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(54) DESIGNING METHOD FOR PRESS-MOLDED ARTICLE, PRESS-MOLDING DIE, PRESS-MOLDED ARTICLE, AND PRODUCTION METHOD FOR PRESS-MOLDED ARTICLE

(57) An object is to suppress falling or rising of an end of a press-formed product and twisting of the press-formed product due to springback so as to suppress a shape defect of the press-formed product due to the springback, and, in designing a shape of a press-formed product produced by press-forming a sheet material, a curvature radius (R1) of a concave curved portion and a curvature radius (R2) of a convex curved portion of a concave and convex curved shape of an additional shape arranged on the press-formed product where the concave curved portion and the convex curved portion are continuous are set to be the same.

FIG. 5(a)

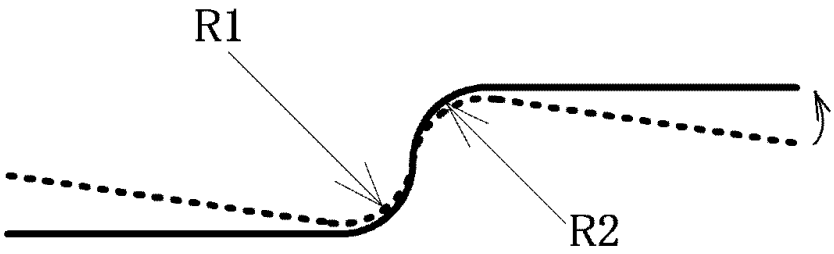

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FIG. 5(b)

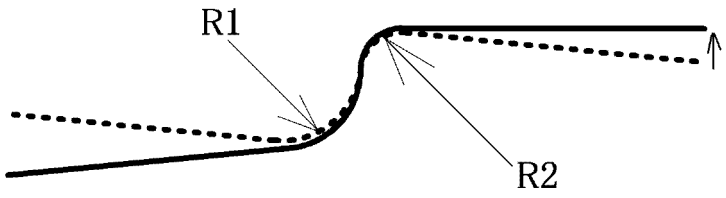
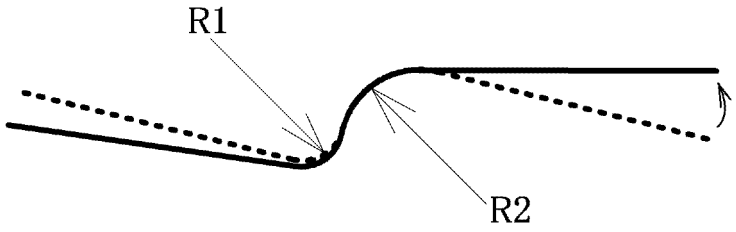


FIG. 5(c)



Description

Technical Field

[0001] The present invention relates to a method for designing a press-formed product, a press-forming die, a press-formed product, and a method for producing the press-formed product for suppressing shape defects such as falling and rising of an end of the press-formed product or overall twisting due to springback at the time when the press-formed product produced by press-forming a sheet material is removed from the press-forming die.

Background Art

[0002] In recent years, high-strength steel sheets have been more widely used in order to reduce the weight of automobile bodies for improved fuel efficiency. With the use of the high strength steel sheet, the strength, rigidity and energy absorbed in a collision of an automobile body can be increased without increasing the sheet thickness.

[0003] However, in press-forming which is widely used for processing of body parts of automobiles, failure in shape freezing called springback becomes a problem. The springback occurs when a press-formed product produced by press-forming a steel sheet as a sheet material is removed from a press-forming die, and becomes larger when the material strength of the steel sheet increases. The shape defect due to the springback not only impairs the external appearance quality, but also causes failure in welding at the time of assembly of an automobile body. Therefore, the expansion of the use of the high strength steel sheet requires springback measures.

[0004] The springback is caused by elastic recovery generated when a bending moment due to a non-uniform residual stress is released at the removal of a press-formed product from a die. Therefore, there has been proposed a method for mitigating the non-uniform residual stress and a method for reducing the springback by improving the rigidity of the press-formed product as a countermeasure for springback. Moreover, an additional shape may be arranged on an intermediate formed product or a final formed product in order to reduce bending moment, improve the rigidity of the press-formed product, control the flow rate of a material, and the like. There have been proposed some methods in which the additional shape is effectively arranged to reduce cracking or wrinkles of the press-formed product and improve the dimension accuracy thereof.

[0005] For example, Patent Literature 1 proposes a method that, as an additional shape, an emboss is arranged on a stretch flange portion and an excess bead is formed on a shrink flange portion to form an intermediate formed product, and, in the subsequent forming of a final formed product, the emboss is crushed to give the stretch flange portion a compression stress and a tensile stress is applied to the shrink flange portion by the excess bead, such that the residual stress distribution of the press-formed product is made uniform.

[0006] Patent Literature 2 proposes a method that a plurality of groove shapes, as an additional shape, having a rectangular or circular cross-section are formed on a metal sheet along a longitudinal direction of a die shoulder, such that a bending/unbending deformation moment applied to the metal sheet when passing through the die shoulder and a residual stress in the metal sheet after passing are reduced to mitigate warpage deformation due to springback after unloading.

[0007] Patent Literature 3 proposes a method for forming a curved flange that is folded from the end of the curved panel to form a shrinking flange, wherein a plurality of convex shapes are formed on the flange along the longitudinal direction as an additional shape to absorb the compressive force generated in the flange in the longitudinal direction and to prevent the panel from being lowered due to springback in the flange.

Citation List

Patent Literature

[0008]

Patent Literature 1: JP-B-5380890
Patent Literature 2: JP-A-H08-281335
Patent Literature 3: JP-A-H07-112219

Summary of Invention

Technical Problem

[0009] Patent Literature 1 proposes a method that, as an additional shape, an emboss is formed on a stretch flange portion and an excess bead is formed on a shrink flange portion to make a residual stress uniform for reduction of the springback. However, in a press-formed product having a low-rigidity shape to which the present invention is mainly directed, the springback is generated even by a low stress, and therefore, even a reduction in stress of a specific portion may be insufficient. In addition, in a state where a new stress is generated as a result of the reduction in stress of a specific portion, springback in another form can occur. Therefore, with a press-formed product having a low-rigidity shape, it is difficult to efficiently take a countermeasure for springback through stress control.

[0010] Patent Literature 2 proposes a method that groove shapes having a rectangular or circular cross-section are arranged on a metal sheet so that a residual stress in the metal sheet is reduced to mitigate warpage deformation after unloading. Patent Literature 3 proposes a method that, in forming a panel with a curved flange to be a shrink flange, convex shapes are formed on the flange to suppress lowering of the panel, but does not particularly specify a curvature radius of the bent portion

of the additional shape. An additional shape protruding or recessed on a planar surface has, on a peripheral portion, a concave and convex curved shape having a substantially S-shaped cross-section where a concave curved portion and a convex curved portion are continuous. Since the springback in the bent portion usually varies with the curvature radius, when the additional shape is provided to the press-formed product, it is necessary to design an appropriate curvature radius of the bent portions of the concave and convex curved shape of the additional shape. However, Patent Literatures 2 and 3 do not describe a method for designing a curvature radius of a bent portion of a concave and convex curved shape in an additional shape.

[0011] The conventional techniques have problems to be solved as listed below.

(1) To set a press-formed product with a low rigidity shape to have an effective measure for springback.
(2) To design an additional shape effective for reducing a shape defect due to springback in a press-formed product with a low rigidity shape.

[0012] In designing the shape of a press-formed product from the past, a curvature radius has been changed to increase the area of a flat surface of a portion where high surface accuracy is required such as a joint portion, by decreasing the curvature radius of a bent portion, or to prevent cracking by increasing the curvature radius of the bent portion. However, as described above, it is known that the larger the curvature radius, the larger the springback amount (springback angle) in the bent portion.

[0013] The inventors of the present application have studied the relevance between the curvature radius of the bent portion and the springback amount, for springback measures with respect to a press-formed product with a low rigidity shape. As a result, the inventors have found that, when the curvature radius of the concave curved portion differs from that of the convex curved portion in a concave and convex curved shape having a substantially S-shaped cross-section where a concave curved portion and a convex curved portion are continuous, the springback amount generated in the concave curved portion differs from that in the convex curved portion, and thus planar portions on both sides of the concave and convex curved shape are not parallel after the springback, causing displacement in a height direction.

[0014] FIGS. 5(a) to 5(c) are explanatory views of a cross-section of planar portions on both sides of a concave and convex curved shape, illustrating a state at a press bottom dead center by a dotted line and a state after springback by a solid line, where FIG. 5(a) illustrates the case where a curvature radius R1 of a concave curved portion is the same as a curvature radius R2 of a convex curved portion, FIG. 5(b) illustrates the case where the curvature radius R1 of the concave curved portion is larger than the curvature radius R2 of the convex curved portion, and FIG. 5(c) illustrates the case where the curvature radius R1 of the concave curved portion is smaller than the curvature radius R2 of the convex curved portion.

[0015] As illustrated in FIG. 5(a), in the case where the curvature radius R1 of the concave curved portion is the same as the curvature radius R2 of the convex curved portion, the springback amounts (springback angles) of the concave curved portion and the convex curved portion are the same as indicated by the arrow. Meanwhile, as illustrated in FIG. 5(b), in the case where the curvature radius R1 of the concave curved portion is larger than the curvature radius R2 of the convex curved portion, the springback amount (springback angle) of the concave curved portion is larger than the springback amount (springback angle) of the convex curved portion as indicated by the arrow. In addition, as illustrated in Fig. 5(c), in the case where the curvature radius R1 of the concave curved portion is smaller than the curvature radius R2 of the convex curved portion, the springback amount (springback angle) of the concave curved portion is larger than the springback amount (springback angle) of the convex curved portion as indicated by the arrow.

[0016] The displacement in the height direction due to a difference in springback amount (springback angle) becomes larger as the distance from the concave and convex curved shape increases. Therefore, this height directional displacement distribution becomes a cause of falling or rising of an end of a press-formed product. Furthermore, when this height directional displacement distribution is tilted relative to the longitudinal direction of the press-formed product, it becomes a cause of twisting of the press-formed product. Furthermore, this tendency is significant in a high strength material or a press-formed product with a low rigidity in which the springback is large.

[0017] The present invention has been made in light of the aforementioned knowledge of the present inventor to solve the problems in prior arts. An object of the present invention is to provide a method for designing a press-formed product that can design a concave and convex curved shape effective for reducing a shape defect after the springback of a press-formed product with a low rigidity shape, a press-forming die and a press-formed product using the design method, and a method for producing the press-formed product.

Solution to Problem

[0018] A method for designing a press-formed product of the present invention is characterized in that:

in order to suppress a shape defect of a press-formed product due to springback at a time when the press-formed product is removed from a die,
in designing a shape of the press-formed product produced by press-forming a sheet material,
an additional shape having a concave and convex curved shape where a concave curved portion and

a convex curved portion are continuous is arranged on the press-formed product, and

a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are set to be the same.

[0019] In addition, a press-forming die of the present invention using the aforementioned design method is,

in order to suppress a shape defect of a press-formed product due to springback at a time when the press-formed product is removed from a die,

a press-forming die for producing a press-formed product provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous from a sheet material,

characterized in that

the press-forming die is provided with a die member including shoulder portions that each form the concave curved portion and the convex curved portion of the convex curved shape of the additional shape arranged on the press-formed product, and

curvature radii of the shoulder portions of the die member are the same.

[0020] Further, a press-formed product of the present invention using the aforementioned design method is,

in order to suppress a shape defect of a press-formed product due to springback at a time when the press-formed product is removed from a die,

a press-formed product produced by press-forming a sheet material and provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous,

in which

a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are the same.

[0021] Further, a method for producing a press-formed product of the present invention is characterized in that:

in order to suppress a shape defect of a press-formed product due to springback at a time when the press-formed product is removed from a die,

in producing a press-formed product provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous by press-forming a sheet material,

a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are set to be the same.

Note that, in this description, "same" may be used when one curvature radius falls within preferably the range of ±10% of the other curvature radius, more preferably within the range of ±5%.

Advantageous Effects of Invention

[0022] By the method for designing a press-formed product of the present invention, the additional shape having the concave and convex curved shape where the concave curved portion and the convex curved portion are continuous is arranged on the press-formed product, and the curvature radius of the concave curved portion and the curvature radius of the convex curved portion of the concave and convex curved shape are set to be the same. Therefore, the planar portions on both sides of the concave and convex curved shape of the press-formed product become parallel to each other after the springback, irrespective of the springback amount, and thus falling or rising of an end of the press-formed product and twisting of the press-formed product can be suppressed, resulting that and a shape defect of the press-formed product due to the springback can be suppressed.

[0023] In addition, the press-forming die of the present invention produces a press-formed product provided with the additional shape having the concave and convex curved shape where the concave curved portion and the convex curved portion are continuous from a sheet material, and is provided with a die member having shoulder portions that form the concave curved portion and the convex curved portion of the concave and convex curved shape, and curvature radii of cross-sections of the shoulder portions are the same. Therefore, the planar portions on both sides of the concave and convex curved shape of the press-formed product whose concave curved portion and convex curved portion are formed by the shoulder portions become parallel to each other after the springback irrespective of the springback amount, and falling or rising of an end of the press-formed product and twisting of the press-formed product can be suppressed, resulting that a shape defect of the press-formed product due to the springback can be suppressed.

[0024] Further, with the press-formed product and by the method for producing the press-formed product of the present invention, the additional shape having the concave and convex curved shape where the concave curved portion and the convex curved portion are continuous is arranged, and the curvature radius of the concave curved portion and the curvature radius of the convex curved portion of the concave and convex curved shape are the same. Therefore, the planar portions on both sides of the concave and convex curved shape of the press-formed product become parallel to each other after the springback, irrespective of the springback amount, and falling or rising of an end of the press-formed product and twisting of the press-formed product can be suppressed and a shape defect of the press-formed product due to the springback can be suppressed.

[0025] Note that, by the method for designing a press-formed product, the press-forming die, the press-formed product, and the method for producing the press-formed product of the present invention, the additional shape having the concave and convex curved shape where the

concave curved portion and the convex curved portion are continuous may be added to improve the rigidity of the press-formed product. Thus, the rigidity of the press-formed product can be improved by the additional shape to reduce the springback amount, and the shape defect of the press-formed product due to the springback can be suppressed.

Brief Description of Drawings

[0026]

FIG. 1 is a perspective view illustrating a press-formed product of an embodiment of the present invention designed by a method for designing a press-formed product of an embodiment of the present invention.

FIGS. 2(a) and 2(b) are cross-sectional views of a rigidity shape of the press-formed product of the aforementioned embodiment along line A-A and line B-B of FIG. 1.

FIG. 3 is a plan view illustrating a height directional displacement distribution by a springback analysis of a press-formed product of a comparative example by displacement contour.

FIG. 4 is a plan view illustrating a height directional displacement distribution by a springback analysis of the press-formed product of the aforementioned embodiment by displacement contour.

FIGS. 5(a) to 5(c) are explanatory views of a cross-section of planar portions on both sides of a concave and convex curved shape, illustrating a state at press bottom dead center by a dotted line and a state after springback by a solid line, where FIG. 5(a) illustrates the case where the curvature radius R1 of a concave curved portion is the same as the curvature radius R2 of a convex curved portion, FIG. 5(b) illustrates the case where the curvature radius R1 of the concave curved portion is larger than the curvature radius R2 of the convex curved portion, and FIG. 5(c) illustrates the case where the curvature radius R1 of the concave curved portion is smaller than the curvature radius R2 of the convex curved portion.

Description of Embodiments

[0027] Embodiments of the present invention will be described in detail below on the basis of the drawings. Here, FIG. 1 is a perspective view illustrating a press-formed product of an embodiment of the present invention designed by a method for designing a press-formed product of an embodiment of the present invention. FIGS. 2(a) and 2(b) are cross-sectional views of a rigidity shape of the press-formed product of the aforementioned embodiment along line A-A and line B-B of FIG. 1. FIG. 3 is a plan view illustrating a height directional displacement distribution by a springback analysis of a press-formed product having an original shape, which is a comparative example, by displacement contour. FIG. 4 is a plan view illustrating a height directional displacement distribution by a springback analysis of the press-formed product of the aforementioned embodiment by displacement contour. In the drawings, reference numeral 1 denotes a press-formed product.

[0028] The method for designing a press-formed product according to the aforementioned embodiment is to design the press-formed product 1, which is a front pillar lower inner material as a type of a body part of an automobile, and the press-formed product 1 has a thin trapezoidal shape that is easy to bend and twist, i.e., a shape with low rigidity, when it is without additional shapes 2, 3 illustrated in FIG. 1. Note that a press-formed product to be an automobile body part often has such low rigidity shape. Therefore, the press-formed product 1 is provided, on a planar surface of the thin trapezoidal shape, with two additional shapes 2, 3 having an elliptical shape in a plan view and a planar top surface, for improvement of the rigidity.

[0029] The additional shapes 2, 3 of the aforementioned press-formed product 1 each have, at a peripheral edge portion, a concave and convex curved shape 4 having a substantially S-shaped cross-section where a concave curved portion and a convex curved portion are continuous, as the cross-sectional shapes are illustrated in FIGS. 2(a) and (b). In designing the shape of the press-formed product 1, in the case of the original shape, a radius R1 of the concave curved portion and a radius R2 of the convex curved portion of the concave and convex curved shape 4 are set to mutually different values, i.e., R1 > R2, as illustrated in FIG. 5(b), for example. The press-formed product 1 having the original shape is subjected to a press formation analysis and a springback analysis with a computer using known software. As a result, as indicated by displacement contours based on a reference height point designated by reference symbol O in FIG. 3, it can be seen that falling occurs largely on the left side of the additional shape 3 because a negative Z-directional displacement is large, and that the press-formed product 1 is twisted in the upper left direction from the additional shape 2 because a negative Z-directional displacement is much larger.

[0030] Therefore, by the method for designing a press-formed product of the present embodiment, a radius R1 of a concave curved portion and a radius R2 of a convex curved portion of a concave and convex curved shape 4 having a substantially S-shaped cross-section where the concave curved portion and the convex curved portion are continuous at a peripheral edge portion of each of the additional shapes 2, 3 are set to the same value, i.e., R1 = R2, as illustrated in FIG. 5(a), for example, thereby designing the press-formed product 1 of the aforementioned embodiment.

[0031] As is the case of the original shape, the press-formed product 1 of the present embodiment in which the radius R1 of the concave curved portion and the radius R2 of the convex curved portion have the same value

is subjected to a press formation analysis and a springback analysis with a computer using known software. As a result, as indicated by displacement contours based on a reference height point designated by reference symbol O in FIG. 4, it can be seen that falling is smaller than the original shape on the left side of the additional shape 3 because a negative Z-directional displacement is decreased, and that the press-formed product 1 is less twisted than the original shape in the upper left direction from the additional shape 2. Thus, by the design method of the present embodiment and with the press-formed product 1 of the present embodiment, falling or rising of an end of the press-formed product and twisting of the press-formed product can be suppressed, and a shape defect of the press-formed product due to the springback can be suppressed.

[0032] A sheet material forming the press-formed product 1 of the present embodiment can be, for example, a 980 MPa-class high-tensile steel sheet having a thickness t: 0.9 mm, a yield point YP: 620 MPa, a tensile strength TS: 1030 MPa, and an elongation El: 15%. The method for producing a press-formed product of an embodiment of the present invention uses a press-forming die of an embodiment of the present invention to press-form the steel sheet so as to form the press-formed product 1 of the aforementioned embodiment.

[0033] Therefore, the press-forming die of the aforementioned embodiment includes, as a die member, a normal punch, die, and blank holder. The die has a thin trapezoidal shape above outward flanges positioned, in FIG. 1, at upper and lower ends of the press-formed product 1 and a concave portion having a shape that corresponds to the additional shapes 2, 3 protruding from a planar surface of the trapezoidal shape. The blank holder holds a steel sheet between the blank holder and a plane surface extending outward from the concave portion of the die. The punch pushes the steel sheet, which is held between the die and the blank holder, into the concave portion of the die to form the steel sheet into a thin trapezoidal shape, and pushes a convex portion of the leading end of the punch into the concave portion of the die so as to form the additional shapes 2, 3 by extrusion on the planar surface of the trapezoidal shape.

[0034] Here, radii of cross-sectional shapes of shoulder portions of concave portions of the die of the press-forming die of the aforementioned embodiment that form the concave curved portions of the additional shapes 2, 3 are made to be substantially equal to the radius R1 of the concave curved portion, and radii of cross-sectional shapes of shoulder portions of convex portions of a leading end of the punch that form the convex curved portions of the additional shapes 2, 3 are made to be substantially equal to the radius R2 of the convex curved portion, such that the radii of the cross-sectional shapes of the shoulder portions are equal to each other.

[0035] The press-formed product 1 produced using the press-forming die of the aforementioned embodiment by the method for producing the press-formed product of the aforementioned embodiment becomes the press-formed product of the aforementioned embodiment in which the radius R1 of the concave curved portion and the radius R2 of the convex curved portion of the additional shapes 2, 3 are the same, and with the press-formed product and the method for producing the press-formed product of the present embodiment, falling or rising of an end of the press-formed product and twisting of the press-formed product due to the springback of the press-formed product can be suppressed, resulting that a shape defect of the press-formed product due to the springback can be suppressed.

[0036] The embodiments have been described heretofore. However, the method for designing a press-formed product, the press-forming die, the press-formed product, and the method for producing the press-formed product of the present invention are not limited to the aforementioned embodiments, but can be appropriately changed within the scope of the claims. For example, the shape of the press-formed product or the additional shapes may be those other than those illustrated in FIG. 1, and the concave and convex curved shape having the substantially S-shaped cross-section where the concave curved portion and the convex curved portion are continuous is not limited to the additional shape for improvement of the rigidity, but may be an additional shape for reduction of a bending moment, control of the flow rate of a material, and the like.

Industrial Applicability

[0037] Thus, by the method for designing a press-formed product, the press-forming die, the press-formed product, and the method for producing the press-formed product of the present invention, falling and rising of an end of the press-formed product and twisting of the press-formed product due to the springback can be suppressed, and a shape defect of the press-formed product due to the springback can be suppressed.

Reference Signs List

[0038]

1	press-formed product
2,3	additional shape
4	concave and convex curved shape
R1	radius of concave curved portion
R2	radius of convex curved portion

Claims

1. A method for designing a press-formed product, **characterized in that**
in designing a shape of a press-formed product produced by press-forming a sheet material,
an additional shape having a concave and convex

curved shape where a concave curved portion and a convex curved portion are continuous is arranged on the press-formed product, and
a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are set to be the same.

2. The method for designing a press-formed product according to claim 1, wherein
the additional shape is added to improve rigidity of the press-formed product.

3. A press-forming die for producing a press-formed product provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous from a sheet material,
characterized in that
the press-forming die is provided with a die member including shoulder portions that each form the concave curved portion and the convex curved portion of the convex curved shape of the additional shape arranged on the press-formed product, and
curvature radii of the shoulder portions of the die member are the same.

4. The press-forming die according to claim 3, wherein the additional shape is added to improve rigidity of the press-formed product.

5. A press-formed product produced by press-forming a sheet material and provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous,
characterized in that
a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are the same.

6. The press-formed product according to claim 5, wherein
the additional shape is added to improve rigidity of the press-formed product.

7. A method for producing a press-formed product,
characterized in that
in producing a press-formed product provided with an additional shape having a concave and convex curved shape where a concave curved portion and a convex curved portion are continuous by press-forming a sheet material,
a curvature radius of the concave curved portion and a curvature radius of the convex curved portion of the concave and convex curved shape are set to be the same.

8. The method for producing a press-formed product according to claim 7, wherein
the additional shape is added to improve rigidity of the press-formed product.

FIG. 1

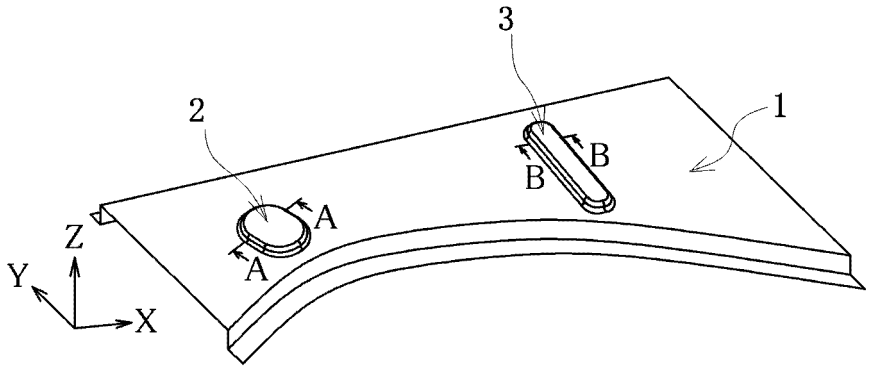


FIG. 2(a)

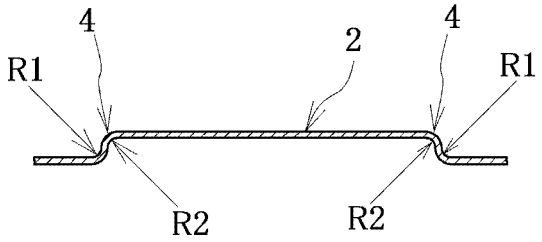


FIG. 2(b)

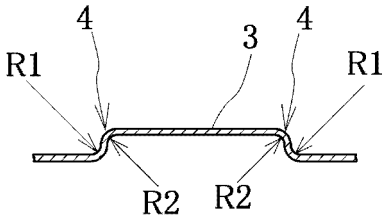


FIG. 3

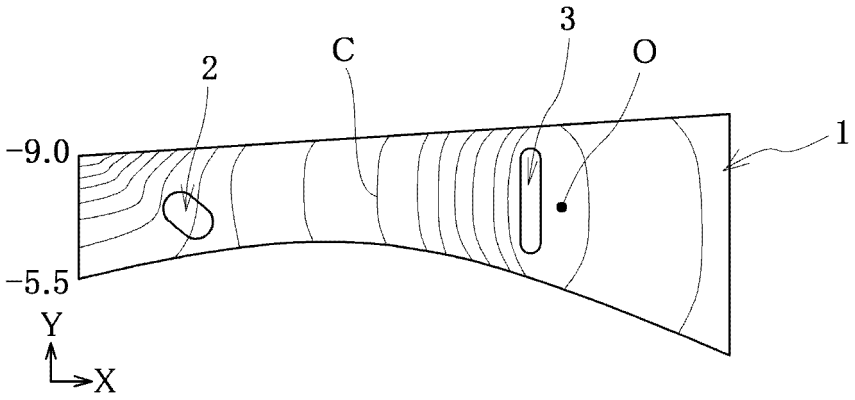


FIG. 4

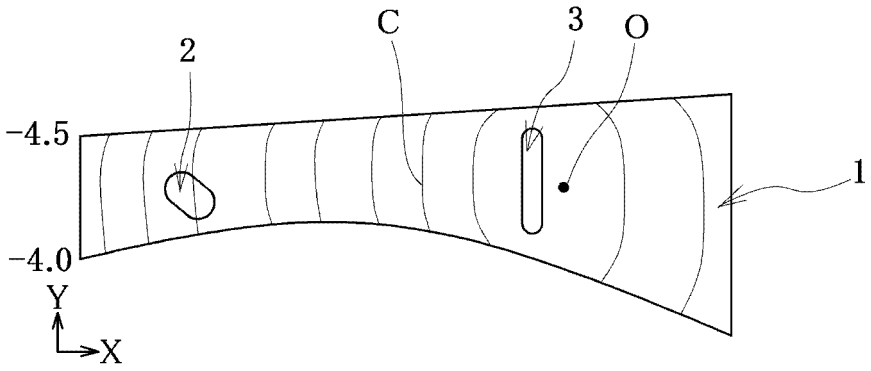


FIG. 5(a)

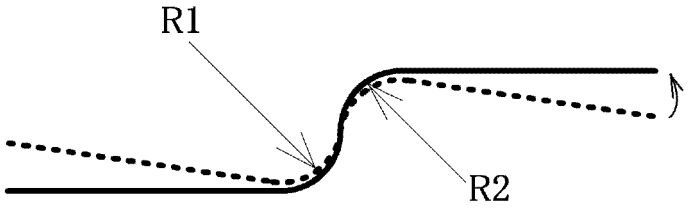


FIG. 5(b)

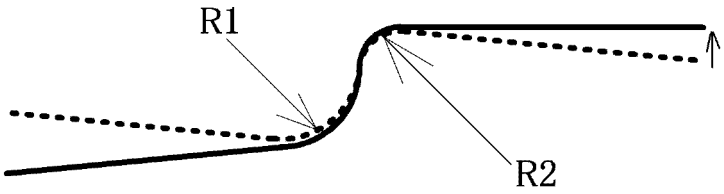
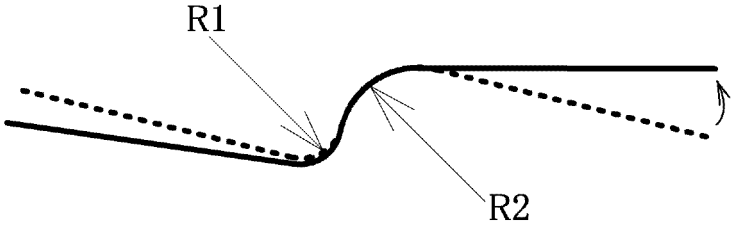


FIG. 5(c)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/006934

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B21D22/00(2006.01)i, B21D22/26(2006.01)i, B21D24/00(2006.01)i

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)
Int.Cl. B21D22/00, B21D22/26, B21D24/00, B21D5/01, G06F17/50

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	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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 2004-337980 A (TOYOTA MOTOR CORPORATION, KOBE STEEL, LTD.) 02 December 2004, paragraphs [0043]-[0051], fig. 9 (Family: none)	1-8
A	WO 2010/038539 A1 (NIPPON STEEL CORPORATION) 08 April 2010, entire text, all drawings & US 2011/0172803 A1, entire text, all drawings & EP 2333684 A1 & CN 102165451 A & BR PI0919464 A2 & TW 201012565 A	1-8

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"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 24.04.2019	Date of mailing of the international search report 14.05.2019
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/006934

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 5380890 B2 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 08 January 2014, entire text, all drawings (Family: none)	1-8
A	JP 8-281335 A (NIPPON STEEL CORPORATION) 29 October 1996, entire text, all drawings (Family: none)	1-8
A	JP 7-112219 A (TOYOTA MOTOR CORPORATION) 02 May 1995, entire text, all drawings (Family: none)	1-8

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5380890 B **[0008]**
- JP H08281335 A **[0008]**
- JP H07112219 A **[0008]**