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(54) FORMED METAL ITEM INCLUDING TUBULAR PART WITH SLIT, METHOD FOR PRODUCING THE SAME, AND PRODUCING DEVICE AND DIE ASSEMBLY USED IN METHOD FOR PRODUCING THE SAME

GEFORMTER METALLGEGENSTAND MIT EINEM ROHRFÖRMIGEN TEIL MIT SCHLITZ, VERFAHREN ZUR HERSTELLUNG DAFÜR UND HERSTELLUNGSVORRICHTUNG UND MATRIZENANORDNUNG, DIE IN DEM VERFAHREN ZUR HERSTELLUNG DAFÜR VERWENDET WERDEN

ARTICLE METALLIQUE FORMÉ COMPRENANT UNE PARTIE TUBULAIRE PRÉSENTANT UNE FENTE, SON PROCÉDÉ DE PRODUCTION ET DISPOSITIF DE PRODUCTION ET ENSEMBLE-MATRICE UTILISES DANS LE PROCÉDÉ DE PRODUCTION

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Description

TECHNICAL FIELD

[0001] The present invention relates to a formed metal item that includes a tubular part with a slit, a method for producing the formed metal item, and a producing device and a die assembly used in the method for producing the formed metal item.

BACKGROUND ART

[0002] Tubular components are widely used in automobile parts and household appliances. Therefore, the development of techniques to produce tubular components is promoted. As a typical method for producing a tubular component using a metal plate as a material, UO forming is known (e.g., Patent Literature 1 and 2).

[0003] In recent years, in the automotive field, there is a demand for a tubular component with a slit in its lengthwise direction. A conventional method for producing such a tubular component has been to perform bending a plurality of times. However, the method has a problem in that it is difficult to form a component having a complex shape, and in that the step thereof is cumbersome. Therefore, the application of the UO forming is expected. However, a typical UO forming is for producing a tubular component without a slit, and a butted part of a formed tubular component is welded. For this reason, it is still difficult to produce a tubular component including a gap in its butted part with precision only by applying a conventional UO forming.

[0004] Patent Literature 3 discloses a method for forming a hollow profile with a slot in its longitudinal direction. FIG. 3 and FIG. 4 of Patent Literature 3 disclose a method in which a core (core 11) that includes a blade for forming the slot is used. In the producing method of Patent Literature 3, closing and welding the slot after forming are prerequisite. Therefore, precision of the breadth of the slot and the precision of a shape before the welding are not taken in consideration. In addition, in the case where the material or the thickness of a metal plate varies, the amount of spring back also varies, and thus variations in breadth of the slot occur. Therefore, in order to change the material or the thickness of the metal plate, a die assembly needs to be modified to adjust the breadth of the slot.

[0005] Patent Literature 1 discloses a method for forming a tubular member having a square cross section by bending a plate material. A die assembly used in this method includes an upper die, a lower die, and side dices. The side dices are dices for pressing side parts of a plate material in such a manner that two end edges facing each other are brought close to each other. The tubular member formed by this method has a butted part that is welded after the forming. Therefore, there is no sufficient consideration is given to control of a gap between the two end edges.

[0006] Furthermore, as the method for producing a tubular component, roll forming is also known (e.g., Patent Literature 4). However, by the roll forming, it is difficult to produce a tubular component having a complex shape, such as a varying-cross-section pipe the cross-sectional shape of which varies in its lengthwise direction.

[0007] As bending of a metal plate, press brake working is known (e.g., Patent Literature 5). It is conceivable that a tubular component including a gap in its butted part is formed by bending with a press brake. However, by the press brake working, it is difficult to decrease the breadth of the gap of the butted part.

[0008] Also in the conventional UO forming, an unintended gap may occur in some cases in a butted part of a tubular component due to spring back after the forming. However, in the conventional UO forming, it is very difficult to control the breadth of the gap of the butted part.

[0009] In addition, for example, as described in Patent Literature 2 and 3, a core is used during O forming in some cases. In this case, it is conceivable that a tubular component including a gap in its butted part is formed by making the width of a metal plate shorter than the cross-section peripheral length of a die assembly. However, this method has a problem of a large spring back due to forming by simple bending. Therefore, also in this case, it is difficult to control the breadth of the gap of the butted part.

[0010] In addition, it is conceivable to design a die assembly by trial and error, and to use the die assembly to form a tubular component including a gap in its butted part by means of spring back. However, when volume production is taken into consideration, the material or the thickness of a metal plate slightly varies between lots. In this case, the amount of spring back also varies, and thus variations occur in the breadth of the gap of the butted part or the shape of the tubular component. Therefore, it is difficult to continuously produce tubular components that have a constant breadth of the gaps of their butted parts and are in good shape precision, in volume. Furthermore, in the case of changing the material or the thickness of a metal plate, the die assembly needs to be modified to adjust the breadth of the gap of the butted part, which requires a tremendous time and labor, accordingly leading to high costs.

[0011] Patent Literature 6 discloses a method for producing a hollow profile from a cut blank using a UO forming technique. In the producing method of Patent Literature 6, a closed hollow profile is formed by butting two opposite edges of a cut blank against each another. At this point, the length of the cut blank in a circumferential direction is made longer than a required forming length by a given redundant length. The redundant length is at least 1% to 10%. Patent Literature 6 discloses that areas of the hollow profile abutting on an edge joint are compressed at least partly in the circumferential direction. In addition, Patent Literature 6 describes that the producing method is executed using the UO forming technique. However, Patent Literature 6 makes no specific description about how to execute the producing method. That is, Patent Literature 6 makes no disclosure about how to compress the hollow profile in the circumferential direction using the UO forming technique. Moreover, the method of Patent Literature 6 has no envisagement of freely controlling the width of the slit.

[0012] US1879077 discloses a method and means for forming pipe blanks, in which the method is for reducing a flat, rectangular blank, and more particularly one of elongated shape, to cylindrical cross-sectional form by a series of successive operations in a single set of dies.

[0013] DE102009017571 discloses a method involving deforming a sheet material i.e. metal sheet, before inserting the material between press tool parts in terms of U-shaped curve so that a center region of the U-shaped bent sheet material supports against one of the press tool parts and end portions of the sheet material against the other press tool part. A molding surface of the latter press tool part is formed by the end portions of the sheet material during locking of the press tool parts until final shape of a pipe bend results. An independent claim is also included for a device for producing pipe bends.

[0014] JP2014004626 discloses a method of manufacturing a different-diameter tubular component comprising a small-diameter part, large-diameter part, and a diameter variation part between the small-diameter part and large-diameter part by pressing a blank of a metal plate, the method including a process of pressing the blank into a U-shaped molding with a U-shape molding metal mold, and then pressing it into a circularly-sectioned molding with an O-shape molding metal mold. A metal mold which has a vertical wall length longer than a vertical wall part length of the U-shaped molding is used as the U-shape molding metal mold, and a metal mold which has a metal mold mating line in a downward oblique direction and satisfies $0.010 \leq t/D \leq 0.080$ for the ratio t/D of a plate thickness (t) of the blank and a diameter D of a metal mold part corresponding to the small-diameter part and large-diameter part is used as the O-shape molding metal mold, compressive strain in a peripheral direction represented as compressive strain in the peripheral direction=(blank width in the plate width direction as tube peripheral direction - peripheral length of metal mold)/peripheral length of metal mold$\times$100(%)) being 0.5% or larger.

[0015] JP 2004298907 discloses a forming machine which suppresses generation of oscillation by changing servo rigidity as needed in a process of sequentially working the material to be formed, since a forming tool is positioned in a predetermined position by switching a positional loop gain according to a phase during forming cycle. Further, the servo rigidity is decreased by changing the positional loop gain in order to release elastic restoration of the material. As a result, machine motion becomes smooth, compared with the case where the elastic restoration is released by moving the forming tool.

[0016] JP2009119466 discloses a method of working a steel sheet into a cylinder, in which a cylindrical body excellent in shape accuracy is obtained by performing roll forming utilizing the properties of a hot-rolled steel sheet. The roll forming is performed by using a cut length sheet composed of an ordinary steel so that the rolling direction is the peripheral direction of the cylinder and the width direction orthogonal to the rolling direction is the axial direction of the cylinder. As compared with a comparison example in which the roll forming is performed so that the width direction orthogonal to the rolling direction is the peripheral direction of the cylinder, the shape accuracy is improved and the deviation from complete roundness is reduced.

[0017] JP2009517222 discloses a coreless process for producing a tube from a sheet by placing it in a die made in two halves and closing them up to produce a tube with a slit. The deformation takes place in the half-dies, and the edges of the sheet are prevented from sliding forward as the die is closed up to form the slit tube.

CITATION LIST

PATENT LITERATURE

[0018]

Patent Literature 1: Japanese Patent Application Publication No. 2001-191112

Patent Literature 2: Japanese Patent Application Publication No. 2004-25224

Patent Literature 3: International Application Publication No. WO2005/002753

Patent Literature 4: Japanese Patent Application Publication No. 2000-616

Patent Literature 5: Japanese Patent Application Publication No. 2000-61551

Patent Literature 6: National Publication of International Patent Application No. 2014-516801

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0019] In the aforementioned circumstances, an objective of the present invention is to provide a producing method capable of forming a formed metal item that includes a tubular part with a slit with precision, and capable of controlling the breadth of the slit.

SOLUTION TO PROBLEM

[0020] A method in an embodiment of the present invention is a producing method for producing a formed metal item that includes a tubular part with a slit. This producing method includes: (i) a step of forming a U-shaped part having a U-shaped cross section by deforming a metal plate; and (ii) a step of forming the tubular part with the slit by deforming the U-shaped part using a die assembly provided with a protruding part in such a manner that two end parts of the U-shaped part clamp the protruding part. In the step (ii), the cross-section peripheral length LH of the tubular part is made shorter than the cross-section length LU of the U-shaped part, and the step (ii) includes:

(ii-1) a step of forming a cylindrical-shape portion by deforming the U-shaped part using the die assembly in such a manner that the two end parts of the U-shaped part clamp the protruding part, the cylindrical-shape portion being to be the tubular part; and
(ii-2) a step of pressing an outer peripheral surface of the cylindrical-shape portion while the two end parts are clamping the protruding part, whereby the cross-section peripheral length LT of the cylindrical-shape portion is shortened.

[0021] A formed metal item in an embodiment of the present invention is a formed metal item that includes a tubular part with a slit. When a variation S in Vickers hardness in the thickness direction of the cross section of the tubular part is expressed by the following expression, an average value of variations S in a circumferential direction is less than 0.4.

$$S = (Bmax - Bmin) / Bmax$$

[0022] Here, Bmin is a minimum value of the Vickers hardnesses in the thickness direction of the cross section. Bmax is a maximum value of the Vickers hardnesses in the thickness direction of the cross section.

[0023] A die assembly in an embodiment of the present invention is a die assembly for producing a formed metal item that includes a tubular part with a slit. This die assembly includes a first die that includes a protruding part for forming the slit, and a second die. The first and second dies include first and second pressing surfaces, respectively, which are configured to deform a U-shaped part having a U-shaped cross section in such a manner that two end parts of the U-shaped part clamp the protruding part to form a cylindrical-shape portion with a gap, the gap being to be the slit. The die assembly has a configuration to press the outer peripheral surface of the cylindrical-shape portion while the two end parts are clamping the protruding part so that the cross-section peripheral length of the cylindrical-shape portion is made short.

ADVANTAGEOUS EFFECTS OF INVENTION

[0024] According to the present invention, it is possible to form a formed metal item that includes a tubular part with a slit with precision, and to control the breadth of the slit. According to the present invention, a formed metal item that includes a tubular part with a slit formed with precision is obtained. Furthermore, according to the present invention, a producing device and a die assembly suitably used in a producing method according to the present invention are obtained.

BRIEF DESCRIPTION OF DRAWINGS

[0025]

[FIG. 1] FIG. 1 schematically illustrates the cross section of an example of a formed metal item according to the present invention.
[FIG. 2A] FIG. 2A is a cross-sectional view schematically illustrating an example of a step of a producing method according to the present invention.
[FIG. 2B] FIG. 2B is a cross-sectional view schematically illustrating an example of a step subsequent to FIG. 2A.
[FIG. 2C] FIG. 2C is a cross-sectional view schematically illustrating a U-shaped part that is formed through steps illustrated in FIG. 2A and FIG. 2B.
[FIG. 3A] FIG. 3A is a cross-sectional view schematically illustrating an example of a die assembly that is used in the producing method according to the present invention.
[FIG. 3B] FIG. 3B is a cross-sectional view schematically illustrating an example of a producing step using the die assembly illustrated in FIG. 3A.
[FIG. 3C] FIG. 3C is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 3B.
[FIG. 3D] FIG. 3D is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 3C.
[FIG. 3E] FIG. 3E is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 3D.
[FIG. 3F] FIG. 3F is a cross-sectional view schematically illustrating an example of a formed metal item that is produced through the steps illustrated in FIG. 3B to FIG. 3E.
[FIG. 4A] FIG. 4A is a cross-sectional view schematically illustrating an example of a die assembly that is used in the producing method according to the present invention.
[FIG. 4B] FIG. 4B is a cross-sectional view schematically illustrating an example of a producing step using the die assembly illustrated in FIG. 4A.
[FIG. 4C] FIG. 4C is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 4B.
[FIG. 4D] FIG. 4D is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 4C.
[FIG. 4E] FIG. 4E is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 4D.
[FIG. 4F] FIG. 4F is a cross-sectional view schematically illustrating an example of a formed metal item that is produced through the steps illustrated in FIG.

4B to FIG. 4E.

[FIG. 5A] FIG. 5A is a cross-sectional view schematically illustrating an example of a die assembly that is used in the producing method according to the present invention.

[FIG. 5B] FIG. 5B is a cross-sectional view schematically illustrating an example of a producing step using the die assembly illustrated in FIG. 5A.

[FIG. 5C] FIG. 5C is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 5B.

[FIG. 5D] FIG. 5D is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 5C.

[FIG. 5E] FIG. 5E is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 5D.

[FIG. 5F] FIG. 5F is a cross-sectional view schematically illustrating an example of a formed metal item that is produced through the steps illustrated in FIG. 5B to FIG. 5E.

[FIG. 6A] FIG. 6A is a cross-sectional view schematically illustrating an example of a die assembly that is used in the producing method according to the present invention.

[FIG. 6B] FIG. 6B is a cross-sectional view schematically illustrating an example of a producing step using the die assembly illustrated in FIG. 6A.

[FIG. 6C] FIG. 6C is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 6B.

[FIG. 6D] FIG. 6D is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 6C.

[FIG. 6E] FIG. 6E is a cross-sectional view illustrating an example of a step subsequent to the step illustrated in FIG. 6D.

[FIG. 6F] FIG. 6F is a cross-sectional view schematically illustrating an example of a formed metal item that is produced through the steps illustrated in FIG. 6B to FIG. 6E.

[FIG. 7] FIG. 7 is a cross-sectional view schematically illustrating a cross section of another example of a die assembly according to the present invention.

[FIG. 8] FIG. 8 is a cross-sectional view illustrating a still another example of a die assembly according to the present invention and an example of a tubular part that is formed using the example of the die assembly.

[FIG. 9A] FIG. 9A is a diagram schematically illustrating an example of the formed metal item according to the present invention.

[FIG. 9B] FIG. 9B is a diagram schematically illustrating another example of the formed metal item according to the present invention.

[FIG. 9C] FIG. 9C is a diagram schematically illustrating a still another example of the formed metal item according to the present invention.

[FIG. 9D] FIG. 9D is a diagram schematically illustrating a still another example of the formed metal item according to the present invention.

[FIG. 9E] FIG. 9E is a diagram schematically illustrating a still another example of the formed metal item according to the present invention.

[FIG. 10A] FIG. 10A schematically illustrates a step of a method for producing a tubular member in Comparative Example 1.

[FIG. 10B] FIG. 10B schematically illustrates a step subsequent to FIG. 10A.

[FIG. 11A] FIG. 11A schematically illustrates a step of a method for producing a tubular member in Comparative Example 2.

[FIG. 11B] FIG. 11B schematically illustrates a step subsequent to FIG. 11A.

[FIG. 12A] FIG. 12A is a graph illustrating strain distributions of tubular members in Example 1, Comparative Example 1, and Comparative Example 2, in a thickness direction.

[FIG. 12B] FIG. 12B is a graph illustrating strain distributions of tubular members in Examples 2 to 4 and Comparative Example 2, in a circumferential direction.

[FIG. 13] FIG. 13 is a graph illustrating relation between the average value of variations S in the circumferential direction and the rate of reduction of uniaxial compressive strength.

[FIG. 14A] FIG. 14A is a diagram illustrating an example of an operation of an example of a producing device of the present invention.

[FIG. 14B] FIG. 14B is a diagram illustrating an example of an operation subsequent to FIG. 14A.

[FIG. 14C] FIG. 14C is a diagram illustrating an example of an operation subsequent to FIG. 14B.

[FIG. 14D] FIG. 14D is a diagram illustrating an example of an operation subsequent to FIG. 14C.

[FIG. 15A] FIG. 15A is a diagram illustrating an example of an operation of another example of the producing device of the present invention.

[FIG. 15B] FIG. 15B is a diagram illustrating an example of an operation subsequent to FIG. 15A.

[FIG. 15C] FIG. 15C is a diagram illustrating an example of an operation subsequent to FIG. 15B.

[FIG. 15D] FIG. 15D is a diagram illustrating an example of an operation subsequent to FIG. 15C.

DESCRIPTION OF EMBODIMENTS

[0026] Hereinafter, embodiments of the present invention will be described. The following description will be made about embodiments of the present invention by way of example, but the present invention is not limited to the examples described below. Although specific numeric values and materials are exemplified in the following description in some cases, other numeric values and materials may apply as long as they allow the advantageous effects of the present invention to be obtained.

(Method for Producing Formed Metal Item)

[0027] A producing method according to the present invention is a method for producing a formed metal item that includes a tubular part with a slit. Matters described about the producing method according to the present invention are applicable to a formed metal item, a producing device, and a die assembly according to the present invention.

[0028] The formed metal item may include a part other than the tubular part with a slit. Alternatively, the formed metal item may be constituted by only the tubular part with a slit. The formed metal item in this case is a tubular formed item with a slit. Examples of the formed metal item to be produced will be described later. The producing method according to the present invention includes step (i) and step (ii), which will be described below.

(Step (i))

[0029] In step (i), a metal plate is deformed, whereby a U-shaped part, which has a U-shaped cross section, is formed. Step (i) has no special limitation, and U forming used in conventional UO forming may be applied thereto. The method for U forming has no special limitation as long as the method allows the metal plate to be formed to have a U-shaped cross section. Examples of the U-forming method include press forming, roll forming, and other kinds of forming. The U forming may be performed in a plurality of steps. In addition, before the U forming, working to bend the ends of the metal plate (working such as what is called C forming) may be performed. In addition, after the U forming, trimming (cutting) of the U-shaped part may be performed.

[0030] In the present specification, the cross section of a tubular part means a cross section in the circumferential direction of the tubular part, unless otherwise noted. In other words, the cross section of the tubular part means a cross section in a direction perpendicular to the axis direction (normally the lengthwise direction) of the tubular part. The same is true for the cross section of the U-shaped part, the cross section of a cylindrical-shape portion, and the cross section of a pressing surface of a die assembly. The pressing surface of a die assembly means a surface of the die assembly that is to come into contact with the outer peripheral surface of the cylindrical-shape portion (or the tubular part), unless otherwise noted. In the case where the die assembly is configured by a plurality of members, the cross-section peripheral length of the pressing surface of the die assembly means the total cross-section length of the pressing surfaces of the plurality of members.

[0031] The metal plate to be subjected to the forming by the producing method according to the present invention may be hereinafter referred to as a blank. The metal plate (blank) has no special limitation as long as the metal plate allows the forming. Examples of the metal plate include a steel plate, for example, a hot-rolled steel plate, a cold-rolled steel plate, a plated steel plate, and other kinds of plates. Furthermore, examples of the metal plate include a metal plate made by joining a plurality of metal plates together (what is called a tailored blank). The tailored blank may be made by joining a plurality of metal plates together in the axis direction of the resultant tubular part, or may be made by joining a plurality of metal plates together in the circumferential direction of the resultant tubular part. Furthermore, as the blank, use may be made of a twin gauge plate, the thickness of which differs from area to area. Further, as the blank, use may be made of what is called a stacked plate. Examples of the stacked plate include a plate made by stacking a plurality of metal plates and a plate made by overlaying a nonmetallic row material on a metal plate. That is, the formed metal item may contain a material other than a metal plate.

[0032] The metal plate (blank) may be a thin-wall metal plate or a high-tensile steel plate (what is called a high-tensile material). These plates tend to have large spring backs and are suitable in particular for the present invention. Examples of the thin-wall metal plate include a metal plate in which the ratio of the thickness to the equivalent diameter, of the metal plate, is 10% or less. The equivalent diameter is a value obtained by dividing the cross-section peripheral length of the tubular part by 3.14. The tensile strength of the high-tensile material is preferably 300 MPa or more and may be 440 MPa or more (e.g. 490 MPa or more or 780 MPa or more). The upper limit of the tensile strength has no special limitation and may be 2000 MPa or less.

[0033] The material of the metal plate has no special limitation as long as the metal plate allows the forming. Examples of the material of the metal plate include Fe-based, Al-based, Cu-based, and Ti-based metal, and other kinds of metals.

[0034] The thickness of the metal plate has no special limitation as long as the thickness allows the forming. The thickness of the metal plate is selected in consideration of the material of the metal plate, the shape of the formed metal item, the usage of the formed metal item, and other factors. As an example, the thickness of the metal plate may fall within a range from 0.4 to 5 mm (e.g., a range from 0.5 to 3 mm or a range from 1 to 3 mm, etc.).

[0035] The shape of the metal plate is selected in conformity with an intended shape of the formed metal item. As will be described later, in the producing method according to the present invention, a cross-section peripheral length LH of the tubular part is made shorter than a cross-section length LU of the U-shaped part. Of the metal plate, a width W of a portion to be made into the tubular part (a length in a direction to be a circumferential direction in the tubular part) is determined in consideration of a compressibility C, which will be described later.

(Step (ii))

[0036] In step (ii), the tubular part with a slit is formed by deforming the U-shaped part using a die assembly provided with a protruding part in such a manner that two end parts of the U-shaped part clamp the protruding part. In step (ii), the cross-section peripheral length LH of the tubular part is made shorter than the cross-section length LU of the U-shaped part. The metal plate constituting the tubular part is thereby compressed in the circumferential direction. Consequently, the spring back of the tubular part is suppressed, which allows the breadth of the slit to be controlled with precision. The gap between the two end parts that are butted against each another across the protruding part (the two end parts of the U-shaped part) serves as a slit. That is, a formed metal item including a tubular part with a slit is produced by step (ii). Of course, the formed metal item obtained by step (ii) may be further worked.

[0037] The difference between the cross-section peripheral length LH of the tubular part and the cross-section length LU of the U-shaped part is preferably 0.2% or more of the cross-section length LU of the U-shaped part. Specifically, it is preferable that the cross-section length LU of the U-shaped part and the cross-section peripheral length LH of the tubular part satisfy an expression of $0.2 \leq 100 \times (LU - LH) / LU$. If the difference is excessively small, the effect of suppressing the spring back and the effect of forming the tubular part with precision may not be obtained. Hereinafter, the value of $100 \times (LU - LH) / LU$ may be referred to as a compressibility C(%) of the tubular part. The compressibility C of the tubular part may be 0.5% or more.

[0038] From the viewpoint of inhibiting buckling, the compressibility C may be set at 2% or smaller or may be set at less than 1%. By setting the compressibility C at less than 1%, it is possible to inhibit buckling better. In particular, a small thickness of the metal plate is likely to give rise to buckling, and thus the compressibility C is preferably set at less than 1%. In a preferable example, an expression of $0.2 \leq 100 \times (LU - LH) / LU < 1$ is satisfied.

[0039] If the difference (LU - LH) between the cross-section peripheral length LH of the tubular part and the cross-section length LU of the U-shaped part is excessively large, there is the risk that buckling (folding of the metal plate) occurs or that the metal plate is caught in a contact portion between an upper die and a lower die. Meanwhile, the larger the thickness of the metal plate, buckling is more difficult to bring about even when the compressibility C is increased. In addition, the smaller the thickness of the metal plate, the greater the effect obtained by the compression. From the viewpoint of this respect, it is preferable that the difference between the cross-section peripheral length LH and the cross-section length LU of the U-shaped part is determined in consideration of the thickness of the metal plate. For example, assuming that the thickness of the metal plate constituting the tubular part is denoted by t, the difference between the cross-section peripheral length LH of the tubular part and the cross-section length LU of the U-shaped part may be set at 8t or smaller. In this case, the difference between the cross-section peripheral length LH of the tubular part and the cross-section length LU of the U-shaped part may be set at 0.1t or larger.

[0040] In a preferable example, the above compressibility C is 0.2% or more, and the difference between the cross-section peripheral length LH and the cross-section length LU is 8t or smaller. In another preferable example, the above compressibility C is 0.2% or more and 2% or less. Consider the case of using, as the blank, a thin-wall metal plate in which the ratio of the thickness to the equivalent diameter, of the metal plate, (the equivalent diameter described above) is 5% or less. In this case, the compressibility C is preferably 0.2% or more and less than 1% (e.g., 0.2% or more and less than 0.5%).

[0041] From the viewpoint of preventing buckling, the compressibility C may be determined in consideration of a yield stress σ (MPa) and the thickness t (mm) of the metal plate (blank) constituting the tubular part. For example, the aforementioned compressibility C(%) may satisfy the following expression. In this case, any of the aforementioned lower limits may be adopted as the lower limit of the compressibility C. The metal plate satisfying the following expression may have any thickness and may have a thickness that falls within the aforementioned range (e.g., range from 0.4 to 5 mm).

$$C \leq (1500 / \sigma) \times t$$

[0042] Step (ii) includes the following steps (ii-1) and (ii-2). In step (ii-1), a cylindrical-shape portion is formed by deforming the U-shaped part using a die assembly in such a manner that the two end parts of the U-shaped part clamp the protruding part, the cylindrical-shape portion being to be the tubular part. The cylindrical-shape portion is a precursor of the tubular part obtained by the step (ii), which can be rephrased into a first tubular part or a tubular part precursor. In step (ii-2), the outer peripheral surface of the cylindrical-shape portion is pressed with the two end part clamping the protruding part of the die assembly, and the cross-section peripheral length LT of the cylindrical-shape portion is thereby shortened. By step (ii-2), the cross-section peripheral length LH of the tubular part is made shorter than the cross-section length LU of the U-shaped part. That is, by step (ii-2), the metal plate constituting the tubular part is compressed in the circumferential direction. By forming the cylindrical-shape portion in step (ii-1) before compressing the cylindrical-shape portion in the circumferential direction in step (ii-2), it is possible to perform the compression stably. Specifically, it is possible to inhibit the occurrence of buckling and the like at the time of forming the cylindrical-shape portion.

[0043] Description will be made below about three examples of step (ii) (an example (A), an example (B), and an example (C not in accordance with the present invention)). Example (A) and example (B) are examples including steps (ii-1) and (ii-2).

(Example (A) of Step (ii))

[0044] A die assembly (a) used in the example (A) has the following configurations (a-1), (a-2), and (a-3).

(a-1) The die assembly (a) includes a first die provided with a protruding part, and a second die.
(a-2) The first and second dies include first and second pressing surfaces, respectively, which are configured to deform the U-shaped part to form the cylindrical-shape portion.
(a-3) At least one die selected from the first die and the second die is separable into a plurality of die members.

[0045] As to the configuration (a-3), both of the first and second dies may be separable. Alternatively, only the first die may be separable, or only the second die may be separable. In the case where both of the first and second dies are separable, the cross-section peripheral length LH of the tubular part can be finely adjusted. As a result, it is possible to reduce variations more in compressive stress acting on the tubular part. Consequently, the slit can be formed with more precision. In an example in which the first die is separable, the first die is separable into a first die member and a second die member. In this case, the protruding part may be configured by a first protruding part included in the first die member and a second protruding part included in the second die member.

[0046] In step (ii-1) of the example (A), the cylindrical-shape portion is formed by deforming the U-shaped part using the die assembly (a) while a plurality of die members are separated. In the subsequent step (ii-2), the outer peripheral surface of the cylindrical-shape portion is pressed by bringing the plurality of die members close to each other, which shortens the cross-section peripheral length LT of the cylindrical-shape portion. With this configuration, the metal plate constituting the tubular part is compressed in the circumferential direction.

[0047] In a preferable example of the example (A), the die assembly (a) moves only in a vertical direction in step (ii-1), and the die assembly (a) moves only in a horizontal direction in step (ii-2). For example, in the case where only an upper die of the die assembly (a) moves in the vertical direction (a pressing direction), the upper die is caused to move to a bottom dead point in step (ii-1). Thereafter, in step (ii-2), the separated plurality of die members are caused to move in the horizontal direction.

(Example (B) of Step (ii))

[0048] A die assembly (b) used in the example (B) has the following configurations (b-1), (b-2), and (b-3).

(b-1) The die assembly (b) includes a first die provided with a protruding part and a second die.
(b-2) The first and second dies include first and second pressing surfaces, respectively, which are configured to deform the U-shaped part to form the cylindrical-shape portion.
(b-3) At least one die selected from the first die and the second die includes a body part and a movable part that is movable relative to the body part.

[0049] As to the configuration (b-3), the first and second dies may each include the movable part. Alternatively, only the first die may include the movable part, or only the second die may include the movable part. In an example, the first and second dies include first and second movable parts, respectively, the first and second movable parts being movable in the pressing direction (the vertical direction). In this case, the first movable part included in the first die may include a protruding part for forming the slit. In another example, at least one of the first and second dies includes first and second movable parts that are movable in a direction orthogonal to the pressing direction. The first and second movable parts are disposed in such a manner as to face each other across the cylindrical-shape portion. The two movable parts (the first and second movable parts) press the outer peripheral surface of the cylindrical-shape portion, which can compress the cylindrical-shape portion in question in the circumferential direction. Here, the pressing direction means a direction in which the body part of the die assembly moves during the forming.

[0050] In step (ii-1) of the example (B), the U-shaped part is deformed using the die assembly while the pressing surface of the movable part does not project from the pressing surface of the body part. In the subsequent step (ii-2), the outer peripheral surface of the cylindrical-shape portion is pressed by causing the pressing surface of the movable part to project from the pressing surface of the body part, which shortens the cross-section peripheral length LT of the cylindrical-shape portion. With this configuration, the metal plate constituting the tubular part is compressed in the circumferential direction. In a typical step (ii-2), the body part is not caused to move, and only the movable part is caused to move.

(Example (C) of Step (ii) not in accordance with the present invention)

[0051] A die assembly (c) used in the example (C) not in accordance with the present invention has the following configurations.

(c-1) The die assembly (c) includes a first die provided with a protruding part and a second die.
(c-2) The first and second dies include first and second pressing surfaces, respectively, which are configured to deform the U-shaped part to form the cylindrical-shape portion.
(c-3) The cross-section peripheral length of the pressing surfaces of the die assembly (the pressing surfaces of the first and second dies) is shorter than

the cross-section length LU of the U-shaped part.

[0052] Unlike the die assembly (a) and the die assembly (b), the first die and the second die constituting the die assembly (c) are each basically a single piece. The protruding part of the first die may be however made replaceable. In the example (C), the U-shaped part is deformed only by bringing the first die and the second die close to each other in step (ii), whereby the tubular part with a slit is formed. The example (C) has a simple configuration of the die assembly and has an advantage that the production of the formed metal item is easy.

[0053] In the producing method according to the present example, the die assembly may include a pressing surface corresponding to the outer peripheral surface of the tubular part, and the cross-section peripheral length of the pressing surface may be shorter than the cross-section length LU of the U-shaped part. With this configuration, the pressing surface of the die assembly presses the outer peripheral surface of the U-shaped part to form the tubular part, whereby the cross-section peripheral length LH of the tubular part can be made shorter than the cross-section length LU of the U-shaped part. As mentioned above, the above die assembly (c) has this configuration, and the above die assembly (a) also has this configuration basically. The above die assembly (b) may or may not have this configuration. The cross-section peripheral length of the pressing surface of the die assembly means the total cross-section length of the pressing surfaces of a plurality of members that constitute the die assembly.

[0054] In the case of using the above die assemblies (a) and (c), it is normally considered that the cross-section peripheral length of the pressing surface of the die assembly is not considerably different from the cross-section peripheral length LH of the tubular part when the tubular part with a slit is formed by closing the die assembly completely. In this case, in the present specification, the cross-section peripheral length LH of the tubular part can be substituted by the cross-section peripheral length of the pressing surface of the die assembly. For example, in the aforementioned expression of the compressibility C and the other expression, the cross-section peripheral length LH of the tubular part can be substituted by the cross-section peripheral length of the pressing surface of the die assembly.

[0055] Step (ii) of the producing method according to the present invention is executed typically without using a core, and may be executed, for example, without using a core that is to come into contact with most of an inner peripheral surface (e.g., 50% or more of the area of the inner peripheral surface) of the tubular part (or the cylindrical-shape portion). By executing step (ii) without using the core, the tubular part becomes easy to compress uniformly in the circumferential direction. In the case of using the core, a metal plate between the die assembly and the core becomes difficult to compress in the circumferential direction. However, the core may be used in step (ii) as necessary. By using the core, it is possible to stably form a formed metal item having a complex cross-sectional shape in the circumferential direction. For example, in the case where an angle θ illustrated in FIG. 1 described later becomes larger than 180°, the core may be used for a stable forming. In the case of using the core, the core may be disposed over the entire part to be made into the tubular part or over only a part to be made into the tubular part.

[0056] In the producing method according to the present invention, the formed metal item may be further worked after step (ii). For example, a protrusion or a flat part may be added to the formed metal item, or a hole may be opened in the formed metal item.

[0057] The producing method according to the present invention is aimed at producing a formed metal item that includes a tubular part with a gap in a butted part. For this reason, the slit (the butted part with a gap) is basically not welded after step (ii). However, part of the butted part may be welded. For example, in the case where part of the butted part has a gap (slit), and the other part has no gap, part or the whole of the butted part having no gap may be welded. Also in this case, it is preferable not to weld the butted part having the gap. At the time of assembling a product including a formed metal item, part of the butted part may be subjected to tack welding.

(Formed Metal Item)

[0058] The formed metal item according to the present invention includes a tubular part with a slit. From a viewpoint, this tubular part is a tubular part having a gap in a butted part. The formed metal item according to the present invention is produced by the producing method according to the present invention. As to matters about this formed metal item that have already described in another part of the description, the redundant description thereof may be omitted. The matters described about the formed metal item according to the present invention are applicable to the producing method, the producing device, and the die assembly according to the present invention.

[0059] The formed metal item according to the present invention may include a part other than the tubular part with a slit. Alternatively, the formed metal item may be constituted by only the tubular part with a slit. The formed metal item in this case is a tubular formed item with a slit. The slit is normally formed along the axis direction (normally the lengthwise direction) of the tubular part. The slit may be formed in the entire tubular part or may be formed only in part of the tubular part. In other words, the formed metal item may have a slit across the overall length of the butted part, or may have a slit only in part of the butted part.

[0060] The shape of the tubular part with a slit has no special limitation as long as the shape is formable by the method according to the present invention. The tubular part has no special limitation in its cross-sectional shape and may have various shapes such as a round, an ellipse, a quadrilateral, a vertically asymmetrical shape, and a horizontally asymmetric shape. The tubular part may be round-tube-shaped or square-tube-shaped.

[0061] Examples of the shape of the tubular part include a straight pipe, a curved pipe, a varying-diameter pipe the outer diameter of which varies in its lengthwise direction, a varying-cross-section pipe the cross-sectional shape of which varies in its lengthwise direction, and the other kinds of pipes. Specifically, examples of the tubular part include pipes illustrated in FIG. 9A, FIG. 9B, FIG. 9C, FIG. 9D, and FIG. 9E (tubular part 1e). In each of these pipes, a slit 3 is formed in a butted part 2.

[0062] The pipe illustrated in FIG. 9A is a straight pipe the cross-sectional shape in the circumferential direction of which is round-shaped. The pipe illustrated in FIG. 9B is a curved pipe the cross-sectional shape in the circumferential direction of which is round-shaped. The pipe illustrated in FIG. 9C is a trumpet-shaped varying-diameter pipe the cross-sectional shape in the circumferential direction of which is round-shaped. The pipe illustrated in FIG. 9D is a varying-cross-section pipe the cross-sectional shape in the circumferential direction of which varies from a round shape to a quadrilateral shape. The pipe illustrated in FIG. 9E is a pipe having the cross-sectional shape in the circumferential direction of which is vertically asymmetrical and horizontally asymmetric. The pipe illustrated in FIG. 9E is a pipe formed of a tailored blank made by joining different metal plates in the circumferential direction.

[0063] A pipe the cross-sectional shape in the circumferential direction of which is a horizontally asymmetric shape and a pipe using a tailored blank as illustrated in FIG. 9E are difficult to form into by conventional UO forming. In contrast, by appropriately selecting the die assembly according to the present invention, it is possible to form pipes of various shapes or various types of blanks.

[0064] The formed metal item according to the present invention is obtained by subjecting a metal plate (blank) to forming. For this reason, the material of the formed metal item is the same as the material of the blank. Furthermore, the thickness of the formed metal item is substantially the same as the thickness of the blank. Therefore, the thickness of the formed metal item (the thickness of the tubular part) may fall within the range exemplified as the thickness of the blank. Some of the physical properties of the formed metal item change from the physical properties of the blank in a working step. In the formed metal item according to the present invention, in particular, since the tubular part is compressed in the circumferential direction, the physical properties thereby change.

[0065] By the producing method according to the present invention, it is possible to produce the formed metal item according to the present invention. Assuming that a variation S in Vickers hardness, of the formed metal item according to the present invention, in a thickness direction of the cross section of the tubular part is expressed by the following expression, the average value of variations S in the circumferential direction is less than 0.4 (0 or more and less than 0.4).

$$S = (Bmax - Bmin) / Bmax$$

[0066] Here, Bmin is a minimum value of the Vickers hardnesses in the thickness direction of the cross section of the tubular part. Bmax is a maximum value of the Vickers hardnesses in the thickness direction of the cross section.

[0067] The average value of the variations S in the circumferential direction is the average value of variations S that are measured at three points of one cross section of the tubular part (a cross section in the circumferential direction). The three positions for the measurement are a first position that is in the vicinity of the slit of the tubular part, a second position that is the furthest from the first position in the circumferential direction, and a third position that is midway between the first position and the second position. Consider that the tubular part is circular-tube-shaped and the slit is positioned in an uppermost part of the tubular part. At this point, assuming that a bottom part of the tubular part is at 0° around the center of the tubular part, the first, second, and third positions lie at about 180°, 0°, and 90°, respectively. The first position is set at a distance within a range of 5 mm or shorter from an end part facing the slit.

[0068] In the producing method according to the present invention, a cross-section peripheral length LH of the tubular part is made shorter than a cross-section length LU of the U-shaped part. Therefore, compressive stress acts on the entire tubular part in the thickness direction, and a variation in compressive stress acting on the tubular part in the circumferential direction is small. For this reason, by forming the tubular part by the producing method according to the present invention, it is possible to increase a Vickers hardness over the entire cross section of the tubular part. As a result, it is possible to reduce the variation in Vickers hardness over the entire cross section of the tubular part. Decreasing the variation in Vickers hardness is useful for the enhancement of the durability and reliability formed metal item with the tubular part.

[0069] In a preferable example, all of the variations S measured at the aforementioned three positions are less than 0.4 (e.g., less than 0.2). With this configuration, the enhancement of the durability and reliability can be expected.

(Method for Measuring Vickers Hardness)

[0070] Hereinafter, description will be made about a method for measuring the Vickers hardness of the tubular part. First, the tubular part is cut in the circumferential direction, and the cut surface is subject to mechanical polishing until the cut surface becomes a mirror plane. Next, to eliminate the influence of work hardening by the mechanical polishing, the cut surface is dissolved up to a depth of 30 to 80 μm from the surface of the cut surface, by chemical polishing or electropolishing. On the cut surface obtained in such a manner, a Vickers hardness is measured.

[0071] The Vickers hardness is measured in compliance with the test method of the Vickers hardness test according to JIS Z 2244 in Japanese Industrial Standards (JIS). In the Vickers hardness test, an indenter is pressed into a test specimen to form an indentation, and a diagonal length of the indentation is measured. To evaluate the variation S for the cut surface of the tubular part, a plurality of indentations are formed on the cut surface for the measurement. In the case where the tubular part is made of a steel, a copper, or a copper alloy, a distance between the centers of adjacent two indentations is set at 3d or longer (d is the value of a longer one of the diagonal lengths of the indentations), distances from the centers of the indentations to the edges of the test specimen (the cut surface of the tubular part) are set at 2.5d or longer. In the case where the tubular part is made of a light metal (including aluminum, an aluminum alloy, titanium, a titanium alloy, magnesium, and a magnesium alloy), the distance between the centers of adjacent two indentations is set at 6d or longer, and the distances from the centers of the indentations to the edges of the test specimen are set at 3d or longer. These distances can be adjusted by intervals for the measurement of the Vickers hardness and a force to pressing the indenter.

[0072] In the aforementioned first position, Vickers hardnesses are measured at five points lying in a straight line at regular intervals in the thickness direction. Then, from the measured values at the five points, the minimum value Bmin and the maximum value Bmax of the Vickers hardnesses are determined, and the aforementioned variation S is calculated. Also in each of the aforementioned second and third positions, Vickers hardnesses are measured in the same manner, and the aforementioned variations S is calculated. Then, by averaging the obtained three variations S, the average value of the variations S in the circumferential direction is obtained.

[0073] The formed metal item according to the present invention is available for various applications. Examples of applications of the formed metal item include components (suspension components, bodies, structural materials, etc.) of various kinds of vehicles (automobiles, railway vehicles, and the other kinds of vehicles), components of various kinds of machines, electronic devices, electrical appliances, components of various kinds of transport aircraft (vessels, aircraft), and the other components.

(Producing Device)

[0074] A producing device according to the present invention is a producing device to produce a formed metal item that includes a tubular part with a slit. This producing device is available for the producing method according to the present invention. With this producing device, it is possible to produce the formed metal item according to the present invention. This producing device is a pressing device from another viewpoint, and to a configuration about which description is not made below, the configuration of a well-known pressing device may be applicable. As to matters about this producing device that have already described in another part of the description, the redundant description thereof may be omitted. The matters described about the producing device according to the present invention are applicable to the producing method, the formed metal item, and the die assembly according to the present invention.

[0075] The producing device according to the present invention includes a die assembly and a movement mechanism for moving the die assembly. The die assembly includes a first die and a second die. The first die includes a protruding part for forming a slit. The first and second dies include first and second pressing surfaces, respectively, which are configured to deform a U-shaped part having a U-shaped cross section to form a cylindrical-shape portion with a gap serving as a slit. The die assembly has a configuration to press the outer peripheral surface of the cylindrical-shape portion so that the cross-section peripheral length LT of the cylindrical-shape portion is made short.

[0076] Hereinafter, description will be made about two examples of the producing device according to the present invention (a producing device (a) and a producing device (b)).

(Producing Device (a))

[0077] The producing device (a) includes the aforementioned die assembly (a). As mentioned above, the die assembly (a) has the following configurations (a-1), (a-2), and (a-3).

(a-1) The die assembly (a) includes a first die provided with a protruding part, and a second die.
(a-2) The first and second dies include first and second pressing surfaces, respectively, which are configured to deform the U-shaped part to form the cylindrical-shape portion.
(a-3) At least one die selected from the first die and the second die is separable into a plurality of die members.

[0078] A movement mechanism of the producing device (a) includes a first movement mechanism and a second movement mechanism. The first movement mechanism is a movement mechanism to bring the first die and the second die close to each other while a plurality of die members are separated. Normally, the first movement mechanism brings the first die and the second die close to each other until the first die and the second die come into contact with each other, with the plurality of die members separated. The second movement mechanism is a movement mechanism to bring the separated plurality of die members close to each other. The first movement mechanism corresponds to the aforementioned step (ii-1) of the example (A). The second movement mechanism corresponds to the step (ii-2) of the example (A). With the producing device (a), the aforementioned step (ii) of the example (A) can be executed.

[0079] The first die of the die assembly (a) may be separable into a first die member and a second die member. In this case, the protruding part for forming the slit may be constituted by a first protruding part included in the first die member and a second protruding part included in the second die member.

(Producing Device (b))

[0080] The producing device (b) includes the aforementioned die assembly (b). As mentioned above, the die assembly (b) has the following configurations (b-1), (b-2), and (b-3).

(b-1) The die assembly (b) includes a first die provided with a protruding part and a second die.

(b-2) The first and second dies include first and second pressing surfaces, respectively, which are configured to deform the U-shaped part to form the cylindrical-shape portion.

(b-3) At least one die selected from the first die and the second die includes a body part and a movable part that is movable relative to the body part.

[0081] A movement mechanism of the producing device (b) includes a first movement mechanism and a second movement mechanism. The first movement mechanism is a movement mechanism to bring the first die and the second die close to each other. Normally, the first movement mechanism brings the first die and the second die close to each other until the first die and the second die come into contact with each other, while the pressing surface of the movable part is not projecting from the pressing surface of the body part. The second movement mechanism is a movement mechanism to move the movable part so that the pressing surface of the movable part projects from the pressing surface of the body part. The first movement mechanism corresponds to the aforementioned step (ii-1) of the example (B). The second movement mechanism corresponds to the step (ii-2) of the example (B). With the producing device (b), the aforementioned step (ii) of the example (B) can be executed.

[0082] As long as the aforementioned operation can be performed, the configurations of the movement mechanisms of the producing devices (a) and (b) have no special limitation, and use may be made of a well-known movement mechanism used in a pressing device of a double acting type. For example, the movement mechanisms of the producing devices (a) and (b) may be each configured by combining an expansion/contraction mechanism and a cam. Examples of the expansion/contraction mechanism include a gas cylinder, a hydraulic cylinder, a spring, and other mechanisms.

[0083] A producing device for executing the aforementioned step (ii) of the example (C) which is not in accordance with the present invention has no special limitation except for using the die assembly (c). The step (ii) of the example (C) which is not in accordance with the present invention can be executed with a typical pressing device.

(Die Assembly)

[0084] A die assembly according to the present invention is a die assembly for producing a formed metal item that includes a tubular part with a slit. This die assembly is available in the producing device according to the present invention. Furthermore, this die assembly is available in the producing method according to the present invention, specifically in the step (ii) of the producing method according to the present invention. By using this die assembly, the formed metal item according to the present invention can be produced. As to matters about this die assembly that have already described in another part of the description, the redundant description thereof may be omitted. The matters described about the die assembly according to the present invention are applicable to the producing method, the formed metal item, and the producing device according to the present invention.

[0085] The die assembly according to the present invention includes a first die that includes a protruding part for forming a slit, and a second die. The first and second dies include first and second pressing surfaces, respectively, which are configured to deform a U-shaped part having a U-shaped cross section in such a manner that two end parts of the U-shaped part clamp the protruding part to form a cylindrical-shape portion with a gap serving as a slit. In the case of forming a cylindrical-shape portion (or a tubular part) the outer circumference of the cross section of which is a round shape, the second pressing surface has a semi-cylinder shape, and the first pressing surface has a semi-cylinder shape except for the protruding part.

[0086] The die assembly according to the present invention has a configuration to press the outer peripheral surface of the cylindrical-shape portion while the two end parts are clamping the protruding part so that the cross-section peripheral length of the cylindrical-shape portion is made short. From another viewpoint, the die assembly according to the present invention has a configuration to compress the cylindrical-shape portion in the circumferential direction. Examples of the die assembly of the present invention include the aforementioned die assembly (a) and die assembly (b).

[0087] Use may be made of the first die including the protruding part as an upper die, and use may be made of the second die as a lower die. Therefore, in the present specification, the first die may be alternatively referred to as the upper die, and the second die may be alternatively referred to as the lower die. In addition, the first die may be alternatively referred to as the lower die, and the second die may be alternatively referred to as the upper die.

[0088] The protruding part has a shape that allows a slit to be formed. By the use of the first die in which a plate-shaped protruding part is disposed along the axis direction of the tubular part, it is possible to form the slit along the axis direction of the tubular part. In a typical example, the protruding part is a plate-shaped salient part and provided at a position in an uppermost part of the semicircular pressing surface of the upper die. In other words, in a typical example, the protruding part is provided in a central portion of the cross section of the pressing surface of the upper die (the cross section in the circumferential direction). However, the protruding part need not be in the central portion and may be at a position shifted from the center. For example, in the case of forming a horizontally-asymmetrical tubular part, the protruding part may be at a position shifted from the central portion. The position of the protruding part in the circumferential direction may be changed along the axis direction. The width of the protruding part may be changed along the axis direction. By the use of the protruding part that changes in the axis direction, it is possible to form a slit that changes in the axis direction.

[0089] Assuming that the inner diameter of the tubular part is denoted by Din, and the thickness of the tubular part is denoted by t, the width of the slit may be set at t or larger and (Din - 2t) or smaller. A width of the slit smaller than t may result in a sufficient strength of the protruding part of the die assembly. A width of the slit larger than (Din-2t) may decrease the advantageous effects of the invention.

[0090] The width of the protruding part is selected in accordance with the width of the slit (the gap of the butted part). The width of the protruding part is preferably set within ±10% of the width of the slit.

[0091] As mentioned above, in the die assembly (a), at least one die selected from the first die and the second die is separable into a plurality of die members. When the number of the die members is large, there is the risk that the U-shaped part is likely to be clamped between adjacent die members in the forming. In addition, when the number of the die members is large, the structures of the die assembly and a device using the die assembly become complex. Therefore, in a preferable example of the case where the first die is divided into a plurality of die members, the first die is divided into two die members. Similarly, in a preferable example of the case where the second die is divided into a plurality of die members, the second die is divided into two die members.

[0092] In the case where the first die and/or the second die is separable into a plurality of die members, the position of the separation has no special limitation. In the case where the first die is separable into the first die member and the second die member, the protruding part may be constituted by a first protruding part included in the first die member and a second protruding part included in the second die member. That is, the first die may be divided at the protruding part. With this configuration, two end parts of the U-shaped part can be guided by the first and second protruding parts, which can prevent the end parts of the U-shaped part from coming into a space between the two die members.

[0093] With the die assembly (a), by moving the plurality of die members individually, it is possible to perform a fine adjustment of the cross-section peripheral length LH of the tubular part easily and to reduce variations in compressive stress acting on the tubular part. Consequently, with the die assembly (a), it is possible to suppress the spring back effectively, with the result that the slit can be formed with precision.

[0094] As mentioned above, in the die assembly (b), at least one die selected from the first die and the second die includes the body part and the movable part that is movable relative to the body part.

[0095] In the die assembly (b), only the first die may include the body part and the movable part, or only the second die may include the body part and the movable part. Alternatively, both of the first and second dies may each include the body part and the movable part. In the case where the both dies each include the body part and the movable part, the area of the pressing surface of the movable part can be increased, and as a result, at the time when the cylindrical-shape portion is pressed and compressed in the circumferential direction, the press can be performed stably.

[0096] The positions at which the movable parts are disposed have no special limitation as long as the positions allow the adjustment of the cross-section peripheral length of the tubular part by the movement of the movable part. For example, the movable parts may be disposed at positions corresponding to a top part and a bottom part of the tubular part or may be disposed at positions corresponding to two side parts of the tubular part. The movable parts are preferably disposed at two positions that are opposed to each other across the center of the tubular part.

[0097] The movable parts are disposed at least in a zone where step (ii) of the example (B) is executed. For example, the movable parts may be disposed over the overall length of the die assembly or may be disposed over only in part of the die assembly.

[0098] In the case where the first die includes a body part and a movable part, the number of movable parts may be one or more. In the case where the number of movable parts is more than one, the cross-section peripheral length of the tubular part is easy to adjust finely in comparison with the case where the number of movable parts is one. Similarly, in the case where the second die includes a body part and a movable part, the number of movable parts may be one or more. In the case where the number of movable parts is more than one, the movable parts may be disposed at both of a position corresponding to the top part (or the bottom part) of the cylindrical-shape portion and positions corresponding to the side parts of the cylindrical-shape portion.

[0099] The movable part(s) can be moved by a cylinder, a cam mechanism, or the like so as to move relative to the body part.

[0100] In the die assembly according to the present invention, the protruding part for forming a slit may be replaceable. For example, in the aforementioned die assemblies (a), (b) and (c), the protruding part may be replaceable. The protruding part easily wears. Thus, by making the protruding part replaceable, the lifetime of the die assembly can be extended. In addition, by replacing the protruding part, the width of the slit becomes easy to adjust. When the physical properties (tensile strength, etc.) or the thickness of a metal plate (blank) varies, the amount of spring back varies. Therefore, in a conventional method, the entire die assembly needs to be changed whenever the physical properties or the thickness of the metal plate varies. However, by replacing the protruding part, the width of the slit becomes easy to adjust without changing the entire die assembly.

[0101] The shape of the die assembly is designed as appropriate in conformity with the shape and the like of an intended tubular part. For example, as illustrated in FIG. 8, the cross-sectional shape in a circumferential direction of the pressing surface of a die assembly may be a vertically asymmetric shape or may be a horizontally asymmetric shape. The cross-sectional shape in the circumferential direction of the pressing surface of the die assembly may be constant in an axis direction or may change in the axis direction. In addition, the pressing surface of the die assembly may be straight in the axis direction or may be bent relative to the axis direction.

[0102] The first die and the second die each may be of a single acting type. The first die and the second die each may be of a double acting type as necessary. In the die assemblies (a) and (b), at least one selected from the first and second dies is of the double acting type. The use of a die assembly of the double acting type allows the cross-section peripheral length of the cylindrical-shape portion to be adjusted finely and allows variations in compressive stress acting on the cylindrical-shape portion to be reduced. Therefore, it is possible to suppress in particular spring back effectively and to increase in particular the precision of the shape of the formed metal item. In the case where the die assembly is of the double acting type, a producing device including the die assembly includes a mechanism used in a pressing device of the double acting type or a mechanism including a cylinder, a cam, or the like.

[0103] In the case where the material or the thickness of a metal plate varies, the amount of spring back also varies accordingly. Therefore, in a forming method using a conventional die assembly, when the material or the thickness of a metal plate varies, the die assembly needs to be changed accordingly. In contrast, with the die assembly according to the present invention, it is possible to change the compressibility of a tubular part without changing the die assembly. For example, with the die assembly (a), the compressibility of the tubular part can be changed by changing distances between a plurality of die members. In addition, with the die assembly (b), the compressibility of the tubular part can be changed by changing the amounts of movement of the movable parts. Therefore, with the die assembly according to the present invention, even in the case where the material or the thickness of a metal plate varies, it is possible to control the breadth of the slit without changing the die assembly. Consequently, the die assembly according to the present invention is suitable for volume production of the formed metal item according to the present invention.

[0104] As will be described later, by the use of the die assembly according to the present invention, it is possible to reduce variations in hardness distribution in the thickness direction and variations in hardness distribution in the circumferential direction, of the tubular part. Therefore, by the use of the die assembly according to the present invention, it is possible to produce a formed metal item having a high fatigue strength.

[0105] Hereinafter, exemplary embodiments of the present invention will be described with reference to the drawings. In the following description, similar parts will be denoted by the same reference characters, and the redundant description thereof may be omitted.

(First Embodiment)

[0106] In a first embodiment, description will be made about an example of the formed metal item according to the present invention. The formed metal item according to the present invention includes a tubular part with a slit. FIG. 1 schematically illustrates a cross section in a direction orthogonal to the axis direction of the tubular part (a cross section in a circumferential direction). A formed metal item 1 includes a tubular part 1e that is formed with a slit 3 and is typically constituted by only the tubular part 1e. In the slit 3, two end parts E1 and E2 are butted against each another. From another viewpoint, the formed metal item 1 is a substantially-closed-cross-sectional component (a tubular component having a substantially-closed cross section). Here, the substantially-closed cross section refers to a cross section in which a gap is present between two butted end parts of a metal plate that is formed to be tubular. The substantially-closed-cross-sectional component may have the gap across the overall length of a butted part or may have the gap only in part of the butted part.

[0107] Here, assume points P1 and P2 that are separated from the two end parts E1 and E2 by 3 mm along the tubular part 1e in the circumferential direction, respectively. Assume that the intersection of a tangential line at the point P1 and a tangential line at the point P2 is denoted by O. An angle θ formed by the line OP1 and the line OP2 is preferably 30° or larger. An excessively small angle θ leads to little difference in cross section between the tubular part 1e and the U-shaped part, which may decrease the strength (flexural strength) of the tubular part after forming. The angle θ in a typical example is 150° or larger (e.g., 170° or larger). The angle θ is preferably 180° or smaller. An excessively large angle θ leads to the risk of an unstable forming.

(Second Embodiment)

[0108] In a second embodiment, description will be made about an example of the producing method according to the present invention and the die assembly used in the producing method. In the following embodiments, description will be made about an example of the case of producing a formed metal item that is constituted by only a tubular part. The producing method in the second embodiment includes step (i) and step (ii).

[0109] Step (i) is schematically illustrated in FIG. 2A and 2B. First, as illustrated in FIG. 2A, a metal plate (blank) 1a is disposed between a die 11 and a punch 12. The die assembly for U forming is configured by the die 11 and the punch 12. Next, as illustrated in FIG. 2B, the metal plate 1a is subjected to press forming to be formed into a U-shaped part 1b having a U-shaped cross section. As illustrated in FIG. 2C, the U-shaped part 1b includes two end parts E1 and E2.

[0110] In step (i), the size relation between a width W of a part to be made into a tubular part (the tubular part 1e) and the cross-section length LU of the U-shaped part 1b, of the metal plate, changes under various conditions (the shape of the tubular part, the conditions of step (i), etc.). These conditions can result in the case where the cross-section length LU is longer than the width W, the case where the cross-section length LU is shorter than the width W, and the case where both are equal to each other. In the producing method according to the present invention, in step (ii), it is important to form the tubular part in such a manner that the cross-section peripheral length LH of the tubular part is shorter than the cross-section length LU of the U-shaped part. Therefore, the relation between the width W and the cross-section length LU in step (i) has no special limitation.

[0111] FIG. 3A schematically illustrates a die assembly used in step (ii) of in the second embodiment. A die assembly 20 in the second embodiment is an example of the aforementioned die assembly (a). The die assembly 20 includes an upper die (first die) 21 and a lower die (second die) 22.

[0112] The upper die 21 includes a plate-shaped protruding part 23 for forming a slit. The upper die 21 includes a first upper die (first die member) 21a and a second upper die (second die member) 21b that are separable in a horizontal direction. The protruding part 23 is configured by a first protruding part 23a included in the first upper die 21a and a second protruding part 23b included in the second upper die 21b. The lower die 22 includes a first lower die (first die member) 22a and a second lower die (second die member) 22b that are separable in the horizontal direction.

[0113] The upper die 21 includes a first pressing surface 21p that is configured to press the outer peripheral surface of the U-shaped part 1b to form the cylindrical-shape portion 1d. The lower die 22 includes a first pressing surface 22p that is configured to press the outer peripheral surface of the U-shaped part 1 b to form the cylindrical-shape portion 1d (FIG. 3D). The protruding part 23 is a plate-shaped salient part, the length of which is equal to or longer than the slit 3 to be formed. The cross-section peripheral length of the entire pressing surface of the die assembly 20 (the first pressing surface 21p and the second pressing surface 22p) is shorter than the cross-section length LU of the U-shaped part 1b.

[0114] The next step (ii) will be described with reference to FIG. 3B to FIG. 3E. Step (ii) in the second embodiment is the aforementioned step of the example (A) and includes step (ii-1) and step (ii-2). By step (ii), the tubular part 1e with a slit can be formed from the U-shaped part 1b.

[0115] In step (ii) of the second embodiment, first, the U-shaped part 1b is disposed in the die assembly 20 as illustrated in FIG. 3B. Next, as illustrated in FIG. 3C and FIG. 3D, the U-shaped part 1b is deformed using the die assembly 20, with the end part E1 and the end part E2 of the U-shaped part 1b (see FIG. 2C) clamping the protruding part 23 (Step (ii-1)). Specifically, the upper die 21 and the lower die 22 are brought close to each other until both come into contact with each other, so that the outer peripheral surface of the U-shaped part 1b is pressed by the pressing surface of the die assembly 20. Step (ii-1) is executed in the state where the first upper die 21a and the second upper die 21b are separated in the horizontal direction, and the first lower die 22a and the second lower die 22b are separated in the horizontal direction. In this state, the upper die 21 and/or the lower die 22 is moved in the vertical direction, so that both are brought close to each other. By step (ii-1), the cylindrical-shape portion 1d is formed. In the step illustrated in FIG. 3C, the U-shaped part 1b is deformed into a U-shaped part 1c. At this point, two end parts of the U-shaped part 1c are butted against the protruding part 23 to stop, so that a gap is generated between the end parts. The gap serves as the slit 3 of the tubular part 1e. In the state illustrated in FIG. 3D, the end part E1 and the end part E2 face each other across the protruding part 23 (the protruding parts 23a and 23b).

[0116] By the producing method in the second embodiment, in the state illustrated in FIG. 3D, the cross-section length of the U-shaped part 1b and the cross-section peripheral length LT of the cylindrical-shape portion 1d may be made substantially equal to each other. This configuration can be implemented by adjusting the interval between the first upper die 21a and the second upper die 21b, and the interval between the first lower die 22a and the second lower die 22b. With this configuration, at the time of deforming the U-shaped part 1b by a large amount to form the cylindrical-shape portion 1d, it is possible to inhibit compressive force from acting in the circumferential direction. Therefore, it is possible to inhibit buckling or the like from occurring at the time of forming the cylindrical-shape portion 1d. Here, being substantially equal to each other means that the difference between both is less than 0.1% (e.g., less than 0.05%) of the length of the larger one.

[0117] Next, as illustrated in FIG. 3E, by pressing the outer peripheral surface of the cylindrical-shape portion 1d while the end parts E1 and E2 of the U-shaped part 1b are clamping the protruding part 23, the cross-section peripheral length LT of the cylindrical-shape portion 1d is shortened (Step (ii-2)). Specifically, by closing the divided die assembly 20, the cross-section peripheral length LT is shortened. More specifically, the first upper die 21a and the second upper die 21b are moved in the horizontal direction to come close to each other, and the first lower die 22a and the second lower die 22b are moved in the horizontal direction to come close to each other. In the example illustrated in FIG. 3E, the first upper die 21a and the second upper die 21b come into contact with each other, and the first lower die 22a and the second lower die 22b are brought close to each other until they come into contact with each other. That is, in the example illustrated in FIG. 3E, the pressing surface of the die assembly 20 in a completely closed state corresponds to the outer peripheral surface of the tubular part 1e. By shortening the cross-section peripheral length LT of the cylindrical-shape portion 1d in step (ii-2), it is possible to make the cross-section peripheral length LH of the tubular part 1e shorter than the cross-section length LU of the U-shaped part 1b. In this manner, a tubular part 1e (formed metal item) illustrated in FIG. 3F is obtained. The butted part 2 of the tubular part 1e is formed with the slit 3.

[0118] FIG. 3E illustrates the case where the die assembly is completely closed in a final phase of the forming. However, in the producing method according to the present invention, as long as the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b, the die assembly need not be completely closed in the final phase of the forming. By determining to what degree the die assembly is closed, the aforementioned compressibility C can be changed. By determining to what degree the die assembly 30 is opened in FIG. 3D, and by determining to what degree the die assembly 20 is closed in FIG. 3E, it is in some cases possible to deal with the case where the thickness or the physical properties of the metal plate 1a vary. Therefore, even in the case where the thickness or the physical properties of the metal plate 1a vary, it is in some cases possible to produce a desired tubular part 1e without changing the die assembly. Furthermore, in FIG. 3E, by determining to what degree the die assembly 20 is closed, it is also possible to change the width of the slit 3.

[0119] In the case of producing a tubular component by conventional UO forming, compressive stress acts on an inner circumferential side of the resultant tubular component, and tensile stress acts on an outer circumference side of the resultant tubular component. Therefore, spring back increases, which makes it difficult to control the spring back. In contrast, in the producing method according to the present invention, the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b. That is, in the producing method according to the present invention, the cylindrical-shape portion 1d is compressed in the circumferential direction, and the tubular part 1e is thereby obtained. As a result, in the tubular part 1e, compressive stress acts on both of the inner circumferential side and the outer circumference side. Consequently, the spring back is inhibited, and the slit 3 can be formed with precision.

[0120] In the producing method according to the present invention, by compressing the cylindrical-shape portion 1d in the circumferential direction, the tubular part 1e is formed. Therefore, in the tubular part 1e, compressive stress acts on both of the inner circumferential side and the outer circumference side. Furthermore, in the tubular part 1e, it is possible to reduce variations in the compressive stress in the circumferential direction. As a result, it is possible to reduce variations in hardness distribution in the thickness direction and to reduce variations in hardness distribution in the circumferential direction, of the tubular part 1e. Consequently, according to the present invention, it is possible to obtain a tubular part having a high fatigue strength.

[0121] In the producing method according to the second embodiment, the cylindrical-shape portion 1d is compressed by moving all of the die members surrounding the cylindrical-shape portion 1d relatively. Therefore, by the producing method and the die assembly in the second embodiment, it is possible to compress the cylindrical-shape portion 1d uniformly in the circumferential direction. Consequently, the spring back can be inhibited effectively, and it is possible to increase the shape precision of the tubular part even more.

(Third Embodiment)

[0122] In a third embodiment, description will be made about another example of the producing method according to the present invention and the die assembly used in the producing method. The producing method in the third embodiment includes step (i) and step (ii). Step (i) is the same as step (i) described in the second embodiment, and thus the redundant description thereof will be omitted.

[0123] FIG. 4A schematically illustrates a die assembly used in step (ii) in the third embodiment. A die assembly 30 in the third embodiment is an example of the aforementioned die assembly (b). The die assembly 30 includes an upper die (first die) 31 and a lower die (second die) 32.

[0124] The upper die 31 includes a plate-shaped protruding part 33 for forming the slit 3. The upper die 31 includes a body part 31a and a movable part 31b that is movable relatively to the body part 31a. The movable part 31b is disposed in a top part of a pressing surface 31ap of the body part 31a and includes the protruding part 33. The lower die 32 includes a body part 32a and a movable part 32b that is movable relatively to body part 32a. The movable part 32b is disposed in a bottom part of a pressing surface 32ap of the body part 32a. In the die assembly 30 in the third embodiment, both of the movable parts 31b and 32b are movable in a pressing direction (the vertical direction). The movable part 31b can be moved in the pressing direction together with the body part 31a. The movable part 32b can be moved in the pressing direction together with the body part 32a.

[0125] In the die assembly (b) according to the present invention, the body part and the movable part can be moved basically together in the pressing direction. In addition, in the die assembly (b) according to the present invention, end faces of the movable parts (the end faces facing a forming space) basically constitute parts of the pressing surface, and rolls or the like are not disposed therein. Furthermore, in the die assembly (b) according to the present invention, the movable parts are basically movable, with first and second body parts lying at a final position in the forming (a dead point).

[0126] The body part 31a and the body part 32a include the pressing surfaces 31ap and 32ap, respectively, the pressing surfaces 31ap and 32ap being configured to press the outer peripheral surface of the U-shaped part 1b to form the cylindrical-shape portion 1d. The movable parts 31b and 32b include pressing surfaces 31bp and 32bp, respectively, the pressing surfaces 31bp and 32bp being configured to press the outer peripheral surface of the U-shaped part 1b. The pressing surface 31ap and the pressing surface 31bp constitute the pressing surface 31p of the upper die 31. The pressing surface 32ap and the pressing surface 32bp constitute the pressing surface 32p of the lower die 32. In the example described in the third embodiment, the cross-section peripheral length of the entire pressing surface is longer than the cross-section peripheral length LH of the tubular part 1e. The cross-section peripheral length of the entire pressing surface may be substantially equal to the cross-section length LU of the U-shaped part 1b.

[0127] The next step (ii) will be described with reference to FIG. 4B to FIG. 4E. Step (ii) in the third embodiment is the aforementioned step of the example (B) and includes step (ii-1) and step (ii-2). By step (ii), the tubular part 1e with a slit can be formed from the U-shaped part 1b.

[0128] In step (ii) of the third embodiment, first, the U-shaped part 1b is disposed in the die assembly 20 as illustrated in FIG. 4B. Next, as illustrated in FIG. 4C and FIG. 4D, the U-shaped part 1b is deformed using the die assembly 30, while the end part E1 and the end part E2 of the U-shaped part 1b (see FIG. 2C) are clamping the protruding part 33 (Step (ii-1)). Specifically, the upper die 31 and the lower die 32 are brought close to each other until both come into contact with each other, so that the outer peripheral surface of the U-shaped part 1b is pressed by the pressing surface of the die assembly 30. Step (ii-1) is executed with the pressing surfaces 31bp and 32bp of the movable parts 31b and 32b not projecting from the pressing surfaces 31p and 32p of the body part. By step (ii-1), the cylindrical-shape portion 1d is formed. That is, in the example illustrated in FIG. 4D, the pressing surfaces 31p and 32p correspond to the outer peripheral surface of the cylindrical-shape portion 1d. In the step illustrated in FIG. 4C, the U-shaped part 1b is deformed into a U-shaped part 1c. At this point, two end parts of the U-shaped part 1c are butted against the protruding part 33 to stop, so that a gap is generated between the end parts. The gap serves as the slit 3 of the tubular part 1e. In the state illustrated in FIG. 4D, the end part E1 and the end part E2 face each other across the protruding part 33.

[0129] In the producing method in the third embodiment, the cross-section peripheral length of the entire pressing surface of the die assembly 30 may be made substantially equal to the cross-section length LU of the U-shaped part 1b. In this case, at the time of deforming the U-shaped part 1b by a large amount to form the cylindrical-shape portion 1d, it is possible to inhibit compressive force from acting in the circumferential direction. Therefore, it is possible to inhibit buckling or the like from occurring at the time of forming the cylindrical-shape portion 1d.

[0130] Next, as illustrated in FIG. 4E, by pressing the outer peripheral surface of the cylindrical-shape portion 1d while the end parts E1 and E2 of the U-shaped part 1b are clamping the protruding part 33, the cross-section peripheral length LT of the cylindrical-shape portion 1d is shortened (Step (ii-2)). Specifically, by causing the pressing surfaces of the movable parts 31b and 32b to project from the pressing surfaces of the body parts 31a and 32a, the outer peripheral surface of the cylindrical-shape portion 1d is pressed. In the third embodiment, the slit 3 and the positions facing the slit 3, of the cylindrical-shape portion 1d, are pressed vertically. By shortening the cross-section peripheral length LT of the cylindrical-shape portion 1d in step (ii-2), the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b. In this manner, a tubular part 1e (formed metal item) illustrated in FIG. 4F is obtained. The butted part 2 of the tubular part 1e is formed with the slit 3.

[0131] Also in the producing method in the third embodiment, by compressing the cylindrical-shape portion 1d in the circumferential direction, the tubular part 1e is formed. Therefore, as described in the second embodiment, the slit 3 can be formed with precision. In addition, in the producing method in the third embodiment, it is possible to change the aforementioned compressibility easily by changing the amount of movement of the movable parts. Therefore, even in the case where the thickness or the physical properties of the metal plate 1a vary, it is in some cases possible to produce a desired tubular part 1e without changing the die assembly. Furthermore, in the die assembly in the third embodiment, the protruding part 33 can be replaced by replacing the movable part 31b, which makes it easy to replace the protruding part 33.

[0132] In the producing method in the third embodiment, since the compression is performed by pressing the cylindrical-shape portion 1d with the movable parts, the cylindrical-shape portion 1d is compressed in the state where a contact area between the cylindrical-shape portion 1d and the die assembly 30 is small. In this case, compressive force exerted in the circumferential direction by the movable parts is likely to be exerted on the entire cylindrical-shape portion 1d. Therefore, by the producing method and the die assembly in the third embodiment, it is possible to compress the cylindrical-shape portion 1d more uniformly in the circumferential direction.

[0133] With reference to FIG. 14A to FIG. 14E, description will be made about an example of a producing device that can be used in step (ii) in the third embodiment. This producing device includes a first support table 141, a second support table 142, expansion/contraction mechanisms 141a, and expansion/contraction mechanisms 142a. On the first support table 141, the expansion/contraction mechanisms 141a and the movable part 31b are disposed. The expansion/contraction mechanisms 141a are expandable in the pressing direction and are configured to press the body part 31a. On the second support table 142, the expansion/contraction mechanisms 142a and the movable part 32b are disposed. The expansion/contraction mechanisms 142a are expandable in the pressing direction and are configured to support the body part 32a. The expansion/contraction mechanisms 141a and 142a have no special limitation, and each may be a gas cylinder, a hydraulic cylinder, a spring, or other mechanisms.

[0134] In step (ii) of the third embodiment, first, the U-shaped part 1b is disposed in the die assembly 30 as illustrated in FIG. 14A. Next, as illustrated in FIG. 14B and 14C, the first support table 141 and the second support table 142 are brought close to each other. The aforementioned step (ii-1) is thereby performed, and the cylindrical-shape portion 1d is obtained. Next, as illustrated in FIG. 14D, by causing the expansion/contraction mechanisms to contract, the first support table 141 and the second support table 142 are brought closer to each other. The pressing surfaces of the movable parts 31b and 32b are thereby caused to project from the pressing surfaces of the body parts 31a and 32a and press the outer peripheral surface of the cylindrical-shape portion 1d, as illustrated in FIG. 14D. In this manner, step (ii-2) is performed.

[0135] In the device illustrated in FIG. 14A, a mechanism to bring the first support table 141 and the second support table 142 close to each other (not illustrated), and the expansion/contraction mechanism 141a and the expansion/contraction mechanism 142a not in an expanding/contracting state correspond to the aforementioned the first movement mechanism of the producing device (b). In addition, a mechanism to bring the first support table 141 and the second support table 142 close to each other, and the expansion/contraction mechanism 141a and the expansion/contraction mechanism 142a in the expanding/contracting state correspond to the second movement mechanism. In this manner, in the die assemblies (a) and (b), the single constituting member may serve as the first movement mechanism and the second movement mechanism. These movement mechanisms may be implemented by using movement mechanisms of a well-known pressing device with the movement mechanisms adapted to the producing device according to the present invention.

(Fourth Embodiment)

[0136] In a fourth embodiment, description will be made about another example of the producing method according to the present invention and the die assembly used in the producing method. The producing method in the fourth embodiment includes step (i) and step (ii). Step (i) is the same as step (i) described in the second embodiment, and thus the redundant description thereof will be omitted.

[0137] FIG. 5A schematically illustrates a die assembly used in step (ii) in the fourth embodiment. A die assembly 30 in the fourth embodiment is an example of the aforementioned die assembly (b). The die assembly 30 includes an upper die (first die) 31 and a lower die (second die) 32.

[0138] The upper die 31 includes a plate-shaped protruding part 33 for forming the slit 3. The upper die 31 includes a body part 31a and two movable parts 31b that are movable relative to the body part 31a. The movable parts 31b are disposed in the lowermost part of the pressing surface of the body part 31a. The lower die 32 includes a body part 32a and two movable parts 32b that are movable relative to body part 32a. The movable parts 32b are disposed in the uppermost part of the pressing surface of the body part 32a. In the die assembly 30 in the fourth embodiment, both of the movable parts 32a and 32b are movable in the horizontal direction. The movable part 31b can be moved in the vertical direction (pressing direction) together with the body part 31a. Similarly, the movable part 32b can be moved in the vertical direction together with the body part 32a.

[0139] The body part 31a and the body part 32a include the pressing surfaces 31ap and 32ap, respectively, the pressing surfaces 31ap and 32ap being configured to press the outer peripheral surface of the U-shaped part 1b to form the cylindrical-shape portion 1d. The movable parts 31b and 32b include pressing surfaces 31bp and 32bp, respectively, the pressing surfaces 31bp and 32bp being configured to press the outer peripheral surface of the U-shaped part 1b. In the example described in the fourth embodiment, the cross-section peripheral length of the entire pressing surface is longer than the cross-section peripheral length LH of the tubular part 1c. The cross-section peripheral length of the entire pressing surface may be substantially equal to the cross-section length LU of the U-shaped part 1b.

[0140] The next step (ii) will be described with reference to FIG. 5B to FIG. 5E. Step (ii) in the fourth embodiment is the aforementioned step of the example (B) and includes step (ii-1) and step (ii-2). By step (ii), the tubular part 1e with a slit can be formed from the U-shaped part 1b.

[0141] In step (ii) of the fourth embodiment, first, the U-shaped part 1b is disposed in the die assembly 30 as illustrated in FIG. 5B. Next, as illustrated in FIG. 5C and FIG. 5D, the U-shaped part 1b is deformed using the die assembly 30, while the end part El and the end part E2 of the U-shaped part 1b (see FIG. 2C) are clamping the protruding part 33 (Step (ii-1)). Specifically, the upper die 31 and the lower die 32 are brought close to each other until both come into contact with each other, so that the outer peripheral surface of the U-shaped part 1b is pressed by the pressing surface of the die assembly 30. Step (ii-1) is executed with the pressing surfaces 31bp and 32bp of the movable parts not projecting from the pressing surfaces 31ap and 32ap of the body part. By step (ii-1), the cylindrical-shape portion 1d is formed. In the step illustrated in FIG. 5C, the U-shaped part 1b is deformed into a U-shaped part 1c. At this point, two end parts of the U-shaped part 1c are butted against the protruding part 33 to stop, so that a gap is generated between the end parts. The gap serves as the slit 3 of the tubular part 1e. In the state illustrated in FIG. 5D, the end part E1 and the end part E2 face each other across the protruding part 33.

[0142] In the producing method in the fourth embodiment, the cross-section peripheral length of the entire pressing surface of the die assembly 30 may be made substantially equal to the cross-section length LU of the U-shaped part 1b. In this case, at the time of deforming the U-shaped part 1b by a large amount to form the cylindrical-shape portion 1d, it is possible to inhibit compressive force from acting in the circumferential direction. Therefore, it is possible to inhibit buckling or the like from occurring at the time of forming the cylindrical-shape portion 1d.

[0143] Next, as illustrated in FIG. 5E, by pressing the outer peripheral surface of the cylindrical-shape portion 1d while the end parts E1 and E2 of the U-shaped part 1b are clamping the protruding part 33, the cross-section peripheral length LT of the cylindrical-shape portion 1d is shortened (Step (ii-2)). Specifically, by causing the pressing surfaces 31bp and 32bp of the movable parts 31b and 32b to project from the pressing surfaces 31ap and 32ap of the body parts 31a and 32b, the outer peripheral surface of the cylindrical-shape portion 1d is pressed. In the fourth embodiment, the side faces of the cylindrical-shape portion 1d are pressed from right and left. By shortening the cross-section peripheral length LT of the cylindrical-shape portion 1d in step (ii-2), the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b. In this manner, a tubular part 1e (formed metal item) illustrated in FIG. 5F is obtained. The butted part 2 of the tubular part 1e is formed with the slit 3.

[0144] Also in the producing method in the fourth embodiment, by compressing the cylindrical-shape portion 1d in the circumferential direction, the tubular part 1e is formed. Therefore, as described in the second and third embodiments, the slit 3 can be formed with precision. In addition, in the producing method in the third and fourth embodiments, it is possible to change the aforementioned compressibility easily by changing the amount of movement of the movable parts. Therefore, even in the case where the thickness or the physical properties of the metal plate 1a slightly vary, it is in some cases possible to produce a desired tubular part 1e without changing the die assembly.

[0145] With reference to FIG. 15A to FIG. 15E, description will be made about an example of a producing device that can be used in step (ii) in the fourth embodiment. This producing device includes a first support table 151, two expansion/contraction mechanisms 141a, two shafts 153, and two cam units 154. The expansion/contraction mechanisms 141a and the shafts 153 are disposed on the first support table 151. The expansion/contraction mechanisms 141a are expandable in the pressing direction and are configured to press the body part 31a.

[0146] In step (ii) of the fourth embodiment, first, the U-shaped part 1b is disposed in the die assembly 30 as illustrated in FIG. 15A. Next, as illustrated in FIGS. 15B and 15C, the first support table 151 is pressed down. The aforementioned step (ii-1) is thereby performed, and the cylindrical-shape portion 1d is obtained. Next, as illustrated in FIG. 15D, by causing the expansion/contraction mechanisms to contract, the first support table 151 is further pressed down. At this point, the two cam units 154 are moved by the two shafts 153, and the movable parts 31b and 32b are moved by the cam units 154. The pressing surfaces of the movable parts 31b and 32b are thereby caused to project from the pressing surfaces of the body parts 31a and 32a and press the outer peripheral surface of the cylindrical-shape portion 1d, as illustrated in FIG. 15D. In this manner, step (ii-2) is performed.

[0147] In the device illustrated in FIG. 15A, a mechanism to move the first support table 151 downward (not illustrated) and the expansion/contraction mechanisms 141a not in an expanding/contracting state correspond to the aforementioned the first movement mechanism of the producing device (b). In addition, a mechanism to move the first support table 151 downward, the shafts 153, and the cam units 154 constitute the second movement mechanism. These movement mechanisms may be implemented by using movement mechanisms of a well-known pressing device with the movement mechanisms adapted to the producing device according to the present invention.

(Fifth Embodiment)

[0148] In a fifth embodiment, description will be made about another example of the producing method according to the present invention and the die assembly used in the producing method. The producing method in the fifth embodiment includes step (i) and step (ii). Step (i) is the same as step (i) described in the second embodiment, and thus the redundant description thereof will be omitted.

[0149] FIG. 6A schematically illustrates a die assembly used in step (ii) in the fifth embodiment. A die assembly 20 in the fifth embodiment includes an upper die (first die) 21 and a lower die (second die) 22.

[0150] The upper die 21 includes a plate-shaped protruding part 23 for forming a slit 3. The first upper die 21 and the second lower die 22 include pressing surfaces 21p and 22p, respectively, the pressing surfaces 21p and 22p being configured to press the outer peripheral surface of the U-shaped part 1b to form the cylindrical-shape portion 1d. In the die assembly 20 in the fifth embodiment, the cross-section peripheral length of the entire pressing surface is shorter than the cross-section length LU of the U-shaped part 1b. By deforming the U-shaped part 1b using this die assembly 20, it is possible to make the cross-section peripheral length LH of the tubular part 1e shorter than the cross-section length LU of the U-shaped part 1b.

[0151] The next step (ii) will be described with reference to FIG. 6B to FIG. 6E. Step (ii) in the fifth embodiment is the aforementioned step of the example (C). In step (ii) of the fifth embodiment, first, the U-shaped part 1b is disposed in the die assembly 20 as illustrated in FIG. 6B. Next, as illustrated in FIG. 6C and FIG. 6D, the cylindrical-shape portion 1d is formed by deforming the U-shaped part 1b using the die assembly 20 in such a manner that the end part E1 and the end part E2 of the U-shaped part 1b clamp the protruding part 23. Specifically, the upper die 21 and the lower die 22 are brought close to each other, so that the outer peripheral surface of the U-shaped part 1b is pressed by the pressing surface of the die assembly 20. In the step illustrated in FIG. 6C, the U-shaped part 1b is deformed into a U-shaped part 1c. At this point, two end parts of the U-shaped part 1c are butted against the protruding part 23 to stop, so that a gap is generated between the end parts. The gap serves as the slit 3 of the tubular part 1e.

[0152] FIG. 6D illustrates an example of the state where the cross-section peripheral length LT of the cylindrical-shape portion 1d is substantially equal to cross-section length LU of the U-shaped part 1b. Since the cross-section peripheral length of the pressing surface of the die assembly 20 is shorter than the cross-section length LU of the U-shaped part 1b, the upper die 21 and the lower die 22 are not in contact with each other in the stage illustrated in FIG. 6D. That is, in the stage illustrated in FIG. 6D, the die assembly 20 is not closed.

[0153] The upper die 21 and the lower die 22 are brought closer to each other from the stage FIG. 6D, so that die assembly 20 is closed as illustrated in FIG. 6E. For example, by moving the upper die 21 to a bottom dead center, the upper die 21 and the lower die 22 are brought into contact with each other. In this process, the outer peripheral surface of the cylindrical-shape portion 1d is pressed by the pressing surface of the die assembly 20 while the two end part E1 and end part E2 are clamping the protruding part 23. A tubular part 1e that includes a slit 3 in its butted part 2 illustrated in FIG. 6F is thereby formed. The cross-section peripheral length of the pressing surface of the die assembly 20 is shorter than the cross-section length LU of the U-shaped part 1b. Therefore, the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b. That is, in the step illustrated in FIG. 6E, the cylindrical-shape portion 1d is compressed in the circumferential direction to be made into the tubular part 1e.

[0154] In the case where the cross-section peripheral length LH of the tubular part 1e is made shorter than the cross-section length LU of the U-shaped part 1b before the die assembly 20 is completely closed, the forming can be terminated before the die assembly 20 is completely closed. In this case, by adjusting to what degree the upper die 21 and the second lower die 22 are brought close to each other, it is possible to adjust the compressibility of the tubular part 1e.

[0155] Also in the producing method in the fifth embodiment, by compressing the cylindrical-shape portion 1d in the circumferential direction, the tubular part 1e is formed. Therefore, as described in the second embodiment, the slit 3 can be formed with precision.

[0156] In the die assembly according to the present invention, the protruding part may be replaceable. FIG. 7 illustrates an example of a die assembly that includes a replaceable protruding part. A die assembly 20 illustrated in FIG. 7 includes an upper die (first die) 21 and a lower die (second die) 22. The upper die 21 includes a part 24 that includes a protruding part 23. The part 24 is inserted into a hole 25 of the upper die 21 and is made replaceable. The protruding part 23 is a part with which the two end parts (end parts E1 and E2) of the U-shaped part are to come into contact and is likely to be abraded or deformed. Therefore, the protruding part 23 is preferably made replaceable. Furthermore, by replacing the protruding part 23, the aforementioned effect is obtained.

[0157] From another viewpoint, the present invention provides a method for producing a substantially-closed-cross-sectional component that includes a gap in its butted part. Hereinafter, the producing method in accordance with this viewpoint is referred to as a producing method (S). The producing method (S) includes a first step and a second step. In the first step, a metal plate is formed to have a U shape, whereby a U-formed item is obtained.

This U-formed item corresponds to a formed item that includes a U-shaped part formed by the aforementioned step (i). In the second step, the U-formed item is formed to have a substantially-closed cross section, using a die assembly, and the cross-section peripheral length of the substantially-closed-cross-sectional component is made shorter than the cross-section peripheral length of the U-formed item. The die assembly in use includes a protruding part corresponding to the butted part of the substantially-closed-cross-sectional component and includes a mechanism that is capable of adjusting the cross-section peripheral length of the substantially-closed-cross-sectional component. Examples of this die assembly include the aforementioned die assemblies (a), (b), and (c). The first step and the second step correspond to the aforementioned steps (i) and (ii), respectively. The substantially-closed-cross-sectional component including the gap corresponds to the aforementioned formed metal item that includes a tubular part with a slit. The substantially-closed-cross-sectional component refers to a component having a substantially-closed cross section. The substantially-closed cross section refers to a cross section in which a gap is present between two butted end parts of a metal plate that is formed to be tubular. The substantially-closed-cross-sectional component may have the gap across the overall length of a butted part or may have the gap only in part of the butted part.

[0158] In the producing method (S), the cross-section peripheral length of the die assembly may be shorter than the cross-section peripheral length of the U-formed item. Here, the cross-section peripheral length of a die assembly refers to the cross-section peripheral length of the die assembly when the die assembly is completely closed. By making the cross-section peripheral length of the die assembly when the die assembly is completely closed shorter than the cross-section peripheral length of the U-formed item, it is possible to make the cross-section peripheral length of the substantially-closed-cross-sectional component shorter than the cross-section peripheral length of the U-formed item. The die assembly having this configuration corresponds to the aforementioned die assemblies (a) and (c).

[0159] In the producing method (S), the die assembly may include an upper die that includes the protruding part, and a lower die, and at least one of the upper die and the lower die may include a body part and a movable part. The die assembly having this configuration corresponds to the aforementioned die assembly (b).

[0160] From another viewpoint, the present invention provides a die assembly for forming a U-formed item to have a substantially-closed cross section so as to produce a substantially-closed-cross-sectional component that includes a gap in its butted part. Hereinafter, this die assembly is referred to as a die assembly (T1). The die assembly (T1) includes an upper die and a lower die that include a protruding part corresponding to the butted part of the substantially-closed-cross-sectional component. The die assembly (T1) includes a mechanism that is capable of adjusting the cross-section peripheral length of the substantially-closed-cross-sectional component. In addition, at least one of the upper die and the lower die is divided into a plurality of pieces. The die assembly (T1) corresponds to the aforementioned die assembly (a). In the die assembly (T1), the protruding part of the upper die may be divided. An example of the die assembly having this configuration is the die assembly 20 illustrated in FIG. 3A.

[0161] From another viewpoint, the present invention provides another die assembly for forming a U-formed item to have a substantially-closed cross section so as to produce a substantially-closed-cross-sectional component that includes a gap in its butted part. Hereinafter, this die assembly is referred to as a die assembly (T2). The die assembly (T2) includes an upper die and a lower die that include a protruding part corresponding to the butted part of the substantially-closed-cross-sectional component. The die assembly (T2) includes a mechanism that is capable of adjusting the cross-section peripheral length of the substantially-closed-cross-sectional component. In addition, at least one of the upper die and the lower die includes a body part and a movable part. The die assembly (T2) corresponds to the aforementioned die assembly (b).

[0162] In the above die assemblies (T1) and (T2), the protruding part may be made replaceable.

EXAMPLES

[0163] Hereinafter, the present invention will be specifically described by way of Examples.

[Example 1]

[0164] In Example 1, a U-formed item (U-shaped part) was formed by the producing method illustrated in FIGS. 2A to 2B, and further, a tubular member (formed metal item) with a slit was fabricated by the producing method illustrated in FIGS. 3B to 3E. As a metal plate (blank), a hot-rolled steel plate having a tensile strength (TS) of 590 MPa and a thickness of 2.3 mm was used. The tubular member was made to have an outer diameter of 50 mm and a length of 200 mm. The width of the protruding part of the upper die was set at 5 mm.

[Example 2]

[0165] In Example 2, a tubular member with a slit was fabricated using the metal plate as in Example 1 by the producing method illustrated in FIGS. 2A to 2B and FIGS. 4B to 4E. The dimensions of the tubular member and of the width of the protruding part of the upper die were set as in Example 1.

[Example 3]

[0166] In Example 3, a U-formed item (U-shaped part) was formed using the metal plate as in Example 1 by the producing method illustrated in FIGS. 2A to 2B, and further, a tubular member with a slit was fabricated by the producing method illustrated in FIGS. 5B to 5E. The dimensions of the tubular member and of the width of the protruding part of the upper die were set as in Example 1.

[Example 4]

[0167] In Example 4, a U-formed item (U-shaped part) was formed using the metal plate as in Example 1 by the producing method illustrated in FIGS. 2A to 2B, and further, a tubular member with a slit was fabricated by the producing method illustrated in FIGS. 6B to 6E. The dimensions of the tubular member and of the width of the protruding part of the upper die were set as in Example 1.

[Comparative Example 1]

[0168] In Comparative Example 1, U forming was performed using the metal plate as in Example 1 by the method illustrated in FIGS. 2A to 2B. Thereafter, as illustrated in FIGS. 10A to 10B, a tubular member 50a was fabricated by performing O forming using a die assembly (an upper die 51 and a lower die 52) that includes no protruding part. The cross-section peripheral length the pressing surface of the die assembly when the die assembly is completely closed was made equal to the cross-section length of the U-formed item (U-shaped part).

[Comparative Example 2]

[0169] U forming was performed using the metal plate as in Example 1 by the method illustrated in FIGS. 2A to 2B. Thereafter, as illustrated in FIGS. 11A to 11B, O forming was performed using a die assembly (an upper die 51 and a lower die 52) that includes no protruding part and includes a core 53. In such a manner, a tubular member 50b with a slit was fabricated. The cross-section peripheral length of the pressing surface of the die assembly when the die assembly is completely closed was made longer than the cross-section length of the U-formed item (U-shaped part).

[0170] In Examples 1 to 4, the compressibility C was set at 0.99%. In Comparative Examples 1 and 2, the compressibility C was set at about 0%.

[Evaluation]

[0171] For the tubular members in Example 1, Comparative Example 1 and Comparative Example 2, strain distributions in the thickness direction in their cross sections were measured. The results of the measurement are illustrated in FIG. 12A. The ordinate of FIG. 12A represents absolute value of strain. As illustrated in FIG. 12A, the tubular member in Example 1 had a large absolute value of strain in comparison with the tubular members in Comparative Examples 1 and 2 and had a narrow strain distribution in the thickness direction. These results suggest that, in the tubular member in Example 1, compressive stress acted over the entire tubular member substantially equally in the thickness direction.

[0172] Furthermore, for the tubular members in Examples 2 to 4 and Comparative Example 2, strain distributions in the circumferential direction in their cross sections were measured. The results of the measurement are illustrated in FIG. 12B. The ordinate of FIG. 12B represents absolute value of strain. In FIG. 12B, it is assumed that the bottom part of the cross section of a tubular member is at 0°, and the butted part thereof is at 180°. As illustrated in FIG. 12B, the tubular members in Examples 2 to 4 had large absolute values of strain in comparison with the tubular member in Comparative Example 2. These results suggest that, in the tubular members in Examples 2 to 4, large compressive stresses were generated over the entire tubular members in the circumferential direction.

[0173] As illustrated in FIG. 12A and FIG. 12B, by the producing methods in Examples 1 to 4, it is possible to equalize compressive stress acting on the tubular member in the thickness direction and the circumferential direction even more. Therefore, by the producing methods in Examples 1 to 4, it is possible to suppress spring back and to produce a formed metal item having a high shape precision.

[0174] For the tubular members in Example 1, Comparative Example 1 and Comparative Example 2, distributions of Vickers hardness were calculated by means of the results of simulations by the finite element method (FEM). From the distributions, the variation S in Vickers hardness at the aforementioned first position in the thickness direction was calculated. Similarly, the variations S of Vickers hardness in the thickness direction were calculated also at the second and third positions. The results thereof were that, in tubular member in Example 1, the variation S was about 0.1 at all of the first, second, and third positions. That is, in the tubular member in Example 1, the average value of the variations S in the circumferential direction was about 0.1. This result suggests that, in the tubular member in Example 1, the variations in Vickers hardness were small in both of the thickness direction and the circumferential direction. Meanwhile, in Comparative Examples 1 and 2, the variations S were about 0.7 at all of the first, second, and third positions. That is, in the tubular members in Comparative Examples 1 and 2, the average values of the variations S in the circumferential direction were about 0.7.

[0175] FIG. 13 is a graph illustrating relation between the average value of variations S in the circumferential direction and the rate of reduction of uniaxial compressive strength. The graph illustrated in FIG. 13 is a graph obtained by assuming a plurality of round tubes in each of which the average value of variations S in the circumferential direction is a given value, and simulating the results of a uniaxial compression test conducted on the plurality of round tubes. The ordinate of the graph illustrated in FIG. 13 represents the rate of reduction of uniaxial compressive strength with respect to the average value of variations S of a round tube in the circumferential direction being zero. Specifically, a simulation of the uniaxial compression test was conducted on the round tubes in question, and the results of calculating the rate of reductions (%) of the uniaxial compressive strengths of other round tubes with reference to the uniaxial compressive strength at that point are illustrated in the ordinate of the graph of FIG. 13.

[0176] For reference purposed, FIG. 13 illustrates two dotted lines that represent the tendencies of changes in rate of reduction of uniaxial compressive strength. As illustrated in FIG. 13, when the average value of the variations S in the circumferential direction is 0.4 or larger, the rate of reduction of uniaxial compressive strength significantly increased. On the other hand, when the average value of the variations S in the circumferential direction is smaller than 0.4, the rate of reduction of uniaxial compressive strength was low. The results illustrated in FIG. 13 suggest that it is important to set the average value of the variations S in the circumferential direction at less than 0.4.

[0177] Conventional O forming (the O forming in Comparative Examples 1 and 2) that does not involve compressing a metal plate in the circumferential direction results in a large spring back, which makes it difficult to form a slit with precision. In contrast, by the producing method according to the present invention, it is possible to form the breadth of a slit with precision. In addition, the conventional O forming is simple bending, which thus leads to a small work hardening in a thickness center, resulting in a low fatigue strength of the resultant formed item. In contrast, by the producing method according to the present invention, a formed metal item having a high fatigue strength is obtained. In addition, by a conventional method for producing a tubular member with a slit, it is in some cases necessary to make a metal plate tubular after bending the metal plate gradually or to make a metal plate tubular after drawing the metal plate. In comparison with such a conventional producing method, according to the present invention, it is possible to reduce the number of steps, which consequently enables cost reduction.

INDUSTRIAL APPLICABILITY

[0178] The present invention is available to a formed metal item that includes a tubular part with a slit, and a method for producing the formed metal item. Furthermore, the present invention is available to a producing device for producing the formed item, and a die assembly used in the producing device.

REFERENCE SIGNS LIST

[0179]

1	formed metal item
1a	metal plate
1b, 1c	U-shaped part
1d	cylindrical-shape portion
1e	tubular part
2	butted part
3	slit (gap)
11	die
12	punch
20, 30	die assembly
21, 31	upper die
21a	first upper die
21b	second upper die
22, 32	lower die
22a	first lower die
22b	second lower die
23, 33	protruding part
23a	first protruding part
23b	second protruding part
31a, 32a	body part
31b, 32b	movable part
E1, E2	end part

Claims

1. A producing method for producing a formed metal item (1) that includes a tubular part (1e) with a slit (3), the producing method comprising:

    (i) a step of forming a U-shaped part (1b, 1c) having a U-shaped cross section by deforming a metal plate (1a); and
    (ii) a step of forming the tubular part (1e) with the slit (3) by deforming the U-shaped part (1b, 1c) using a die assembly (20, 30) provided with a protruding part (23, 33) in such a manner that two end parts (E1, E2) of the U-shaped part (1b, 1c) clamp the protruding part (23, 33), wherein

    in the step (ii), the cross-section peripheral length LH of the tubular part (1e) is made shorter than the cross-section length LU of the U-shaped part (1b, 1c) and
    the step (ii) includes:

    (ii-1) a step of forming a cylindrical-shape portion (1d) by deforming the U-shaped part (1b, 1c) using the die assembly (20, 30) in such a manner that the two end parts (E1, E2) of the U-shaped part (1b, 1c) clamp the protruding part (23, 33), the cylindrical-shape portion (1d) being to be the tubular part; and
    (ii-2) a step of pressing an outer peripheral surface of the cylindrical-shape portion (1d) while the two end parts (E1, E2) are clamping the protruding part (23, 33), whereby the cross-section peripheral length LT of the cylindrical-shape por-

tion (1d) is shortened.

2. The producing method according to claim 1, wherein the cross-section length LU of the U-shaped part (1b, 1c) and the cross-section peripheral length LH of the tubular part (1e) satisfy an expression of $0.2 \leq 100 \times (LU - LH) / LU < 1$.

3. The producing method according to claim 1 or 2, wherein
the die assembly (20) includes a first die (21) including the protruding part (23), and includes a second die (22),
the first and second dies include first and second pressing surface, respectively, the first and second pressing surface being configured to deform the U-shaped part (1b, 1c) to form the cylindrical-shape portion (1d),
at least one die selected from the first die (21) and the second die (22) is separable into a plurality of die members (21a, 21b, 22a, 22b),
in the step (ii-1), the cylindrical-shape portion (1e) is formed by deforming the U-shaped part (1b, 1c) using the die assembly (20) while the plurality of die members (21a, 21b, 22a, 22b) are separated, and
in the step (ii-2), the outer peripheral surface of the cylindrical-shape portion is pressed by bringing the plurality of die members (21a, 21b, 22a, 22b) close to each other, whereby the cross-section peripheral length LT of the cylindrical-shape portion (1e) is shortened.

4. The producing method according to any one of claims 1 to 3, wherein
the die assembly (20, 30) includes a pressing surface that corresponds to an outer peripheral surface of the tubular part (1e), and
a cross-section peripheral length of the pressing surface is shorter than the cross-section length LU of the U-shaped part (1b, 1c).

5. The producing method according to claim 1 or 2, wherein
the die assembly (30) includes a first die (31) including the protruding part, and includes a second die (33),
the first and second dies include first and second pressing surface, respectively, the first and second pressing surface being configured to deform the U-shaped part (1b, 1c) to form the cylindrical-shape portion (1d),
at least one die selected from the first die and the second die includes a body part (31a, 32a) and a movable part (31b, 32b) that is movable relative to the body part (31a, 32a),
in the step (ii-1), the cylindrical-shape portion (1e) is formed by deforming the U-shaped part (1b, 1c) using the die assembly (30) while a pressing surface of the movable part (31b, 32b) does not project from a pressing surface of the body part (31a, 32a), and
in the step (ii-2), the outer peripheral surface of the cylindrical-shape portion is pressed by causing the pressing surface of the movable part (31b, 32b) to project from the pressing surface of the body part (31a, 32a), whereby the cross-section peripheral length LT of the cylindrical-shape portion (1e) is shortened.

6. A formed metal item (1) that includes a tubular part (1e) with a slit (3), wherein
when a variation S in Vickers hardness in a thickness direction of a cross section of the tubular part (1e) is expressed by a following expression, an average value of variations S in a circumferential direction is less than 0.4,

$$S = (Bmax - Bmin) / Bmax$$

where Bmin is a minimum value of Vickers hardnesses in a thickness direction of the cross section, and Bmax is a maximum value of Vickers hardnesses in the thickness direction of the cross section.

7. A die assembly (20, 30) for producing a formed metal item (1) that includes a tubular part (1e) with a slit (3), the die assembly (20, 30) comprising
a first die (21, 31) that includes a protruding part (23, 33) for forming the slit (3), and a second die (22, 32), wherein
the first and second dies include first and second pressing surfaces, respectively, the first and second pressing surfaces being configured to deform a U-shaped part (1b, 1c) having a U-shaped cross section in such a manner that two end parts (E1, E2) of the U-shaped part (1b, 1c) clamp the protruding part (22, 32) to form a cylindrical-shape portion (1d) with a gap, the gap being to be the slit (3), and
the die assembly (20, 30) is configured to press an outer peripheral surface of the cylindrical-shape portion (1d) while the two end parts (E1, E2) are clamping the protruding part (23, 33) so that a cross-section peripheral length of the cylindrical-shape portion (1d) is shortened.

8. The die assembly (20) according to claim 7, wherein at least one die selected from the first die and the second die is separable into a plurality of die members (21a, 21b, 22a, 22b).

9. The die assembly (20) according to claim 8, wherein the first die (21) is separable into a first die member (21a) and a second die member (21b), and
the protruding part (23) is configured by a first protruding part (23a) included in the first die member

(21a) and a second protruding part (23b) included in the second die member (21b).

10. The die assembly (30) according to claim 7, wherein at least one die selected from the first die (31) and the second die (32) includes a body part (31a, 32a) and a movable part (31b, 32b) that is movable relative to the body part (31a, 32a).

11. The die assembly (20, 30) according to any one of claims 7 to 10, wherein the protruding part (23, 33) is replaceable.

12. A producing device for producing a formed metal item (1) that includes a tubular part (1e) with a slit (3), the producing device comprising:
the die assembly (20, 30) according to claim 7 and a movement mechanism for moving the die assembly.

13. The producing device according to claim 12, wherein at least one die selected from the first die (21) and the second die (22) is separable into a plurality of die members (21a, 21b, 22a, 22b), and
the movement mechanism includes:

a first movement mechanism to bring the first die (21) and the second dies (22) close to each other while the plurality of die members (21a, 21b, 22a, 22b) are separated; and
a second movement mechanism to bring the plurality of die members (21a, 21b, 22a, 22b) being separated close to each other.

14. The producing device according to claim 12, wherein at least one die selected from the first die (31) and the second die (32) includes a body part (31a, 32a) and a moveable part (31b, 32b) that is movable relative to the body part (31a, 32a), and
the movement mechanism includes:

a first movement mechanism to bring the first die (31) and the second die (32) close to each other, while the movable part (31b, 32b) is not projecting from the first and second pressing surfaces; and
a second movement mechanism to move the movable part (31b, 32b) so that the movable part (31b, 32b) projects from the pressing surface.

Patentansprüche

1. Herstellungsverfahren zur Herstellung eines geformten Metallgegenstands (1), der ein rohrförmiges Teil (1e) mit einem Schlitz (3) umfasst, wobei das Herstellungsverfahren Folgendes umfasst:

(i) einen Schritt zum Bilden eines U-förmigen Teils (1b, 1c) mit einem U-förmigen Querschnitt durch Verformen einer Metallplatte (1a); und
(ii) einen Schritt des Formens des rohrförmigen Teils (1e) mit dem Schlitz (3) durch Verformen des U-förmigen Teils (1b, 1c) unter Verwendung einer Matrizenanordnung (20, 30), die mit einem hervorstehenden Teil (23, 33) versehen ist, so dass zwei Endteile (E1, E2) des U-förmigen Teils (1b, 1c) das hervorstehende Teil (23, 33) festklemmen, wobei

in dem Schritt (ii) die Querschnittsumfangslänge LH des rohrförmigen Teils (1e) kürzer gemacht wird als die Querschnittslänge LU des U-förmigen Teils (1b, 1c) und
der Schritt (ii) Folgendes umfasst:

(ii-1) einen Schritt des Bildens eines zylindrisch geformten Abschnitts (1d) durch Verformen des U-förmigen Teils (1b, 1c) unter Verwendung der Matrizenanordnung (20, 30), so dass die beiden Endteile (E1, E2) des U-förmigen Teils (1b, 1c) das hervorstehende Teil (23, 33) festklemmen, wobei der zylindrisch geformte Abschnitt (1d) der rohrförmige Teil werden soll; und
(ii-2) einen Schritt des Pressens einer äußeren Umfangsfläche des zylindrisch geformten Abschnitts (1d), während die zwei Endteile (E1, E2) den hervorstehenden Teil (23, 33) festklemmen; wobei die Querschnittsumfangslänge LT des zylindrisch geformten Abschnitts (1d) verkürzt wird.

2. Herstellungsverfahren nach Anspruch 1, wobei die Querschnittslänge LU des U-förmigen Teils (1b, 1c) und die Querschnittsumfangslänge LH des rohrförmigen Teils (le) den Ausdruck $0{,}2 \leq 100 \times (LU - LH) / LU < 1$ erfüllen.

3. Herstellungsverfahren nach Anspruch 1 oder 2, wobei
die Matrizenanordnung (20) eine erste Matrize (21) mit dem hervorstehenden Teil (23) und eine zweite Matrize (22) umfasst,
die erste und die zweite Matrize eine erste bzw. eine zweite Pressfläche umfassen, die erste und die zweite Druckfläche so konfiguriert sind, dass sie das U-förmige Teil (1b, 1c) verformen, um das zylindrische Teil (1d) zu bilden,
mindestens eine aus der ersten Matrize (21) und der zweiten Matrize (22) ausgewählte Matrize in eine Vielzahl von Matrizenelementen (21a, 21b, 22a, 22b) trennbar ist,
in Schritt (ii-1) der zylindrisch geformte Abschnitt (le) durch Verformen des U-förmigen Teils (1b, 1c) unter Verwendung der Matrizenanordnung (20) gebildet wird, während die Vielzahl der Matrizenelemente

(21a, 21b, 22a, 22b) getrennt sind, und
in Schritt (ii-2) die äußere Umfangsfläche des zylindrisch geformten Abschnitts gedrückt wird, indem die Vielzahl von Matrizenelementen (21a, 21b, 22a, 22b) nahe beieinander gebracht werden; wobei die Querschnittsumfangslänge LT des zylindrisch geformten Abschnitts (1e) verkürzt wird.

4. Herstellungsverfahren nach einem der Ansprüche 1 bis 3, wobei
die Matrizenanordnung (20, 30) eine Pressfläche umfasst, die einer äußeren Umfangsfläche des rohrförmigen Teils (le) entspricht, und
eine Querschnittsumfangslänge der Pressfläche kürzer ist als die Querschnittslänge LU des U-förmigen Teils (1b, 1c).

5. Herstellungsverfahren nach Anspruch 1 oder 2, wobei
die Matrizenanordnung (30) eine erste Matrize (31) mit dem hervorstehenden Teil umfasst und eine zweite Matrize (33) umfasst,
die erste und die zweite Matrize eine erste bzw. eine zweite Pressfläche umfassen, wobei die erste und die zweite Pressfläche so konfiguriert sind, dass sie das U-förmige Teil (1b, 1c) verformen, um den zylindrisch geformten Abschnitt (1d) zu bilden,
mindestens eine Matrize, die aus der ersten Matrize und der zweiten Matrize ausgewählt ist, einen Körperteil (31a, 32a) und einen beweglichen Teil (31b, 32b), der relativ zu dem Körperteil (31a, 32a) beweglich ist, umfasst,
in Schritt (ii-1) der zylindrisch geformte Abschnitt (le) durch Verformen des U-förmigen Teils (1b, 1c) unter Verwendung der Matrizenanordnung (30) gebildet wird, während eine Druckfläche des beweglichen Teils (31b, 32b) nicht von einer Druckfläche des Körperteils (31a, 32a) vorsteht, und
in Schritt (ii-2) die äußere Umfangsfläche des zylindrisch geformten Abschnitts gedrückt wird, indem bewirkt wird, dass die Druckfläche des beweglichen Teils (31b, 32b) von der Druckfläche des Körperteils (31a, 32a) vorsteht; wodurch die Querschnittsumfangslänge LT des zylindrisch geformten Abschnitts (le) verkürzt wird.

6. Geformter Metallgegenstand (1), der ein rohrförmiges Teil (le) mit einem Schlitz (3) umfasst, wobei wenn eine Variation S der Vickers-Härte in einer Dickenrichtung eines Querschnitts des rohrförmigen Teils (le) durch einen folgenden Ausdruck ausgedrückt wird, ein Durchschnittswert der Variationen S in einer Umfangsrichtung weniger als 0,4 beträgt,

$$S = (Bmax - Bmin) / Bmax$$

wobei Bmin ein Minimalwert der Vickers-Härten in einer Dickenrichtung des Querschnitts ist und Bmax ein Maximalwert der Vickers-Härten in der Dickenrichtung des Querschnitts ist.

7. Matrizenanordnung (20, 30) zur Herstellung eines geformten Metallgegenstands (1), der ein rohrförmiges Teil (1e) mit einem Schlitz (3) umfasst, wobei die Matrizenanordnung (20, 30) Folgendes umfasst:

eine erste Matrize (21, 31) mit einem hervorstehenden Teil (23, 33) zum Bilden des Schlitzes (3) und eine zweite Matrize (22, 32), wobei
die erste und die zweite Matrize eine erste bzw. eine zweite Pressfläche umfassen, wobei die erste und die zweite Pressfläche so konfiguriert sind, dass sie ein U-förmiges Teil (1b, 1c) mit einem U-förmigen Querschnitt verformen, so dass zwei Endteile (E1, E2) des U-förmigen Teils (1b, 1c) den vorstehenden Teil (22, 32) festklemmen, um einen zylindrisch geformten Abschnitt (1d) mit einem Spalt zu bilden, wobei der Spalt der Schlitz (3) sein wird, und
die Matrizenanordnung (20, 30) dafür konfiguriert ist, eine äußere Umfangsfläche des zylindrisch geformten Abschnitts (1d) zu drücken, während die zwei Endteile (E1, E2) den hervorstehenden Teil (23, 33) klemmen, so dass eine Querschnittsumfangslänge des zylindrisch geformten Abschnitts (1d) verkürzt wird.

8. Matrizenanordnung (20) nach Anspruch 7, wobei mindestens eine aus der ersten Matrize und der zweiten Matrize ausgewählte Matrize in mehrere Matrizenelemente (21a, 21b, 22a, 22b) trennbar ist.

9. Matrizenanordnung (20) nach Anspruch 8, wobei die erste Matrize (21) in ein erstes Matrizenelement (21a) und ein zweites Matrizenelement (21b) trennbar ist, und
das hervorstehende Teil (23) durch ein erstes hervorstehendes Teil (23a), das in dem ersten Matrizenelement (21a) enthalten ist, und ein zweites hervorstehendes Teil (23b), das in dem zweiten Matrizenelement (21b) enthalten ist, konfiguriert ist.

10. Matrizenanordnung (30) nach Anspruch 7, wobei mindestens eine Matrize, ausgewählt aus der ersten Matrize (31) und der zweiten Matrize (32), ein Körperteil (31a, 32a) und ein bewegliches Teil (31b, 32b) umfasst, das relativ zum Körperteil (31a, 32a) beweglich ist.

11. Matrizenanordnung (20, 30) nach einem der Ansprüche 7 bis 10, wobei das hervorstehende Teil (23, 33) austauschbar ist.

12. Herstellungsvorrichtung zum Herstellen eines ge-

formten Metallgegenstands (1), der ein rohrförmiges Teil (le) mit einem Schlitz (3) umfasst, wobei die Herstellungsvorrichtung Folgendes umfasst:
die Matrizenanordnung (20, 30) nach Anspruch 7 und einen Bewegungsmechanismus zum Bewegen der Matrizenanordnung.

13. Herstellungsvorrichtung nach Anspruch 12, wobei mindestens eine aus der ersten Matrize (21) und der zweiten Matrize (22) ausgewählte Matrize in mehrere Matrizenelemente (21a, 21b, 22a, 22b) trennbar ist und
der Bewegungsmechanismus Folgendes umfasst:

einen ersten Bewegungsmechanismus, um die erste Matrize (21) und die zweite Matrize (22) nahe beieinander zu bringen, während die Vielzahl der Matrizenelemente (21a, 21b, 22a, 22b) getrennt sind; und
einen zweiten Bewegungsmechanismus, um die Vielzahl der Matrizenelemente (21a, 21b, 22a, 22b) nahe beieinander zu bringen.

14. Herstellungsvorrichtung nach Anspruch 12, wobei mindestens eine aus der ersten Matrize (31) und der zweiten Matrize (32) ausgewählte Matrize ein Körperteil (31a, 32a) und ein bewegliches Teil (31b, 32b) umfasst, das relativ zum Körperteil (31a, 32a) beweglich ist, und
der Bewegungsmechanismus Folgendes umfasst:

einen ersten Bewegungsmechanismus, um die erste Matrize (31) und die zweite Matrize (32) nahe beieinander zu bringen, während der bewegliche Teil (31b, 32b) nicht von der ersten und zweiten Druckfläche vorsteht; und
einen zweiten Bewegungsmechanismus zum Bewegen des beweglichen Teils (31b, 32b), so dass das bewegliche Teil (31b, 32b) von der Druckfläche vorsteht.

Revendications

1. Procédé de production pour la production d'un élément métallique formé (1) qui comprend une partie tubulaire (le) avec une fente (3), le procédé de production comprenant :

(i) une étape de formation d'une partie en forme de U (1b, 1c) ayant une section transversale en forme de U par déformation d'une plaque métallique (1a) ; et
(ii) une étape de formation de la partie tubulaire (1e) avec la fente (3) par déformation de la partie en forme de U (1b, 1c) en utilisant un ensemble filière (20, 30) muni d'une partie en protubérance (23, 33) de telle sorte que deux parties d'extrémité (E1, E2) de la partie en forme de U (1b, 1c) serrent la partie en protubérance (23, 33),

dans l'étape (ii), la longueur périphérique de section transversale LH de la partie tubulaire (le) étant faite plus petite que la longueur de section transversale LU de la partie en forme de U (1b, 1c) et
l'étape (ii) comprenant :

(ii-1) une étape de formation d'une partie de forme cylindrique (1d) par déformation de la partie en forme de U (1b, 1c) en utilisant l'ensemble filière (20, 30) de telle sorte que les deux parties d'extrémité (E1, E2) de la partie en forme de U (1b, 1c) serrent la partie en protubérance (23, 33), la partie de forme cylindrique (1d) devenant la partie tubulaire ; et
(ii-2) une étape de compression d'une surface périphérique extérieure de la partie de forme cylindrique (1d) pendant que les deux parties d'extrémité (E1, E2) serrent la partie en protubérance (23, 33), ce qui permet de raccourcir la longueur périphérique de section transversale LT de la partie de forme cylindrique (1d).

2. Procédé de production selon la revendication 1, dans lequel la longueur de section transversale LU de la partie en forme de U (1b, 1c) et la longueur périphérique de section transversale LH de la partie tubulaire (le) satisfont l'expression $0,2 \leq 100 \times (LU - LH) / LU < 1$.

3. Procédé de production selon la revendication 1 ou 2, dans lequel
l'ensemble filière (20) comprend une première filière (21) comprenant la partie en protubérance (23), et comprend une deuxième filière (22),
la première et la deuxième filière comprennent respectivement une première et une deuxième surface de compression, la première et la deuxième surface de compression étant configurées pour déformer la partie en forme de U (1b, 1c) pour former la partie de forme cylindrique (1d),
au moins une filière sélectionnée parmi la première filière (21) et la deuxième filière (22) étant séparable en une pluralité d'éléments de filière (21a, 21b, 22a, 22b),
dans l'étape (ii-1), la partie de forme cylindrique (le) est formée par déformation de la partie en forme de U (1b, 1c) en utilisant l'ensemble filière (20) pendant que la pluralité d'éléments de filière (21a, 21b, 22a, 22b) sont séparés, et
dans l'étape (ii-2), la surface périphérique extérieure de la partie de forme cylindrique est comprimée par rapprochement les uns des autres de la pluralité d'éléments de filière (21a, 21b, 22a, 22b), ce qui permet de raccourcir la longueur périphérique de section transversale LT de la partie de forme cylindrique

(le).

4. Procédé de production selon l'une quelconque des revendications 1 à 3, dans lequel
l'ensemble filière (20, 30) comprend une surface de compression qui correspond à une surface périphérique extérieure de la partie tubulaire (le), et
une longueur périphérique de section transversale de la surface de compression est plus courte que la longueur de section transversale LU de la partie en forme de U (1b, 1c).

5. Procédé de production selon la revendication 1 ou 2, dans lequel
l'ensemble filière (30) comprend une première filière (31) comprenant la partie en protubérance, et comprend une deuxième filière (33),
la première et la deuxième filière comprennent respectivement une première et une deuxième surface de compression, la première et la deuxième surface de compression étant configurées pour déformer la partie en forme de U (1b, 1c) pour former la partie de forme cylindrique (1d),
au moins une filière sélectionnée parmi la première filière et la deuxième filière comprend une partie corps (31a, 32a) et une partie mobile (31b, 32b) qui est mobile par rapport à la partie corps (31a, 32a),
dans l'étape (ii-1), la partie de forme cylindrique (le) est formée par déformation de la partie en forme de U (1b, 1c) en utilisant l'ensemble filière (30) pendant qu'une surface de compression de la partie mobile (31b, 32b) ne se projette pas à partir d'une surface de compression de la partie corps (31a, 32a), et
dans l'étape (ii-2), la surface périphérique extérieure de la partie de forme cylindrique est comprimée en amenant la surface de compression de la partie mobile (31b, 32b) à se projeter à partir de la surface de compression de la partie corps (31a, 32a), ce qui permet de raccourcir la longueur périphérique de section transversale LT de la partie de forme cylindrique (le).

6. Élément métallique formé (1) qui comprend une partie tubulaire (le) avec une fente (3), dans lequel
lorsqu'une variation S de la dureté de Vickers dans une direction d'épaisseur d'une section transversale de la partie tubulaire (le) est exprimée par une expression suivante, une valeur moyenne de variations S dans une direction circonférentielle est inférieure à 0,4,

$$S = (Bmax - Bmin) / Bmax$$

dans laquelle Bmin est une valeur minimale de duretés de Vickers dans une direction d'épaisseur de la section transversale, et Bmax est une valeur maximale de duretés de Vickers dans la direction d'épaisseur de la section transversale.

7. Ensemble filière (20, 30) pour la production d'un élément métallique formé (1) qui comprend une partie tubulaire (le) avec une fente (3), l'ensemble filière (20, 30) comprenant
une première filière (21, 31) qui comprend une partie en protubérance (23, 33) pour former la fente (3), et une deuxième filière (22, 32),
la première et la deuxième filière comprenant respectivement une première et une deuxième surface de compression, la première et la deuxième surface de compression étant configurées pour déformer une partie en forme de U (1b, 1c) ayant une section transversale en forme de U de telle sorte que deux parties d'extrémité (E1, E2) de la partie en forme de U (1b, 1c) serrent la partie en protubérance (22, 32) pour former une partie de forme cylindrique (1d) avec un espace, l'espace devenant la fente (3), et
l'ensemble filière (20, 30) étant configuré pour comprimer une surface périphérique extérieure de la partie de forme cylindrique (1d) pendant que les deux parties d'extrémité (E1, E2) serrent la partie en protubérance (23, 33), ce qui permet de raccourcir une longueur périphérique de section transversale de la partie de forme cylindrique (1d).

8. Ensemble filière (20) selon la revendication 7, dans lequel au moins une filière sélectionnée parmi la première filière et la deuxième filière est séparable en une pluralité d'éléments de filière (21a, 21b, 22a, 22b).

9. Ensemble filière (20) selon la revendication 8, dans lequel la première filière (21) est séparable en un premier élément de filière (21a) et un deuxième élément de filière (21b), et
la partie en protubérance (23) est configurée par une première partie en protubérance (23a) comprise dans le premier élément de filière (21a) et une deuxième partie en protubérance (23b) comprise dans le deuxième élément de filière (21b).

10. Ensemble filière (30) selon la revendication 7, dans lequel au moins une filière sélectionnée parmi la première filière (31) et la deuxième filière (32) comprend une partie corps (31a, 32a) et une partie mobile (31b, 32b) qui est mobile par rapport à la partie corps (31a, 32a).

11. Ensemble filière (20, 30) selon l'une quelconque des revendications 7 à 10, dans lequel la partie en protubérance (23, 33) est remplaçable.

12. Dispositif de production pour la production d'un élément métallique formé (1) qui comprend une partie tubulaire (le) avec une fente (3), le dispositif de pro-

duction comprenant :
l'ensemble filière (20, 30) selon la revendication 7 et un mécanisme de mouvement pour déplacer l'ensemble filière.

13. Dispositif de production selon la revendication 12, dans lequel
au moins une filière sélectionnée parmi la première filière (21) et la deuxième filière (22) est séparable en une pluralité d'éléments de filière (21a, 21b, 22a, 22b), et
le mécanisme de mouvement comprend :

un premier mécanisme de mouvement pour rapprocher l'une de l'autre la première filière (21) et la deuxième filière (22) pendant que la pluralité d'éléments de filière (21a, 21b, 22a, 22b) sont séparés ; et
un deuxième mécanisme de mouvement pour rapprocher les uns des autres la pluralité d'éléments de filière (21a, 21b, 22a, 22b) séparés.

14. Dispositif de production selon la revendication 12, dans lequel
au moins une filière sélectionnée parmi la première filière (31) et la deuxième filière (32) comprend une partie corps (31a, 32a) et une partie mobile (31b, 32b) qui est mobile par rapport à la partie corps (31a, 32a), et
le mécanisme de mouvement comprend :

un premier mécanisme de mouvement pour rapprocher l'une de l'autre la première filière (31) et la deuxième filière (32), pendant que la partie mobile (31b, 32b) ne se projette pas à partir de la première et de la deuxième surface de compression ; et
un deuxième mécanisme de mouvement pour déplacer la partie mobile (31b, 32b) de telle sorte que la partie mobile (31b, 32b) se projette à partir de la surface de compression.

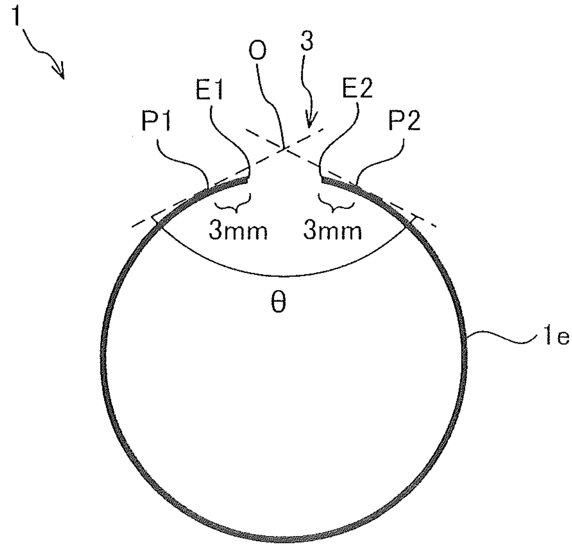


Fig. 1

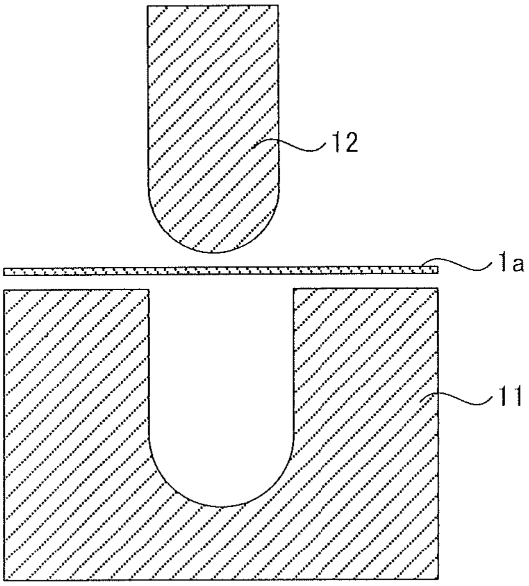


Fig. 2A

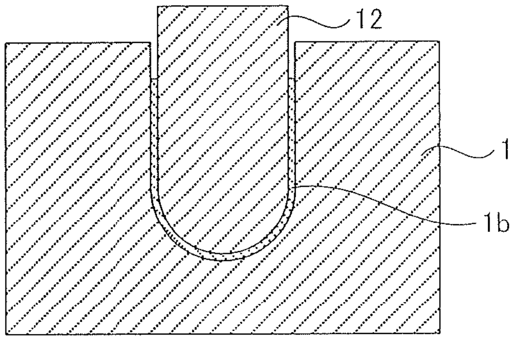


Fig. 2B

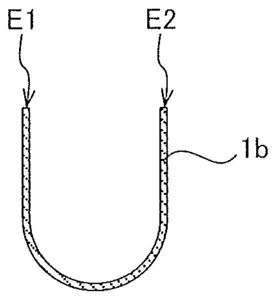


Fig. 2C

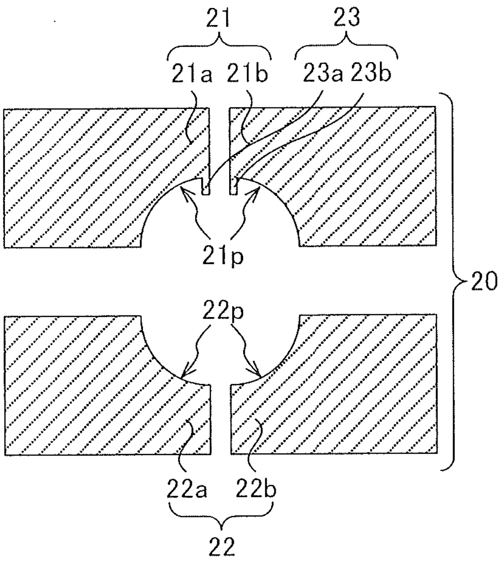


Fig. 3A

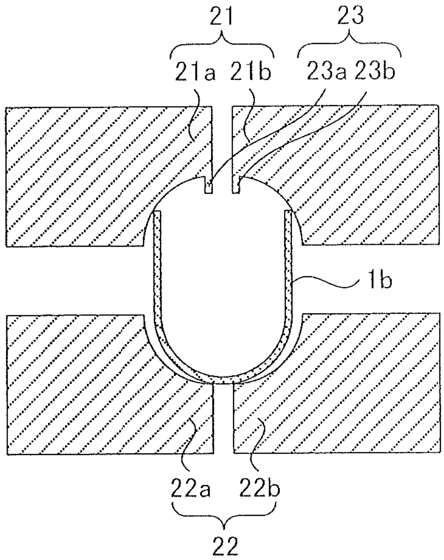


Fig. 3B

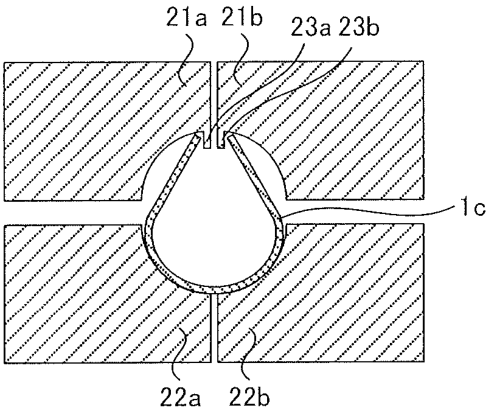


Fig. 3C

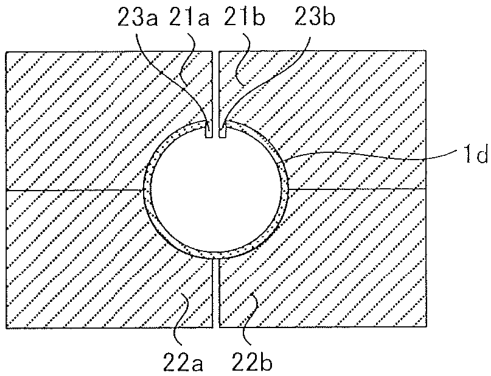


Fig. 3D

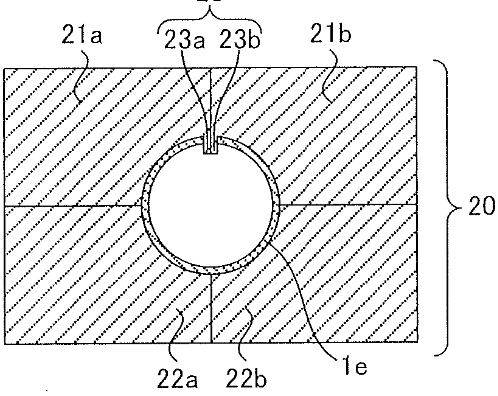


Fig. 3E

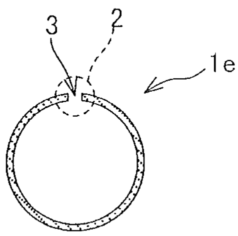


Fig. 3F

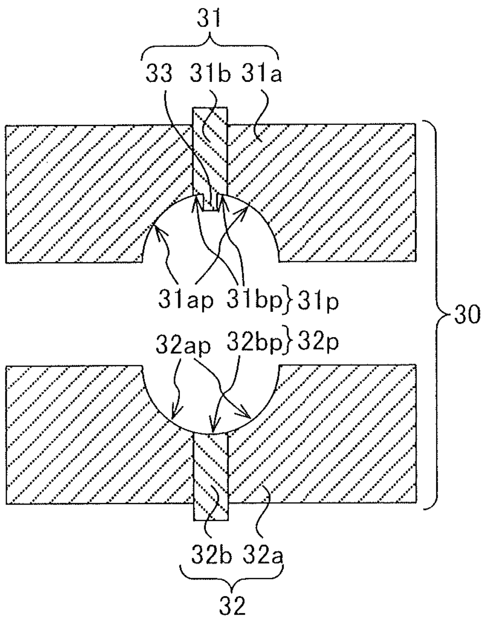


Fig. 4A

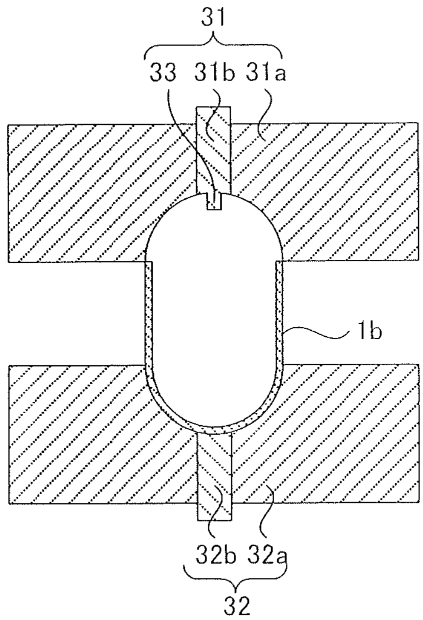


Fig. 4B

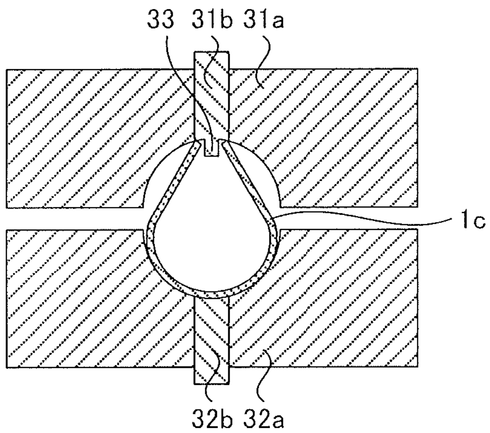


Fig. 4C

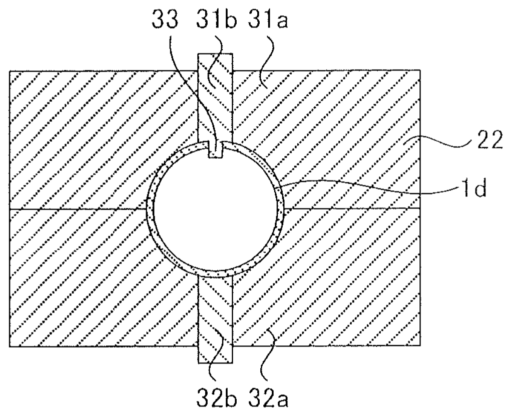


Fig. 4D

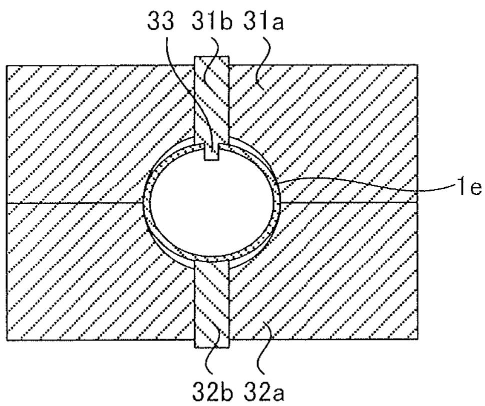


Fig. 4E

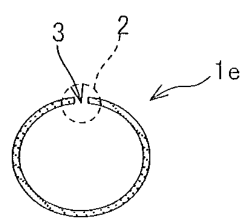


Fig. 4F

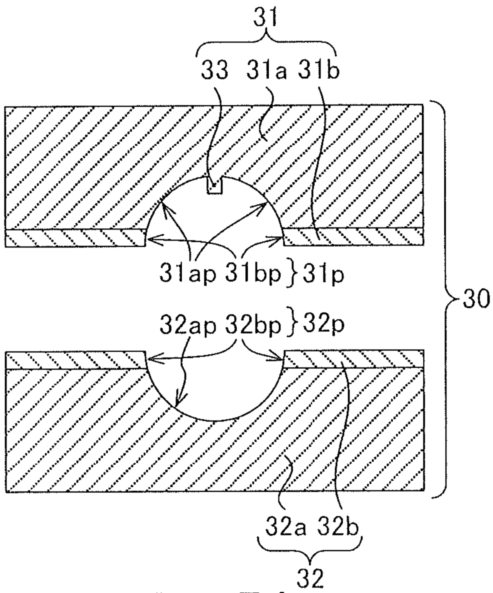


Fig. 5A

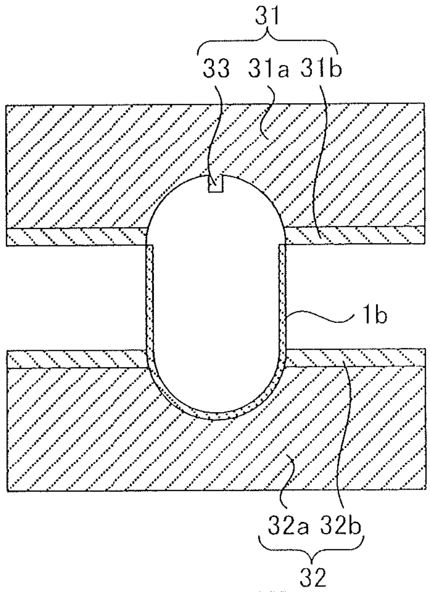


Fig. 5B

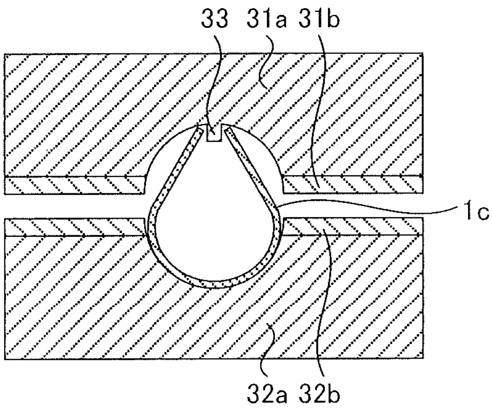


Fig. 5C

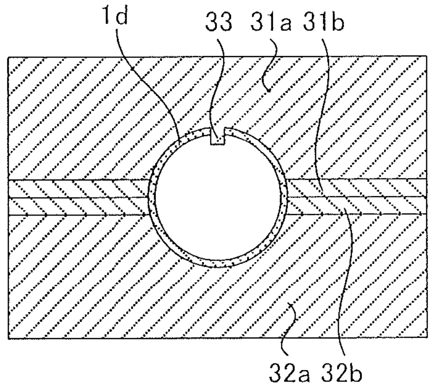


Fig. 5D

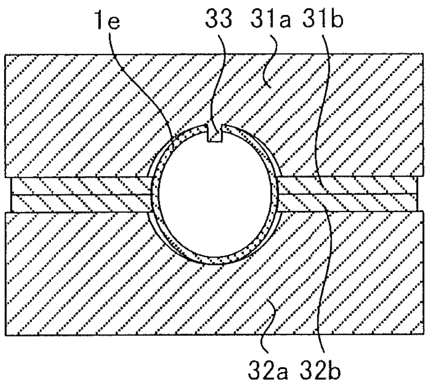


Fig. 5E

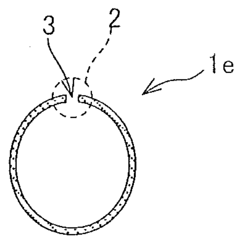


Fig. 5F

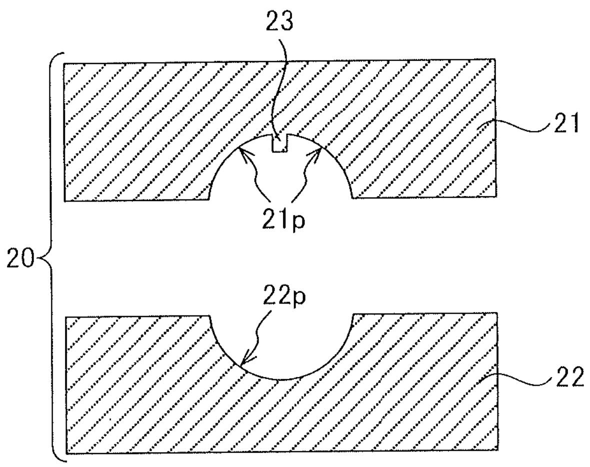


Fig. 6A

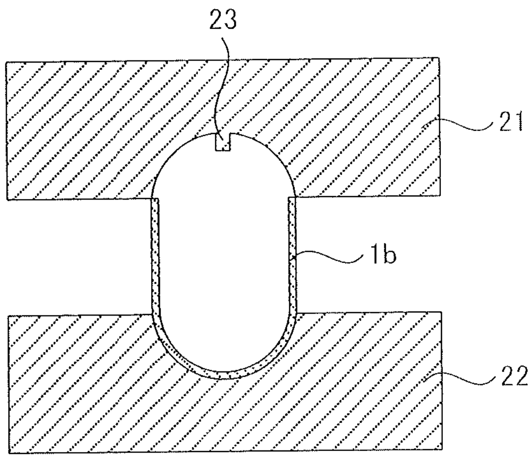


Fig. 6B

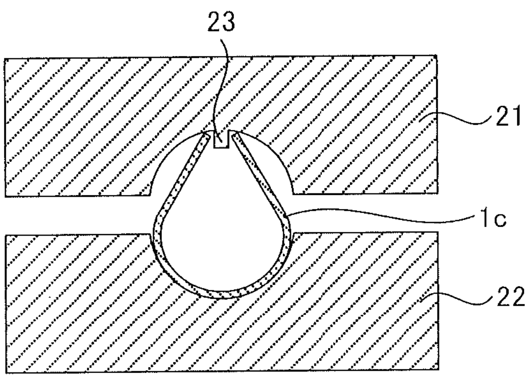
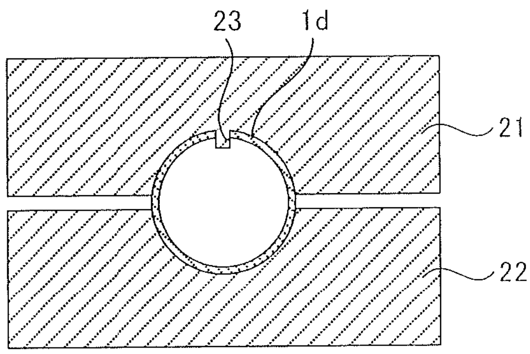


Fig. 6C



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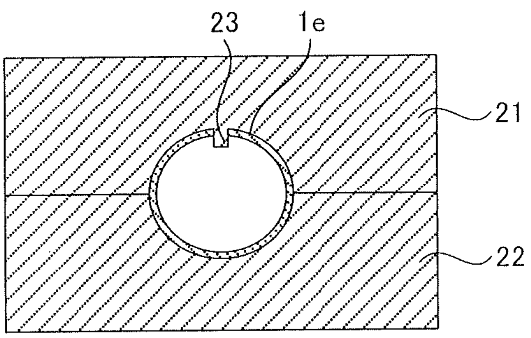

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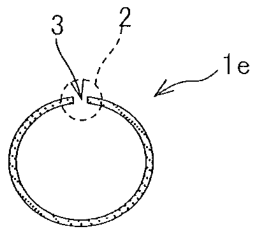

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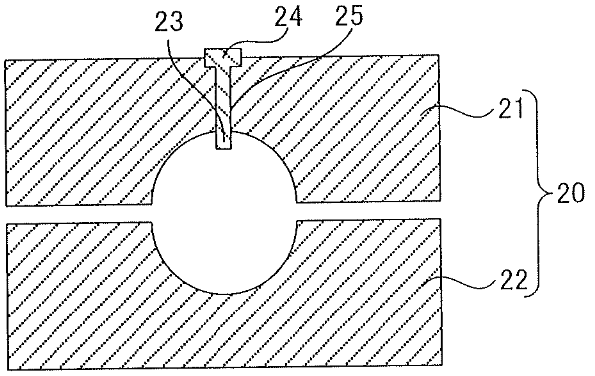


Fig. 7

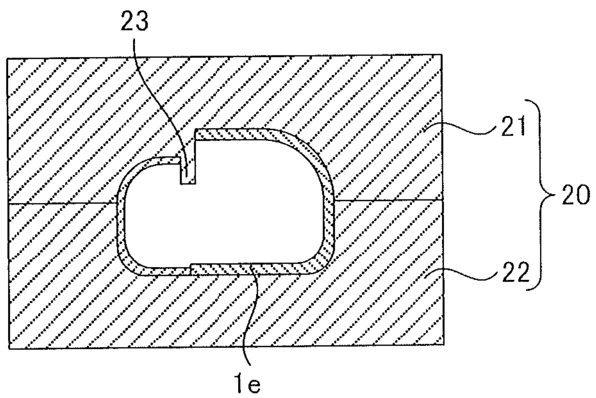


Fig. 8

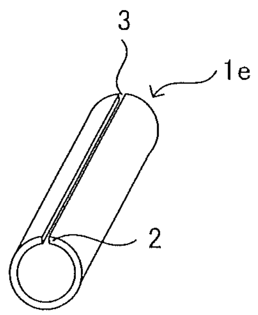


Fig. 9A

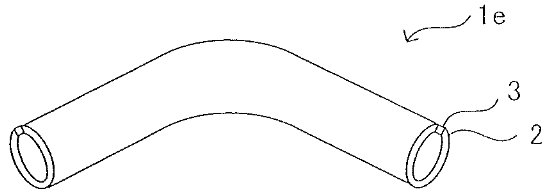


Fig. 9B

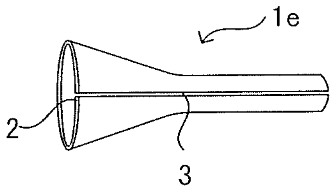


Fig. 9C

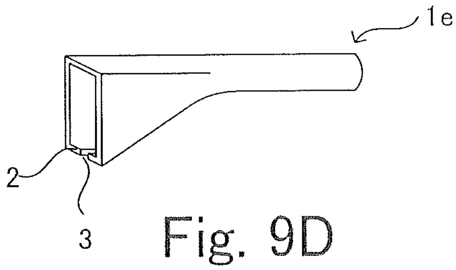
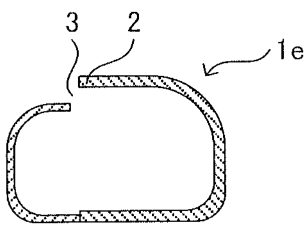


Fig. 9D



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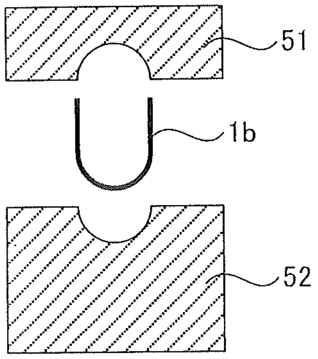

Fig. 10A

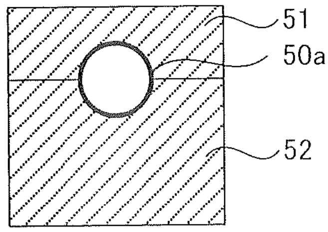

Fig. 10B

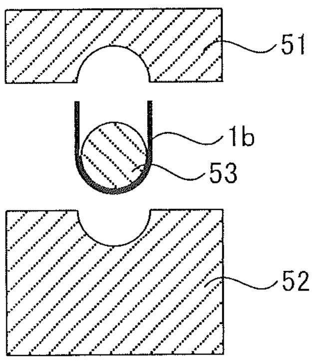

Fig. 11A

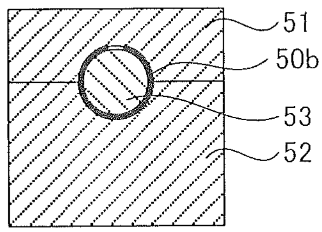

Fig. 11B

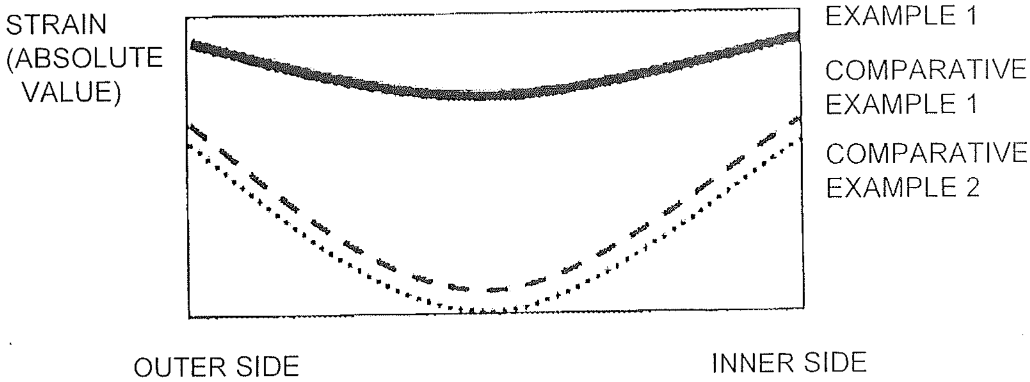

Fig. 12A

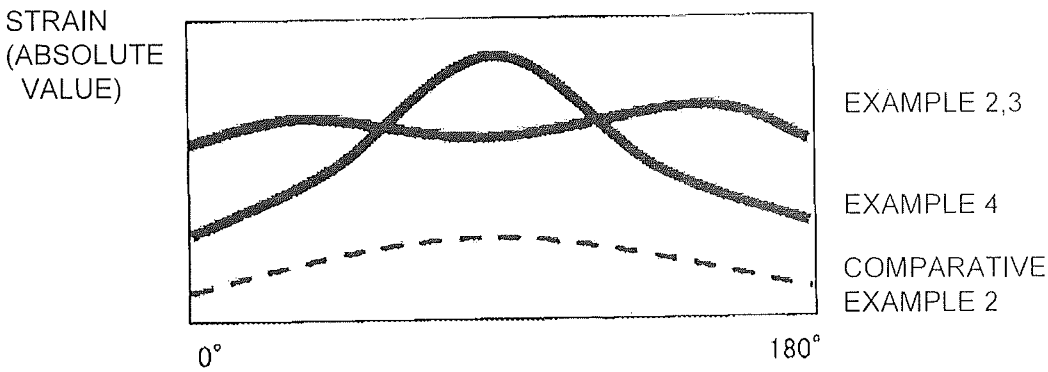

Fig. 12B

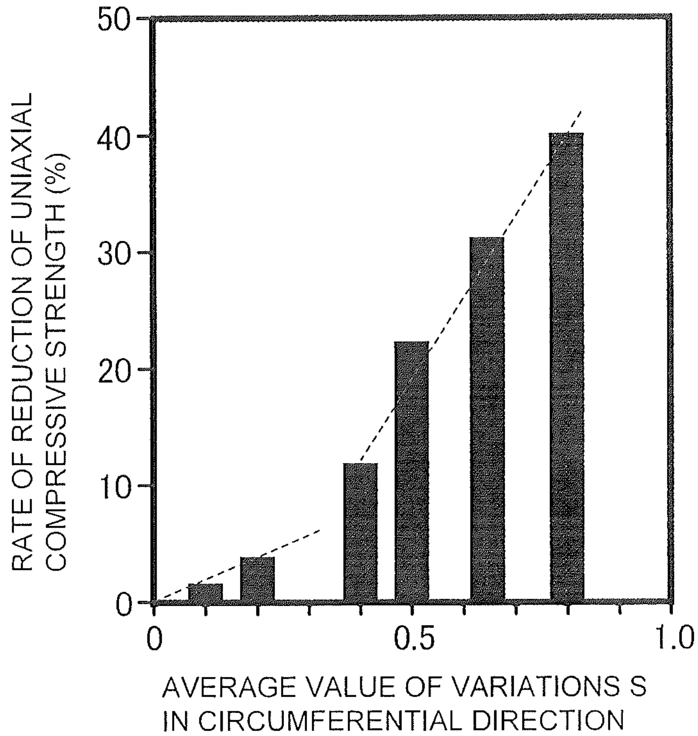
50
40
30
20
10
0
RATE OF REDUCTION OF UNIAXIAL COMPRESSIVE STRENGTH (%)
0
0.5
1.0
AVERAGE VALUE OF VARIATIONS S IN CIRCUMFERENTIAL DIRECTION

Fig. 13

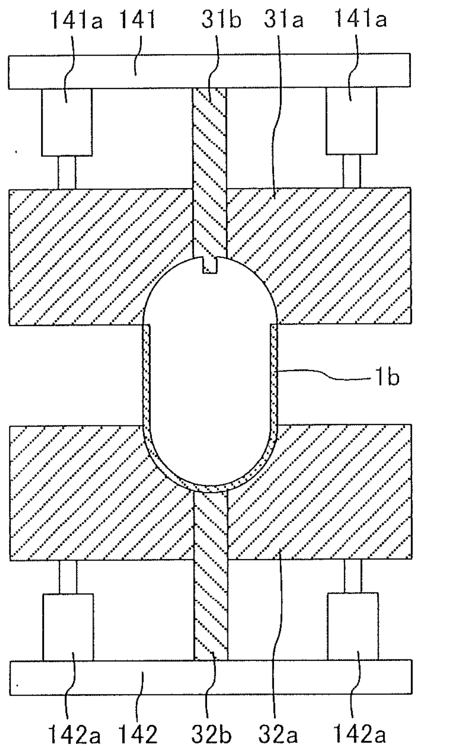

Fig. 14A

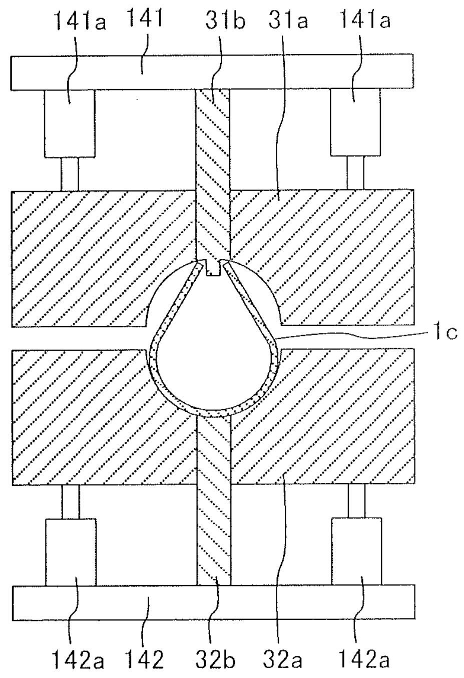

Fig. 14B

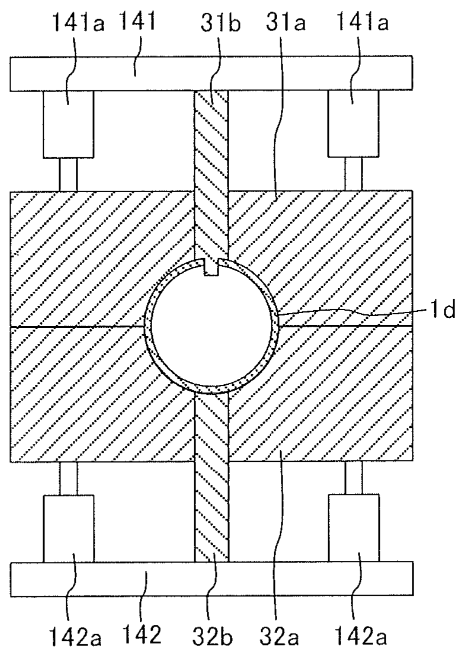

Fig. 14C

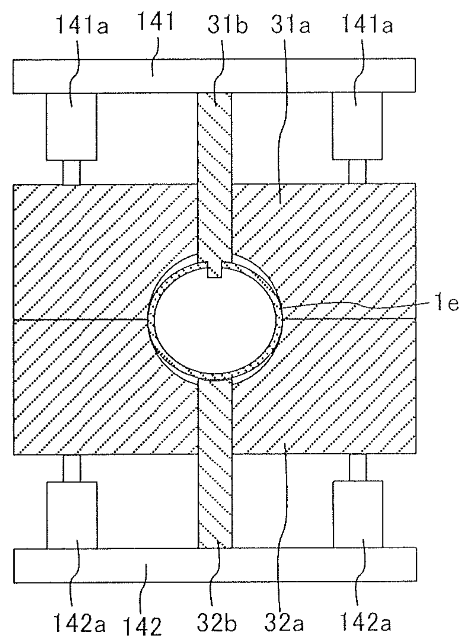

Fig. 14D

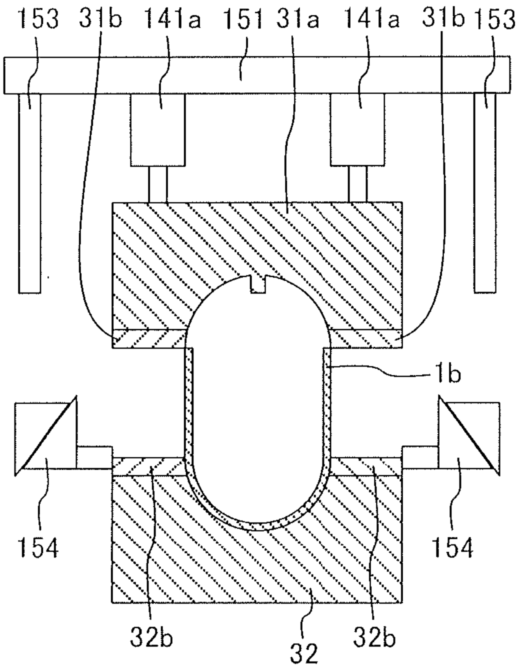

Fig. 15A

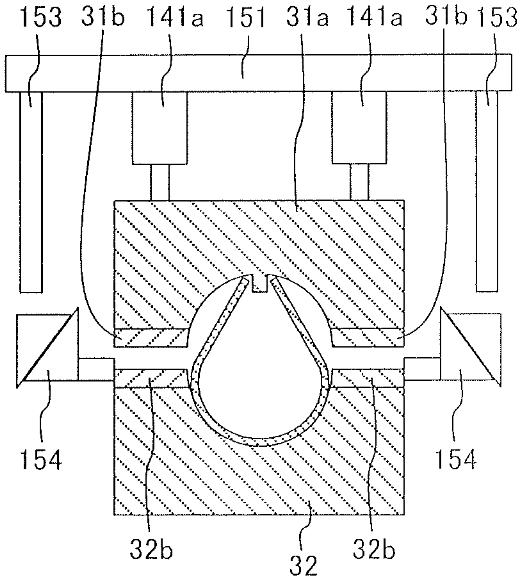

Fig. 15B

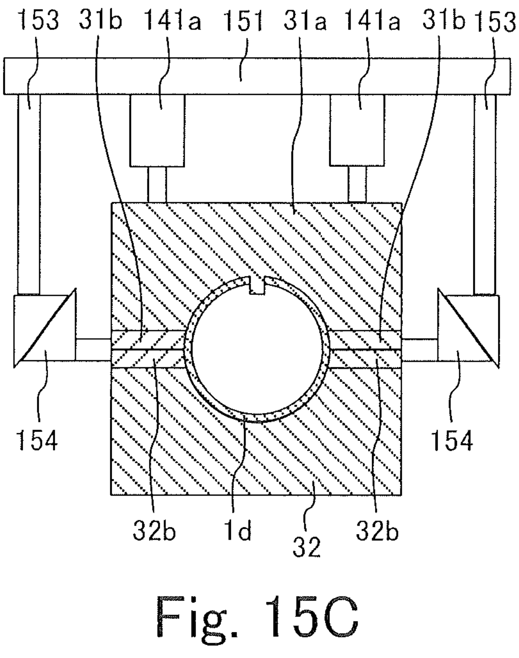

Fig. 15C

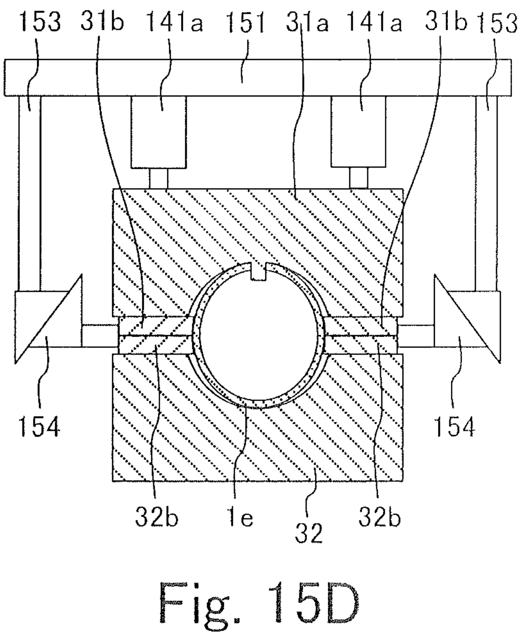

Fig. 15D

REFERENCES CITED IN THE DESCRIPTION

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