the embodiments of the present invention. However, the present invention also includes, for example, using the press forming part 1 illustrated in FIG. 1 as a pre-formed part and performing press forming of the pre-formed part into a target shape. In the press forming part 1 that is the pre-formed part, a bending radius of a die shoulder 9 in a middle portion of a curved portion 13 may be made larger than the target shape. That is, a press forming method including two steps that are a step of press forming the press forming part 1 that is the pre-formed part, and a step of press forming the press forming part 1 into a press forming part having the target shape is included.

[0045] Then, when a press forming part 101 in which a bending radius of a conventional punch shoulder 105 is set to a target shape and which is illustrated as an example in FIG. 7 is press formed in one step, even in a case where a fracture of a flange portion 111 and wrinkles of a top portion 103 and a punch shoulder 105 in a curved portion 113 of a press forming part 101 are generated, it is possible to control the fracture of the flange portion 111 and the wrinkles of the top portion 103 and the punch shoulder 105 in the curved portion 113 and to acquire the press forming part 101 having the target shape according to the press forming method of the present invention.

[0046] Although not being specifically limited in terms of a type of a metal sheet to be a raw material of the blank, the press forming method according to the present invention can be preferably applied in a case where a metal sheet having low ductility is used. Specifically, it is preferable to use a metal sheet having tensile strength of a 440 MPa-grade or more and a 1600 MPa-grade or less and having a thickness of 0.5 mm or more and 3.6 mm or less.

[0047] A metal sheet having the tensile strength of less than the 440 MPa-grade has high ductility, whereby the fracture due to the stretch flange deformation is hardly generated, and there are few advantages of using the present invention. However, the present invention is preferably used even for the metal sheet having the tensile strength of less than the 440 MPa-grade when a part shape is difficult to be press formed. Although there is not specifically an upper limit in the tensile strength, since a metal sheet exceeding the 1600 MPa-grade has poor ductility, a fracture in a punch shoulder and a die shoulder becomes likely to be generated and press forming becomes difficult.

[0048] In addition, the press forming method according to the present invention can prevent a fracture of a metal sheet due to a stretch flange deformation in an automotive part having an L-shaped, T-shaped, Y-shaped, or S-shaped portion curved in a top view. As a specific example, the present invention can be preferably applied to a case where an A pillar lower or the like having an L-shaped portion, a B pillar or the like having a T-shaped portion, or a rear side member or the like having an S-shaped portion is an object to be formed.

[Examples]

[0049] A specific press forming experiment has been performed on the effects of the press forming method according to the present invention, and a description thereof will be made in the following.

[0050] In the press forming experiment, a steel sheet having a mechanical property of material illustrated in Table 1 was used as a blank, and the press forming part 1 (FIG. 1), the press forming part 21 (FIG. 3), the press forming part 41 (FIG. 4), and the press forming part 51 (FIG. 5) described in the above-described embodiment were used as objects to be formed, and crash forming was performed in an invention example.

[0051] A radius of the curve of the curved portion in the middle in a height direction of the side wall portion of each of the press forming parts was set to 153 mm, a bending radius of the punch shoulder in the curved portion was set to 7 mm, the smallest bending radius of the die shoulder was set to 6 mm, a flange width of the flange portion was set to 25 mm, and a side wall height in a press forming direction of the side wall portion was set to 60 mm. Furthermore, in a case where the flange width of the flange portion 11 in the press forming part 1 was made larger in the middle portion than on the end sides, the flange width of the flange portion 61 in the middle portion of the curve was set to be 1.5 times as large as the flange width on the end sides of the curve (= 25 mm).

Table 1

Thickness/mm	Yield strength/MPa	Tensile strength/MPa	Stretch/%
1.6	880	1210	13

[0052] In the press forming experiment, a ratio of the bending radius Rd of the die shoulder in the press forming part to be an object to be formed was changed. Here, the ratio of the bending radius Rd of the die shoulder is a ratio between the largest bending radius and the smallest bending radius (6 mm) in a ridge direction along the curve of the die shoulder.

[0053] Furthermore, in the press forming experiment, as a comparative object, a press forming part 101 acquired by press forming in a state in which a portion corresponding to a top portion 103 of the press forming part 101 illustrated in FIG. 7 is pressed by a pad and a rotational motion of a blank in a horizontal plane parallel to the top portion 103 is allowed in accordance with the method disclosed in Patent Literature 1 was set as a conventional example.

[0054] In the conventional example, a curvature radius of a curve of a curved portion 113, a bending radius of a punch shoulder 105, and a side wall height of a side wall portion 107 were set to be the same as those of the press forming part according to the invention example. Furthermore, a bending radius of a die shoulder 109 was set to be constant (= 6 mm) in a direction along the curve as the smallest bending radius of the die shoulder.

[0055] Then, a fracture and wrinkles in each of the press forming parts according to the invention examples and the conventional example were evaluated. In the evaluation of the fracture, a thickness reduction ratio in which a difference between a thickness of a blank and a thickness of a flange portion tip (such as a C portion illustrated in FIG. 2) of the deepest bottom portion of a recessed portion in a curved portion was divided by the thickness of the blank was calculated, and it was evaluated that fracture control was better as a value thereof became smaller. On the other hand, in the evaluation of the wrinkles, sensory evaluation was performed on a top portion and a punch shoulder in the curved portion by visual inspection, a case where there were significant wrinkles being evaluated as "×", a case where there were minute wrinkles that could be visually confirmed but were allowable in terms of part performance being evaluated as "△", and a case where wrinkles could not be visually confirmed being evaluated as "○". Results of the evaluation of the fracture and wrinkles for each of the press forming parts were illustrated in Table 2 and Table 3.

Table 2

No.	Conventional example	First invention example	Second invention example	Third invention example
Content	Make bending radius of die shoulder constant	Increase bending radius R_d of die shoulder in curved portion	←	←
Ratio of bending radius R_d of die shoulder	1.0	1.1	1.5	2.0
Evaluation of fracture (thickness reduction ratio (%))	18	17	14	12
Sensory evaluation of wrinkle	△	○	○	○

Table 3

No.	Fourth invention example	Fifth invention example	Sixth invention example	Seventh invention example	Comparative example
Content	Increase bending radius R_d of die shoulder in curved portion + restrain rotational motion of blank (bent shape)	Increase bending radius R_d of die shoulder in curved portion + restrain rotational motion of blank (bead shape)	Give excess material to blank of first invention example	Give excess material to blank of second invention example	Uniformly increase bending radius R_P of punch shoulder of entire part (1.5 time)

(continued)

No.	Fourth invention example	Fifth invention example	Sixth invention example	Seventh invention example	Comparative example
Ratio of bending radius R_d of die shoulder R portion	1.5	←	1.1	1.5	←
Evaluation of fracture (thickness reduction ratio (%))	15	14	8	9	9
Sensory evaluation of wrinkle	○	○	○	○	×

[0056] In the conventional example, the thickness reduction ratio was large and was 18%, and fine wrinkles were generated.

[0057] In a first invention example, the press forming part 1 (FIG. 1) is set as an object to be formed, and the bending radius Rd of the die shoulder 9 is increased at a ratio of 1.1 from the middle of the curve toward the end sides. As illustrated in Table 2, the thickness reduction ratio was 17% and was reduced as compared with the conventional example, and generation of wrinkles was not observed.

[0058] In a second invention example, the press forming part 1 is set as an object to be formed, and a ratio of the bending radius Rd of the die shoulder 9 is set to 1.5, which is larger than that in the first invention example. As illustrated in Table 2, the thickness reduction ratio was 14% and was reduced as compared with the first invention example, and generation of wrinkles was not observed.

[0059] In a third invention example, the press forming part 1 is set as an object to be formed, and a ratio of the bending radius Rd of the die shoulder 9 is set to 2.0, which is larger than that in the second invention example. As illustrated in Table 2, the thickness reduction ratio was 12% and was further reduced as compared with the second invention example, and generation of wrinkles was not observed.

[0060] In a fourth invention example, the press forming part 21 (FIG. 3) was set as an object to be formed, a ratio of the bending radius Rd of the die shoulder 29 was set to 1.5, and the bent-shaped portion 37 of shape that restrains rotational motion was formed between the top portion 23 and the side wall portion 39. As illustrated in Table 3, the thickness reduction ratio was 15% and was reduced as compared with the conventional example, and generation of wrinkles was not observed.

[0061] In a fifth invention example, the press forming part 41 (FIG. 4) is set as an object to be formed, a ratio of the bending radius of the die shoulder 29 is made equal to that in the fourth invention example, and the bead-shaped portion 43 of shape that restrains rotational motion is formed from the end side of the curve to the straight portion on the top portion 23. As illustrated in Table 3, the thickness reduction ratio was 14% and was reduced as compared with the conventional example, and generation of wrinkles was not observed.

[0062] In a sixth invention example, the press forming part 51 (FIG. 5) is set as an object to be formed, and the blank 75 having a shape in which an excess material is given to the flange equivalent portion 77 (see FIG. 6) is used. Similarly to the first invention example, a ratio of the bending radius Rd of the die shoulder 59 is set to 1.1, and the flange width of the flange portion 61 in the middle portion of the curved portion 63 is set to be 1.5 times as large as the flange width on the end sides of the curve (= 25 mm). As illustrated in Table 3, the thickness reduction ratio was 8% and was reduced as compared with the first invention example, and generation of wrinkles was not observed.

[0063] In a seventh invention example, the press forming part 51 (FIG. 5) is set as an object to be formed, and the blank 75 having a shape in which an excess material is given to the flange equivalent portion 77 (see FIG. 6) is used. Similarly to the second invention example, a ratio of the bending radius Rd of the die shoulder 59 is set to 1.5, and the flange width of the flange portion 61 in the middle portion of the curved portion 63 is set to be 1.5 times as large as the flange width on the end sides of the curve (= 25 mm). As illustrated in Table 3, the thickness reduction ratio was 9% and was reduced as compared with the second invention example, and generation of wrinkles was not observed.

[0064] Note that an example of a press forming part 101 in which a bending radius of a die shoulder 109 is uniformly

increased as compared with the conventional example is illustrated in Table 3 as a comparative example. In the comparative example, a bending radius of a ridge line of an entire punch shoulder 105 of the conventional example was increased by 1.5 times and was made constant at 10.5 mm. As a result, although the thickness reduction ratio was 9% and was well, significant wrinkles were generated, which was a problem.

[0065] As described above, it has been demonstrated that the press forming method according to the present invention can control a fracture of a flange portion in a curved portion and to control wrinkles of a top portion and a punch shoulder in the curved portion.

Industrial Applicability

[0066] According to the present invention, it is possible to provide a press forming method capable of controlling, in a press forming part having a top portion, a side wall portion, and a flange portion and curved in a recessed manner in a top view, a fracture in the flange portion in which a stretch flange deformation is generated, and wrinkles of the top portion on a side of the flange portion and a punch shoulder.

Reference Signs List

[0067]

1 PRESS FORMING PART
3 TOP PORTION
5 PUNCH SHOULDER
7 SIDE WALL PORTION
9 DIE SHOULDER
11 FLANGE PORTION
13 CURVED PORTION
15 STRAIGHT PORTION
21 PRESS FORMING PART
23 TOP PORTION
25 PUNCH SHOULDER
27 SIDE WALL PORTION
29 DIE SHOULDER
31 FLANGE PORTION
33 CURVED PORTION
35 STRAIGHT PORTION
37 PORTION OF SHAPE THAT RESTRAINS ROTATIONAL MOTION
39 SIDE WALL PORTION
41 PRESS FORMING PART
43 PORTION OF SHAPE THAT RESTRAINS ROTATIONAL MOTION
51 PRESS FORMING PART
53 TOP PORTION
55 PUNCH SHOULDER
57 SIDE WALL PORTION
59 DIE SHOULDER
61 FLANGE PORTION
63 CURVED PORTION
71 BLANK
73 FLANGE EQUIVALENT PORTION
75 BLANK
77 FLANGE EQUIVALENT PORTION
101 PRESS FORMING PART
103 TOP PORTION
105 PUNCH SHOULDER
107 SIDE WALL PORTION
109 DIE SHOULDER
111 FLANGE PORTION
113 CURVED PORTION
115 STRAIGHT PORTION

Claims

1. A press forming method of press forming a press forming part that includes a top portion, a side wall portion continuous from the top portion via a punch shoulder, and a flange portion continuous from the side wall portion via a die shoulder, the press forming part having a curved portion curved in a recessed manner in a top view, the press forming method comprising:
making a bending radius of the die shoulder in the curved portion increased from an end side toward a middle portion of the curve.

2. The press forming method according to claim 1, wherein a minimum bending radius of the die shoulder is made smaller than a bending radius of the punch shoulder.

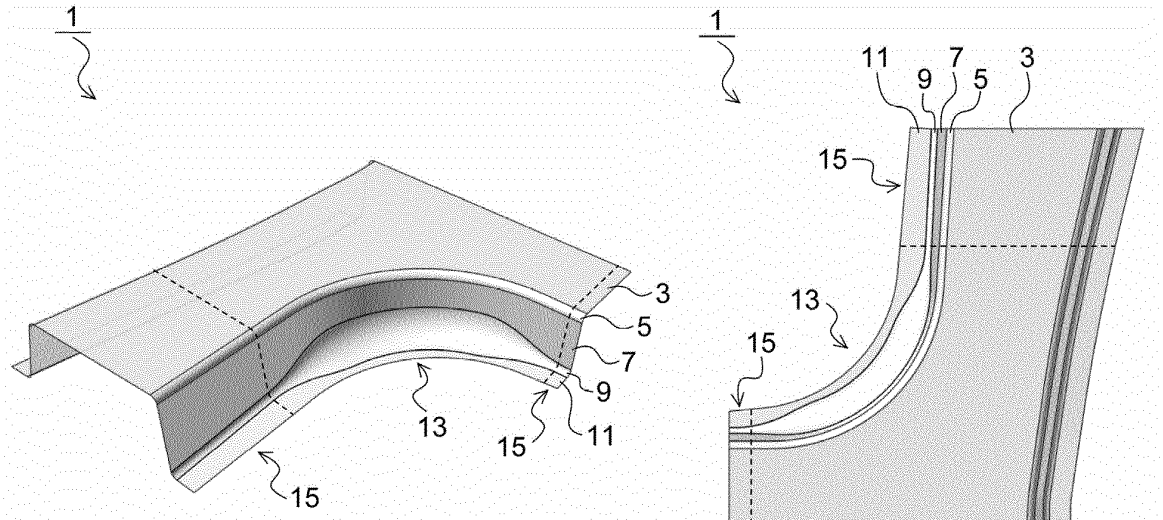
3. The press forming method according to claim 1 or 2, wherein a portion of shape that restrains rotational motion, which restrains a rotational motion of a blank in a press forming process, is formed on the top portion on the end side of the curve.

4. The press forming method according to any one of claims 1 to 3, wherein a flange width of the flange portion in the curved portion is larger in the middle portion than on the end side of the curve.

5. The press forming method according to any one of claims 1 to 4, wherein a blank used for the press forming of the press forming part is a metal sheet having tensile strength of a 440 MPa-grade to a 1600 MPa-grade.

6. A press forming method of further performing, with a press forming part press formed by the press forming method according to any one of claims 1 to 5 being a pre-formed part, press forming of the pre-formed part into a target shape, the press forming method comprising:
making, in the pre-formed part, a bending radius of the die shoulder in the middle portion of the curved portion larger than the target shape.

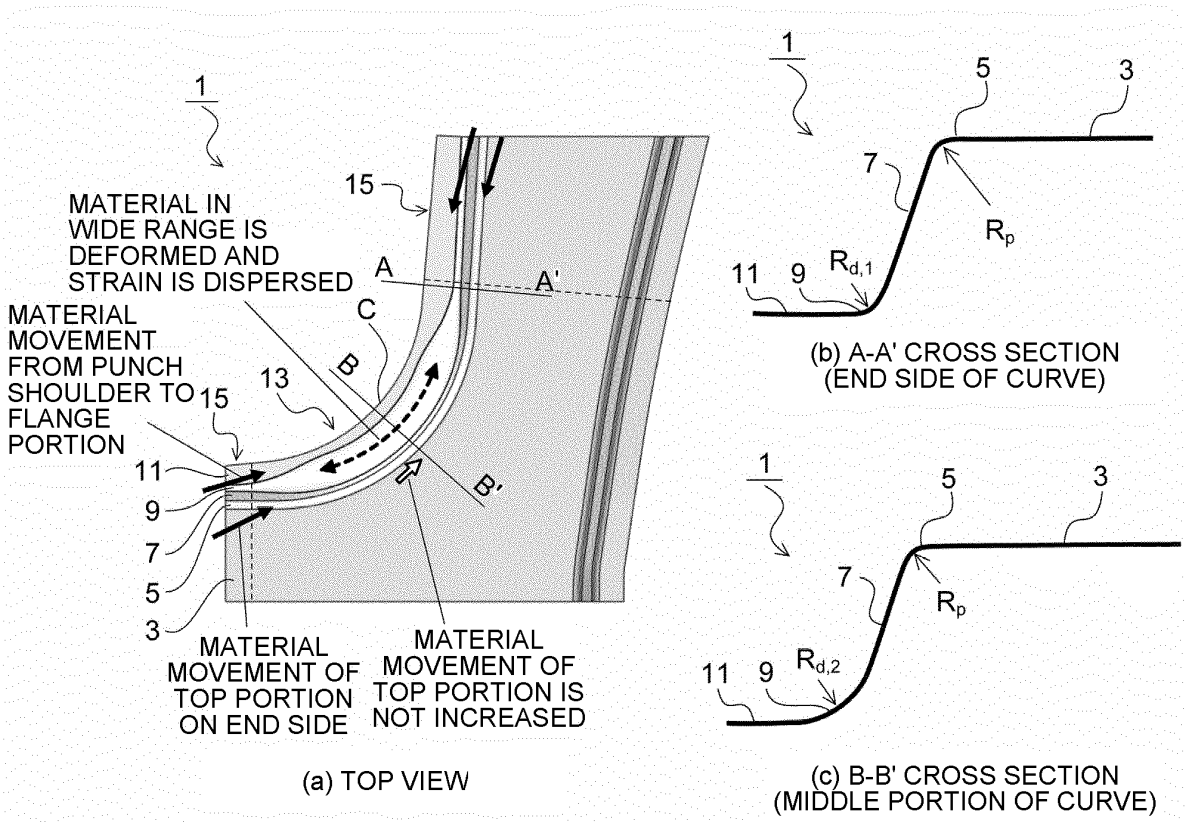
FIG.1



(a) PERSPECTIVE VIEW

(b) TOP VIEW

FIG.2

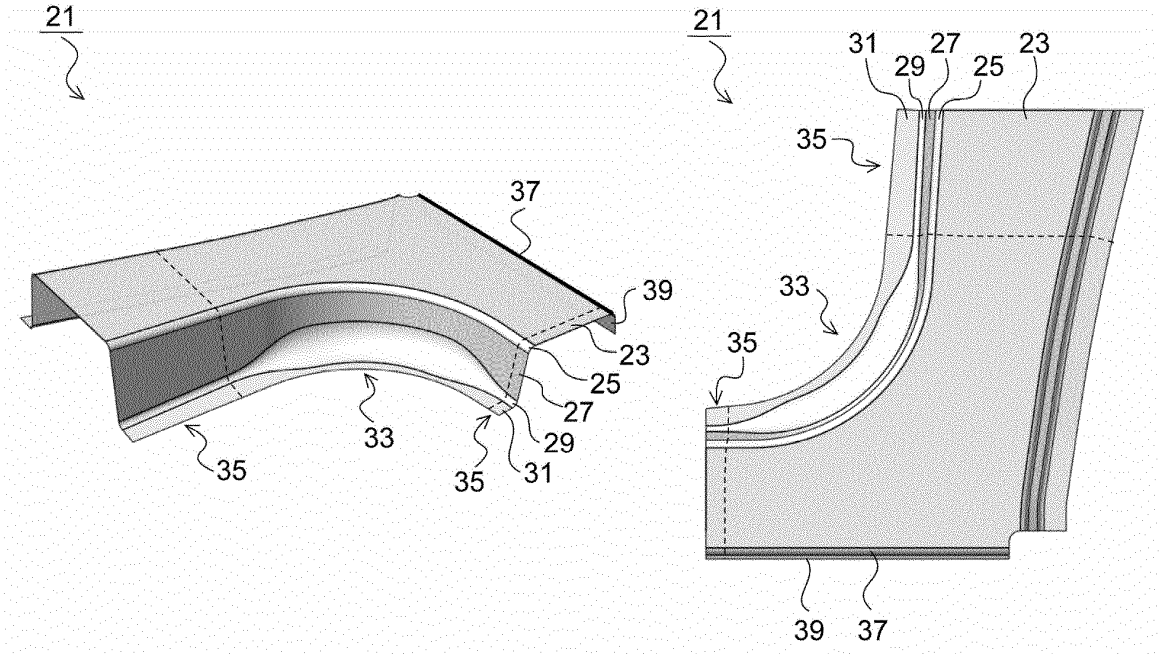


(a) TOP VIEW

(b) A-A' CROSS SECTION (END SIDE OF CURVE)

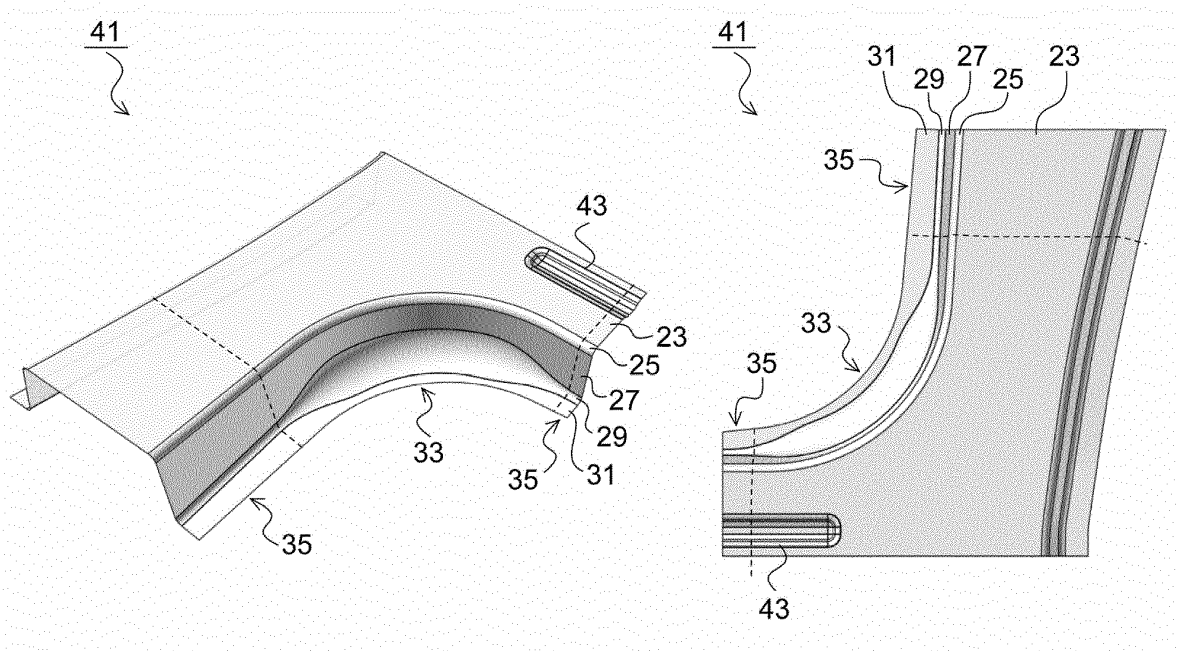
(c) B-B' CROSS SECTION (MIDDLE PORTION OF CURVE)

FIG.3



(a) PERSPECTIVE VIEW (b) TOP VIEW

FIG.4



(a) PERSPECTIVE VIEW (b) TOP VIEW

FIG.5

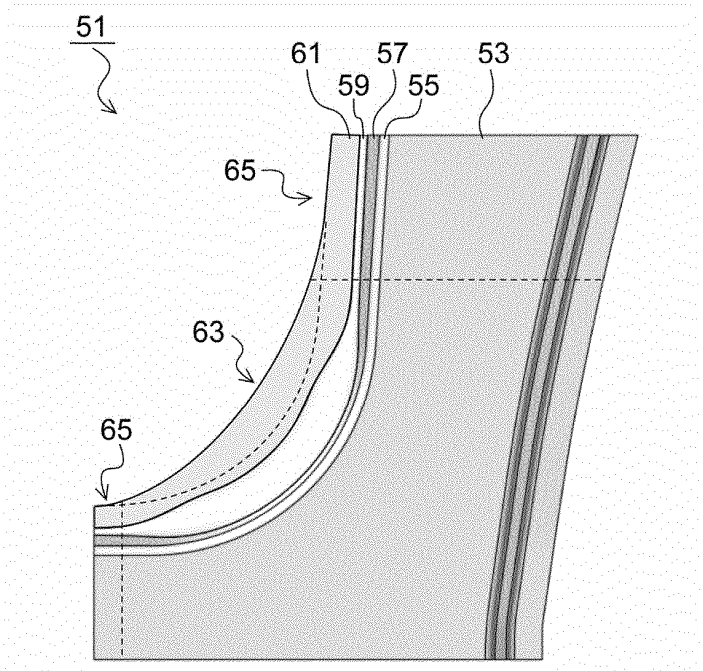
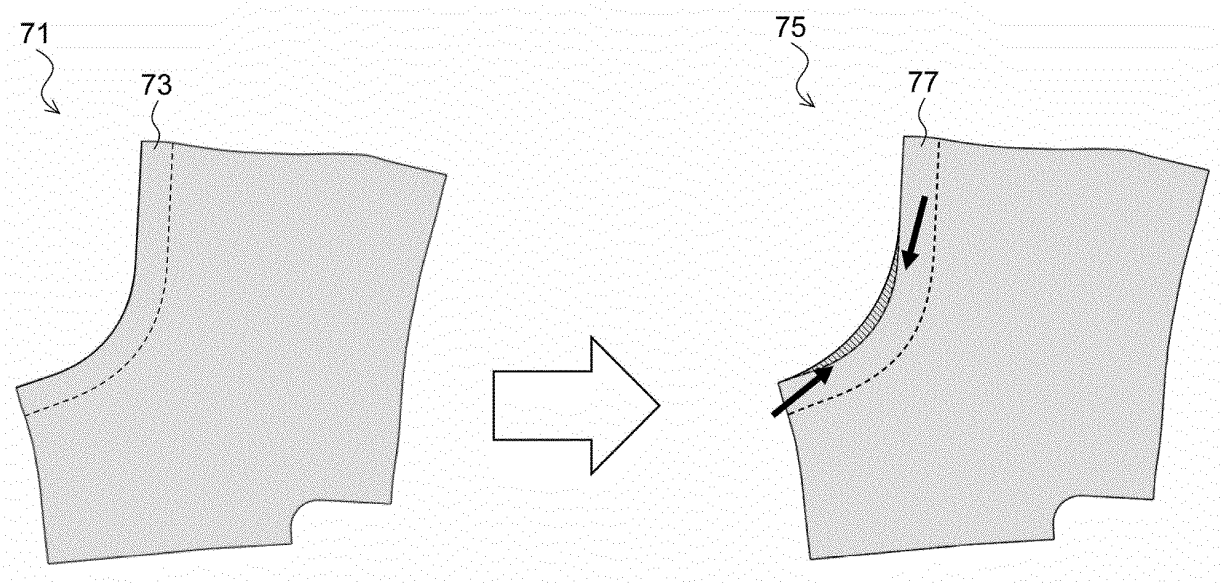


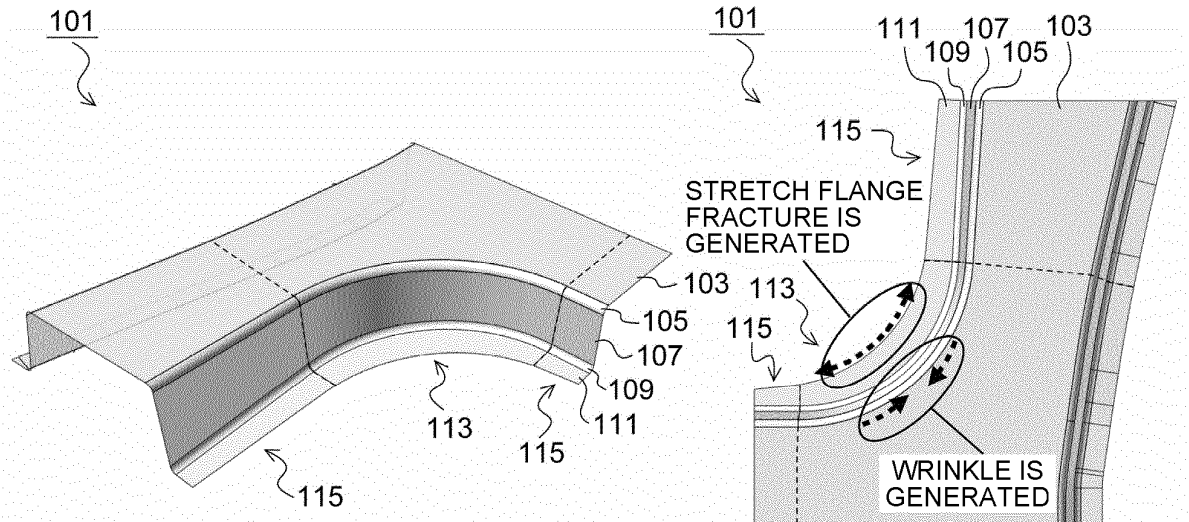
FIG.6



(a) GENERAL BLANK SHAPE

(b) BLANK SHAPE OF PRESENT INVENTION

FIG.7



(a) PERSPECTIVE VIEW

(b) TOP VIEW

FIG.8

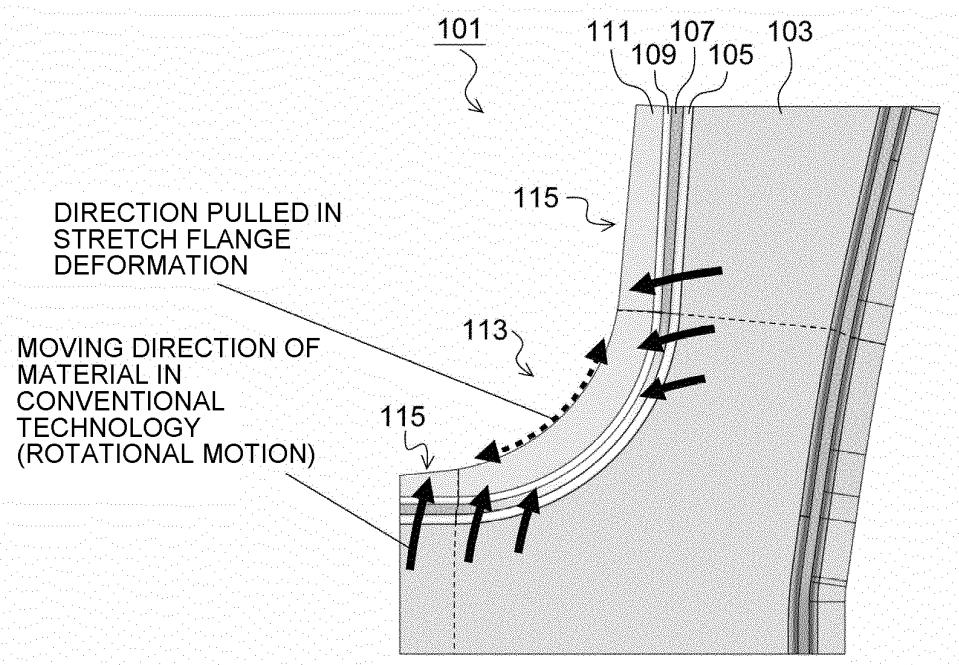
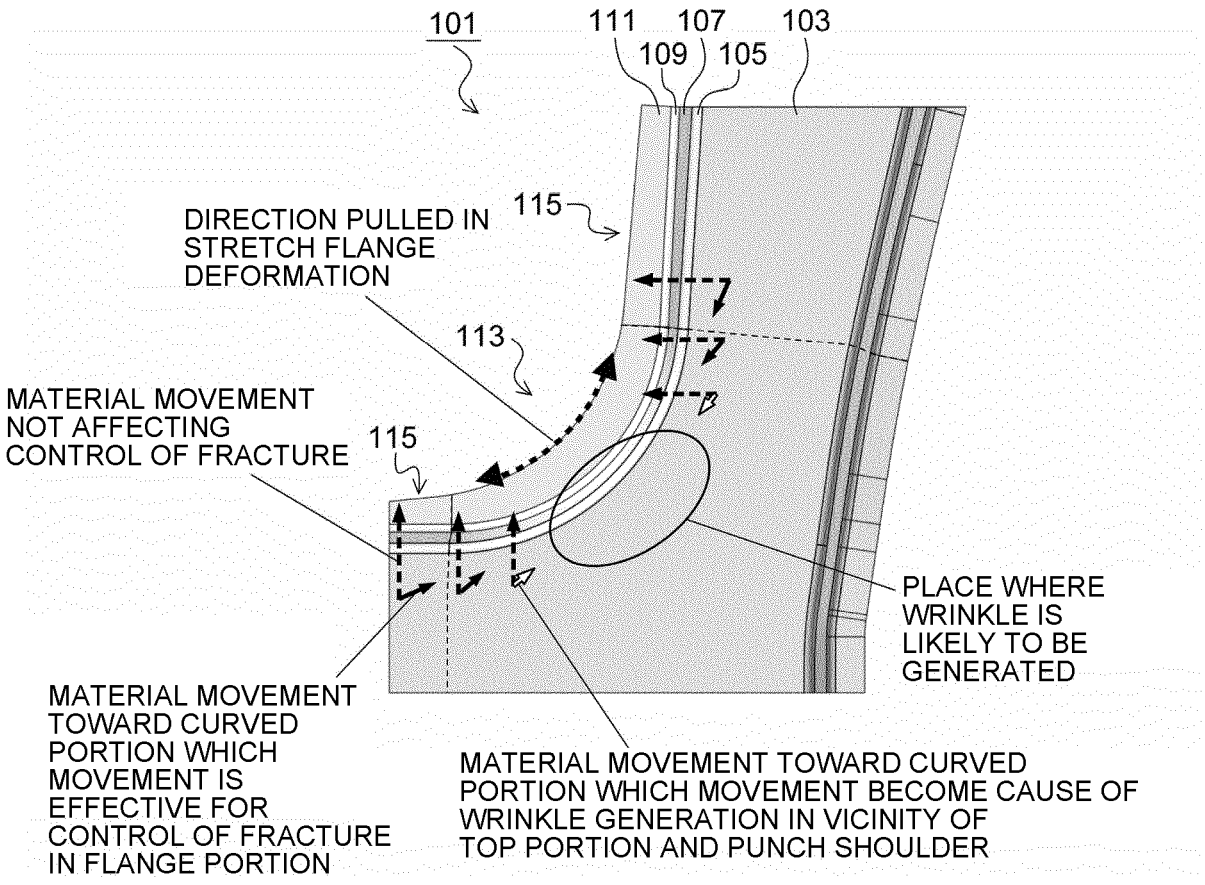


FIG.9


101
111
107
103
109
105
115
DIRECTION PULLED IN STRETCH FLANGE DEFORMATION
113
MATERIAL MOVEMENT NOT AFFECTING CONTROL OF FRACTURE
115
PLACE WHERE WRINKLE IS LIKELY TO BE GENERATED
MATERIAL MOVEMENT TOWARD CURVED PORTION WHICH MOVEMENT IS EFFECTIVE FOR CONTROL OF FRACTURE IN FLANGE PORTION
MATERIAL MOVEMENT TOWARD CURVED PORTION WHICH MOVEMENT BECOME CAUSE OF WRINKLE GENERATION IN VICINITY OF TOP PORTION AND PUNCH SHOULDER

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/024791

A. CLASSIFICATION OF SUBJECT MATTER
B21D 22/20(2006.01)i; B21D 22/26(2006.01)i
FI: B21D22/26 D; B21D22/20 E

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 - 26/14

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	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-202189 A (NIPPON STEEL CORP.) 10 September 2009 (2009-09-10) paragraphs [0012], [0021], [0030]-[0033], table 1, fig. 9	1
Y	paragraphs [0012], [0021], [0030]-[0033], table 1, fig. 9	4-6
A	paragraphs [0012], [0021], [0030]-[0033], table 1, fig. 9	2-3
Y	WO 2014/106932 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 10 July 2014 (2014-07-10) paragraphs [0024], [0053]-[0060], fig. 3-4, 9	4-6
Y	JP 2019-171440 A (JFE STEEL CORPORATION) 10 October 2019 (2019-10-10) paragraphs [0014], [0044]-[0066], fig. 2, 11	6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 August 2021 (31.08.2021)	07 September 2021 (07.09.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/024791

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2009-202189 A	10 Sep. 2009	(Family: none)	
WO 2014/106932 A1	10 Jul. 2014	US 2015/0336619 A1 paragraphs [0025], [0101]-[0109], fig. 3-4, 9 EP 2942123 A1 CN 104870118 A KR 10-2015-0103214 A	
JP 2019-171440 A	10 Oct. 2019	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 5168429 B **[0006]**
- JP 6028956 B **[0006]**