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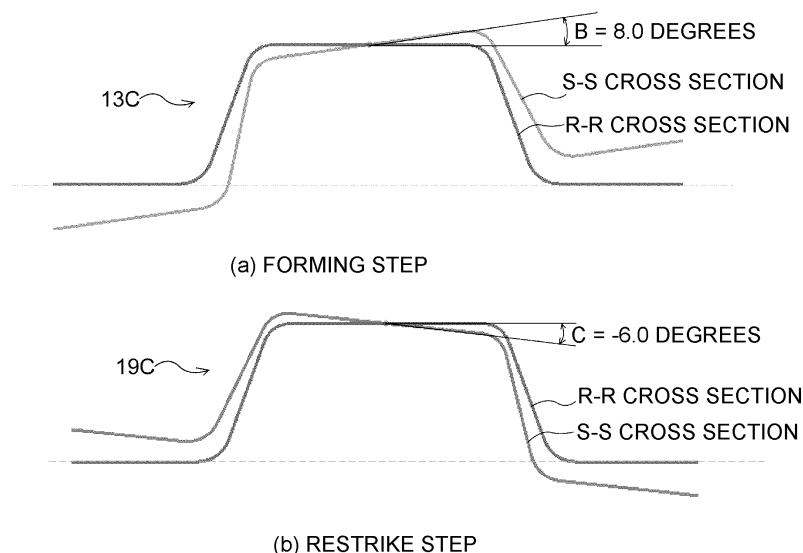
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(54) **METHOD FOR MANUFACTURING PRESS-FORMED PRODUCT**

(57) A method of manufacturing a press-formed part 1 according to the present invention reduces an error from a target shape caused by springback after mold release. The press-formed part 1 is curved in top view, and includes at least a top portion 3 and side wall portions 5 continuous from the top portion 3. The method includes: a forming step of performing press forming by using a forming mold having a first estimated angle, which leaves

twist (reverse twist) caused by springback in a direction opposite to twist (forward twist) generated by springback in a case where press forming is performed in one step without giving an estimated angle to a mold; and a restrike step of press-forming a formed part 17 formed in the forming step by using a restrike mold having a second estimated angle that reduces the reverse twist.

FIG.1



Description

Field

- 5 **[0001]** The present invention relates to a method of manufacturing a press-formed part curved in top view and including at least a top portion and side wall portions continuous from the top portion.

Background

- 10 **[0002]** Tightening of automotive collision safety standards improves collision safety of automotive bodies. In order to comply with a carbon dioxide emission regulation, weight reduction of automotive bodies is also required for improving fuel economy and performing shift to EV. In order to achieve both improvement in collision safety and weight reduction of automotive bodies, high-strength steel sheet (also referred to as high-tensile steel sheet) of 590 MPa-class or more have been increasingly applied to automotive body structural parts.
- 15 **[0003]** Automotive parts include some of the structures. Examples of the automotive parts include a press-formed part 1 curved in top view and including at least a top portion 3 and side wall portions 5 continuous from the top portion 3 as illustrated in FIG. 3. In a case where press-forming is performed to form such a press-formed part, springback is generated by mold release after a mold is moved to a forming bottom dead center, which easily generates twist in the press-formed part. Particularly in a case of a high tensile strength steel sheet, stress generated at the forming bottom dead center by an increase in strength is increased, and the increased stress is released after mold release, which causes a problem of easily generated large twist.
- 20 **[0004]** For example, Patent Literature 1 discloses a method of reducing generated stress by forming a through hole, a groove, or the like in a press-formed part as a method of reducing such twist caused by springback. Furthermore, Patent Literature 2 discloses, in Paragraph [0004], a method of performing press forming with a mold having a twist angle in a direction opposite to springback.
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Citation List

Patent Literature

- 30 **[0005]**

Patent Literature 1: JP 2007-253173 A

Patent Literature 2: JP 2007-130671 A

- 35
- Summary

Technical Problem

- 40 **[0006]** In the press-forming method in Patent Literature 1, a through hole or a groove is shaped in a press-formed part, so that the press-formed part has a shape different from a target shape. This causes problems of decreased rigidity at the time when the press-formed part is assembled to an automotive body and of difficulty in joining parts to each other.
- [0007]** Furthermore, in the press-forming method in Patent Literature 2, a twist angle in one direction, that is, only a direction opposite to springback, is given to a mold to perform press forming, which causes a problem of difficulty in setting a twist angle to be given to the mold. That is, too small a twist angle cannot sufficiently eliminate twist which is springback, and too large a twist angle leaves twist in the opposite direction. An appropriate twist angle is required to be given, but this is difficult.
- 45 **[0008]** Moreover, a case where blanks having different material strengths are press-formed by using the same mold and a case where blanks to be subjected to press forming have variations in material, plate thickness, and the like have the following problem. That is, even when press forming is performed by using the same mold having a conventional twist angle only in one direction, a difference in material strength and variations in plate thickness and materials cause different degrees of springback, and variation in springback of the press-formed part.
- 50 **[0009]** The present invention has been made in view of the above-described problems, and an object thereof is to provide a method of manufacturing a press-formed part, capable of reducing a shape error caused by springback after mold release. The press-formed part is curved in top view, and includes at least a top portion and side wall portions continuous from the top portion.
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Solution to Problem

[0010] To solve the problem and achieve the object, (1) a method of manufacturing a press-formed part according to the present invention is the method of manufacturing the press-formed part curved in top view and including at least a top portion and a side wall portion continuous from the top portion. The method includes: a forming step of performing press forming by using a forming mold having a first estimated angle, which leaves twist (reverse twist) caused by springback in a direction opposite to twist (forward twist) generated by springback in a case where press forming is performed in one step without giving an estimated angle to a mold; and a restrike step of press-forming a formed part formed in the forming step by using a restrike mold having a second estimated angle.

[0011] (2) Moreover, in the method of manufacturing the press-formed part according to above (1), the first estimated angle may be larger than a one-step estimated angle at which twist caused by springback in a case where press forming is performed in one step to form the press-formed part has a predetermined threshold or less.

[0012] (3) Moreover, in the method of manufacturing the press-formed part according to above (2), a direction of twist caused by springback and the one-step estimated angle may be determined by preliminarily performing press-forming analysis and springback analysis of the press-formed part.

[0013] (4) Moreover, in the method of manufacturing the press-formed part according to above (2), a direction of twist caused by springback and the one-step estimated angle may be determined by preliminarily performing actual press forming of the press-formed part.

[0014] (5) Moreover, in the method of manufacturing the press-formed part according to any one of above (1) to (4), the first estimated angle or the second estimated angle may be defined as an inclination angle of a top portion forming surface portion of a cross section in a width direction at an end of the forming mold or the restrike mold in the longitudinal direction with reference to a top portion forming surface portion of a cross section in a width direction at a center of the forming mold or the restrike mold in the longitudinal direction.

[0015] (6) Moreover, in the method of manufacturing the press-formed part according to any one of above (1) to (5), an absolute value of the second estimated angle in the restrike step may be smaller than an absolute value of the first estimated angle.

Advantageous Effects of Invention

[0016] Twist, which is springback, after mold release can be sufficiently reduced by a method of manufacturing a press-formed part according to the present invention. As a result, effects are exhibited in which a through hole or a groove is unnecessary, a target press-formed part shape is held, and a press-formed part having a better shape than a conventional press-formed part can be manufactured. Furthermore, the method of manufacturing a press-formed part according to the present invention exhibits an effect of being able to manufacture a press-formed part in which springback is sufficiently reduced by using the same mold even from blanks having different material strengths and variations in plate thickness and material.

Brief Description of Drawings

[0017]

FIG. 1 is an explanatory view of mold estimated angles in a forming step and a restrike step in an invention example. FIG. 2 is an explanatory view of stress states at forming bottom dead centers in the forming step and the restrike step in the invention example.

FIG. 3 is an explanatory view of an example of a press-formed part targeted by the present invention.

FIG. 4 is an explanatory view of the forming step and the restrike step according to an embodiment.

FIG. 5 is an explanatory view of a twist angle of the press-formed part.

FIG. 6 is an explanatory view of a mold estimated angle.

FIG. 7 is an explanatory view of twist angles of a formed part after the forming step and a press-formed part after the restrike step in the conventional example.

FIG. 8 is an explanatory view of stress states at forming bottom dead centers in the forming step and the restrike step in the conventional example.

FIG. 9 is an explanatory view of mold estimated angles in the forming step and the restrike step in a comparative example.

FIG. 10 is an explanatory view of stress states at forming bottom dead centers in the forming step and the restrike step in the comparative example.

FIG. 11 is an explanatory view (part 1) of a press-formed part targeted in an example.

FIG. 12 is an explanatory view (part 2) of the press-formed part targeted in the example.

Description of Embodiments

[0018] An embodiment of a method of manufacturing a press-formed part according to the present invention will be described below. Note that the present invention is not limited by the embodiment.

[0019] As illustrated in FIG. 3 as an example, a press-formed part 1 targeted by the present invention is curved in top view. The press-formed part 1 has a hat-shaped cross section with at least a top portion 3, side wall portions 5, and flange portions 7. The side wall portions 5 are continuous from the top portion 3. The flange portions 7 are provided at lower ends of the side wall portions 5. Note that, although, in the example of FIG. 3, the flange portions 7 are provided in addition to the top portion 3 and the side wall portions 5, the flange portions 7 are not necessarily required to be provided. The function of the present invention will be described below by citing the press-formed part 1 in FIG. 3 as an example. The press-formed part 1 has been formed by using a 1470 MPa-class steel sheet having a plate thickness of 1.0 mm as a blank 9.

[0020] As illustrated in FIG. 4, the press-formed part 1 in FIG. 3 is formed by a forming step (FIG. 4(a)) and a restrike step (FIG. 4(b)). In the forming step, the blank 9, which is a metal plate, is pressed by a pad 11 and a forming punch 13. A forming die 15 is relatively moved to form a formed part 17 including the top portion 3, the side wall portions 5, and the flange portions 7. Then, in the restrike step, the formed part 17 formed in the forming step is formed by a restrike punch 19 and a restrike die 21.

[0021] The shape, particularly a twist angle, of the press-formed part 1 after the restrike will be described with reference to FIG. 5. FIG. 5(a) is a plan view of the press-formed part 1. FIG. 5(b) illustrates a P-P cross section of the press-formed part 1 at a central portion in a longitudinal direction together with a forming surface of the restrike punch 19 at a central portion in a longitudinal direction. FIG. 5(c) illustrates a Q-Q cross section of the press-formed part 1 in the vicinity of an end in the longitudinal direction together with the forming surface of the restrike punch 19 at the central portion in the longitudinal direction.

[0022] As illustrated in FIG. 5, when the cross section of a top portion forming surface of the restrike punch 19 at the central portion in the longitudinal direction coincides with the top portion 3 of a P-P cross section of the press-formed part 1 at the central portion in the longitudinal direction, the shape of the Q-Q cross section in the vicinity of the end in the longitudinal direction rotates clockwise (in right-handed rotation in paper surface in case where an outside of a curve is defined as left and an inside of the curve is defined as right) with respect to the cross section of the top portion forming surface of the restrike punch 19 at the central portion in the longitudinal direction. This indicates that the press-formed part 1 is twisted by springback.

[0023] In the following description, a twist angle of the formed part 17 or the press-formed part 1 is defined as an angle formed by the cross section of the top portion 3 at the end (approximately 10 mm close to center from outermost end in example) in the longitudinal direction with the cross section of the top portion forming surface of the forming punch 13 or the restrike punch 19 at the central portion in the longitudinal direction with reference to the cross section of the top portion forming surface of the forming punch 13 or the restrike punch 19 at the central portion in the longitudinal direction (see FIG. 5(b)). Then, when the angle shifts in a left-handed rotation (counterclockwise) in the paper surface in which the outside of the curve is defined as left and the inside of the curve is defined as right, a value of plus (+) is given. When the angle shifts in the right-handed rotation (clockwise) in the paper surface, a value of minus (-) is given.

[0024] Furthermore, a mold estimated angle is defined as an angle in a cross section (S-S cross section) at an end (e.g., approximately 10 mm inside from outermost end) (see FIGS. 6(a), (c)) in the longitudinal direction with reference to a cross section (R-R cross section) (see FIGS. 6(a), (b)) of the top portion forming surface portion of the forming punch 13 or the restrike punch 19 at the central portion in the longitudinal direction. Then, when the mold estimated angle shifts in a left-handed rotation (counterclockwise) in the paper surface in which the outside of the curve is defined as left and the inside of the curve is defined as right, a value of plus (+) is given. When the mold estimated angle shifts in the right-handed rotation (clockwise) in the paper surface, a value of minus (-) is given.

[0025] Circumstances leading to the present invention will be described below through descriptions of a conventional example and a comparative example.

<Conventional Example>

[0026] In the conventional example, restrike is performed by a mold having the same shape after the forming step is performed. FIG. 7 illustrates Q-Q cross sections (see FIG. 5) of a formed part 17A after the forming step (FIG. 7(a)) and a press-formed part 1A after the restrike step (FIG. 7(b)) in the conventional example in the vicinities of ends in the longitudinal direction. In the conventional example, as illustrated in FIG. 7, the twist angle caused by springback after the forming step remains minus, and remains almost as it is without being corrected even in the restrike step. The twist angle caused by springback of the formed part 17A after a press-forming step in FIG. 7(a) is -3.1 degrees. The twist angle caused by springback of a press-formed part 1A after the restrike in FIG. 7(b) is -3.4 degrees.

[0027] Press-forming analysis is performed by a finite element method (FEM) for two steps (forming step and restrike step) in the conventional example. FIG. 8 includes contour diagrams of an analysis result. FIG. 8(a) illustrates stress

distribution of the formed part 17A after the forming step at a forming bottom dead center. FIG. 8(b) illustrates stress distribution of the press-formed part 1A after the restrike step at a forming bottom dead center. As illustrated in FIG. 8, at the central portions of both the formed part 17A and the press-formed part 1A in the longitudinal direction, large compressive stress is generated by contraction flange deformation at flange portions 177A and 7A on the outside, and large tensile stress is generated by expansion flange deformation at flange portions 177A and 7A on the inside. Furthermore, large tensile stress is generated on the outside of the curve of each top portions 173A and 3A. Large compressive stress is generated on the inside of the curve of each top portions 173A and 3A. Furthermore, the compressive stress and the tensile stress described above are reduced in the vicinities of the ends of both the formed part 17A and the press-formed part 1A in the longitudinal direction.

[0028] Therefore, when these pieces of stress are released by mold release, in the conventional example, twist is generated at an end in the longitudinal direction by these pieces of stress as driving force.

<Comparative Example>

[0029] In the comparative example, in order to eliminate the twist generated in the conventional example, forming is performed by using a forming mold (forming punch 13B) having a one-step estimated angle in the vicinity of an end (10 mm inside from outermost end) in the longitudinal direction from the central portion in the longitudinal direction toward the end in the longitudinal direction in the forming step (see FIG. 9(a)). Forming is then performed by using a restrike mold (restrike punch 19B) having a target shape in the restrike step (see FIG. 9(b)). Here, the one-step estimated angle is given to an end of the forming mold in the longitudinal direction so that twist caused by springback at the time when press-forming is performed in one step to form a press-formed part has a predetermined threshold or less. Furthermore, the predetermined threshold is an upper limit value of a twist angle that can be allowed as a press-formed part. The one-step estimated angle in the example is 6.0 degrees in a direction opposite to the twist caused by springback with respect to the mold having a target shape.

[0030] In the comparative example, since springback is expected in the forming step and a one-step estimated angle is given, twist caused by springback is hardly generated after the forming step. When forming is performed by using the restrike mold 19B having a target shape in the restrike step, a shape close to the target shape is obtained.

[0031] Press-forming analysis is performed by a finite element method (FEM) for the forming step and the restrike step in the comparative example. FIG. 10 includes contour diagrams of an analysis result. FIG. 10(a) illustrates stress distribution of a formed part 17B after the forming step at a forming bottom dead center. FIG. 10(b) illustrates stress distribution of a press-formed part 1B after the restrike step at a forming bottom dead center. As illustrated in FIG. 10(a), in the comparative example, at the forming bottom dead center, at the central portion of the formed part 17B in the longitudinal direction, large compressive stress is generated by contraction flange deformation at a flange portion 177B on the outside, and large tensile stress is generated by expansion flange deformation at a flange portion 177B on the inside. Furthermore, large tensile stress is generated on the outside of the curve of a top portion 173B. Large compressive stress is generated on the inside of the curve of a top portion 173B.

[0032] Although springback is generated after mold release in the forming step, the one-step estimated angle causes springback in a direction opposite to the springback in the conventional example. The target shape is substantially obtained after the springback. Therefore, as illustrated in FIG. 10(b), generated stress is reduced at the forming bottom dead center in the restrike step than in the conventional example. When mold release is performed after the forming bottom dead center in the restrike step, springback is hardly generated, and the target shape is obtained.

[0033] At the forming bottom dead center in the restrike step, however, some compressive stress remains on a flange portion 7B on the outside and a top portion 3B on the inside of the curve, and tensile stress remains on a flange portion 7B on the inside and a top portion 3B on the outside of the curve. Stress is not sufficiently reduced. Therefore, when blanks 9 having different material strengths are press-formed or blanks 9 having variations in material, plate thickness, and the like are press-formed by using the same mold, twist may be generated by springback after the restrike step. That is, as illustrated in the comparative example, in a method in which a one-step estimated angle is given only in the forming step, distributions of remaining stress of the press-formed part 1B differ depending on the difference in material strength and variations in material, plate thickness, and the like. As a result, in some cases, springback cannot sufficiently reduced even by using the same mold.

[0034] Therefore, in the present invention, the forming step and the restrike step are performed as follows.

<Forming Step>

[0035] In the forming step, press forming is performed by using a forming mold 13C (see FIG. 1(a)) having a first estimated angle. The first estimated angle leaves twist (reverse twist) caused by springback in a direction opposite to twist (forward twist) caused by springback in a case where press forming is performed in one step without giving an estimated angle to a mold. As illustrated in the comparative example, in the example, the one-step estimated angle of 6.0 degrees

most reduces twist after springback. A first estimated angle of more than 6.0 degrees is given in order to leave the reverse twist. Specifically, in the forming step in FIG. 1(a), a first estimated angle of 8.0 degrees in the S-S cross section of the mold in the longitudinal direction is given with respect to the R-R cross section of the central portion of the mold in the longitudinal direction in FIG. 6.

<Restrike Step>

[0036] In the restrike step, a formed part 17C formed in the forming step is press-formed by using a restrike mold 19C having a second estimated angle that reduces the reverse twist. Reverse twist caused by springback remains after mold release in the forming step. In order to reduce the reverse twist, as illustrated in FIG. 1(b), forming is performed by the restrike mold 19C, and a target shape is obtained. The second estimated angle (in example, angle of -6.0 degrees of S-S cross section in vicinity of end of mold in longitudinal direction with respect to R-R cross section of central portion of mold in longitudinal direction in FIG. 6) in the same direction as springback is given to the restrike mold 19C in order to reduce the reverse twist. Note that the absolute value of the second estimated angle in the restrike step is preferably smaller than the absolute value of the first estimated angle.

[0037] FIG. 2 illustrates stress distribution at the forming bottom dead center obtained by performing FEM analysis on the forming step and the restrike step. As illustrated in FIG. 2(a), in the forming step, at the central portion of the formed part 17C in the longitudinal direction, large compressive stress is generated by contraction flange deformation at a flange portion 177C on the outside, and large tensile stress is generated by expansion flange deformation at a flange portion 177C on the inside. Furthermore, large tensile stress is generated on the outside of the curve of a top portion 173C. Large compressive stress is generated on the inside of the curve of a top portion 173C.

[0038] As illustrated in FIG. 2(b), at the central portion of a press-formed part 1C in the restrike step in the longitudinal direction, all of compressive stress of a flange portions 7C on the outside, tensile stress of a top portion 3C on the outside of the curve, tensile stress of a flange portions 7C on the inside, and compressive stress of the top portion 3C on the inside of the curve are significantly reduced.

[0039] When FIG. 2(b) of the present invention is compared with FIG. 10(b) of the comparative example, compressive stress of the flange portions 7C on the outside and tensile stress of the flange portions 7C on the inside in a case of the present invention in FIG. 2(b) are smaller than those in the comparative example. Moreover, tensile stress of the top portion 3C on the outside of the curve and compressive stress of the top portion 3C on the inside of the curve in a case of the present invention in FIG. 2(b) are smaller than those in the comparative example. That is, stress of the entire press-formed part in stress distribution of the press-formed part 1C after restrike step in FIG. 2(b) of the present invention is smaller than that in stress distribution of the press-formed part 1B after the restrike step in FIG. 10(b) of the comparative example. Twist caused by springback can be sufficiently reduced. Furthermore, at the same time, even when the blanks 9 having different material strengths and the blanks 9 having variations in material, plate thickness, and the like are press-formed by using the same mold, stress generated in the press-formed part 1C can be sufficiently reduced. As a result, springback of the press-formed part 1C can be reduced.

[0040] Note that, although a hat-shaped cross-sectional part has been described above, the present invention is not limited thereto. That is, the present invention can be applied to a U-shaped cross-sectional part, a Z-shaped cross-sectional part, and an L-shaped cross-sectional part. The U-shaped cross-sectional part is curved in top view, and has a top portion and side wall portions on both sides thereof. The Z-shaped cross-sectional part includes a side wall portion provided on one side of a top portion and a flange portion. The L-shaped cross-sectional part includes a top portion and a side wall portion provided only on one side thereof. Furthermore, the present invention can also be applied to a partially curved press-formed part.

[Example]

[0041] In order to confirm the effect of the present invention, a difference between a twist angle which is springback and a twist angle caused by a difference in material strength was studied by using, as blanks 9, a 1470 MPa-class steel sheet and a 980 MPa-class steel sheet both having a plate thickness of 1.0 mm. As illustrated in FIG. 11, the press-formed part 1 has a hat-shaped cross section with the top portion 3, the side wall portions 5, and the flange portions 7. The side wall portions 5 are continuous with the top portion 3. The flange portions 7 are continuous with the side wall portions 5. The cross-sectional dimension is as illustrated in FIG. 12. Note that, as described above, with reference to the cross section of a top portion forming portion at a central portion of a mold in the longitudinal direction, when the twist angle caused by springback and the mold estimated angle shifted in a left-handed rotation in the paper surface in which the outside of the curve was defined as left and the inside of the curve was defined as right, a value of plus (+) was given. When the twist angle caused by springback and the mold estimated angle shifted in a right-handed rotation in the paper surface, a value of minus (-) was given.

[0042] First, forming was performed with a mold without a mold estimated angle, and a direction of twist (forward twist)

caused by springback was determined. Moreover, a determined one-step estimated angle capable of reducing twist caused by springback in one step as much as possible was 6.0 degrees. Thereafter, the forming step and the restrike step in each of the conventional example, the comparative example, and the invention example as described above were performed. Table 1 illustrates the results.

Table 1

No.	Press-forming step			Restrike step		Difference in twist angle between 1470 MPa-class material and 980 MPa-class material in restrike step (degree)	Notes
	Material strength (MPa-class)	Mold estimated angle (degree)	Press-formed part twist angle (degree)	Mold estimated angle (degree)	Press-formed part twist angle (degree)		
1-1	1470	0	-3.2	0	-3.4	-1.1	Conventional example
1-2	980	0	-2.1	0	-2.3		
2-1	1470	6.0	1.5	0	0.6	-1.4	Comparative example 1
2-2	980	6.0	3.4	0	2.0		
3-1	1470	7.0	1.5	-2.0	0.3	-0.3	Invention example 1
3-2	980	7.0	3.4	-2.0	0.6		
4-1	1470	8.0	3.5	0	2.2	-1.2	Comparative example 2
4-2	980	8.0	5.4	0	3.4		
5-1	1470	8.0	3.5	-6.0	0.1	-0.1	Invention example 2
5-2	980	8.0	5.4	-6.0	0.2		

[0043] In No. 1-1 (1470 MPa-class material) and No. 1-2 (980 MPa-class material), which were conventional examples, a mold estimated angle was set to 0 degrees and a mold having a target shape was used as it was in both the forming step and the restrike step. Twist angles of press-formed parts 1A after the restrike were -3.4 degrees and -2.3 degrees. Twist was greatly generated by springback. Furthermore, the difference between twist angles caused by material strength after the restrike step was as large as -1.1 degrees.

[0044] In No. 2-1 (1470 MPa-class material) and No. 2-2 (980 MPa-class material), which were comparative examples, a one-step estimated angle in the forming step was set to 6.0 degrees, and a mold estimated angle in the restrike step was set to 0 degrees. In No. 2-1 (1470 MPa-class material), the twist angles of the press-formed parts 1A after the restrike were 0.6 degrees, and twist was successfully reduced. In contrast, in No. 2-2 (980 MPa-class material), the twist angle was 2.0 degrees, and twist was greatly generated by springback. As a result, the difference between twist angles caused by material strength after the restrike step was -1.4 degrees, and was larger than the difference between that in No. 1-1 and that in No. 1-2 in the conventional example.

[0045] In contrast, in No. 3-1 (1470 MPa-class material) and No. 3-2 (980 MPa-class material), which were invention examples, the first estimated angle in the forming step was set to 7.0 degrees, and the second estimated angle in the restrike step was set to -2.0 degrees. In No. 3-1 (1470 MPa-class material), the twist angles of the press-formed part 1C after the restrike were 0.3 degrees. In No. 3-2 (980 MPa-class material), the twist angles were 0.6 degrees, and twist caused by springback was successfully reduced. As a result, the difference between twist angles caused by material strength after the restrike step was -0.3 degrees. Although the material strength of the 1470 MPa-class material was greatly different from that of the 980 MPa-class material, only a slight difference occurred between the twist angles caused by a difference in material strength in a case where the same mold was used. Therefore, it has been found that springback can be sufficiently reduced even when press forming is performed on different materials by using the same mold.

[0046] In No. 4-1 (1470 MPa-class material) and No. 4-2 (980 MPa-class material), which were comparative examples, the first estimated angle in the forming step was increased to 8.0 degrees, and the mold estimated angle in the restrike step was set to 0 degrees. In No. 4-1 (1470 MPa-class material), the twist angles of the press-formed part 1B after the restrike were 2.2 degrees. In No. 4-2 (980 MPa-class material), the twist angles were 3.4 degrees. Furthermore, the difference

between twist angles caused by material strength after the restrike step was as large as - 1.2 degrees.

[0047] In No. 5-1 (1470 MPa-class material) and No. 5-2 (980 MPa-class material), which were invention examples, the first estimated angle in the forming step was set to 8.0 degrees, and the second estimated angle in the restrike step was set to -6.0 degrees. In No. 5-1 (1470 MPa-class material), the twist angles of the press-formed part 1C after the restrike were 0.1 degrees. In No. 5-2 (980 MPa-class material), the twist angles were 0.2 degrees, and twists caused by springback of the 1470 MPa-class material and the 980 MPa-class material were successfully and sufficiently reduced. Furthermore, the difference between twist angles caused by material strength after the restrike step was -0.1 degrees. Although the material strength of the 1470 MPa-class material was greatly different from that of the 980 MPa-class material, only a slight difference occurred between the difference in material strength even when the same mold was used. Therefore, according to the present invention, it has been found that springback can be sufficiently reduced even when press forming was performed on different materials by using the same mold.

Industrial Applicability

[0048] The present invention can provide a method of manufacturing a press-formed part, capable of reducing a shape error caused by springback after mold release. The press-formed part is curved in top view, and includes at least a top portion and side wall portions continuous from the top portion.

Reference Signs List

[0049]

1 PRESS-FORMED PART
 3 TOP PORTION
 5 SIDE WALL PORTION
 7 FLANGE PORTION
 9 BLANK
 11 PAD
 13 FORMING PUNCH
 15 FORMING DIE
 17 FORMED PART
 19 RESTRIKE PUNCH
 21 RESTRIKE DIE
 1A PRESS-FORMED PART (CONVENTIONAL EXAMPLE)
 3A TOP PORTION
 7A FLANGE PORTION
 1B PRESS-FORMED PART (COMPARATIVE EXAMPLE)
 3B TOP PORTION
 7B FLANGE PORTION
 1C PRESS-FORMED PART (INVENTION EXAMPLE)
 3C TOP PORTION
 7C FLANGE PORTION
 13A FORMING PUNCH (CONVENTIONAL EXAMPLE)
 13B FORMING PUNCH (COMPARATIVE EXAMPLE)
 13C FORMING PUNCH (INVENTION EXAMPLE)
 17A FORMED PART (CONVENTIONAL EXAMPLE)
 173A TOP PORTION
 177A FLANGE PORTION
 17B FORMED PART (COMPARATIVE EXAMPLE)
 173B TOP PORTION
 177B FLANGE PORTION
 17C FORMED PART (INVENTION EXAMPLE)
 173C TOP PORTION
 177C FLANGE PORTION
 19A RESTRIKE PUNCH (CONVENTIONAL EXAMPLE)
 19B RESTRIKE PUNCH (COMPARATIVE EXAMPLE)
 19C RESTRIKE PUNCH (INVENTION EXAMPLE)

Claims

1. A method of manufacturing a press-formed part curved in top view and including at least a top portion and a side wall portion continuous from the top portion, the method comprising:

a forming step of performing press forming by using a forming mold having a first estimated angle, which leaves twist (reverse twist) caused by springback in a direction opposite to twist (forward twist) generated by springback in a case where press forming is performed in one step without giving an estimated angle to a mold; and
a restrike step of press-forming a formed part formed in the forming step by using a restrike mold having a second estimated angle.

2. The method of manufacturing a press-formed part according to claim 1, wherein the first estimated angle is larger than a one-step estimated angle at which twist caused by springback in a case where press forming is performed in one step to form the press-formed part has a predetermined threshold or less.

3. The method of manufacturing a press-formed part according to claim 2, wherein a direction of twist caused by springback and the one-step estimated angle are determined by preliminarily performing press-forming analysis and springback analysis of the press-formed part.

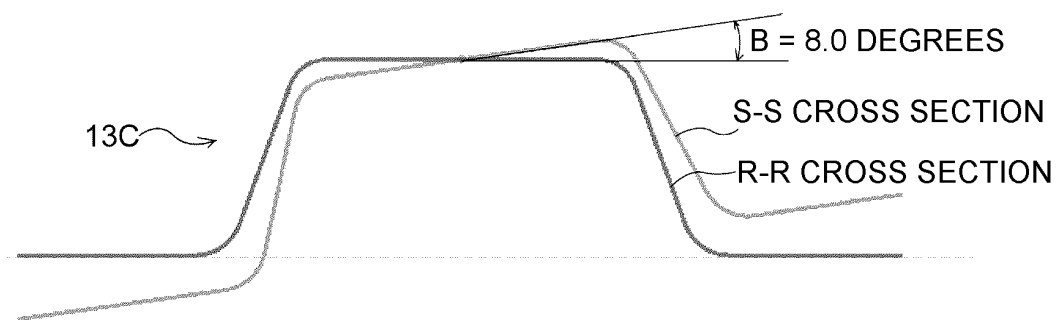
4. The method of manufacturing a press-formed part according to claim 2, wherein a direction of twist caused by springback and the one-step estimated angle are determined by preliminarily performing actual press forming of the press-formed part.

5. The method of manufacturing a press-formed part according to any one of claims 1 to 4, wherein the first estimated angle or the second estimated angle is defined as an inclination angle of a top portion forming surface portion of a cross section in a width direction at an end of the forming mold or the restrike mold in the longitudinal direction with reference to a top portion forming surface portion of a cross section in a width direction at a center of the forming mold or the restrike mold in the longitudinal direction.

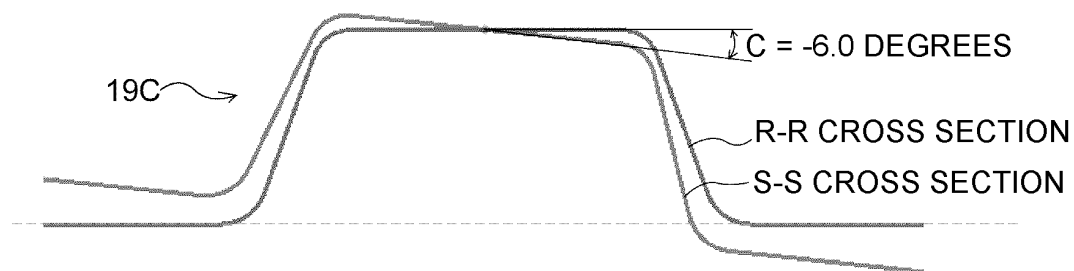
6. The method of manufacturing a press-formed part according to any one of claims 1 to 4, wherein an absolute value of the second estimated angle in the restrike step is smaller than an absolute value of the first estimated angle.

7. The method of manufacturing a press-formed part according to claim 5, wherein an absolute value of the second estimated angle in the restrike step is smaller than an absolute value of the first estimated angle.

FIG.1



(a) FORMING STEP



(b) RESTRIKE STEP

FIG.2

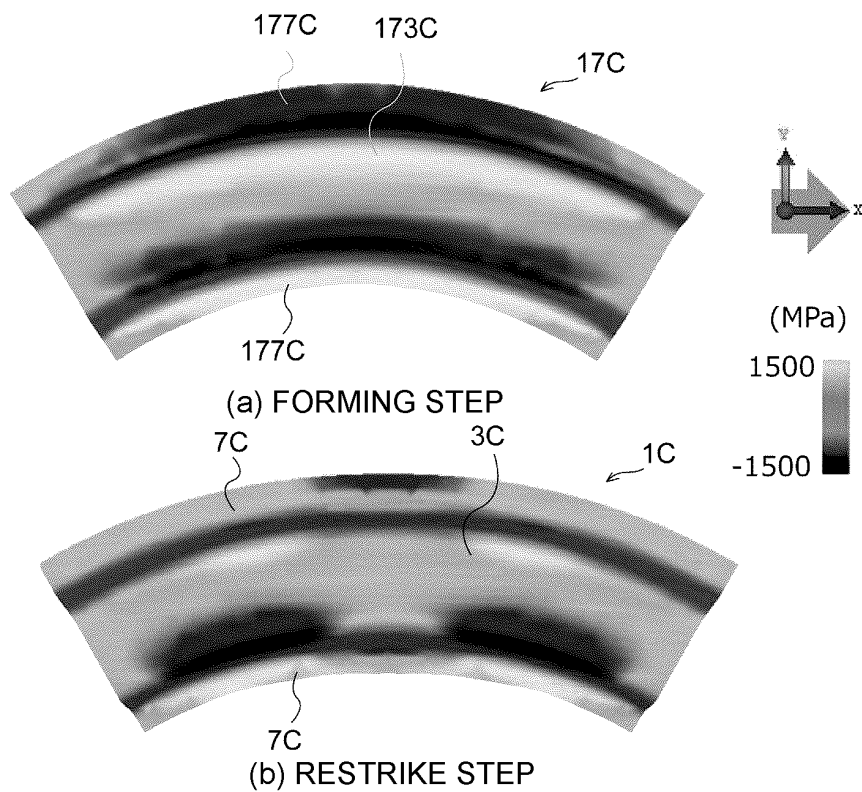
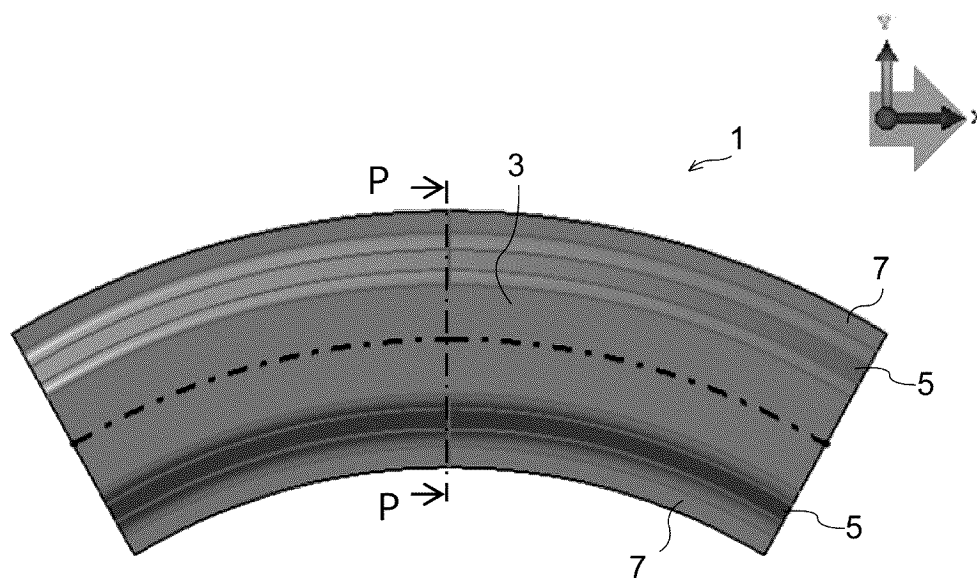
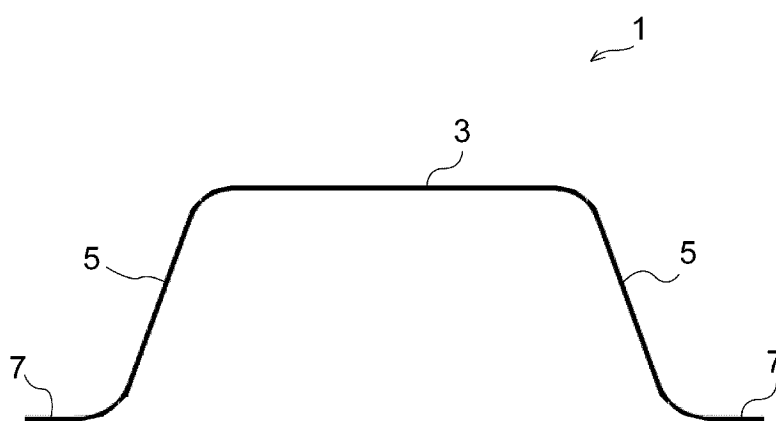


FIG.3



(a)



(b)

FIG.4

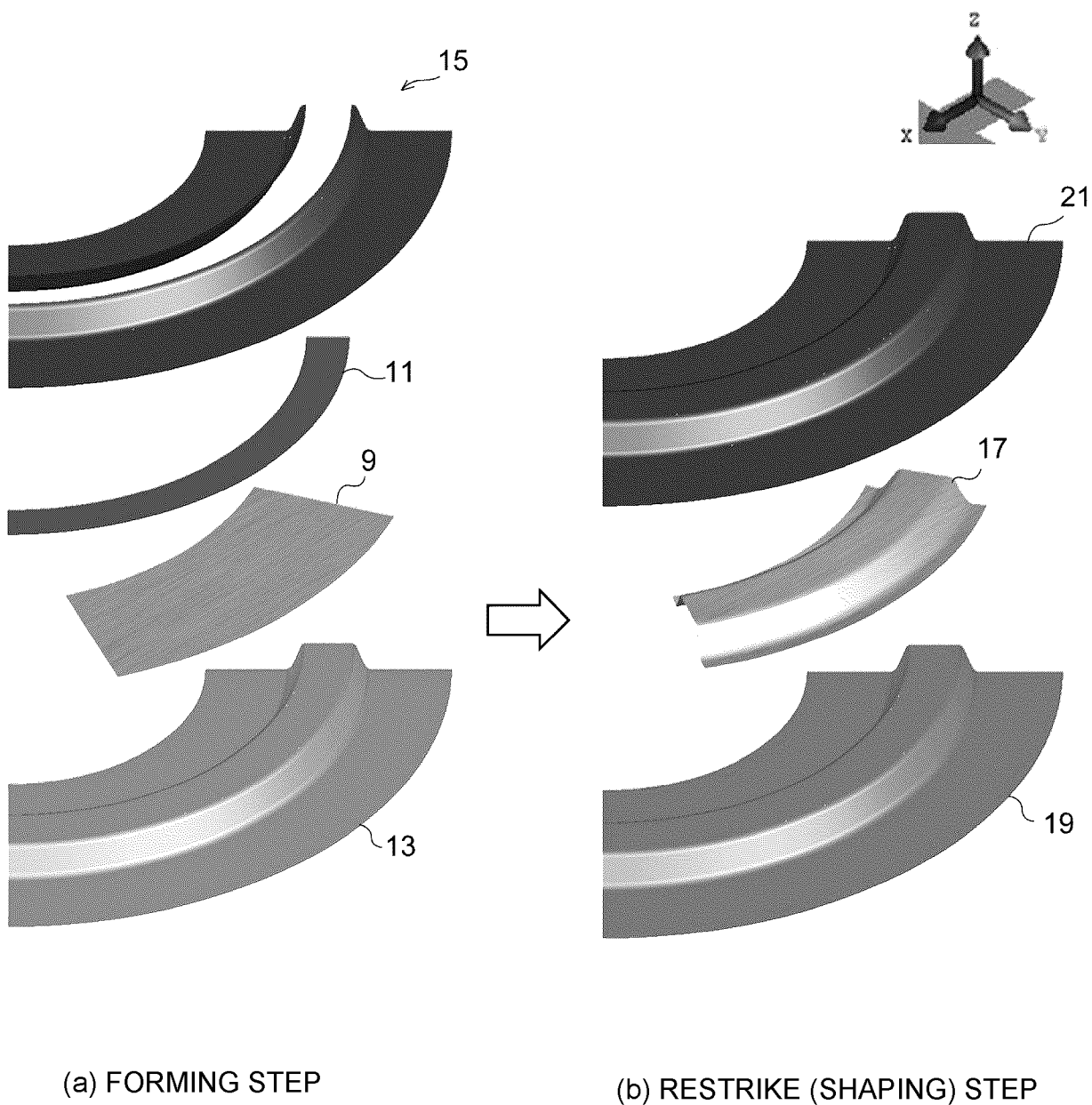


FIG.5

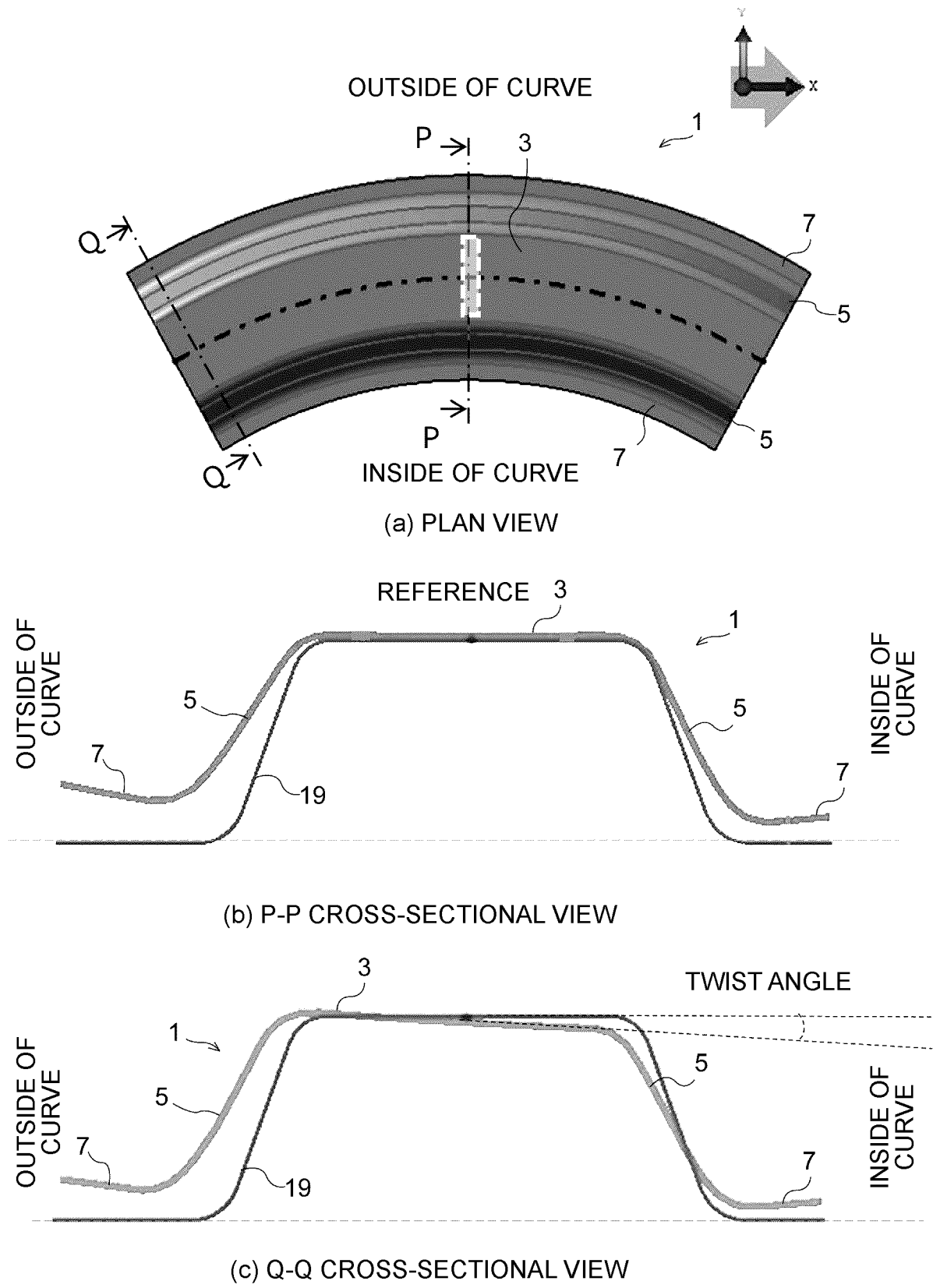


FIG.6

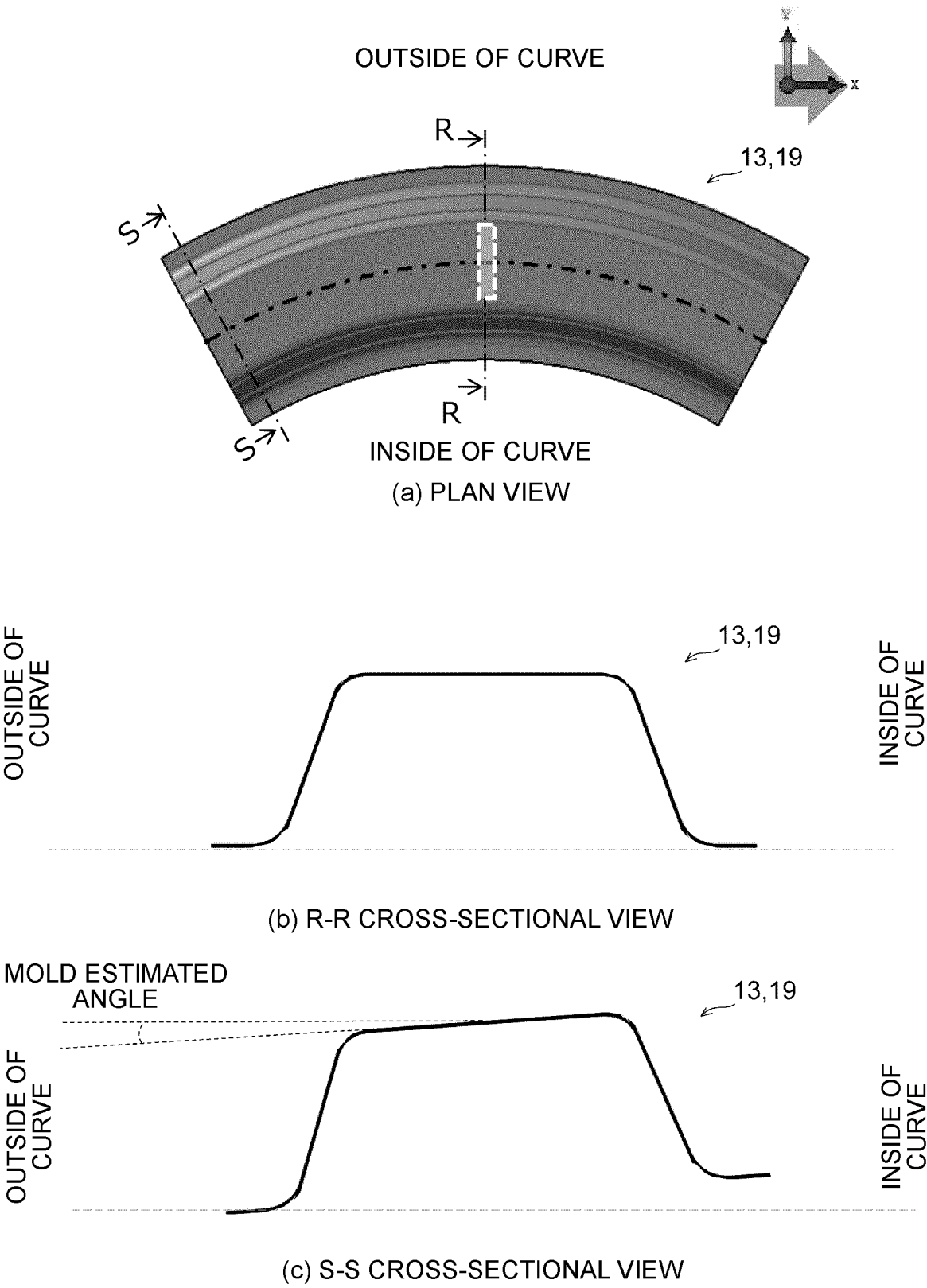
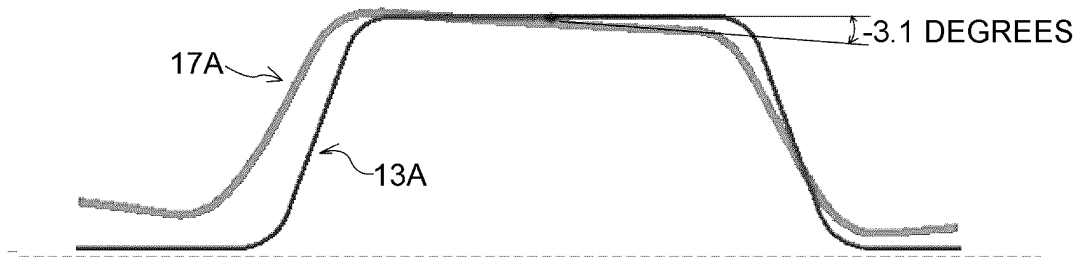
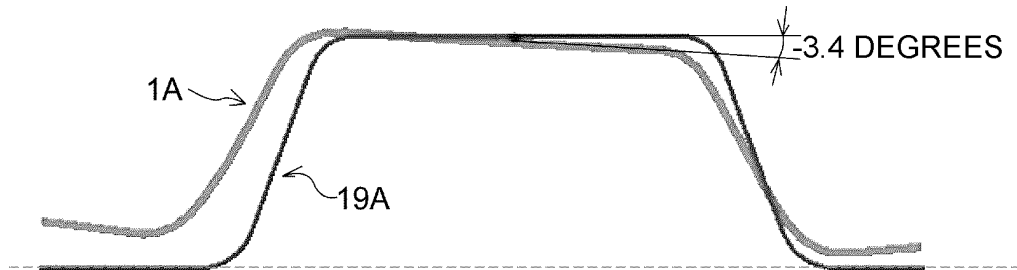


FIG.7

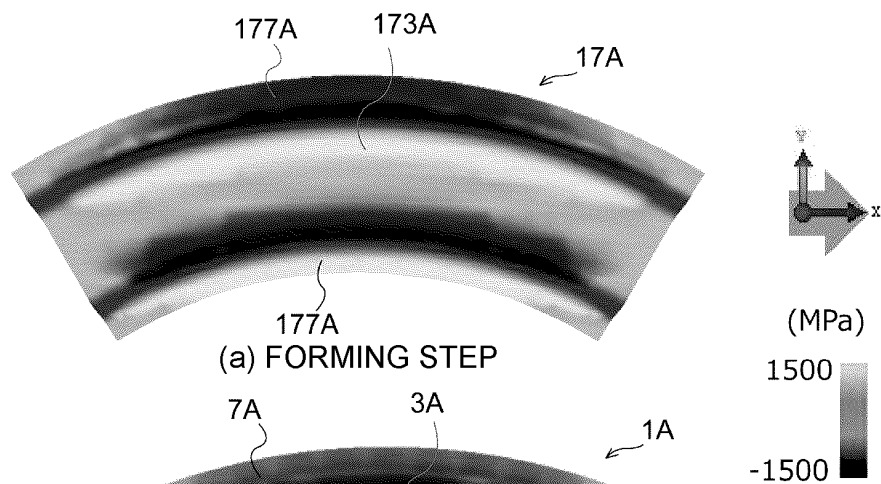


(a) PRESS-FORMING STEP



(b) RESTRIKE STEP

FIG.8



(a) FORMING STEP

(b) RESTRIKE (SHAPING) STEP

FIG.9

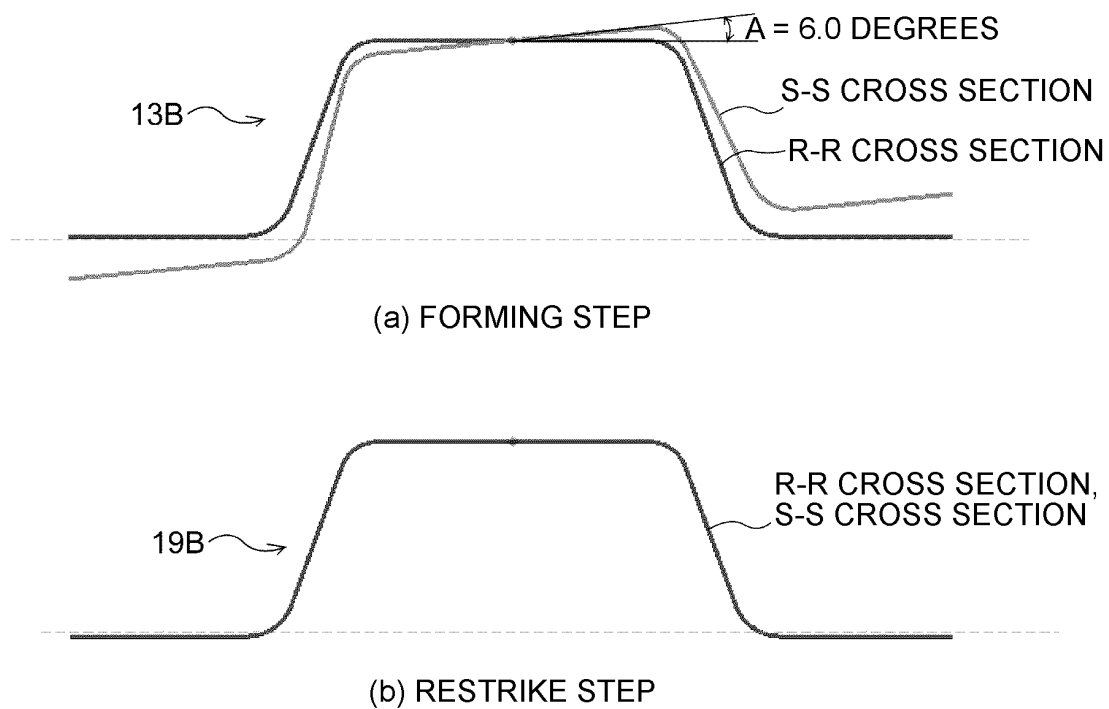


FIG.10

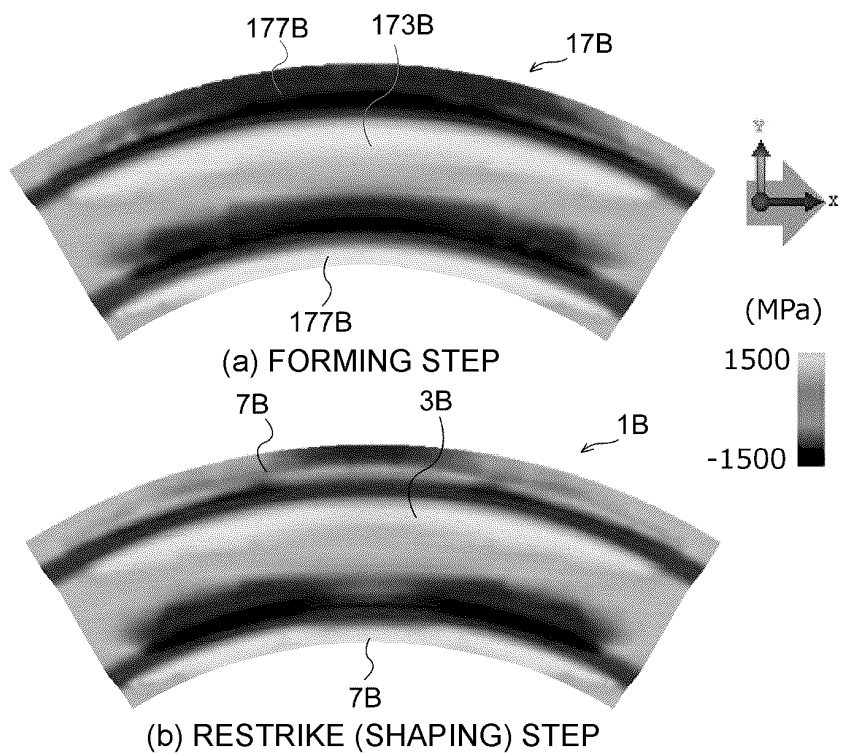


FIG.11

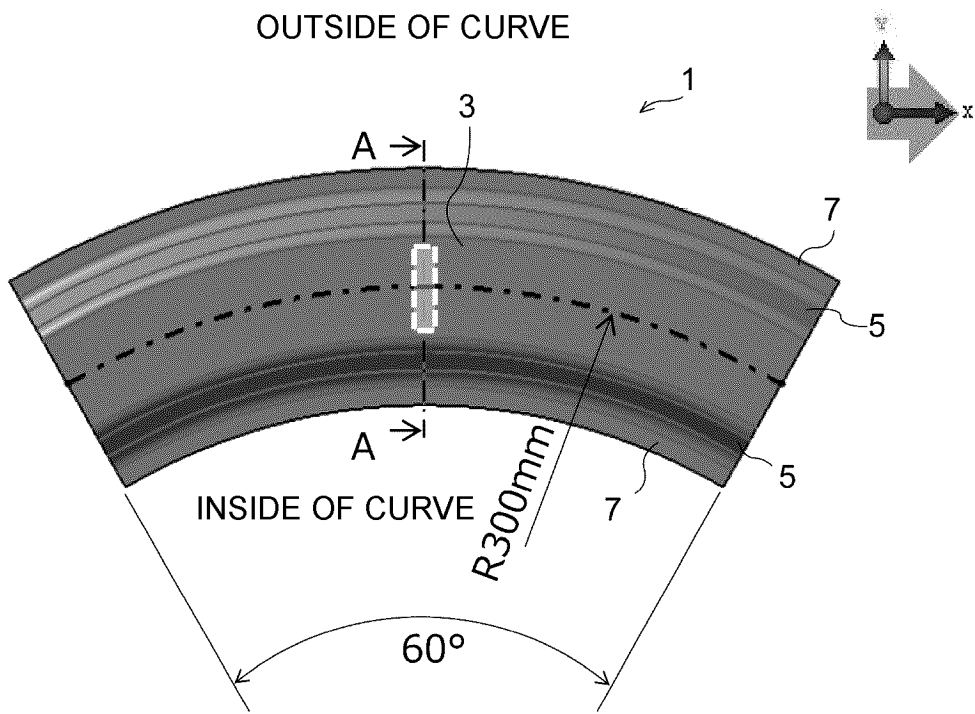
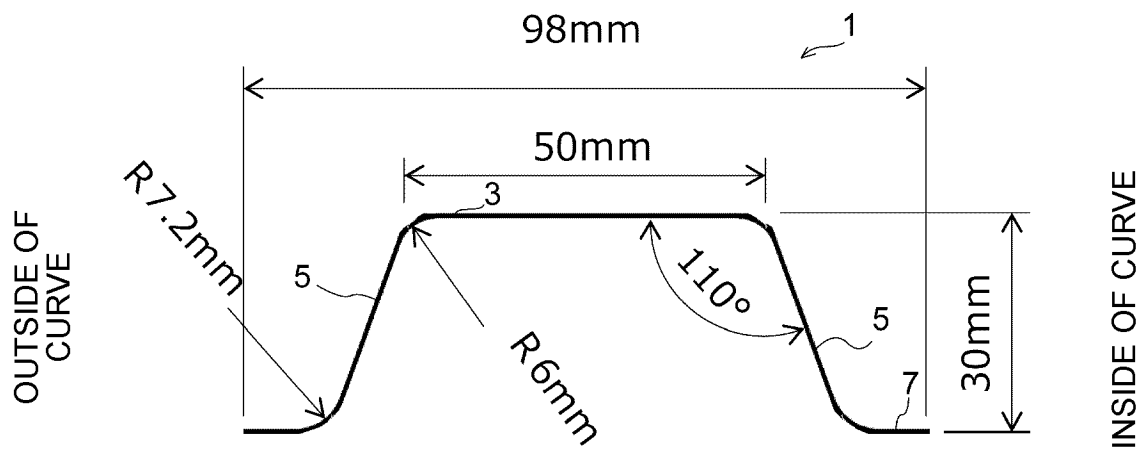


FIG.12



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/020982

A. CLASSIFICATION OF SUBJECT MATTER

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

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B21D22/26; B21D24/00

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2020/235152 A1 (JFE STEEL CORP.) 26 November 2020 (2020-11-26) entire text, all drawings	1-7
A	JP 2016-150354 A (JFE STEEL CORP.) 22 August 2016 (2016-08-22) entire text, all drawings	1-7
A	JP 2022-87659 A (KOBE STEEL, LTD.) 13 June 2022 (2022-06-13) entire text, all drawings	1-7

☐ 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
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

17 August 2023

Date of mailing of the international search report

29 August 2023

Name and mailing address of the ISA/JP

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Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2023/020982

5	Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
10	WO 2020/235152 A1	26 November 2020	US 2022/0212243 A1 entire text, all drawings EP 3974078 A1 KR 10-2021-0152555 A CN 113874134 A	
15	JP 2016-150354 A	22 August 2016	US 2018/0065164 A1 entire text, all drawings WO 2016/132905 A1 EP 3260215 A1 KR 10-2017-0103952 A CN 107249773 A	
20	JP 2022-87659 A	13 June 2022	WO 2022/118622 A1 entire text, all drawings	
25				
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Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2007130671 A [0005]