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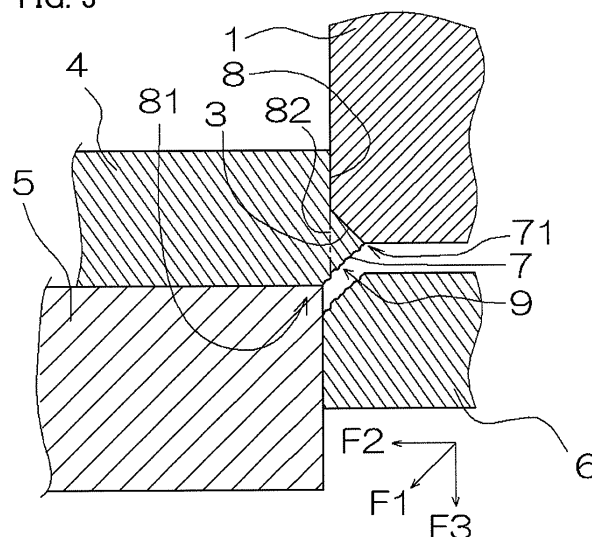
(54) **Method of manufacturing metal plate having hole, metal plate with hole, external gear with peripheral hole, external gear, metal plate for cam, method of manufacturing metal plate, and metal plate**

(57) A method of manufacturing a metal plate having a hole in which an inner surface of the punched hole is a smooth surface, a metal plate with hole manufactured by the method, an external gear with peripheral hole, an external gear, and a metal plate for cam are provided.

The method of manufacturing a metal plate having a hole includes a punching step of performing punching to a metal plate material placed on a die (5) by a punch (1) to form a through hole (8). In the punching step, breaking occurs during the punching for the through hole, a

temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole (8) is formed, and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface (3) included in a distal end edge of the punch to have a smooth surface (71). The recessed portion forming step can be further included.

FIG. 3



Description

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The present invention relates to a method of manufacturing a metal plate having a hole formed by punching, a metal plate with hole manufactured by the method, an external gear with peripheral hole, an external gear, and a metal plate for cam. More specifically, the present invention relates to a method of manufacturing a metal plate having a hole in which an inner surface of the punched hole is a smooth surface, a metal plate with hole manufactured by the method, an external gear with peripheral hole, an external gear, and a metal plate for cam. The present invention relates to a method of manufacturing a metal plate by punching and a metal plate manufactured by the method, and more specifically to a method of manufacturing a metal plate in which an outer surface of a punched outside portion is a smooth surface and a metal plate manufactured by the method.

(2) Description of Related Art

[0002] A hole is commonly formed in a metal plate by punching. Fig. 27 shows a conventional punching method. Fig. 27(1) shows a state in which a punch 102 is driven partway into a metal plate 101 placed on a die 100. In this state, in the metal plate 101, a punching scrap 103 is broken on a fracture surface 104 to expose the fracture surface 104 on an inner circumferential surface of a through hole 105 formed partway by punching. When the punch 102 moves further downward, as shown in Fig. 27(2), a thickness around the fracture surface moves downward by pressure generated by the punch 102. Upon completion of the punching, as shown in Fig. 27(3), a burr 106 is formed.

[0003] An outside portion is popularly formed on a metal plate by punching. Figs. 28(1) to 28(3) show a conventional punching method. Fig. 28(1) shows a state in which a punch 102A is driven partway into a metal plate material 101A' placed on a die 100A. In this state, in the metal plate material 101A', a punching scrap 103A is broken on a fracture surface 104A to expose the fracture surface 104A on an outer circumferential surface of an outside portion 105A formed partway by punching. As shown in Figs. 28(2) and 28(3), when the punch 102A is moved further downward to complete punching, a metal plate 101A (product) having the outside portion 105A can be obtained.

[0004] As described above, since the fracture surface 104 is exposed to the through hole 105 to form a rough surface, it has been desired that the inner surface of the punched hole 105 should be finished to be a smooth surface. Since the fracture surface 104A is exposed to the outside portion 105A to form a rough surface, it has been desired that the outer surface of the punched outside

portion 105A should be finished to be a smooth surface. In this case, the smooth surface means a surface which is smooth enough to be used for a hole or an outside portion.

[0005] For this reason, an application intended to make the inner surface of a through hole smooth is proposed (for example, see JP 2002-206563 A). The invention described in JP 2002-206563 A is to perform shaving to the inner surface of the through hole after a punching step.

SUMMARY OF THE INVENTION

[0006] However, in the invention described in JP 2002-206563 A, a step to perform shaving to the inner surface of a through hole or the outer surface of an outside portion is additionally required after the punching step, resulting in increases in complexity and time required for all the steps.

[0007] The present invention has been made in consideration of the above circumstances, and its object is to provide a method of manufacturing a metal plate having a hole in which the metal plate can be punched to make an inner surface of a through hole smooth, a metal plate with hole manufactured by the method, an external gear with peripheral hole, an external gear, and a metal plate for cam. The present invention has been made in consideration of the above circumstances, and its object is to provide a method of manufacturing a metal plate which can be punched out to make an outer surface of an outside portion smooth and a metal plate manufactured by the method.

Means for Solving the Problem

[0008] The present invention will be described below.

1. A method of manufacturing a metal plate having a hole, including a punching step of performing punching to a metal plate material placed on a die by a punch to form a through hole, wherein: in the punching step, breaking occurs during the punching for the through hole; a temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole is formed; and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

2. The method of manufacturing a metal plate having a hole described in the section 1, wherein: a recessed portion forming step is further performed before the punching step; the recessed portion forming step is a step of forming a recessed portion surrounded by a bottom surface and an inclined side surface at a position where the through hole is formed by performing hot forging or cool forging on a surface

of the metal plate material; in the punching step, a projecting portion is vertically formed on a peripheral edge of a die hole of the die to face the metal plate material; the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed; and the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface.

3. The method of manufacturing a metal plate having a hole described in the section 1 or 2, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .

4. A metal plate with hole including a metal plate and a through hole formed in the metal plate, wherein the through hole is manufactured by the method of manufacturing a metal plate having a hole described in any one of the sections 1 to 3, and an inner surface of the through hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.

5. A method of manufacturing an external gear with peripheral hole which is configured by a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate, comprising an external tooth forming step of forming the external tooth portion, and a punching step of forming the shaft hole and the peripheral holes, wherein: in the punching step, the holes are formed such that punching is performed to the metal plate material placed on a die by a punch at a time or in a plurality of times; in the punching step, breaking occurs during the punching for each of the holes to form a temporarily residual portion which is a peripheral edge of each of the holes on the die side and protrudes inward from a position corresponding to an inner surface of each of the holes; and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

6. The method of manufacturing an external gear with peripheral hole described in the section 5, wherein: the external tooth forming step is a step of forming the external tooth portion and a recessed portion which is located on a surface of the metal plate material at a position where the shaft hole and the peripheral holes are formed and surrounded by a bottom surface and an inclined side surface by performing hot forging or cool forging; in the punching step, a projecting portion is vertically formed on a peripheral edge of a die hole of the die to face the

metal plate material; the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed; and the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface.

7. The method of manufacturing an external gear with peripheral hole described in the section 5 or 6, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .

8. The method of manufacturing an external gear with peripheral hole described in any one of the sections 5 to 7, wherein, after the external tooth forming step, the punching step is performed in a state in which the metal plate material is positioned with reference to a position of the external tooth portion.

9. The method of manufacturing an external gear with peripheral hole described in any one of the sections 5 to 8, wherein, in the punching step, the peripheral holes are formed by performing punching in a plurality of times, and formation of each of the peripheral holes is performed in a state in which a guide pin having a diameter equal to that of the peripheral hole is inserted into a peripheral hole which has been formed, in order to prevent deformation of each of the peripheral holes which have been formed.

10. An external gear with peripheral hole including a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate, wherein

the shaft hole and the peripheral holes are formed by the method of manufacturing a metal plate with hole described in any one of the sections 5 to 9, an inner surface of each of the holes on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during the punching.

11. An external gear including a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, and an external tooth portion formed on a peripheral edge of the metal plate, wherein the shaft hole is manufactured by the method of manufacturing a metal plate having a hole described in any one of the sections 1 to 3, and an inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.

12. A metal plate for cam including a metal plate, a shaft hole which is formed in the metal plate and to which a rotating shaft is attached, and a sliding surface formed on a peripheral edge of the metal plate, wherein the shaft hole is manufactured by the meth-

od of manufacturing a metal plate having a hole described in any one of the sections 1 to 3, and an inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.

13. The method of manufacturing a metal plate including a punching step of performing punching to a metal plate material placed on a die by the punch or a press mold to form an outside portion, wherein, in the punching step, breaking occurs in the metal plate material during the punching for the outside portion, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes outward from a position corresponding to an outer surface of the outside portion, and thereafter, with the punching, the temporarily residual portion is pressed toward a central axis of the die hole by a pressing surface included in a distal end edge of the die hole of the die to have a smooth surface.

14. The method of manufacturing a metal plate described in the section 13, wherein the punching step is the step of forming the outside portion and performing punching to the metal plate material by the punch to form a through hole, in the punching step, breaking occurs during the punching for the through hole, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes inward from a position corresponding to an inner surface of the through hole, and thereafter, with the punching, the temporarily residual portion is pressed in a direction away from a central axis of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

15. The method of manufacturing a metal plate described in the section 13 or 14, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .

16. A metal plate manufactured by the method of manufacturing a metal plate described in any one of the sections 13 to 15, wherein an outer surface of the outside portion on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during the punching.

Effect of the Invention

[0009] When a through hole is formed in a metal plate by punching, in a conventional technique, surfaces of rough fracture surfaces formed by breaking a punching scrap are exposed on an inner surface of the hole. The fracture surface is formed on a temporarily residual portion protruding toward a center side of the through hole from a position corresponding to the inner surface of the through hole in which a large number of fracture surfaces

are formed.

[0010] The method of manufacturing a metal plate includes a punching step of performing punching to a metal plate material placed on a die by a punch to form a through hole. In the punching step, breaking occurs during the punching for the through hole, a temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole is formed, and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface. More specifically, a pressing surface of a punch causes the temporarily residual portion to serve as a part of the thickness of a through hole periphery of a metal plate material and forms the surface including the fracture surface of the temporarily residual portion as a smooth surface by pressure. As a result, the overall inner surface of the through hole including a sheared surface which is normally sheared is a smooth surface, and the temporarily residual portion hardly remains even after the punching step. For this reason, a post-process such as shaving or machining need not be performed.

[0011] A recessed portion forming step is further performed before the punching step. The recessed portion forming step is a step of forming a recessed portion surrounded by a bottom surface and an inclined side surface at a position where the through hole is formed by performing hot forging or cool forging on a surface of the metal plate material. In the punching step, a projecting portion is vertically formed on a peripheral edge of a die hole of the die to face the metal plate material, the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed, and when the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface, the temporarily residual portion is guided by the guide surface along the surface such that the pressure of the punch causes the temporarily residual portion to flow on the inner surface side of the through hole in the metal plate material so as to more efficiently cause the temporarily residual portion to serve as a part of a thickness of a through hole periphery. Since the temporarily residual portion efficiently serves as a part of the through hole periphery, the inner surface of the through hole can be made a smoother surface. In addition, the temporarily residual portion can be more suppressed from remaining as a burr. Time required to form the recessed portion can be made extremely shorter than that in machining.

[0012] The shape of the recessed portion is not specified and may be a shape having an inclined side surface of various shapes such as a circular conical surface or a pyramid surface.

[0013] When the arithmetic average roughness of the smoothed surface is 0.04 to 0.4 μm , a step of performing

processes such as shaving and machining to the inner surface is not necessary, and time required for manufacturing can be shortened.

[0014] According to the metal plate with hole, since an inner surface in the through hole on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during punching, the inner surface of the hole including a portion configured by a surface formed by pressing the temporarily residual portion becomes a smooth surface and a post-process such as shaving or machining need not be performed.

[0015] The method of manufacturing an external gear with peripheral hole which is configured by a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate includes an external tooth forming step of forming the external tooth portion, and a punching step of forming the shaft hole and the peripheral holes. In the punching step, the shaft hole and each of the peripheral holes are formed by performing punching at a time or in a plurality of times to the metal plate material placed on a die. For this reason, the inner surfaces of the shaft hole and each of the peripheral holes can be made smoother surfaces. In addition, since a burr can be suppressed from being formed, a step of smoothing the holes after the shaft hole and each of the peripheral holes are punched can be omitted, and time required to manufacture an external gear with peripheral hole can be considerably shortened.

[0016] When the external gear forming step is a step of forming, by hot forging or cool forging, an external tooth portion and a recessed portion which is located on a surface of the metal plate material at a position where the shaft hole and the peripheral holes are formed and which is surrounded by a bottom surface and an inclined side surface, the external tooth portion and the recessed portion can be formed by one step performed by forging. For this reason, time required to manufacture an external gear with peripheral hole can be shortened. In addition, since the temporarily residual portion efficiently serves as a part of a through hole periphery, the inner surface of the through hole can be made a smoother surface. Since the temporarily residual portion can be suppressed from remaining and forming a burr.

[0017] When the punching step is performed in a state in which the metal plate material is positioned after the external tooth forming step, the positions of the shaft hole and each of the peripheral holes can be accurately determined, and a high-precision external gear with peripheral hole can be manufactured.

[0018] In the punching step, in a case where punching is performed in a plurality of times to form the peripheral holes and the formation of the peripheral holes is performed in a state in which a guide pin having a diameter

equal to that of the peripheral hole is inserted into each of the formed peripheral holes in order to prevent deformation of the formed peripheral holes, even though the plurality of peripheral holes are sequentially formed, each of the peripheral holes is protected with a guide pin to be prevented from being deformed. For this reason, the accuracy of each of the peripheral holes can be kept, and a high-precision gear can be manufactured.

[0019] According to the external gear with peripheral hole manufactured as described above, the inner surfaces of the shaft hole and each of the peripheral holes can be made smoother surfaces, and a burr can be suppressed from being formed. For this reason, a step of removing burrs in the holes performed after the shaft hole and the peripheral holes are punched out can be simplified or omitted, and time required to manufacture an external gear with peripheral hole can be considerably shortened.

[0020] According to the external gear, the shaft hole is manufactured by the method of manufacturing a metal plate having a hole, and the inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during punching. For this reason, the external gear having the shaft hole having a smoother inner surface can be obtained. Furthermore, since a burr is also suppressed from being formed, a step of removing a burr from a shaft hole after the shaft hole is punched out can be simplified or omitted, and time required to manufacture an external gear can be shortened.

[0021] The metal plate for cam includes a metal plate, a shaft hole which is formed in the metal plate and to which a rotating shaft is attached, and a sliding surface formed on a peripheral edge of the metal plate. The shaft hole is manufactured by the method of manufacturing a metal plate having the hole, and an inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching. For this reason, the metal plate for cam having the shaft hole having a smoother inner surface can be obtained. A rotating shaft is fitted in the metal plate for cam, and when the rotating shaft is rotated in a state in which a follower is in contact with the sliding surface, the follower slides on the sliding surface. The metal plate for cam can be functioned like a plate cam in which a follower operates to follow the contour of a peripheral edge. Furthermore, according to the metal plate for cam, since a burr is also suppressed from being formed, a step of removing a burr from a shaft hole after the shaft hole is punched out can be simplified or omitted, and time required to manufacture a metal plate for cam can be shortened.

[0022] When an outside portion of a metal plate is formed by punching, in a conventional technique, surfaces of rough fracture surfaces formed by breaking a punching scrap are exposed on an outer surface of an outside portion.

[0023] The method of manufacturing a metal plate in-

cludes a punching step of performing punching to a metal plate material placed on a die by a punch or a press mold to form an outside portion. In the punching step, breaking occurs in the metal plate material during the punching for the outside portion, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes outward from a position corresponding to an outer surface of the outside portion, and thereafter, with the punching, the temporarily residual portion is pressed toward a central axis of the die hole by a pressing surface included in a distal end edge of the die hole of the die to have a smooth surface. More specifically, the pressing surface of the die hole causes the temporarily residual portion to serve as a part of the thickness of an outside portion periphery of a metal plate material and forms the surface including the fracture surface of the temporarily residual portion as a smooth surface by pressing. As a result, the overall outer surface of the through hole including a sheared surface which is normally sheared is a smooth surface, and the temporarily residual portion hardly remains even after the punching step. For this reason, a post-process such as shaving or machining need not be performed.

[0024] The punching step is the step of forming the outside portion and performing punching to the metal plate material by the punch to form a through hole, in the punching step, breaking occurs in the metal plate material during the punching for the through hole, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes inward from a position corresponding to an inner surface of the through hole, and thereafter, with the punching, the temporarily residual portion is pressed in a direction away from a central axis of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface. In this case, the pressing surface of the punch causes the temporarily residual portion to serve as a part of the thickness of a through hole periphery of a metal plate material and forms the surface including the fracture surface of the temporarily residual portion as a smooth surface by pressing. As a result, the entire outer surface of the outside portion and the overall inner surface of the through hole including a sheared surface which is normally sheared are smooth surfaces, and the temporarily residual portion hardly remains even after the punching step. For this reason, a post-process such as shaving or machining need not be performed.

[0025] When the arithmetic average roughness of the smoothed surface is 0.04 to 0.4 μm , a step of performing processes such as shaving and machining to the outer surface is not necessary, and time required for manufacturing can be shortened.

[0026] According to the metal plate, since an outer surface on the outside portion on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during

punching, the outer surface of the outside portion including a portion configured by a surface formed by pressing the temporarily residual portion becomes a smooth surface and a post-process such as shaving or machining need not be performed.

Brief Description of the Drawings

[0027] The present invention is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:

Fig. 1 is a side view showing a positional relationship between a metal plate material, a punch, and a die to perform a punching step;

Fig. 2 is a sectional view showing a state in which a punch is slightly inserted into a metal plate material; Fig. 3 is a sectional view showing a state in which a punch is inserted into the metal plate material more deeply than in Fig. 2;

Fig. 4 is a sectional view showing a state in which a punch is inserted into the metal plate material more deeply than in Fig. 3;

Fig. 5 is a sectional view showing a state in which a punch is inserted into the metal plate material more deeply than in Fig. 4;

Fig. 6 is a sectional view of a metal plate in a state in which a through hole is formed in the metal plate; Figs. 7(1), 7(2), and 7(3) show a recessed portion forming step, in which Fig. 7(1) is a side view showing a state in which a mold is arranged above the metal plate material, Fig. 7(2) is a side view showing a state in which a surface of the metal plate material is pressed by the mold; and Fig. 7(3) is a sectional view showing a state in which the mold is separated from the surface of the metal plate material;

Fig. 8(1) is a side view showing a state in which a punch is arranged above a metal plate material placed on a die, and Fig. 8(2) is a sectional view of a metal plate material in a state in which a punch is slightly inserted into the metal plate material;

Fig. 9(3) is a sectional view showing a state in which the punch is inserted into the metal plate material more deeply than in Fig. 8(2), and Fig. 9(4) is a sectional view of a metal plate showing a state in which the metal plate is punched out by a punch;

Fig. 10(1) is a front view of an external gear with peripheral hole in another embodiment, and Fig. 10(2) is a sectional view along an X - X line in Fig. 10(1);

Fig. 11(1) is a front view of a metal plate material in which a recessed portion for shaft hole and a recessed portion for peripheral hole are formed in another embodiment, and Fig. 11 (2) is a sectional view

along an X - X line in Fig. 11(1);

Fig. 12(1) is a front view of a metal plate material in a state in which a shaft hole is punched out in the state shown in Figs. 11(1) and 11(2), and Fig. 12(2) is a sectional view along an X - X line in Fig. 12(1); Fig. 13(1) a front view of a metal plate material in which a shaft hole and two peripheral holes are formed in another embodiment, and Fig. 13(2) is a sectional view along an X - X line in Fig. 13(1); Fig. 14 a front view of a metal plate material in which a shaft hole and four peripheral holes are formed in another embodiment;

Fig. 15 is a front view of a metal plate material in which guide pins are inserted into a shaft hole and two peripheral holes and the guide pins are fitted in four recessed portions for peripheral hole in another embodiment;

Fig. 16 is a sectional view along an X - X line in Fig. 15 in another embodiment;

Fig. 17 is a sectional view along a Y - Y line in Fig. 15 in another embodiment;

Fig. 18 is a sectional view showing a relationship between a die, a metal plate, and a punch; and

Fig. 19 is a longitudinal sectional view of a pressing machine used in the method of manufacturing a metal plate according to the embodiment;

Figs. 20(1), 20(2), and 20(3) are explanatory diagrams for explaining the method of manufacturing a metal plate, in which Fig. 20(1) shows a state in which a metal plate material is broken by a punch, Fig. 20(2) shows a state in the middle of formation of an outside portion between the punch and a die, and Fig. 20(3) shows a state in which a metal plate on which an outside portion is formed is obtained;

Figs. 21(1), 21(2), and 21(3) are enlarged views of main parts of Figs. 20(1) to 20(3), in which Fig. 21(1) shows a portion viewed in an arrow A, Fig. 21(2) shows a portion viewed in an arrow B, and Fig. 21(3) shows a portion viewing in an arrow C;

Figs. 22(1), 22(2), and 22(3) are explanatory diagrams for explaining a method of manufacturing a metal plate according to another embodiment, in which Fig. 22(1) shows a state in which a metal plate material is placed on a die, Fig. 22(2) shows a state in the middle of formation of an outside portion between a press mold and a die, and Fig. 22(3) shows a state in which a metal plate in which an outside portion and a through hole are formed is obtained;

Figs. 23(1) and 23(2) are enlarged views of main parts of Figs. 22(1) to 22(3), in which Fig. 23(1) shows a portion viewed in an arrow A and Fig. 23(2) shows a portion viewed in an arrow B;

Figs. 24(1), 24(2), and 24(3) are explanatory diagrams for explaining a method of manufacturing a metal plate according to still another embodiment, in which Fig. 24(1) shows a state in which a metal plate material is placed on a punch, Fig. 24(2) shows a state in the middle of formation of an through hole

between a press mold and the punch, and Fig. 24(3) shows a state in which a metal plate in which an outside portion and a through hole are formed is obtained;

Figs. 25(1) and 25(2) are enlarged views of main parts of Figs. 24(1) to 24(3), in which Fig. 25(1) shows a portion viewed in an arrow A and Fig. 25(2) shows a portion viewed in an arrow B;

Figs. 26(1), 26(2), and 26(3) are plan views of a metal plate obtained by the method of manufacturing a metal plate, in which Fig. 26(1) shows a state in which outer circumferences of an outside portion and a through hole are circular, Fig. 26(2) shows a state in which the outer circumferences of the outside portion and the through hole are polygonal, and Fig. 26(3) shows a state that the outer circumferences of the outside portion and the through hole have gear teeth each;

Fig. 27 is an explanatory diagram showing a hole punching method according to a conventional technique.

Fig. 28 is an explanatory diagram showing an outside portion punching method according to a conventional technique.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0028] Embodiments of the present invention are described in detail below with reference to the drawings.

[0029] The particulars shown herein are by way of example and for purposes of illustrative discussion of the embodiments of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the present invention. In this regard, no attempt is made to show structural details of the present invention in more detail than is necessary for the fundamental understanding of the present invention, the description is taken with the drawings making apparent to those skilled in the art how the forms of the present invention may be embodied in practice.

[0030] A method of manufacturing a metal plate having a hole is a manufacturing method including at least a punching step of performing punching to a metal plate material placed on a die by a punch to form a through hole. The method can further include a recessed portion forming step. The recessed portion forming step and the punching step can be performed in the order named.

[0031] The material, size, and thickness of a metal plate having a hole manufactured by the manufacturing method are not specified. Applications of the through hole manufactured by the manufacturing method are not specified, either. For example, holes and the like for fixing fastening members such as holes and screws which fix or insert various shafts can be given.

[0032] Furthermore, as concrete applications of the metal plate having a hole, (1) an external gear including

a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, and an external tooth portion formed on a peripheral edge of the metal plate, (2) an external gear with peripheral hole for planet gear including a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate, and (3) a metal plate for cam including a metal plate, a shaft hole which is formed in the metal plate and to which a rotating shaft is attached, and a sliding surface formed on a peripheral edge of the metal plate can be given. The metal plate for cam is inserted with a rotating shaft, and when the rotating shaft is rotated in a state in which a follower is in contact with the sliding surface, the follower slides on the sliding surface. The metal plate for cam can be functioned like a plate cam in which a follower operates to follow the contour of a peripheral edge. The sliding surface is normally formed on a side surface of the metal plate.

[0033] The present invention is not limited to the above applications and can be used in an arbitrary application. For example, (4) a pinwheel including a disk-like metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, and a plurality of peripheral holes formed along the circumference of the metal plate and to which pins are attached can be given.

[0034] In the punching step, breaking occurs during the punching for the through hole, a temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole is formed, and, thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

[0035] The punch used in the punching step, as exemplified as a punch 1 in Fig. 1, includes a pressing surface 3 at a distal end edge 2 of the punch. The pressing surface 3 has a shape having an inclined surface obtained by performing chamfering or the like to the distal end edge of the punch 1, and presses the temporarily residual portion toward the side surface during the punching. An angle K of the chamfering of the pressing surface 3 is arbitrarily set by a material of a metal plate to be punched, a punching rate, and the like. A distance D of the chamfering is arbitrarily set.

[0036] The fracture surface, as exemplified in Fig. 3, is a surface 7 formed with breaking of a punching scrap 6 on a metal plate material 4 of a peripheral edge 81 of the hole on the die side in the middle of formation of the through hole in the metal plate material 4 by the punch 1 in the step. The fracture surface 7 protrudes on the center side of the hole from a position 82 corresponding to the inner surface of a through hole to be formed. When

the fracture surface 7 is formed, a portion of the metal plate material 4 protruding from the position 82 on the center side of the hole is defined as a temporarily residual portion 9. In completion of the punching, a portion called the temporarily residual portion 9 is almost eliminated on a metal plate 40.

[0037] The direction toward the side surface is a direction from the central axis of the punch toward the side surface of the punch. More specifically, the direction, as exemplified in Fig. 1, includes a direction C perpendicular to a punching direction A of the punch 1 and an inclined direction (For example, a diagonally outward direction B can be given.) which is closer to the punching direction A than the direction C. The angle is arbitrarily set by the material of the metal plate, a punching rate, or the like.

[0038] The smoothness of the surface formed by pressing the surface including the fracture surfaces of the temporarily residual portion with the punch only needs to be almost equal to (for example, the same roughness classification) the surface roughness of sheared surface obtained by performing punching without forming fracture surfaces on the inner surface of the through hole. The surface roughness is arbitrarily changed depending on punching conditions. However, as a range of an arithmetic average roughness conforming to, for example, JIS B0601 : 2013 (ISO 4287 : 1997), a range of 0.04 to 0.4 μm (more preferably, 0.05 to 0.1 μm) can be given.

[0039] The recessed portion forming step is a step of forming a recessed portion surrounded by a bottom surface and an inclined side surface on the surface of the metal plate by hot forging or cool forging.

[0040] The bottom surface is entirely punched out by a punch, and has a shape which is arbitrarily selected depending on a punching shape of the punch. The inclined side surface is a surface inclined with respect to a punching direction of the punch. An inclined angle E (see the inclined angle E of an inclined side surface 26 exemplified in Fig. 7(3)) of the inclined side surface is arbitrarily set and is preferably set to 1 to 60° with respect to the surface of the metal plate.

[0041] The recessed portion has a size such that the through hole can be stored inside the recessed portion, and the bottom of the recessed portion is entirely punched out in a punching step serving as a post-process. A bottom side of the inclined side surface may be punched out. Furthermore, a boundary such as a flexion is not present between the bottom surface and the inclined side surface, and the overall recessed portion may have a semispherical shape such as a bowl-like shape. Although the formation of the recessed portion is performed by hot forging or cool forging, hot forging is more preferable. This is because the recessed portion can be easily formed. The formation can be performed simultaneously with a step of forming an outer circumference shape of the metal plate which requires hot forging.

[0042] When the through hole is formed in the metal plate in which the recessed portion is formed in the

punching step, a die in which a projecting portion is vertically formed in a die hole is used to perform punching. As the projecting portion, as exemplified in Figs. 8(1) and 8(2), a projecting portion is vertically formed toward the metal plate side on the peripheral edge of a die hole of a die 29. The projecting portion has a guide surface that guides a direction in which a temporarily residual portion is pressed. A more concrete shape of the projecting portion is a shape which can be in contact with the recessed portion of the metal plate. For example, when the shape of the recessed portion is a truncated cone shape, the projecting portion has a diameter almost equal to that of the truncated cone shape and has a truncated cone shape which is penetrated at a position corresponding to the die hole. The angle of the guide surface is almost equal to the inclined angle E of the inclined side surface and is preferably set to 1 to 60° with respect to the surface of the die.

[0043] Punching is performed in a state in which the metal plate is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface. In the recessed portion forming step, another process may be performed simultaneously with the formation of the recessed portion. For example, the peripheral edge of the metal plate is punched to make it possible to form external teeth or the like of a gear.

[0044] In the metal plate having a through hole manufactured by the above manufacturing method, the inner surface of the through hole on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion including fracture surfaces formed during the punching. The inner surface on one surface side of the metal plate is an inner surface serving as a surface facing the die in the punching step. For example, in Fig. 6, the surface is a surface 71 located on a surface side facing a die 5 of the metal plate material 4 placed on the die 5. The surface 71 is formed to have a smooth surface by pressing the temporarily residual portion formed during the punching.

[0045] Also in the concrete example of the metal plate having a hole described above, the same manufacturing processes can be employed. For example, (1) a manufacturing method includes a punching step of performing punching to a metal plate material which is an external gear including a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, and an external tooth portion formed on a peripheral edge of the metal plate and which is placed on a die to form the shaft hole. In the punching step, breaking occurs during the punching for the shaft hole, a temporarily residual portion which is a peripheral edge of the shaft hole on the die side and protrudes inward from a position corresponding to an inner surface of the shaft hole is formed, and, thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface

can be provided.

[0046] The external tooth portion may be formed before the punching step or may be formed after the punching step. In the manufacturing method, the recessed portion forming step may be further performed before the punching step. Furthermore, in the recessed portion forming step, the external tooth portion may be formed simultaneously with the recessed portion.

[0047] Furthermore, (2) a method of manufacturing an external gear with peripheral hole which is configured by a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate, including an external tooth forming step of forming the external tooth portion, and a punching step of forming the shaft hole and the peripheral holes. In the punching step, the holes are formed such that punching is performed to the metal plate material placed on a die by a punch at a time or in numbers, in the punching step, breaking occurs during the punching for each of the holes to form a temporarily residual portion which is a peripheral edge of each of the holes on the die side and protrudes inward from a position corresponding to an inner surface of each of the holes, and, thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface can be provided.

[0048] The external tooth forming step is a step of forming the external tooth portion and a recessed portion which is located on a surface of the metal plate material at a position where the shaft hole and the peripheral holes are formed and surrounded by a bottom surface and an inclined side surface by performing hot forging or cool forging. In the punching step, a projecting portion is vertically formed on a peripheral edge of a die hole of the die to face the metal plate material, the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed, and the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface. The external tooth forming step may be performed as a step different from the step of forming a recessed portion.

[0049] After the external tooth forming step, the punching step is performed in a state in which the metal plate material is positioned with reference to a position of the external tooth portion. A method of positioning a metal plate material can be arbitrarily selected. For example, a method of gripping and fixing the peripheral edge of a metal plate material can be given.

(3) A manufacturing method including a punching step of performing punching to a metal plate material

which is a metal plate for cam including a metal plate, a shaft hole formed in the metal plate and to which a rotating shaft is attached, and a sliding surface formed on a peripheral edge of the metal plate, and which is placed on a die by a punch to form the shaft hole. In the punching step, breaking occurs during the punching for the shaft hole, a temporarily residual portion which is a peripheral edge of the shaft hole on the die side and protrudes inward from a position corresponding to an inner surface of the shaft hole is formed, and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface can be provided.

The sliding surface may be formed before the punching step or may be formed after the punching step. In the manufacturing method, the recessed portion forming step may be further performed before the punching step. Furthermore, in the recessed portion forming step, the sliding surface may be formed simultaneously with the recessed portion.

[0050] A method of manufacturing a metal plate is a manufacturing method including at least a punching step of performing punching to a metal plate material placed on a die by a punch or a press mold to form an outside portion.

[0051] The material, size, and thickness of a metal plate manufactured by the manufacturing method are not specified. Applications of the outside portion manufactured by the manufacturing method are not specified. For example, the outside portion may be used as a tooth portion of a gear, a sliding portion on which a cam is slid, a circumferential portion, or the like.

[0052] In the punching step, breaking occurs in the metal plate material during the punching for the outside portion, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes outward from a position corresponding to an outer surface of the outside portion, and thereafter, with the punching, the temporarily residual portion is pressed toward a central axis of a die hole by a pressing surface included in a distal end edge of the die hole of the die to have a smooth surface.

[0053] The die used in the punching step, as exemplified as a die 12 in Fig. 19, includes a pressing surface 13a at a distal end edge of a die hole 13. The pressing surface 13a has a shape having an inclined surface obtained by performing chamfering or the like to the distal end edge of the die hole 13, and presses a temporarily residual portion R1, for example, as shown in Fig. 20 toward the central axis of the die hole 13 during the punching. An angle K of the chamfering of the pressing surface 13a is arbitrarily set by a material of a metal plate to be punched, a punching rate, and the like. A distance D of the chamfering is arbitrarily set. The angle K of the chamfering of the pressing surface 13a can be set within,

for example, a range of 1 to 65° when a metal plate made of bearing steel such as SUJ2 is used. When the angle K exceeds the range, breaking after the processes are so large that a smooth surface is not easily formed.

[0054] The fracture surface, as exemplified in Fig. 21(1), is a surface formed with breaking of a punching scrap S1 on a part of a metal plate material W' serving as a peripheral edge of the outside portion 17 in the middle of formation of the outside portion 17 in the metal plate material W' by the die 12 in the step. At least a part of the fracture surface protrudes outward from a position P1 corresponding to an outer surface of the outside portion 17. When the fracture surface is formed, a portion of the metal plate material W' protruding outward from the position P1 on the outside portion 17 is defined as the temporarily residual portion R1. In completion of the punching, a portion called the temporarily residual portion R1 is almost eliminated on a metal plate W.

[0055] As a direction toward the central axis of the die hole 13, for example, as explained in Fig. 19(1), a direction C perpendicular to a punching direction A of a punch 15, an oblique direction crossing the direction C at an acute angle (For example, an obliquely outward direction B can be given.), and the like are given. The angle is arbitrarily set by the material of the metal plate, a punching rate, or the like.

[0056] The punching step can be, for example, the step of forming the outside portion and performing punching to the metal plate material by the punch to form a through hole.

[0057] In the punching step, breaking occurs in the metal plate material during the punching for the through hole, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes inward from a position corresponding to an inner surface of the through, and thereafter, with the punching, the temporarily residual portion is pressed in a direction away from the central axis of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

[0058] In the punching step for the through hole, a configuration of the punching step explained in the method of manufacturing a metal plate with the hole can be applied.

[0059] When the outside portion and the through hole are to be formed, for example, as shown in Fig. 22, by using a pressing machine including a die 62, a press mold 64 disposed above the metal plate material W' set on the die 62, and a punch 65 disposed under the set metal plate material W', the metal plate material W' placed on the die 62 is pressed with the press mold 64 to press the temporarily residual portion with a pressing surface 63a of a die hole 63 so as to form an outside portion 67 having a smoothed surface, and, thereafter, the metal plate material W' placed on the punch 65 is further pressed with the press mold 64 to press the temporarily residual portion with a pressing surface 65a of the punch 65 to make it possible to form a through hole

68 having a smoothed surface.

[0060] For example, as shown in Fig. 24, by using a pressing machine including a die 72, a press mold 74 disposed above the metal plate material W' set on the die 72, and a punch 75 disposed under the set metal plate material W', the metal plate material W' placed on the punch 75 is pressed with the press mold 74 to press the temporarily residual portion with a pressing surface 75a of the punch 75 so as to form a through hole 78 having a smoothed surface, and, thereafter, the metal plate material W' placed on the die 72 is further pressed with the press mold 74 to press the temporarily residual portion with a pressing surface 73a of a die hole 73 to make it possible to form an outside portion 77 having a smoothed surface.

[0061] The smoothness of the surface formed by pressing the surface including the fracture surfaces of the temporarily residual portion with the pressing surface (or a pressing surface of a punch) the die hole only needs to be almost equal to (for example, the same roughness classification) the surface roughness of sheared surface obtained by performing punching without forming fracture surfaces on the outer surface (or an inner surface of a through hole) of the outside portion. The surface roughness is arbitrarily changed depending on punching conditions. However, as a range of an arithmetic average roughness conforming to, for example, JIS B0601 : 2013 (ISO 4287 : 1997), a range of 0.04 to 0.4 μm (more preferably, 0.05 to 0.1 μm) can be given.

[0062] In the metal plate manufactured by the above manufacturing method, the outer surface of the outside portion on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion including fracture surfaces formed during the punching.

[0063] When the outside portion and the through hole are to be formed, the inner surface of the through hole on one surface side of the metal plate and the outer surface of the outside portion on one surface side of the metal plate are configured by smooth surfaces formed by pressing the temporarily residual portion including fracture surfaces formed during the punching.

[0064] The outer surface on one surface side of the metal plate, for example, in Fig. 21(3), may be a surface F1 located on a surface side pressed with the punch 15, for example, in Fig. 23(2), may be surfaces F1 and F2 located on a surface side pressed with the press mold 64, or, for example, in Fig. 25(2), may be surfaces F1 and F2 located on a surface side pressed with the press mold 74. The surfaces F1 and F2 are formed to be smooth surfaces by pressing the temporarily residual portion formed during the punching.

(First Embodiment)

[0065] On the basis of an embodiment for forming a circular through hole in a metal plate by punching, a method of manufacturing a metal plate having the hole will be

described below. According to the manufacturing method, not only a circular hole but also holes having various shapes such as a square hole can be formed by punching.

[0066] The punch 1 of the pressing machine used in the manufacturing method, as exemplified in Fig. 1, has a distal end having a columnar shape and a distal end edge 2 which is chamfered to be the pressing surface 3 facing in the diagonally outward direction B serving as a side surface direction with respect to the punching direction A of the punch 1. The angle K of the chamfering of the pressing surface 3 is arbitrarily set depending on a material of a metal plate to be punched, a punching rate, or the like. However, when a metal plate made of bearing steel such as SUJ2 is used, for example, a range of 1 to 65° can be given. When the angle K exceeds the range, breaking after the processes are so large that a smooth surface is not easily formed. A distance D of the chamfering is arbitrarily set.

[0067] A punching step of forming a through hole in the metal plate material 4 used as an external gear by punching using the punch 1 will be described below. The punching step, as exemplified in Fig. 1, the metal plate material 4 which is made of a bearing steel such as SUJ2 in which a through hole should be formed is placed on the die 5 of the pressing machine, and the punch 1 is arranged above the metal plate material 4. Thereafter, as exemplified in Fig. 2, when the punch 1 is moved downward and sunk into the metal plate material 4, a portion serving as the punching scrap 6 of the metal plate material 4 is displaced downward. As exemplified in Fig. 3, when the punch 1 is moved further downward, breaking occurs near the peripheral edge 81 of the metal plate material 4 on the die 5 side, and the fracture surface 7 appears on the temporarily residual portion 9 or the like located inside the position 82 corresponding to the inner surface of a through hole 8. At the same time, the punching scrap 6 is separated from the fracture surface 7 of the metal plate material 4.

[0068] When the punch 1 moves further downward, the pressing surface 3 of the punch 1, by a divided force F2 of a pressing force F1 diagonally pressing the pressing surface downward in Fig. 3, moves downward while pressing the temporarily residual portion 9 from an end of the fracture surface 7 toward the peripheral edge 81 side of the through hole 8 on the die 5 side. The temporarily residual portion 9 pressed by the pressing surface 3 is pressed to the position corresponding to the inner surface of the through hole 8 to become a part of the thickness of the metal plate material 4.

[0069] Furthermore, the remaining thickness (portion which does not completely become a part of the thickness of the metal plate material 4) of the temporarily residual portion 9 is pressed downward by a divided force F3 of the pressing surface 3 of the punch 1, and becomes an expanded portion 10 expanded downward as shown in Fig. 4. The expanded portion 10, as shown in Fig. 5, moves below the metal plate material 4 with the down-

ward movement of the punch 1. As a result, as shown in Fig. 6, the expanded portion 10 becomes a small burr 11.

[0070] When the punch 1 punches out the metal plate material 4 to obtain the metal plate 40 in which the through hole 8 is formed, the temporarily residual portion 9 becomes the smooth surface 71 by the pressure.

(Effect of First Embodiment)

[0071] As described above, in the punching step, the pressing surface 3 of the punch 1 moves downward the temporarily residual portion 9 remaining at a position corresponding to the inner surface of the through hole 8 of the metal plate material 4 while being pressed to the position corresponding to the inner surface of the through hole 8. After the punching step, although the small burr 11 is present in the through hole 8 formed as shown in Fig. 6, on the inner surface of the through hole 8 on one surface side of the metal plate material 4, i.e., the inner surface facing the die in the embodiment, unlike in a conventional technique, a fracture surface is not formed but the smooth surface 71 is formed. The arithmetic average roughness of the surface 71 is about 0.04 to 0.4 μm . For this reason, after the punching step, unlike in the conventional technique, a step of performing shaving, machining, and the like is not necessary, and time required for manufacturing can be shortened.

[0072] Since the metal plate 40 near the surface 71 formed to be smoothed includes a thickness located in the temporarily residual portion 9 by pressure, the corresponding portion of the metal plate 40 is compressed more strongly than other portions of the metal plate 40 to have a work-hardened texture. For this reason, in some target product, heat treatment can be omitted.

(Second Embodiment)

[0073] A second embodiment will be described below. In the second embodiment, the recessed portion forming step exemplified in Fig. 7 and the punching step exemplified in Figs. 8 and 9 are sequentially performed to a metal plate material 21 to obtain a metal plate 20. The recessed portion forming step, as exemplified in Fig. 7(3), is a step of forming a recessed portion 22 on the surface of the metal plate material 21.

(Recessed Portion Forming Step)

[0074] In a recessed portion forming step, as exemplified in Fig. 7(1), first the heated metal plate material 21 is set on a placing table (not shown), and a processing mold 23 is arranged above the metal plate material 21. In this state, the processing mold 23 is moved downward, as exemplified in Fig. 7(2), hot forging which presses a surface 24 of the metal plate material 21 with the processing mold 23 is performed, as exemplified in Fig. 7(3), to form the recessed portion 22 on the surface of the metal plate material 21. The recessed portion 22 may be formed

by cool forging.

[0075] The formed recessed portion 22 has the same shape as that of the distal end of the processing mold 23, and the recessed portion 22 includes a bottom surface 25 and the inclined side surface 26. A portion including the bottom surface 25 of the recessed portion 22 and an inclined side surface 261 on the bottom surface 25 side are removed by punching. An inclined side surface 262 remaining after the punching can exert a chamfering effect for a through hole. Although the inclined side surface 26 has a conical surface in the embodiment, the shape thereof is not limited to this.

(Punching Step)

[0076] Figs. 8 and 9 show, in a step-by-step manner, the step of punching the inside of the recessed portion 22 formed in the metal plate material 21 by a punch 27 as described above to obtain a metal plate. As exemplified in Fig. 8(1), the outer shape of the punch 27 is the same as that of the punch 1 described in the first embodiment, and a pressing surface 28 is formed on the distal end edge 2 of the punch 27. The die 29 has a shape obtained by forming a projecting portion 31 on an edge of a die hole 30. The projecting portion 31 is vertically formed to protrude from a surface 291 of the die 29 to the metal plate material 21 side, and has a truncated cone shape which is vertically formed along the edge of the die hole 30 and has a penetrated central portion. An inner surface 311 is formed on the same plane as that of the inner surface of the die hole 30, an outer surface of the projecting portion 31 is a conical surface of the truncated cone to serve as a guide surface 32 inclined with reference to the punching direction A. The guide surface 32 guides a direction in which a temporarily residual portion 37 formed during punching is pressed such that the direction becomes the direction B. The inclined angle E of the guide surface 32 is preferably set to 1 to 60°. Furthermore, the guide surface is more preferably formed to be almost parallel with the direction B perpendicular to the pressing surface 28 of the punch 27.

[0077] The punching step, as exemplified in Fig. 8(1), first sets the metal plate material 21 on the die 29. In this case, the inclined side surface 26 of the recessed portion 22 of the metal plate material 21, as exemplified in Fig. 8(1), is formed to be brought into contact with the guide surface 32 of the die 29 when the metal plate material 21 is set on the die 29. The punch 27 having a predetermined outer diameter is arranged above the metal plate material 21. As the outer diameter of the punch 27, as exemplified in Fig. 8(1), an outer diameter set such that an extended line 34 of an outside surface 33 of the punch 27 overhangs the inclined side surface 26 of the recessed portion 22 of the metal plate material 21 is selected. More specifically, the punch 27 having an outer diameter large enough to punch out the metal plate material from the bottom surface 25 of the recessed portion 22 to the inclined side surface 261 of the recessed portion 22 on the

bottom surface 25 side at a time is used.

[0078] When the punch 27 is moved downward in the state exemplified in Fig. 8(1), as shown in Fig. 8(2), the metal plate material 21 is broken as shown in Fig. 8(2) to form a fracture surface 35, and a punching scrap 36 is separated from the fracture surface 35. When the punch 27 moves further downward in this state, as shown in Fig. 9(3), an end of the fracture surface 35 pressed with the pressing surface 28 of the punch 27 is guided by the inclined guide surface 32 of the die 29 such as to flow in a direction G shown in the drawing. The temporarily residual portion 37 near the fracture surface 35 is pressed to a position corresponding to a peripheral edge 381 of a through hole 38 of the metal plate material 21 to become a part of the thickness of the metal plate material 21. The temporarily residual portion 37 (portion which does not become a part of the thickness of the metal plate material 21) remaining as exemplified in Fig. 9(4) becomes a burr 39. Of the inclined side surface, the inclined side surface 262 serving as an edge side of the recessed portion 22 remains.

(Effect of Second Embodiment)

[0079] In the second embodiment, the temporarily residual portion 37 including the fracture surface 35 pressed with the pressing surface 28 of the punch 27, as shown in Fig. 9(3), is guided by the guide surface 32 of the die 29 such as to flow to the peripheral edge 381 on the die 29 side to have a smooth surface. A part of the temporarily residual portion 37 remaining without flowing to the peripheral edge 381, as shown in Fig. 9(4), becomes the burr 39. However, an amount of the burr is smaller than that in the first embodiment. More specifically, in the second embodiment, the inner surface of the through hole 38 is a smooth surface, and an amount of the burr 39 is suppressed to be small. The inclined side surface 262 remains on the peripheral edge of the through hole 38, and the inclined side surface 262 can exert the same effect as that of chamfering. For this reason, an additional step of performing chamfering is not necessary, and operations are simplified.

[0080] In the recessed portion forming step described above, as shown in Fig. 7, the case in which the inclined side surface 26 of the recessed portion 22 is formed to be a conical surface is described. However, when the distal end shape of the processing mold 23 is changed into a pyramid shape, the inclined side surface 26 of the recessed portion 22 can be changed into a pyramid surface.

[0081] Furthermore, the recessed portion 22 can be formed by hot forging or the like without using machining, and the through hole 38 can be easily formed in the metal plate material 21 by punching. For this reason, a metal plate with hole can be manufactured within a period of time shorter than that in the machining, without requiring so much manpower. Since a residual stress occurring in each of the recessed portion forming step and the punch-

ing step is almost equal to that in machining, even though heat treatment is performed in a subsequent step, a risk of causing warpage or the like does not easily occur.

5 (Method of Manufacturing External Gear with Peripheral Hole for Planet Gear)

[0082] As a third embodiment, a method of manufacturing an external gear with peripheral hole for planet gear by using the recessed portion forming step and the punching step will be described below. As shown in Fig. 10, on an external gear with peripheral hole 41, an external tooth portion 43 obtained by forming teeth along the outer circumference of a circular metal plate 42, a shaft hole 44 formed at the center of the metal plate 42, and a plurality of peripheral holes 45 formed around the shaft hole 44 to surround the shaft hole 44 are formed.

[0083] The external tooth portion 43 includes external teeth of a gear to transmit motion of the metal plate 42 rotating as a planet carrier. The outer diameter, the tooth shapes, and the number of teeth of the external tooth portion 43 are arbitrarily set depending on applications.

[0084] The shaft hole 44 is a hole into which a rotating shaft is to be inserted, the shape of the shaft hole 44 is determined depending on the shape of the rotating shaft, and the diameter of the shaft hole 44 is set depending on the diameter of the rotating shaft. The outer diameter of the external gear with peripheral hole 41, the tooth shapes and the number of teeth of the external tooth portion 43, the diameter of the shaft hole, and the diameter of each of the peripheral holes, the number of peripheral holes, and the like can be arbitrarily changed depending on applications. For example, in the external gear with peripheral hole having a diameter of 250 mm in the embodiment, the number of peripheral holes 45 can be set to 2 to 8. The thickness in the embodiment is 1 to 50 mm. However, the thickness is not limited thereto, and can be arbitrarily selected depending on the diameter.

[0085] The peripheral holes 45 are holes to insert rotating shafts of planet gears into the metal plate 42 to fix the rotating shafts. The number of peripheral holes 45 is equal to the number of planet gears, and the diameters of the peripheral holes 45 are diameters corresponding to the diameters of the rotating shafts of the planet gears. The hole shape of each of the peripheral holes 45 can be not only a circular shape but also an arbitrary square shape.

[0086] Steps in manufacturing the external gear with peripheral hole 41 will be described below with reference to the manufacturing method exemplified in the second embodiments. The steps in manufacturing an external gear with peripheral hole includes an external tooth forming step, a shaft hole forming step, and a peripheral hole forming step. The external tooth forming step, the shaft hole forming step, and the peripheral hole forming step are executed in the order named. Of the steps, the manufacturing method is performed in the shaft hole forming

step and the peripheral hole forming step

[0087] The steps will be sequentially described below.

(External Tooth Forming Step)

[0088] The external tooth forming step is a step of obtaining a first intermediate workpiece 51 exemplified in Fig. 11 from a circular metal plate material. In this case, the first intermediate workpiece 51 is a workpiece in a state in which the external tooth portion 43, a recessed portion for shaft hole 46, and recessed portions for peripheral hole 47 are formed on a metal plate material 48.

[0089] In the step, the recessed portion for shaft hole 46 and the recessed portions for peripheral hole 47 are formed by executing the recessed portion forming step exemplified in the second embodiment to the surface of the metal plate material 48, and the external tooth portion 43 is formed by executing conventional punching to the outer circumference of the metal plate material 48. In this case, the recessed portion for shaft hole 46 is formed at a position where the shaft hole 44 shown in Fig. 10 should be formed, and the recessed portions for peripheral hole 47 are formed at positions where the peripheral holes 45 shown in Fig. 10 should be formed.

[0090] The recessed portion forming step of forming the recessed portion for shaft hole 46 and the recessed portions for peripheral hole 47 and the step of punching for forming the external tooth portion 43 are preferably executed at a time by the external tooth forming step. However, the steps may be independently executed. The drawings of the embodiment show the example in which the recessed portion forming step is performed to both the front and rear surfaces of the metal plate material 48 to form the recessed portion for shaft hole 46 and the recessed portions for peripheral hole 47 on both the front and rear surfaces of the metal plate material 48. However, the recessed portion forming step may be performed on only one surface of the metal plate material 48.

(Heat Treatment Step)

[0091] A heat treatment step is a step of performing hardening to the first intermediate workpiece 51 formed in the external tooth forming step described above. Conditions for heat treatment in the step are not specified, and normal hardening conditions may be employed. After the heat treatment, shot blasting may be performed to process the surface of the first intermediate workpiece 51. Conditions for the shot blasting are not specified. Furthermore, after the heat treatment, finish forging for fixing the shapes of the external tooth portion 43 and the like may be performed to the first intermediate workpiece 51. The finish forging, for example, is performed in a manner that the first intermediate workpiece 51 to which the heat treatment is performed penetrates a die having a predetermined shape in a direction of thickness.

(Shaft Hole Forming Step)

[0092] A shaft hole forming step will be described below with reference to Fig. 12. The shaft hole forming step is a step of executing the punching step exemplified in the second embodiment to the recessed portion for shaft hole 46 of the first intermediate workpiece 51 exemplified in Fig. 11 to form the shaft hole 44 so as to form a second intermediate workpiece 52. In the shaft hole forming step, when the shaft hole 44 is formed in the recessed portion for shaft hole 46 exemplified in Fig. 11 while the external tooth portion 43 is nipped, the shaft hole 44 exemplified in Fig. 12 is consequently formed in a state in which the first intermediate workpiece 51 is positioned with reference to the external tooth portion 43. Thus, the processing accuracy of the shaft hole 44 can be improved. On the edge of the shaft hole 44, an inclined side surface 44a which is like the inclined side surface 262 shown in Fig. 9(4) is formed.

(Peripheral Hole Forming Step)

[0093] A peripheral hole forming step will be described below with reference to Figs. 13 and 14. The peripheral hole forming step is a step of executing the punching step exemplified in the second embodiment to the recessed portions for peripheral hole 47 of the second intermediate workpiece 52 exemplified in Fig. 12 to form the peripheral holes 45. In this step, all the peripheral holes 45 may be formed by performing punching once, or punching for forming one or two of the peripheral holes 45 at a time may be repeated. However, punching for the peripheral holes 45 is preferably executed in a plurality of times because a pressure generated in punching can be lower than that generated when punching for all the peripheral holes 45 is executed at a time.

[0094] Furthermore, when the number of peripheral holes 45 is an even number, the recessed portions for peripheral hole 47 located at positions symmetrical about the shaft hole 44 are preferably punched out at a time. For example, as exemplified in Fig. 13, two peripheral holes 45a located at positions symmetrical about the shaft hole 44 are formed first, and, as shown in Fig. 14, two peripheral holes 45b located on the immediately left sides of the peripheral holes 45a are formed, respectively. Thereafter, peripheral holes are sequentially formed in two recessed portions for peripheral hole 47c located on the immediately left sides of the peripheral holes 45b and two recessed portions for peripheral hole 47d located on the immediately left sides of the recessed portions for peripheral hole 47c. As exemplified in Fig. 14, on the edges of each of the peripheral holes 45a, an inclined side surface 45e which is like the inclined side surface 26 shown in Fig. 9(4) is formed, and, similarly, the inclined side surface 45e is also formed on the edge of each of the peripheral holes 45b.

[0095] As described above, when the peripheral holes are formed by performing punching in a plurality of times,

guide pins are inserted into the formed shaft hole 44 and the formed peripheral holes 45 to protect the shaft hole 44 and the peripheral holes 45, so that the formed shaft hole 44 and the formed peripheral holes 45 can be prevented from being deformed in formation of a new peripheral hole 45. The guide pins have columnar shapes having diameters almost equal to those of the shaft hole 44 and the peripheral holes 45 and are inserted into the existing shaft hole 44 and the existing peripheral holes 45 to prevent the existing shaft hole 44 and the existing peripheral holes 45 from being deformed by stress occurring with punching in formation of a new peripheral hole 45. In the embodiment, of the peripheral holes 45 at all the eight positions, the peripheral holes 45 at two positions are formed at a time. For this reason, the guide pin for the shaft hole 44 and the guide pins for the peripheral holes 45 at the remaining 6 positions are prepared.

[0096] For example, as shown in Fig. 15, the shaft hole 44 and the two peripheral holes 45a are formed, and the recessed portions for peripheral hole 47 remain without forming the remaining peripheral holes, a guide pin 53 for the shaft hole 44 is arranged above the shaft hole 44, and guide pins for the peripheral holes 45 are arranged above the four unprocessed recessed portions for peripheral hole 47 and the two peripheral holes 45a. The guide pin 53 is inserted into the formed shaft hole 44. Furthermore, except for recessed portions for peripheral hole 47b in which the peripheral holes (45b) are formed by a punch 55, guide pins 54a are inserted into the formed peripheral holes 45a, respectively. Guide pins 54b are fitted in the recessed portions for peripheral hole 47, respectively. The guide pins 54a and 54b have the same configurations except that the guide pins 54a are inserted into the peripheral holes 45 and the guide pins 54b are not inserted into the peripheral holes 45.

[0097] Fig. 16 shows a sectional view along an X - X line shown in Fig. 15, and Fig. 17 shows a sectional view along a Y - Y line in Fig. 15. As shown in Fig. 16, when the peripheral holes 45 are not formed, the guide pins 54b are brought into contact with the recessed portions for peripheral hole 47 of the metal plate material 48, respectively. On the other hand, as shown in Fig. 17, when the peripheral holes 45 are formed, the guide pins 54a penetrate the peripheral holes 45 to fill the peripheral holes 45, respectively. In Figs. 16 and 17, the guide pin 53 penetrates the shaft hole 44 to fill the shaft hole 44. In this state, when punching is performed to the recessed portions for peripheral hole 47b shown in Fig. 15 by the punch 55, force acting on the formed shaft hole 44 and the formed peripheral holes 45 is received by the guide pins 53 and 54a to make it possible to prevent the shaft hole 44 and the peripheral holes 45 from being deformed. The step of punching the two recessed portions for peripheral hole 47 is repeated four times to punch all the recessed portions for peripheral hole 47, so that the external gear with peripheral hole 41 obtained by forming the external tooth portion 43, the shaft hole 44, and all

the peripheral holes 45 in the metal plate 42 shown in Fig. 10 is manufactured.

(Effect of Third Embodiment)

[0098] In the embodiment, without performing cutting or the like by machining, formation or the like of an external tooth portion, a shaft hole, and peripheral holes is performed by the recessed portion forming step and the punching step of the manufacturing method. For this reason, an external gear with peripheral hole can be manufactured within a period of time extremely shorter than that in machining, and manpower can be reduced. Furthermore, even though heat treatment is performed to the manufactured external gear with peripheral hole, since residual stress is at the same level as that in machining, distortion such as warpage does not occur.

[0099] Since the inclined side surfaces formed on the edges of the shaft hole and the peripheral holes of the external gear with peripheral hole function as chambers, even though chamfering or the like is not performed by machining, there are no sharp angles, and a burr or the like does not easily occur. Furthermore, since the recessed portion for shaft hole and the recessed portions for peripheral hole are formed in an external tooth forming step before the heat treatment step, the recessed portion for shaft hole and the recessed portions for peripheral hole can be formed more easily than in a case where the recessed portion for shaft hole and the recessed portions for peripheral hole which are formed after the heat treatment step. Furthermore, the external tooth portion is formed in the external tooth forming step before the shaft hole and the peripheral holes are formed. Thereafter, when manufacturing is performed by a series of procedures of forming the shaft hole in the shaft hole forming step and forming the peripheral holes in the peripheral hole forming step, the external tooth portion, the shaft hole, and the peripheral holes are improved in processing accuracy, and finishing can be simplified.

[0100] In the embodiment, the external gear with peripheral hole in which the number of peripheral holes is set to eight is given. However, the configuration need not be always used, and the number of peripheral holes 45 can be arbitrarily changed depending on applications, sizes, or the like.

[0101] Fig. 18 shows a fourth embodiment. In Fig. 8(1), of the bottom surface 25 to the inclined side surface 26 in the recessed portion 22, a portion corresponding to the inclined side surface 261 on the bottom surface side is punched with the punch 27. However, as shown in Fig. 18, only the bottom surface 25 (portion surrounded by a line 34a) of the recessed portion 22 of the metal plate material 21 is punched with a punch 27a. Even though the punching is performed as described above, the inclined side surface 26 remains on the peripheral edge of the through hole to be formed, and the inclined side surface 26 can exert the same effect as that of chamfering. For this reason, an additional step of performing cham-

fering is not necessary, and operations are simplified.

[0102] The present invention is not limited to the embodiments described above, and embodiments variously changed within the scope of the present invention depending on objects and applications can be obtained. For example, as a concrete application of a metal plate with hole, the external gear with peripheral hole for planet gear is given in the third embodiment. However, the external gear with peripheral hole need not be always used, and a normal external gear, a normal metal plate for cam, a normal pinwheel, and the like can be given. The metal plate can be used as a metal plate in which holes for fastening members such as various shafts and screws are formed.

(Fifth Embodiment)

[0103] In a method of manufacturing a metal plate according to a fifth embodiment, as shown in Fig. 19, a pressing machine including the die 12 and the punch 15 disposed above the metal plate material W' set on the die 12 is used. The distal end edge of the die hole 13 of the die 12 is chamfered to form the pressing surface 13a being inclined with reference to a punching direction A of the punch 15 and facing a side surface.

[0104] A punching step using the pressing machine will be described below. In the punching step, as shown in Fig. 19, the metal plate material W' is placed and set on the die 12. Thereafter, as shown in Fig. 20(1), the punch 15 moves downward to perform punching to the metal plate material W' placed on the die 12. At this time, in the metal plate material W', a portion near a part where a distal outer peripheral edge side of the punch 15 punched into the metal plate material W' and a distal inner peripheral edge side of the die hole 13 are connected to each other is broken. At this time, the temporarily residual portion R1 is formed in the fracture portion of the metal plate material W' to protrude outward (more specifically, a side being away from the central axis side of the die hole 13) from a position P1 corresponding to an outer surface of the outside portion 67 through the pressing surface 13a of the die hole 13 (see Fig. 21(1)). Note that a punching scrap S is separated from the fracture surface of the metal plate material W' and left on the die 12.

[0105] As shown in Fig. 20(2), when the punch 15 moves further downward, the temporarily residual portion R1 is pressed toward the central axis of the die hole 13 with the pressing surface 13a of the die hole 13. The temporarily residual portion R1 pressed with the pressing surface 13a is moved upward while being pressed to the position P1 corresponding to the outer surface of the outside portion 17 and serves as a part of the thickness of the metal plate material W' (see Fig. 21(2)). Thereafter, as shown in Fig. 20(3), the metal plate W (product) on which the outside portion 17 having a predetermined shape is formed is obtained. The thickness (portion which does not completely serve as a part of the thickness of

the metal plate material W') of the remaining temporarily residual portion R1 is pressed upward with the pressing surface 13a of the die hole 13 to form a small burr B1 (see Fig. 21(3)).

(Effect of Fifth Embodiment)

[0106] According to the method of manufacturing a metal plate of the fifth embodiment, in the punching step, the pressing surface 13a of the die hole 13 moves upward the temporarily residual portion R1 remaining outside the position P1 corresponding to the outer surface of the outside portion 17 of the metal plate material W' while pressing the temporarily residual portion R1 to the position P1 corresponding to the outside portion 17. After the punching step, although it is recognized that a small burr B1 is present on the formed outside portion 17, on the outer surface of the outside portion 17 on one surface side of the metal plate W, i.e., the outer surface on one surface side pressed with the punch 15, unlike in a conventional technique, a fracture surface is not formed but a smooth surface F1 is formed (see Fig. 21(3)). The arithmetic average roughness of the surface F1 is about 0.04 to 0.4 μm . For this reason, after the punching step, unlike in the conventional technique, a step of performing shaving, machining, and the like is not necessary, and time required for manufacturing can be shortened.

[0107] Since the metal plate W near the surface F1 formed to be smoothed includes a thickness located in the temporarily residual portion R1 by pressing, the corresponding portion of the metal plate W is compressed more strongly than other portions of the metal plate W to have a work-hardened texture. For this reason, in some target product, heat treatment can be omitted.

(Sixth Embodiment)

[0108] In a method of manufacturing a metal plate according to a sixth embodiment, as shown in Fig. 22, a pressing machine including the die 62, the press mold 64 disposed above the metal plate material W' set on the die 62, and the punch 65 disposed under the set metal plate material W' is used. The distal end edge of the die hole 63 of the die 62 is chamfered to form the pressing surface 63a being inclined with reference to the punching direction A of the press mold 64 and facing a side surface. The press mold 64 has a cylindrical portion 64a having the outside portion 67 formed between the press mold 64 and the die 62 and a through hole 68 between the press mold 64 and the punch 65. The distal end edge of the punch 65 is chamfered to form the pressing surface 65a being inclined with reference to a punching direction A of the punch 65 and facing a side surface.

[0109] A punching step using the pressing machine will be described below. In the punching step, as shown in Fig. 22(1), the metal plate material W' is placed and set on the die 62. Thereafter, as shown in Fig. 22(2), the press mold 64 moves downward to perform punching to

the metal plate material W' placed on the die 62. At this time, in the metal plate material W', a portion near a part where a distal outer peripheral edge side of a cylindrical portion 64a of the press mold 64 punched into the metal plate material W' and a distal inner peripheral edge side of the die hole 63 are connected to each other is broken. At this time, the temporarily residual portion R1 is formed in the fracture portion of the metal plate material W' to protrude outward (more specifically, a side being away from the central axis side of the die hole 13) from the position P1 corresponding to the outer surface of the outside portion 67 through the pressing surface 63a of the die hole 63 (see Fig. 23(1)).

[0110] When the press mold 64 moves further downward, the temporarily residual portion R1 is pressed toward the central axis of the die hole 63 with the pressing surface 63a of the die hole 63. The temporarily residual portion R1 pressed with the pressing surface 63a of the die hole 63 is moved upward while being pressed to the position P1 corresponding to the outer surface of the outside portion 67 and serves as a part of the thickness of the metal plate material W'. Note that the punching scrap S1 is separated from the fracture surface of the metal plate material W' and left on the die 62.

[0111] Thereafter, when the press mold 64 moves further downward, in the metal plate material W', a portion near a part where a distal inner peripheral edge side of a cylindrical portion 64a of the press mold 64 punched into metal plate material W' and a distal outer peripheral edge side of the punch 65 are connected to each other is broken. At this time, the temporarily residual portion (see a temporarily residual portion 9 in Figs. 3 to 5) is formed in the fracture portion of the metal plate material W' to protrude inward (more specifically, a side approaching the central axis side of the punch 65) from a position P2 corresponding to an inner surface of the through hole 68 through the pressing surface 65a of the punch 65.

[0112] When the press mold 64 moves further downward, the temporarily residual portion is pressed in a direction away from toward the central axis of the punch 65 with the pressing surface 65a of the punch 65. The temporarily residual portion pressed with the pressing surface 65a of the punch 65 is moved upward while being pressed to the position P2 corresponding to the inner surface of the through hole 68 and serves as a part of the thickness of the metal plate material W'. Thereafter, as shown in Fig. 22(3), the metal plate W (product) on which the outside portion 67 and the through hole 68 which have predetermined shapes are formed is obtained. Note that a punching scrap S2 is separated from the fracture surface of the metal plate material W' and left on the punch 65. The thickness (portion which does not completely serve as a part of the thickness of the metal plate material W') of the remaining temporarily residual portion R1 is pressed upward with the pressing surface 63a of the die hole 63 and the pressing surface 65a of the punch 65 to form small burrs B1 and B2 (see Fig. 23(2)).

(Effect of Sixth Embodiment)

[0113] According to the method of manufacturing a metal plate according to the sixth embodiment, in the punching step, after the pressing surface 63a of the die hole 63 moves upward the temporarily residual portion R1 remaining outside the position P1 corresponding to the outer surface of the outside portion 67 of the metal plate material W' while pressing the temporarily residual portion R1 to the position P1 corresponding to the outer surface of the outside portion 67, the pressing surface 65a of the punch 65 moves upward the temporarily residual portion remaining inside the position P2 corresponding to the inner surface of the through hole 68 of the metal plate material W' while pressing the temporarily residual portion to the position P2 corresponding to the inner surface of the through hole 68. After the punching step, although it is recognized that the small burrs B1 and B2 are present on the outside portion 67 and the through hole 68, on the outer surface of the outside portion 67 on one surface side of the metal plate W, i.e., the outer surface on one surface side pressed with the press mold 64, unlike in a conventional technique, a fracture surface is not formed but the smooth surface F1 is formed (see Fig. 23(2)). On the inner surface of the through hole 68 on one surface side of the metal plate W, i.e., the inner surface on one surface side pressed with the press mold 64, unlike in a conventional technique, a fracture surface is not formed but the smooth surface F2 is formed (see Fig. 23(2)). The arithmetic average roughnesses of the surfaces F1 and F2 are about 0.04 to 0.4 μm . For this reason, after the punching step, unlike in the conventional technique, a step of performing shaving, machining, and the like is not necessary, and time required for manufacturing can be shortened.

[0114] Since the metal plate W near the surfaces F1 and F2 formed to be smooth surfaces includes a thickness configuring the temporarily residual portion R1 by pressing, the corresponding portion of the metal plate W is compressed more strongly than other portions of the metal plate W to have a work-hardened texture. For this reason, in some target product, heat treatment can be omitted.

(Seventh Embodiment)

[0115] In a method of manufacturing a metal plate according to a seventh embodiment, as shown in Fig. 24, a pressing machine including the die 72, the press mold 74 disposed above the metal plate material W' set on the die 72, and the punch 75 disposed under the set metal plate material W' is used. The distal end edge of the die hole 73 of the die 72 is chamfered to form the pressing surface 73a being inclined with reference to the punching direction A of the press mold 74 and facing a side surface. The press mold 74 has a cylindrical portion 74a having the outside portion 77 formed between the press mold 74 and the die 72 and the through hole 78 between the

press mold 74 and the punch 75. The distal end edge of the punch 75 is chamfered to form the pressing surface 75a being inclined with reference to a punching direction A of the press mold 74 and facing a side surface.

[0116] A punching step using the pressing machine will be described below. In the punching step, as shown in Fig. 24(1), the metal plate material W' is placed and set on the punch 75. Thereafter, the press mold 74 moves downward to perform punching to the metal plate material W' placed on the punch 75. At this time, in the metal plate material W', a portion near a part where a distal inner peripheral edge side of the cylindrical portion 74a of the press mold 74 punched into metal plate material W' and a distal outer peripheral edge side of the punch 75 are connected to each other is broken. At this time, the temporarily residual portion (see the temporarily residual portion 9 in Figs. 3 to 5) is formed in the fracture portion of the metal plate material W' to protrude inward (more specifically, a side approaching the central axis side of the punch 75) from the position P2 corresponding to an inner surface of the through hole 78 through the pressing surface 75a of the punch 75.

[0117] As shown in Fig. 24(2), when the press mold 74 moves further downward, the temporarily residual portion is pressed in a direction away from toward the central axis of the punch 75 with the pressing surface 75a of the punch 75. The temporarily residual portion pressed with the pressing surface 75a of the punch 75 is moved upward while being pressed to the position P2 corresponding to the inner surface of the through hole 78 and serves as a part of the thickness of the metal plate material W'. Note that a punching scrap S1 is separated from the fracture surface of the metal plate material W' and left on the punch 75.

[0118] Thereafter, when the press mold 74 moves further downward, in the metal plate material W', a portion near a part where a distal outer peripheral edge side of the cylindrical portion 74a of the press mold 74 punched into metal plate material W' and a distal inner peripheral edge side of the die hole 73 are connected to each other is broken. At this time, the temporarily residual portion (see the temporarily residual portion R1 in Fig. 21) is formed in the fracture portion of the metal plate material W' to protrude outward from the position P1 corresponding to an outer surface of the outside portion 77 through the pressing surface 73a of the die hole 73.

[0119] When the press mold 74 moves further downward, the temporarily residual portion is pressed toward the central axis of the die hole 73 with the pressing surface 73a of the die hole 73. The temporarily residual portion pressed with the pressing surface 73a of the die hole 73 is moved upward while being pressed to the position P1 corresponding to the outer surface of the outside portion 77 and serves as a part of the thickness of the metal plate material W'. Thereafter, as shown in Fig. 24(3), the metal plate W (product) on which the outside portion 77 and the through hole 78 which have predetermined shapes are formed is obtained. Note that the punching scrap S2

is separated from the fracture surface of the metal plate material W' and left on the die 72. The thickness (portion which does not completely serve as a part of the thickness of the metal plate material W') of the remaining temporarily residual portion is pressed upward with the pressing surface 73a of the die hole 73 and the pressing surface 75a of the punch 75 to form small burrs B1 and B2 (see Fig. 25(2)).

10 (Effect of Seventh Embodiment)

[0120] According to the method of manufacturing a metal plate according to the seventh embodiment, in the punching step, after the pressing surface 75a of the punch 75 moves upward the temporarily residual portion remaining inside the position P2 corresponding to the inner surface of the through hole 78 of the metal plate material W' while pressing the temporarily residual portion to the position P2 corresponding to the inner surface of the through hole 78, the pressing surface 73a of the die hole 73 moves upward the temporarily residual portion remaining outside the position P1 corresponding to the outer surface of the outside portion 77 of the metal plate material W' while pressing the temporarily residual portion to the position P1 corresponding to the outer surface of the outside portion 77. After the punching step, although it is recognized that the small burrs B1 and B2 are present on the outside portion 77 and the through hole 78, on the outer surface of the outside portion 77 on one surface side of the metal plate W, i.e., the outer surface on one surface side pressed with the press mold 74, unlike in a conventional technique, a fracture surface is not formed but the smooth surface F1 is formed (see Fig. 25(2)). On the inner surface of the through hole 78 on one surface side of the metal plate W, i.e., the inner surface on one surface side pressed with the press mold 74, unlike in a conventional technique, a fracture surface is not formed but the smooth surface F2 is formed (see Fig. 25(2)). The arithmetic average roughnesses of the surfaces F1 and F2 are about 0.04 to 0.4 μm . For this reason, after the punching step, unlike in the conventional technique, a step of performing shaving, machining, and the like is not necessary, and time required for manufacturing can be shortened.

[0121] Since the metal plate W near the surfaces F1 and F2 formed to be smoothed includes a thickness configuring the temporarily residual portion by pressing, the corresponding portion of the metal plate W is compressed more strongly than other portions of the metal plate W to have a work-hardened texture. For this reason, in some target product, heat treatment can be omitted.

[0122] The present invention is not limited to the embodiments described above, and embodiments variously changed within the scope of the present invention depending on objects and applications can be obtained. For example, in the sixth and seventh embodiments, outer peripheral shapes of the outside portions 67 and 77 and the through holes 68 and 78 of the metal plate W

may be, for example, the same shapes as shown in Fig. 21 or may be different shapes. As the outer peripheral shapes of the outside portions 67 and 77 and the through holes 68 and 78, for example, as shown in Fig. 21, circular shapes, polygonal shapes, and gear-like shapes can be given.

[0123] In the sixth and seventh embodiments, the outside portions 67 and 77 and the through holes 68 and 78 are formed by the pressing machine in a predetermined order. However, the order of formation is not limited thereto, and, for example, the outside portions and the through holes may be almost simultaneously formed by the pressing machine. Furthermore, for example, the outside portions and the through hole may be separately formed by using the pressing machine.

[Industrial Applicability]

[0124] A metal plate with hole formed by the method of manufacturing a metal plate having a hole is widely used in a machine product such as a gear or a cam. A metal plate having an outside portion formed by the method of manufacturing a metal plate is widely used in a machine product such as a gear or a cam.

[0125] A method of manufacturing a metal plate having a hole in which an inner surface of the punched hole is a smooth surface, a metal plate with hole manufactured by the method, an external gear with peripheral hole, an external gear, and a metal plate for cam are provided.

[0126] The method of manufacturing a metal plate having a hole includes a punching step of performing punching to a metal plate material placed on a die (5) by a punch (1) to form a through hole (8). In the punching step, breaking occurs during the punching for the through hole, a temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole (8) is formed, and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface (3) included in a distal end edge of the punch to have a smooth surface (71). The recessed portion forming step can be further included.

Claims

1. A method of manufacturing a metal plate having a hole comprising a punching step of performing punching to a metal plate material placed on a die by a punch to form a through hole, wherein in the punching step, breaking occurs during the punching for the through hole, a temporarily residual portion which is a peripheral edge of the through hole on the die side and protrudes inward from a position corresponding to an inner surface of the through hole is formed, and thereafter, with the punching, the temporarily resid-

ual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

2. The method of manufacturing a metal plate having a hole according to claim 1, wherein a recessed portion forming step is further performed before the punching step, the recessed portion forming step is a step of forming a recessed portion surrounded by a bottom surface and an inclined side surface at a position where the through hole is formed by performing hot forging or cool forging on a surface of the metal plate material, in the punching step, a projecting portion is vertically formed on an edge of a die hole of the die to face the metal plate material, the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed, and the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface.
3. The method of manufacturing a metal plate having a hole according to claim 1 or 2, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .
4. A metal plate with hole, comprising a metal plate and a through hole formed in the metal plate, wherein the through hole is manufactured by the method of manufacturing a metal plate having a hole according to any one of claims 1 to 3, and an inner surface of the through hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.
5. A method of manufacturing an external gear with peripheral hole which is configured by a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral edge of the metal plate, including an external tooth forming step of forming the external tooth portion, and a punching step of forming the shaft hole and the peripheral holes, wherein in the punching step, the holes are formed such that punching is performed to the metal plate material placed on a die by a punch at a time or in a plurality of times, in the punching step, breaking occurs during the punching for each of the holes to form a temporarily residual portion which is a peripheral edge of each

of the holes on the die side and protrudes inward from a position corresponding to an inner surface of each of the holes, and thereafter, with the punching, the temporarily residual portion is pressed toward a side surface of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

6. The method of manufacturing an external gear with peripheral hole according to claim 5, wherein the external tooth forming step is a step of forming the external tooth portion and a recessed portion which is located on a surface of the metal plate material at a position where the shaft hole and the peripheral holes are formed and surrounded by a bottom surface and an inclined side surface by performing hot forging or cool forging, in the punching step, a projecting portion is vertically formed on an edge of a die hole of the die to face the metal plate material, the projecting portion includes a guide surface which guides a direction in which the temporarily residual portion is pressed, and the punching is performed in a state in which the metal plate material is placed on the die such that the inclined side surface of the recessed portion is brought into contact with the guide surface.
7. The method of manufacturing an external gear with peripheral hole according to claim 5 or 6, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .
8. The method of manufacturing an external gear with peripheral hole according to any one of claims 5 to 7, wherein, after the external tooth forming step, the punching step is performed in a state in which the metal plate material is positioned with reference to a position of the external tooth portion.
9. The method of manufacturing an external gear with peripheral hole according to any one of claims 5 to 8, wherein, in the punching step, the peripheral holes are formed by performing punching in a plurality of times, and formation of each of the peripheral holes is performed in a state in which a guide pin having a diameter equal to that of the peripheral hole is inserted into a peripheral hole which has been formed, in order to prevent deformation of each of the peripheral holes which have been formed.
10. An external gear with peripheral hole including a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, a plurality of peripheral holes which are formed in the metal plate around the shaft hole and to which rotating shafts of planet gears are attached, and an external tooth portion formed on a peripheral

edge of the metal plate, wherein the shaft hole and each of the peripheral holes are formed by the method of manufacturing a metal plate having a hole according to any one of claims 5 to 9, and an inner surface of each of the holes on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during the punching.

11. An external gear comprising a metal plate, a shaft hole which is formed at a center of the metal plate and to which a rotating shaft is attached, and an external tooth portion formed on a peripheral edge of the metal plate, wherein the shaft hole is manufactured by the method of manufacturing a metal plate having a hole according to any one of claims 1 to 3, and an inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.
12. A metal plate for cam, comprising a metal plate, a shaft hole which is formed in the metal plate and to which a rotating shaft is attached, and a sliding surface formed on a peripheral edge of the metal plate, wherein the shaft hole is manufactured by the method of manufacturing a metal plate having a hole according to any one of claims 1 to 3, and an inner surface of the shaft hole on one surface side of the metal plate is configured by a smooth surface formed by pressing a temporarily residual portion formed during punching.
13. A method of manufacturing a metal plate comprising a punching step of performing punching to a metal plate material placed on a die by a punch or a press mold to form an outside portion, wherein in the punching step, breaking occurs in the metal plate material during the punching for the outside portion, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes outward from a position corresponding to an outer surface of the outside portion, and thereafter, with the punching, the temporarily residual portion is pressed toward a central axis of the die hole by a pressing surface included in a distal end edge of the die hole of the die to have a smooth surface.
14. The method of manufacturing a metal plate according to claim 13, wherein the punching step is the step of forming the outside portion and performing punching to the metal plate material by the punch to form a through hole, in the punching step, breaking occurs in the metal

plate material during the punching for the through hole, a temporarily residual portion is formed on a fracture portion of the metal plate material such that the temporarily residual portion protrudes inward from a position corresponding to an inner surface of the through hole, and thereafter, with the punching, the temporarily residual portion is pressed in a direction away from a central axis of the punch by a pressing surface included in a distal end edge of the punch to have a smooth surface.

15. The method of manufacturing a metal plate having a hole according to claim 13 or 14, wherein the smoothed surface has an arithmetic average roughness of 0.04 to 0.4 μm .
16. A metal plate manufactured by the method of manufacturing a metal plate described in any one of claims 13 to 15, wherein an outer surface of the outside portion on one surface side of the metal plate is configured by a smooth surface formed by pressing the temporarily residual portion formed during the punching.

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FIG. 1

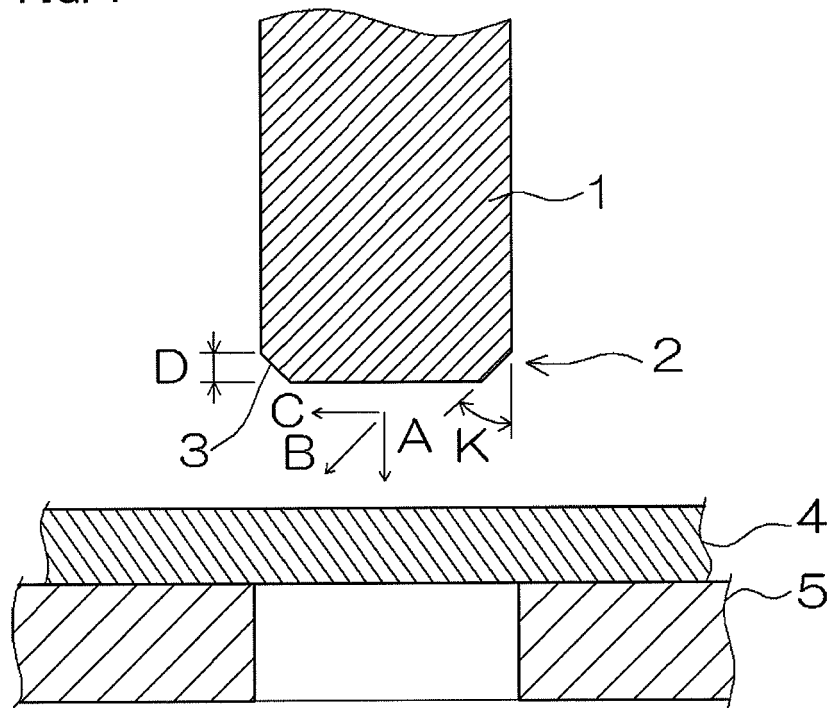


FIG. 2

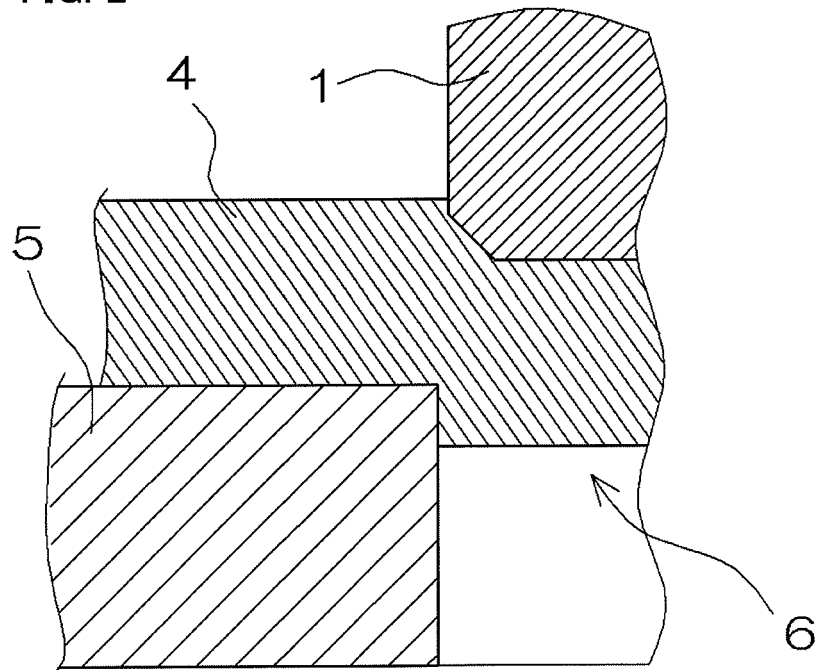


FIG. 3

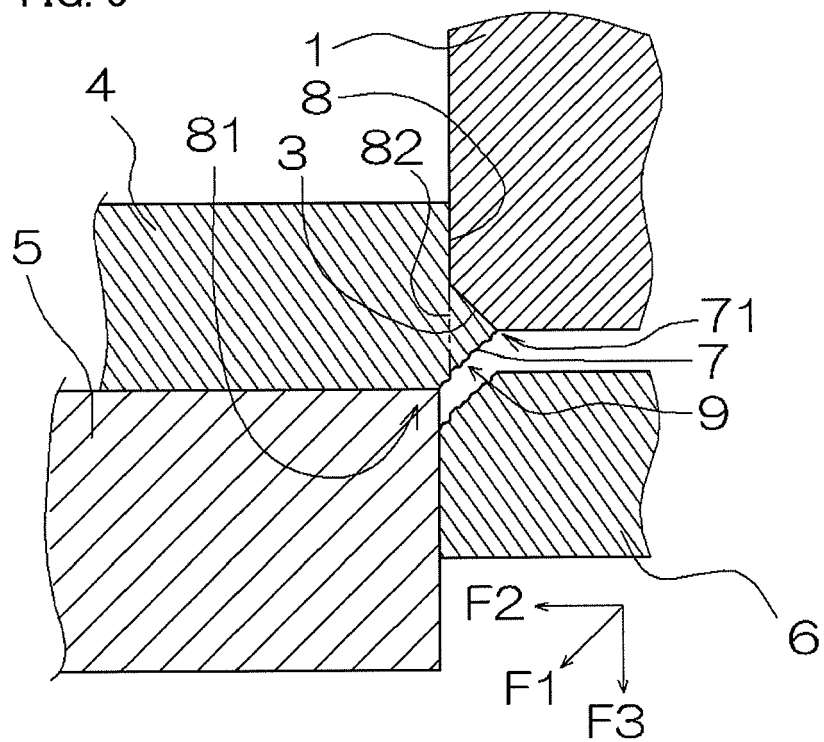


FIG. 4

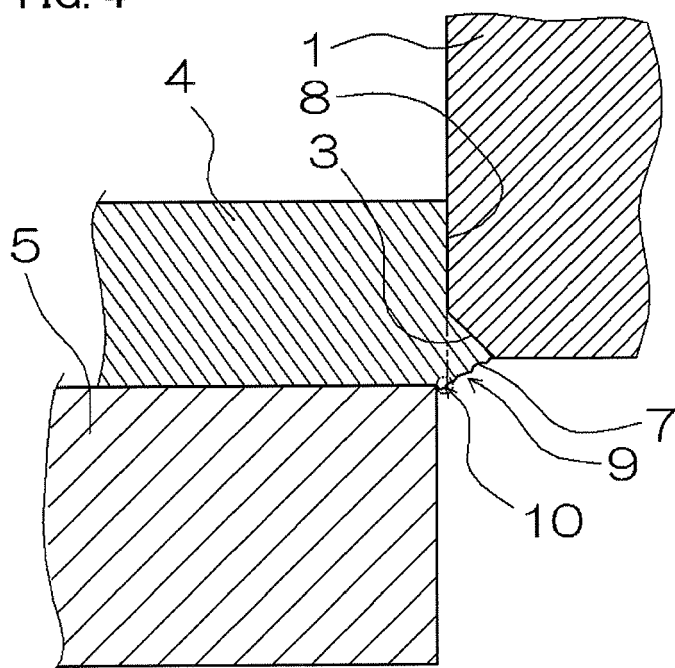


FIG. 5

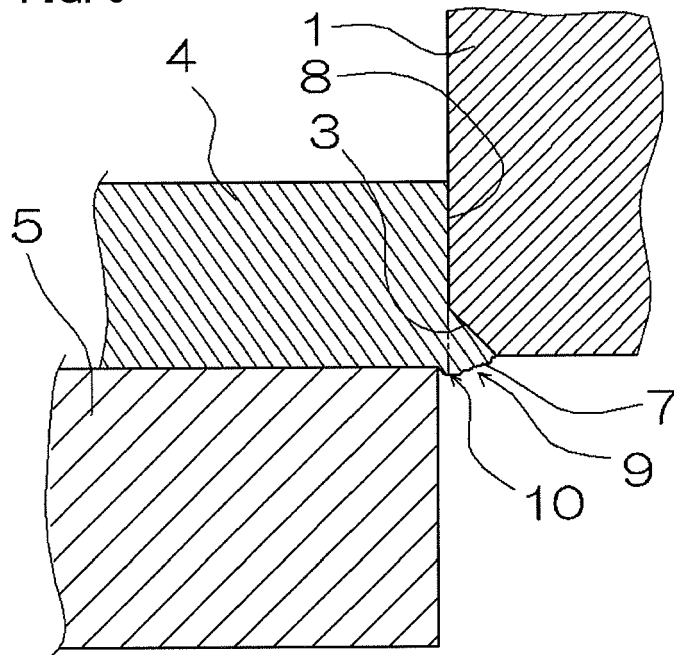


FIG. 6

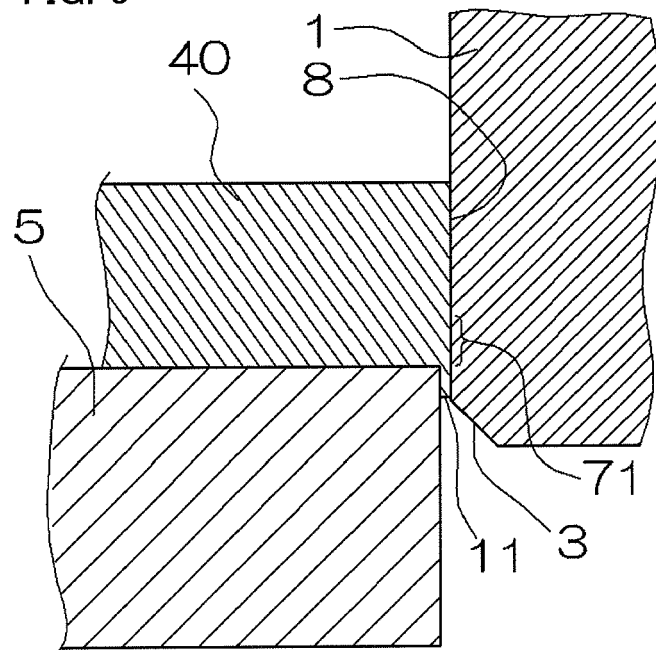
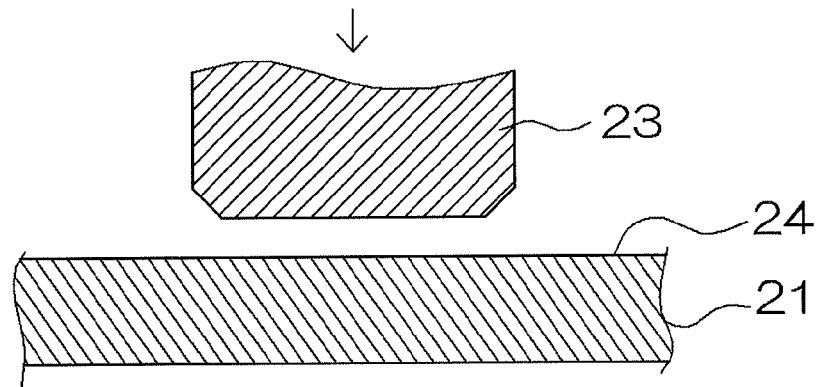
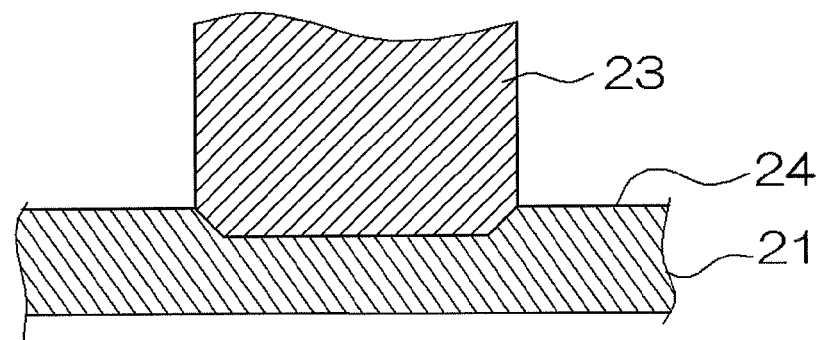


FIG. 7
(1)



(2)



(3)

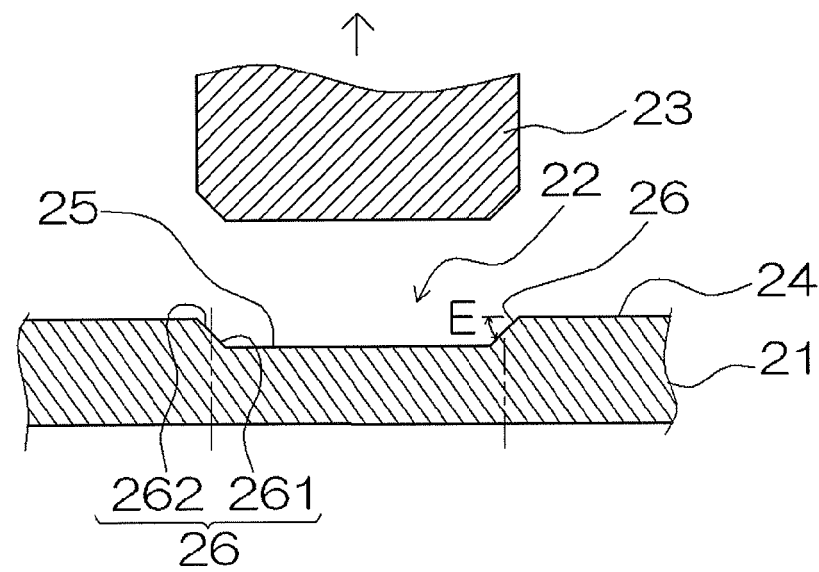
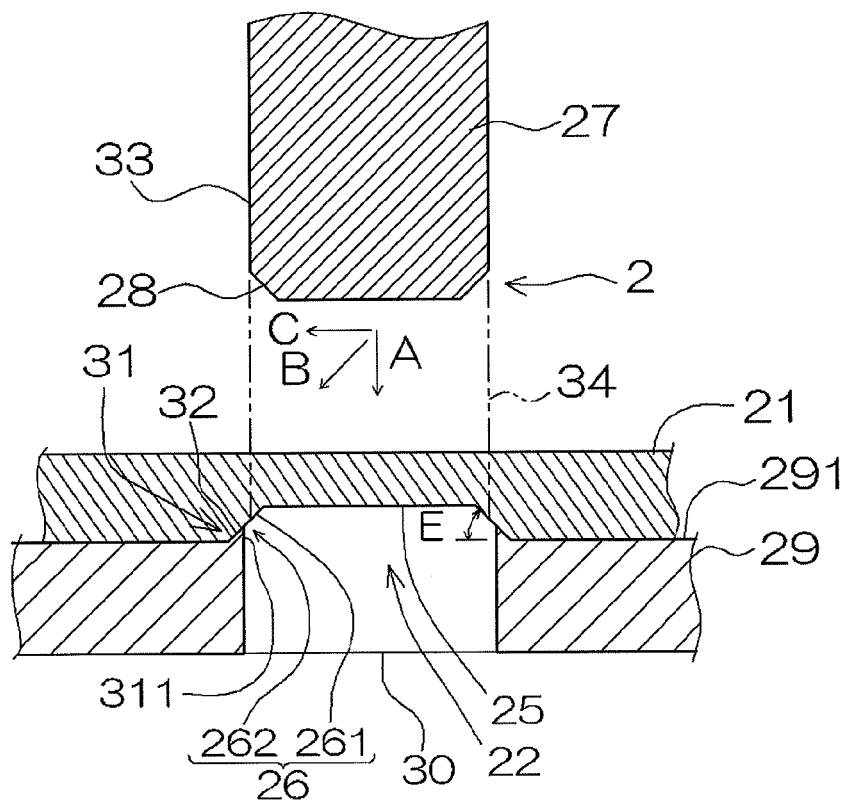


FIG. 8
(1)



(2)

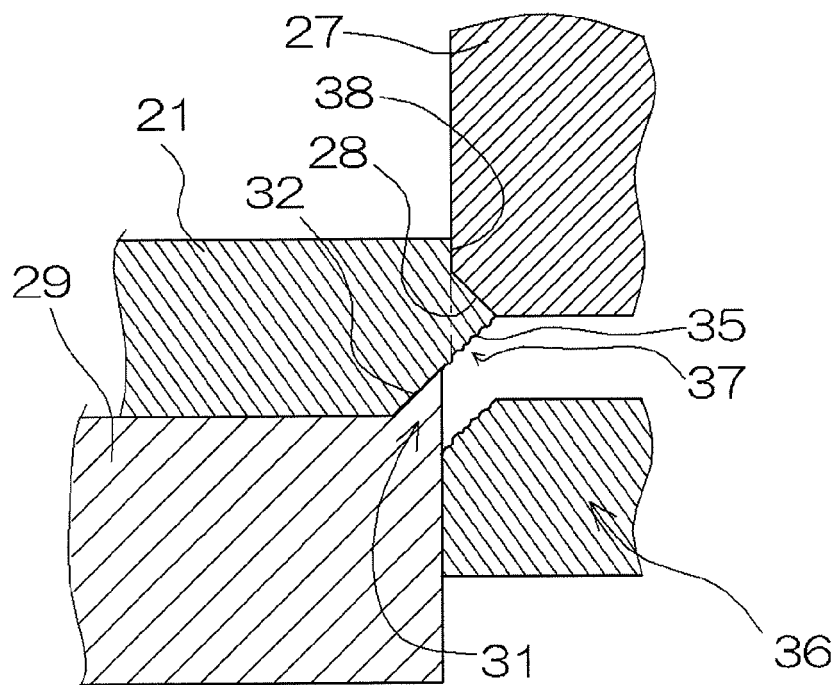
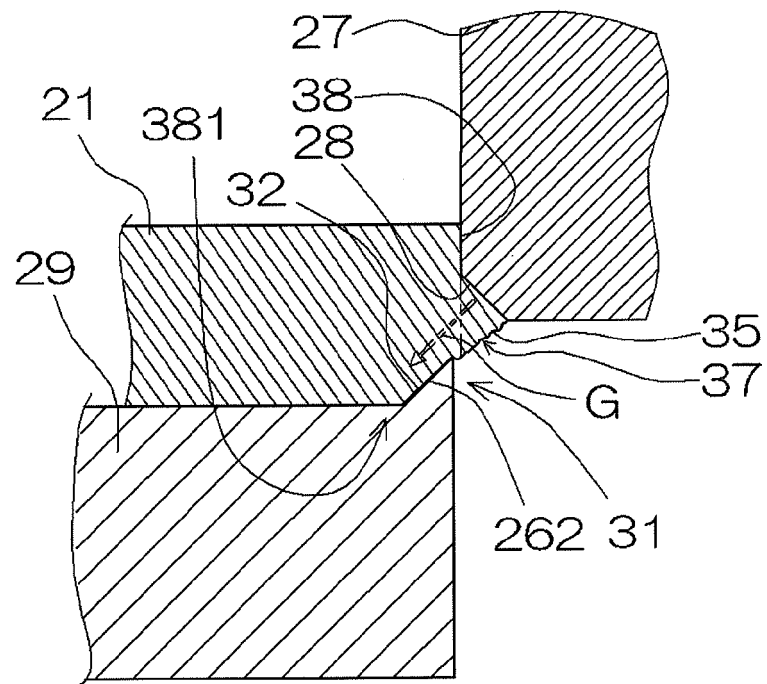


FIG. 9
(3)



(4)

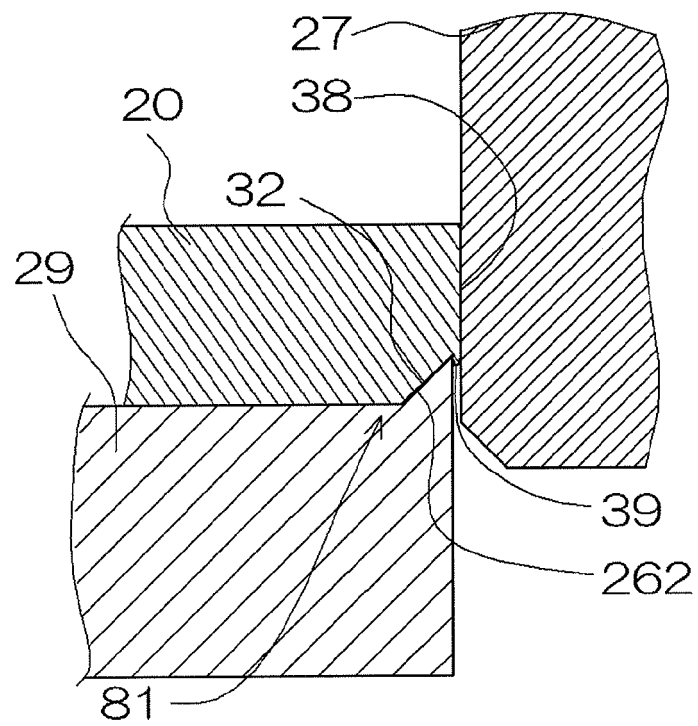
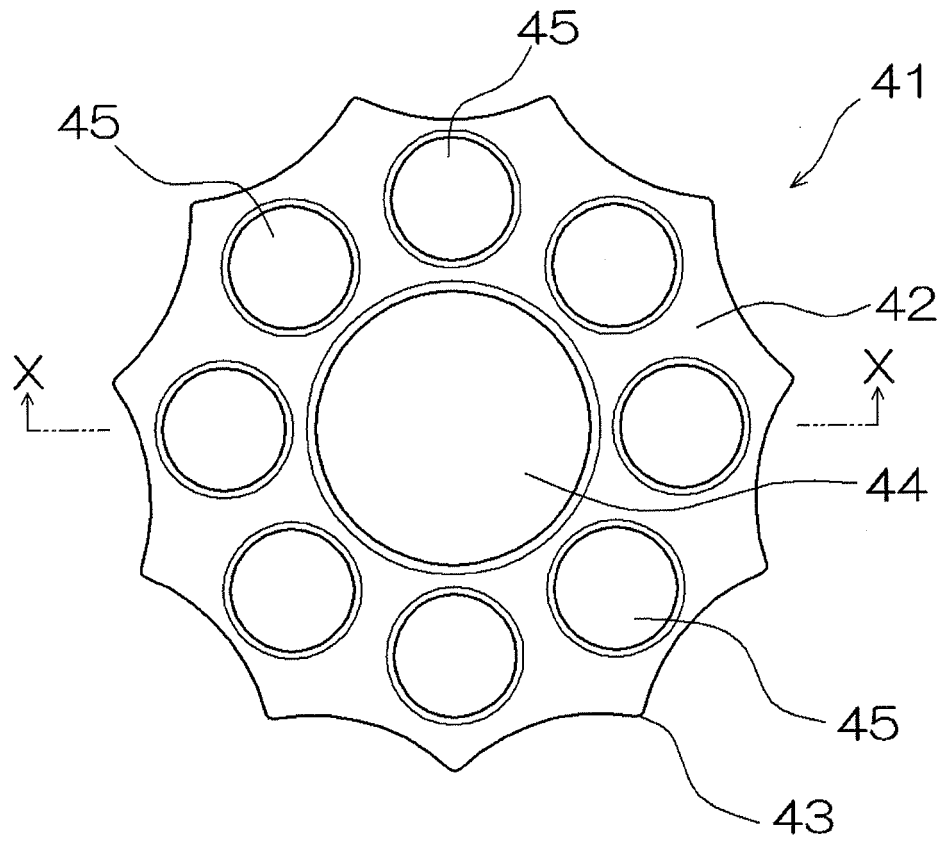


FIG.10
(1)



(2)

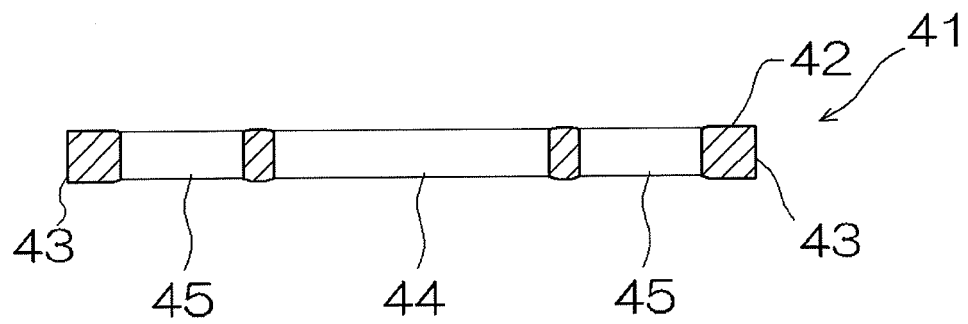
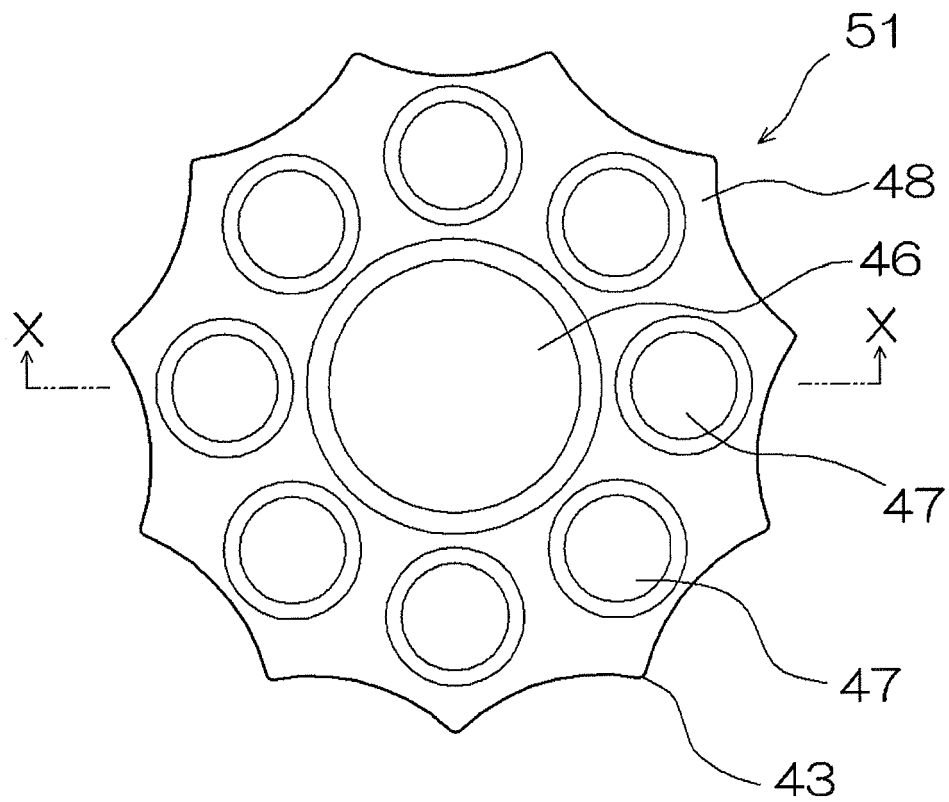


FIG.11
(1)



(2)

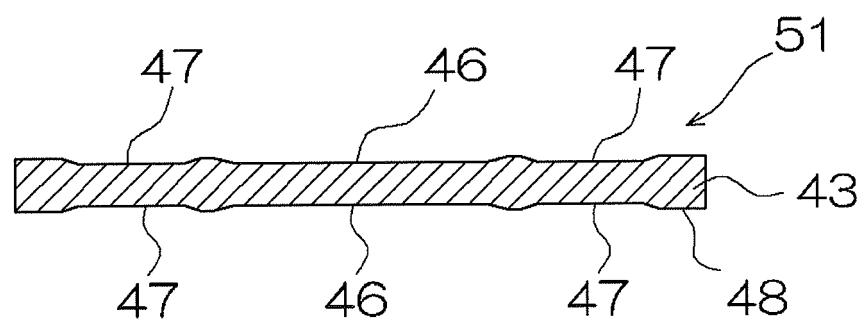
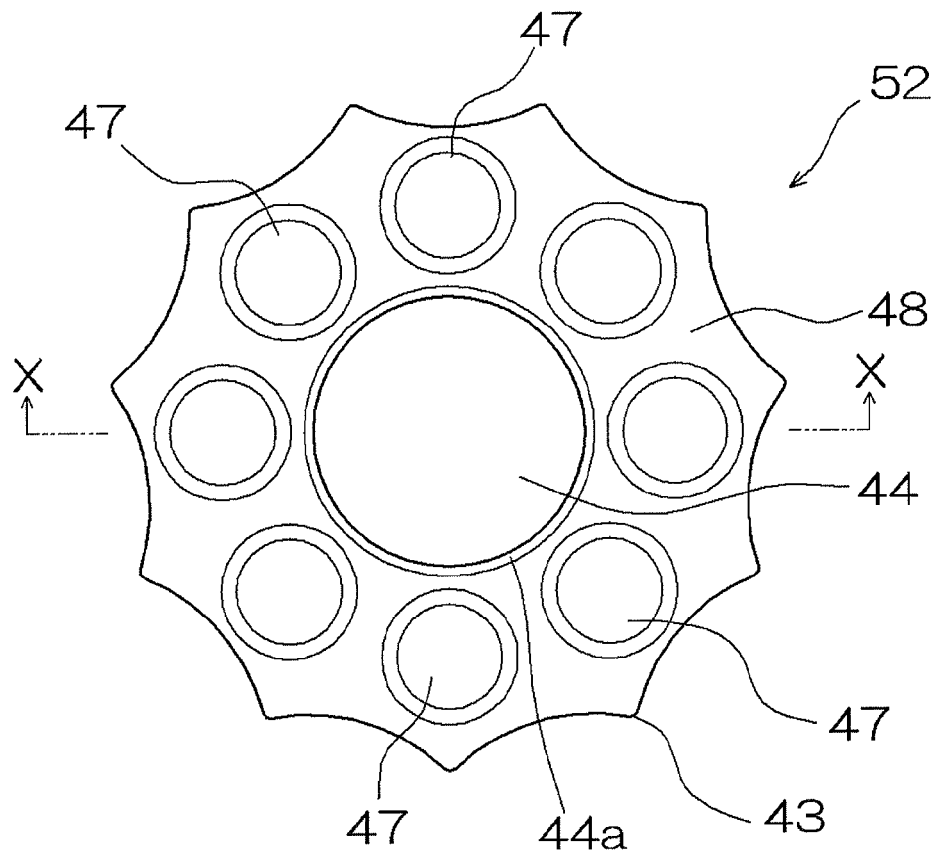


FIG.12
(1)



(2)

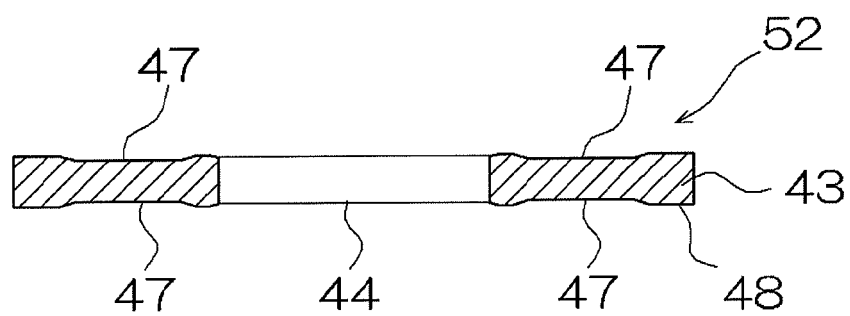
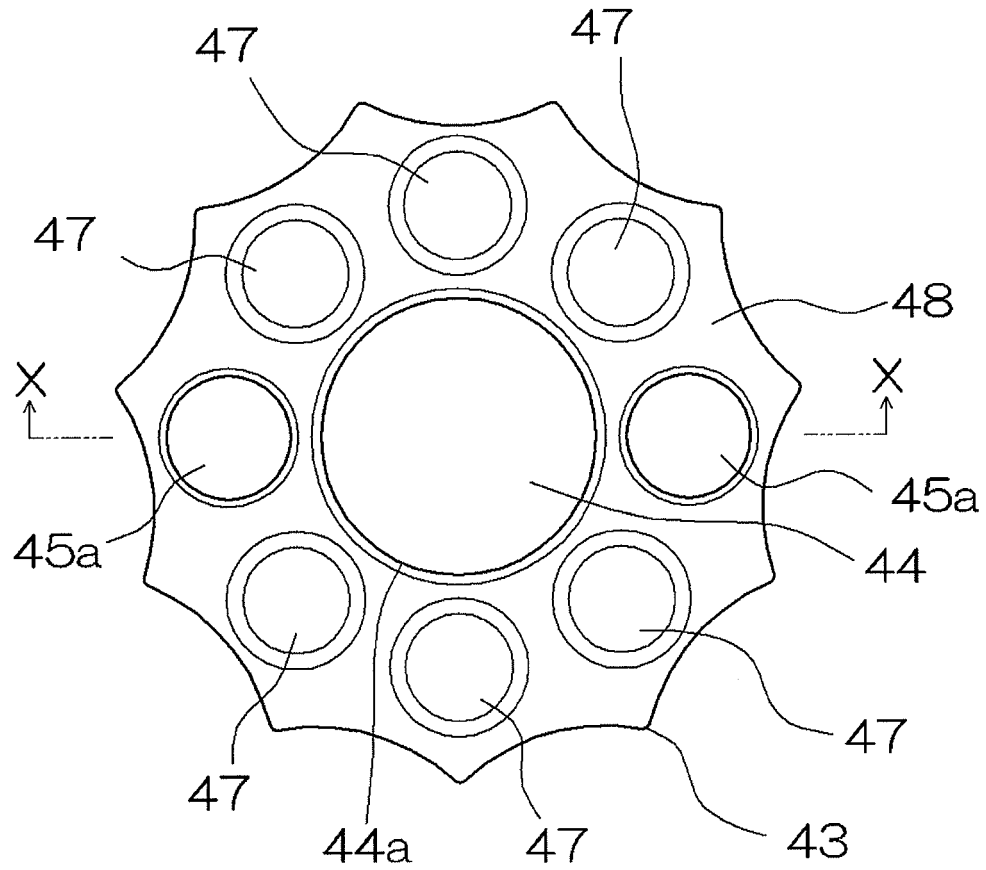


FIG.13
(1)



(2)

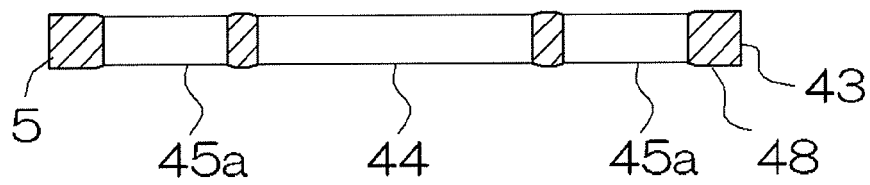


FIG.14

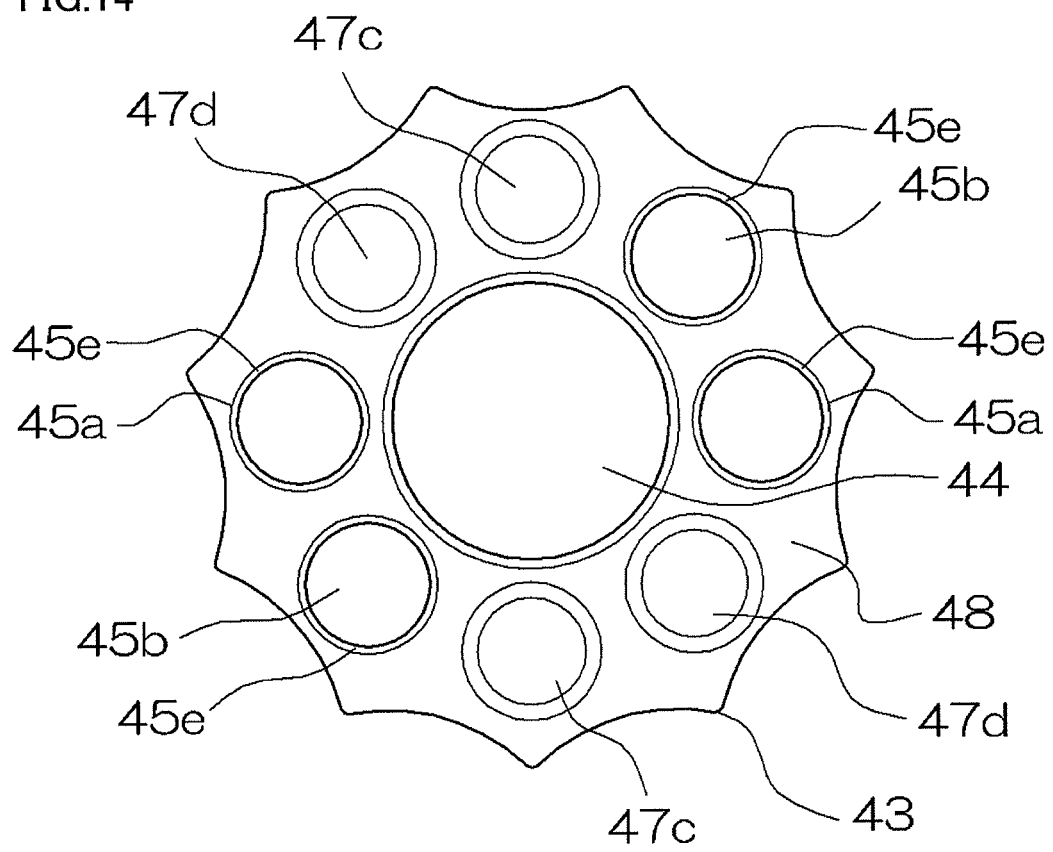


FIG.15

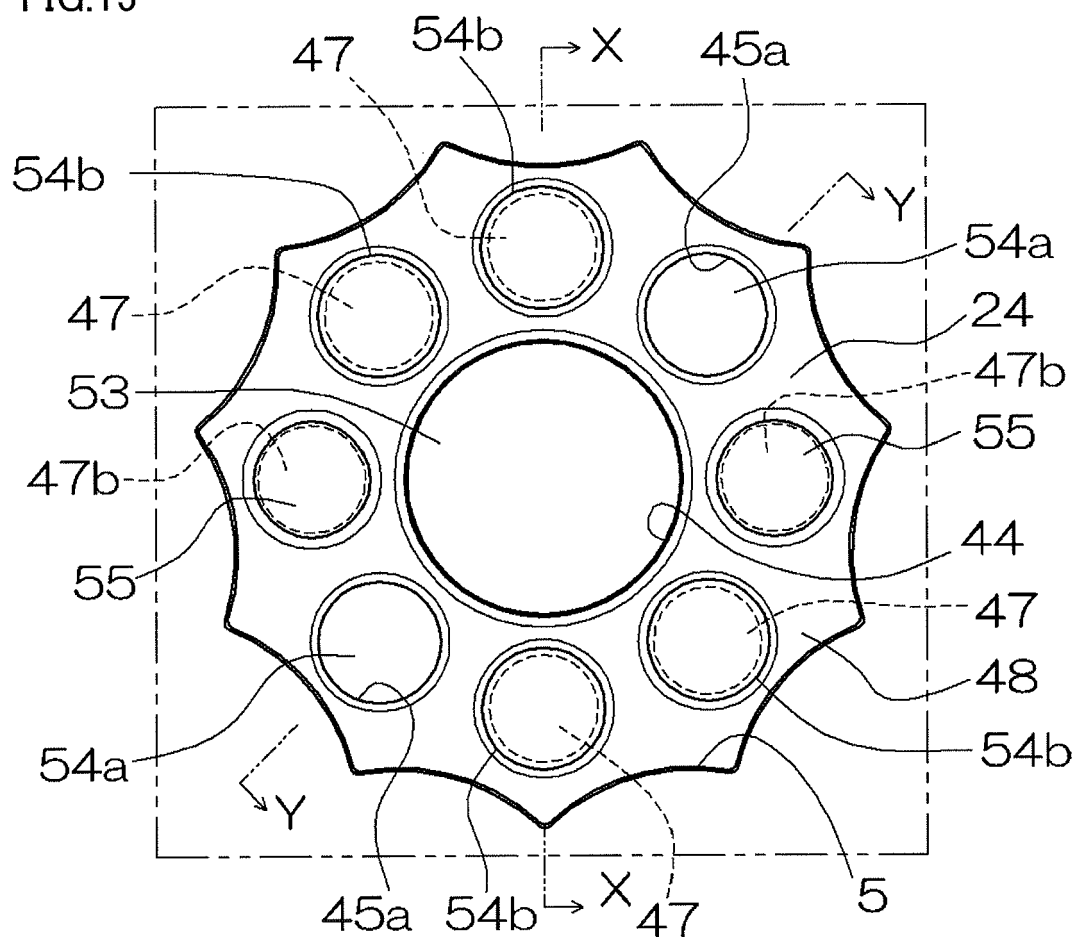


FIG.16

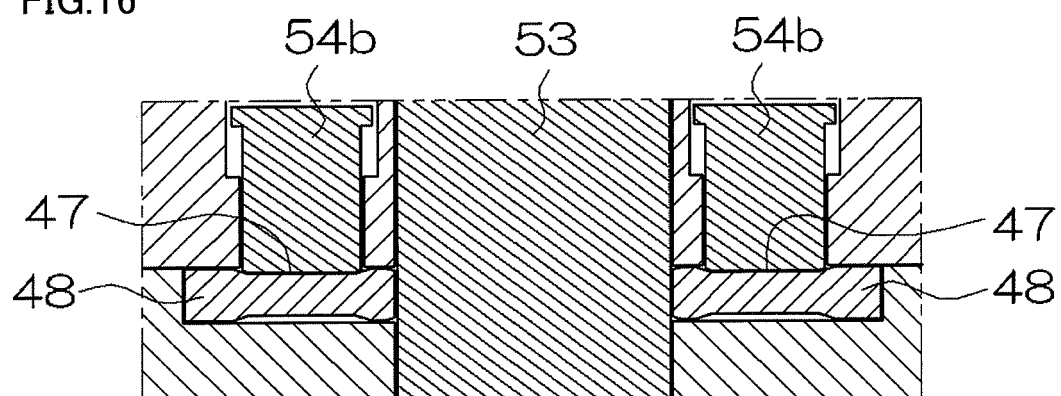


FIG.17

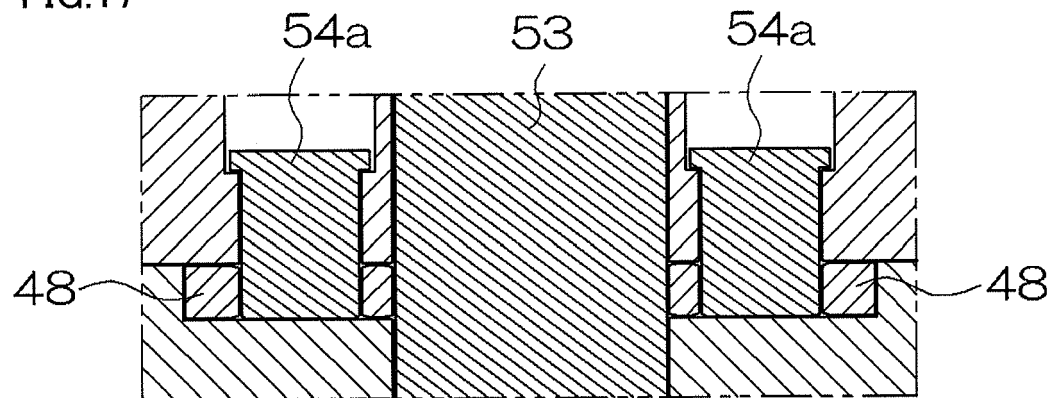


FIG.18

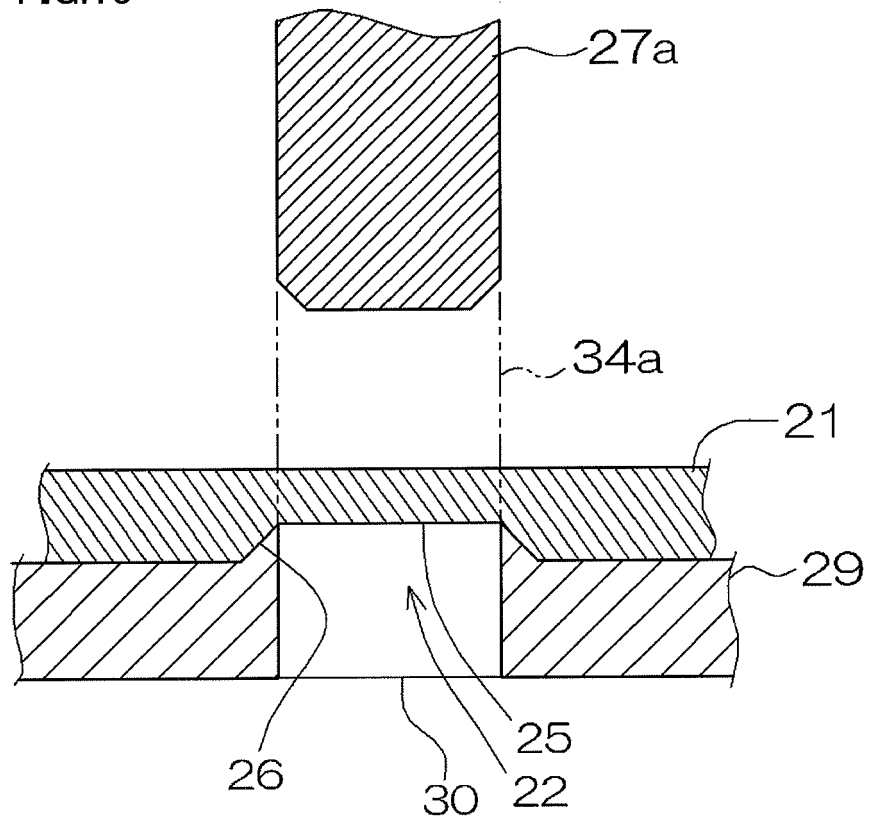


FIG.19

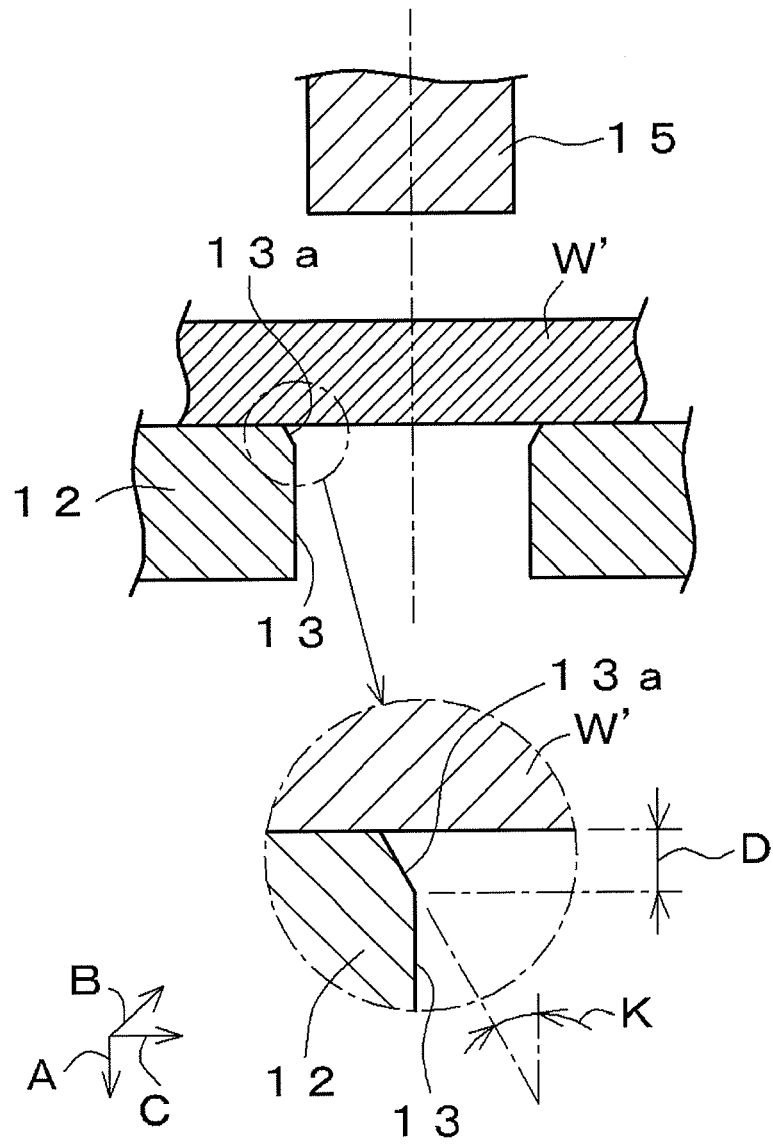


FIG.20

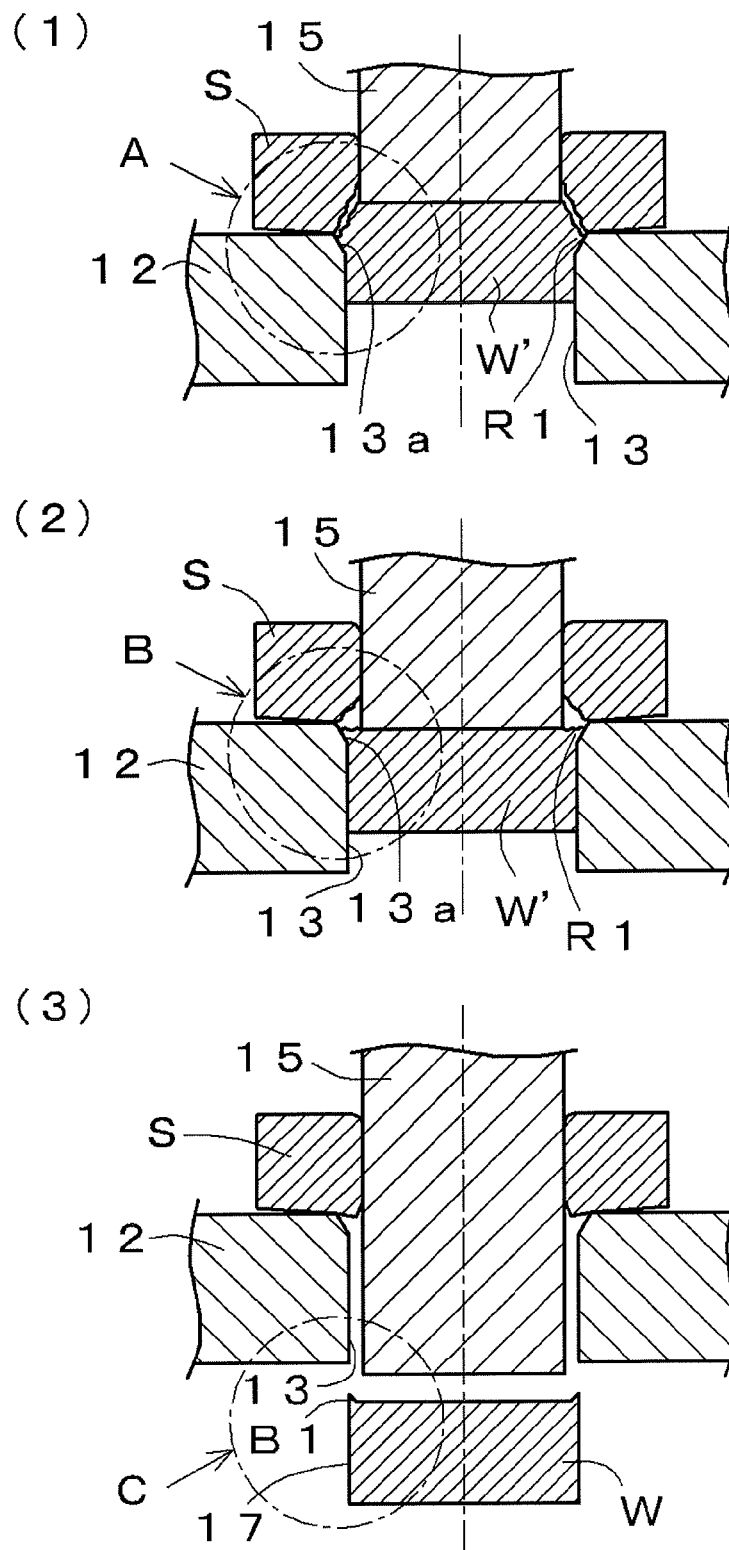
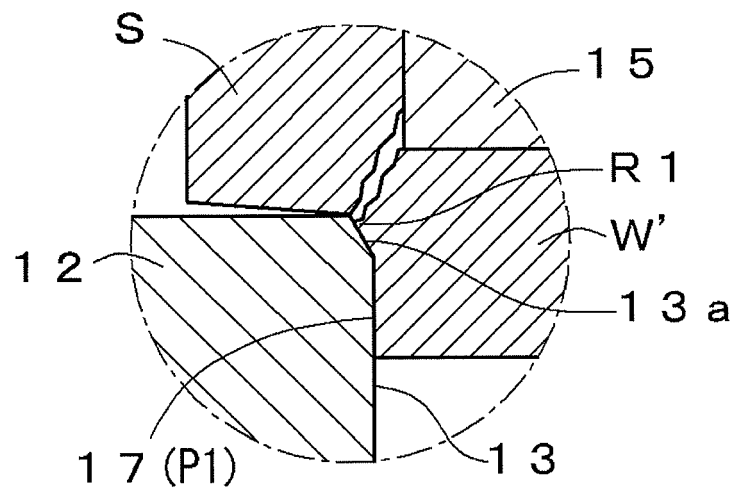
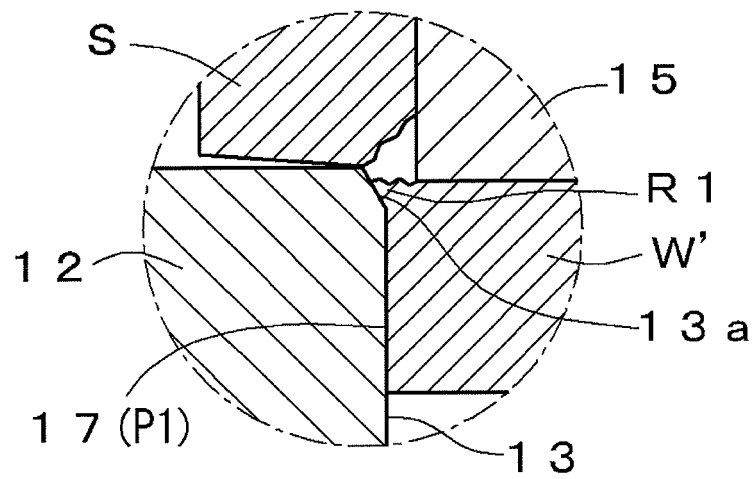


FIG.21

(1)



(2)



(3)

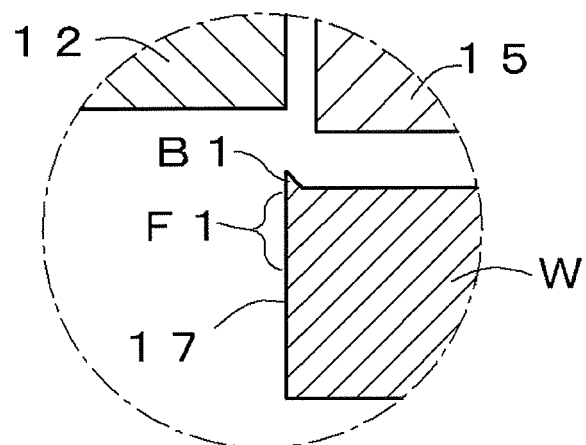
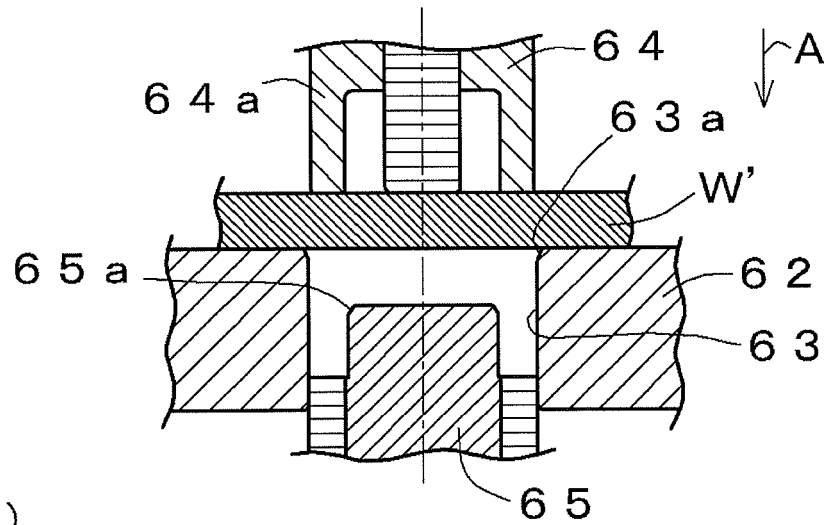
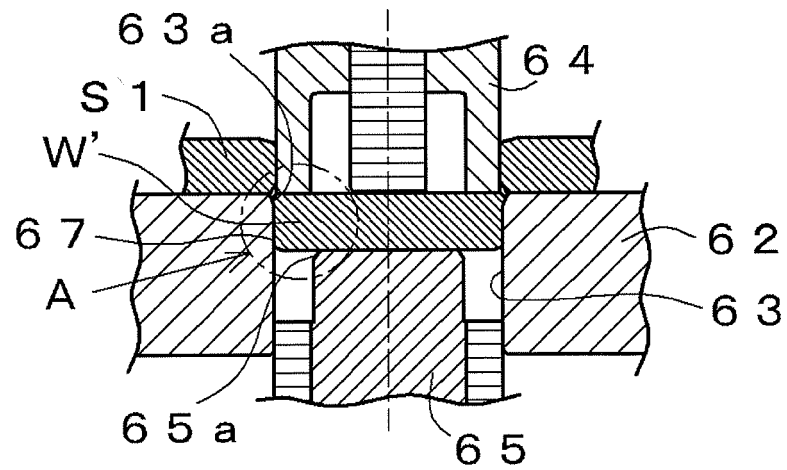


FIG.22

(1)



(2)



(3)

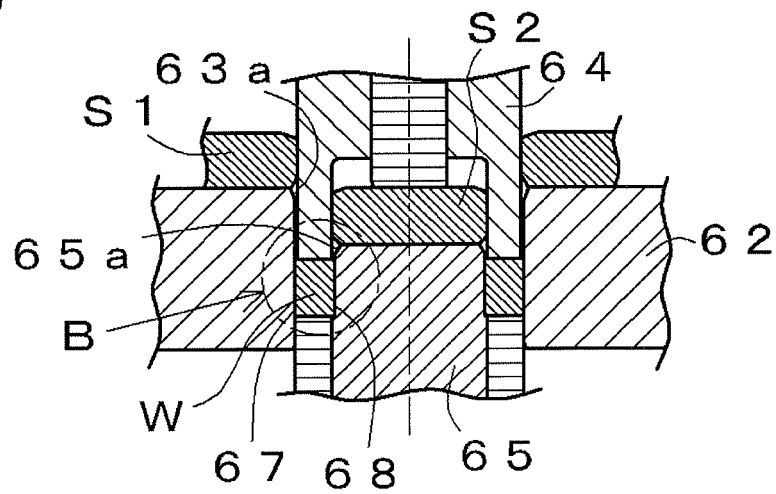


FIG.23

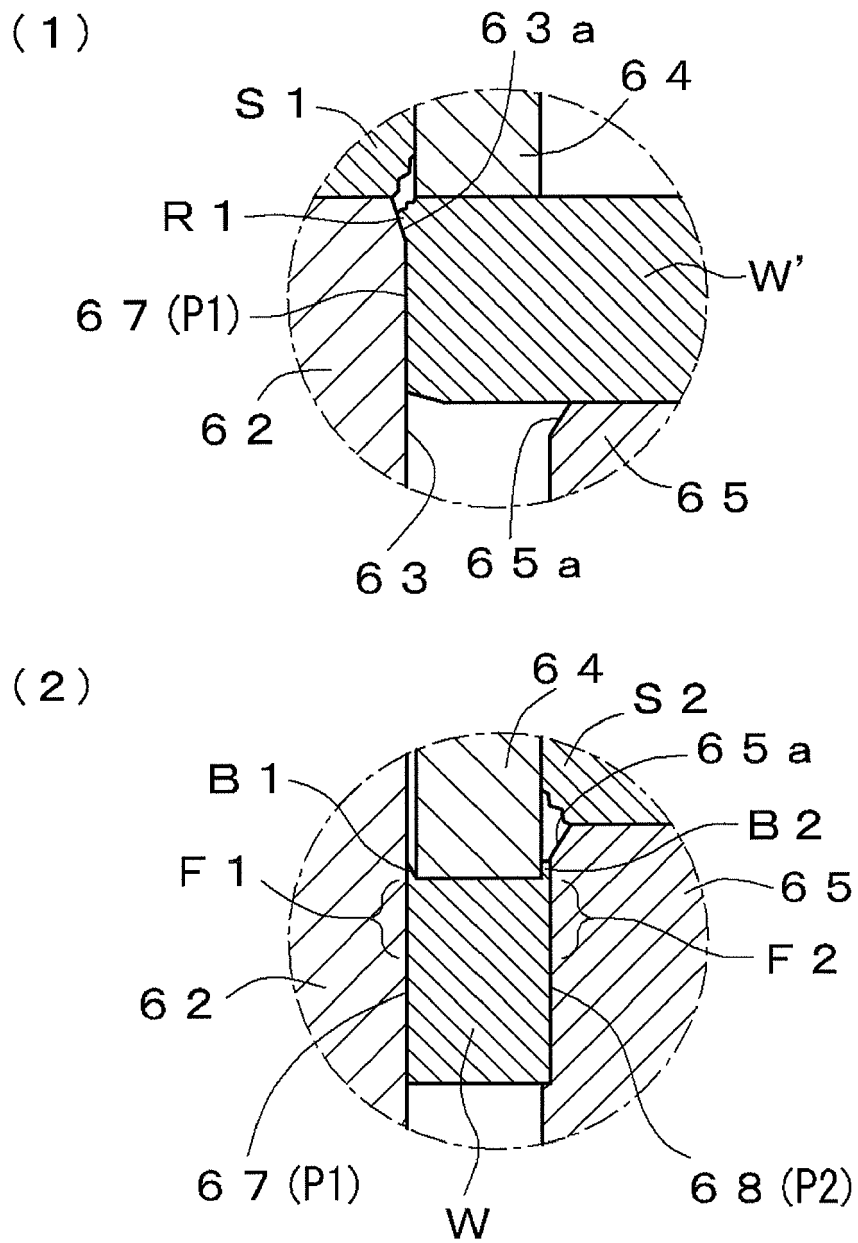
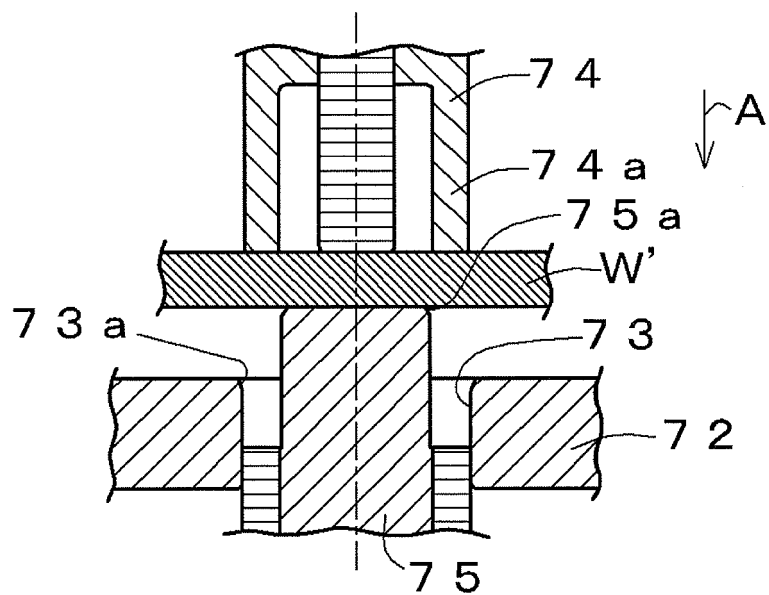
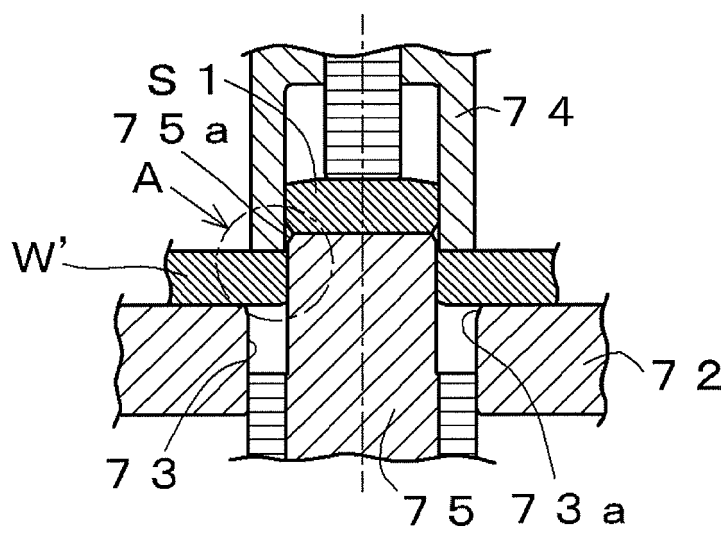


FIG.24

(1)



(2)



(3)

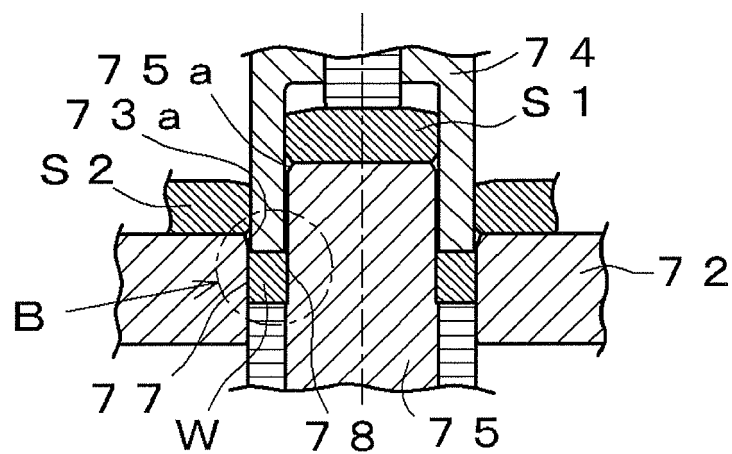
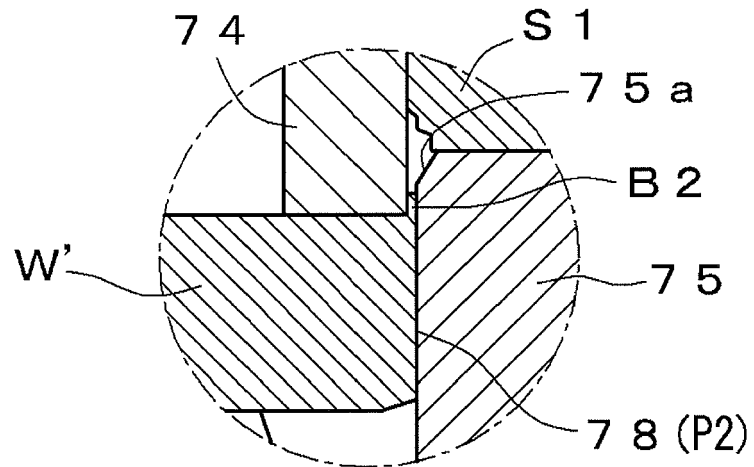


FIG.25

(1)



(2)

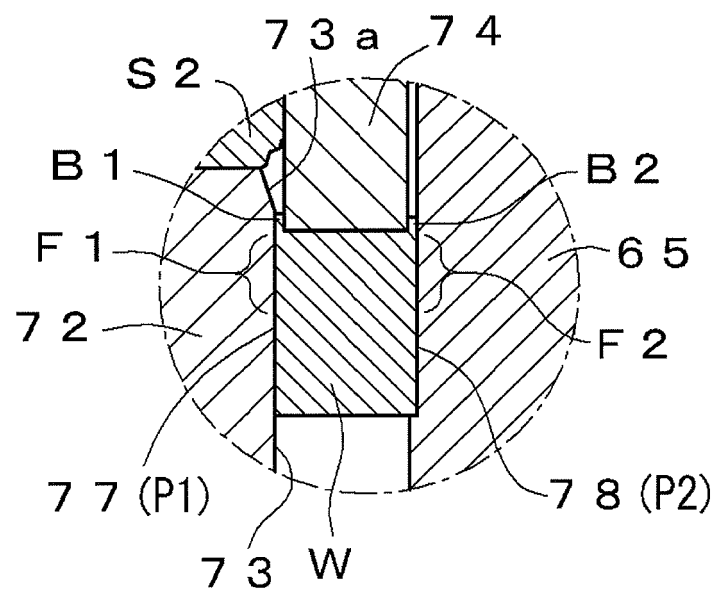
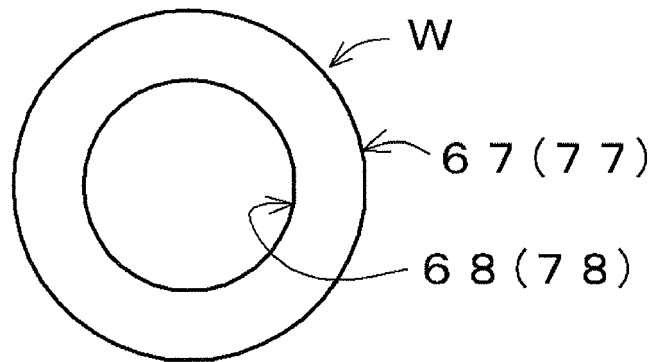
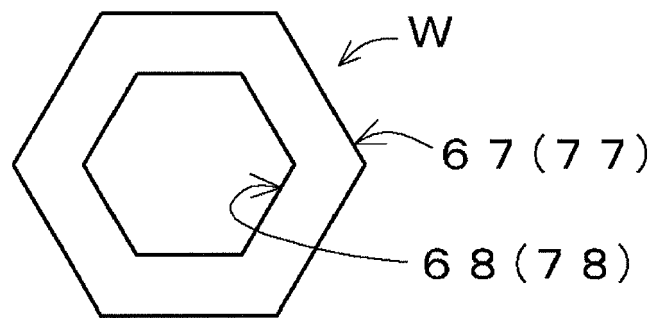


FIG.26

(1)



(2)



(3)

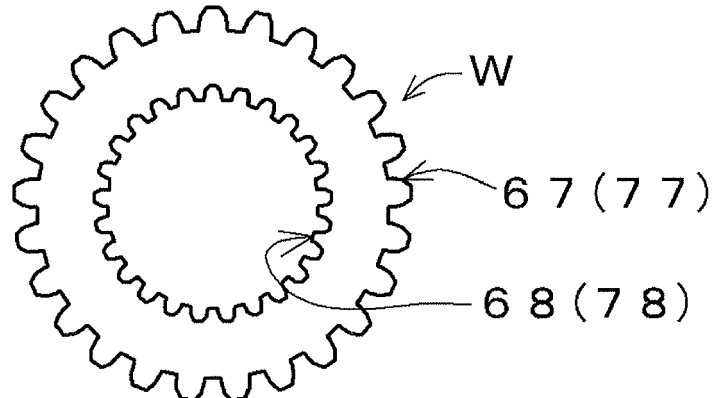
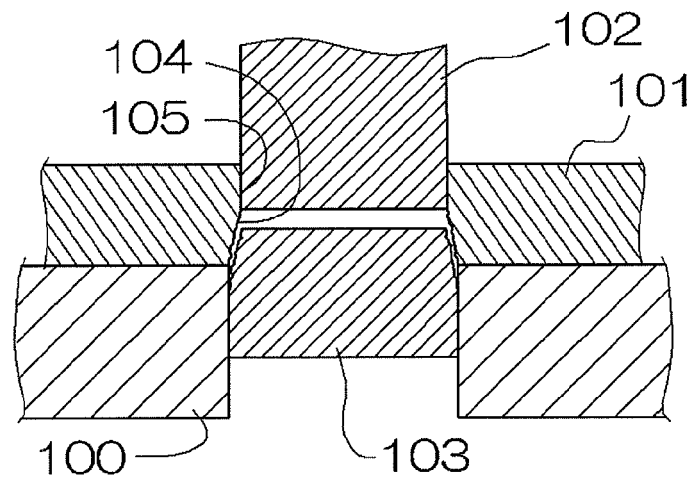
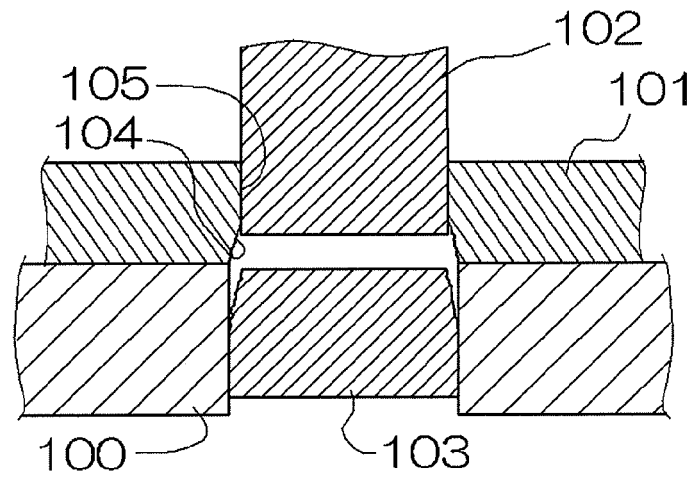


FIG.27
(1)



(2)



(3)

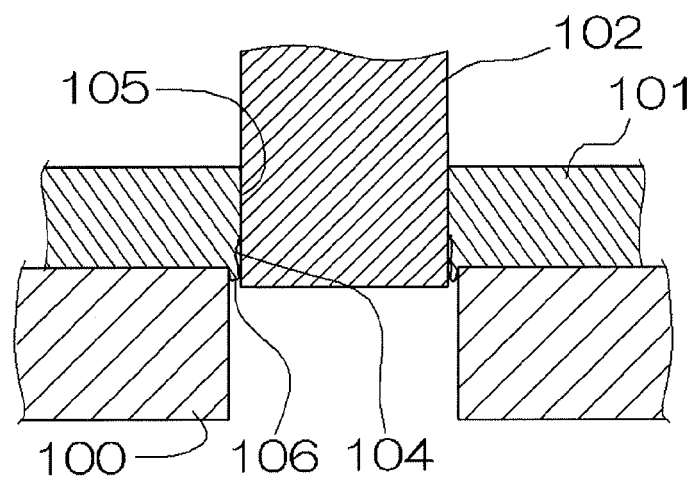
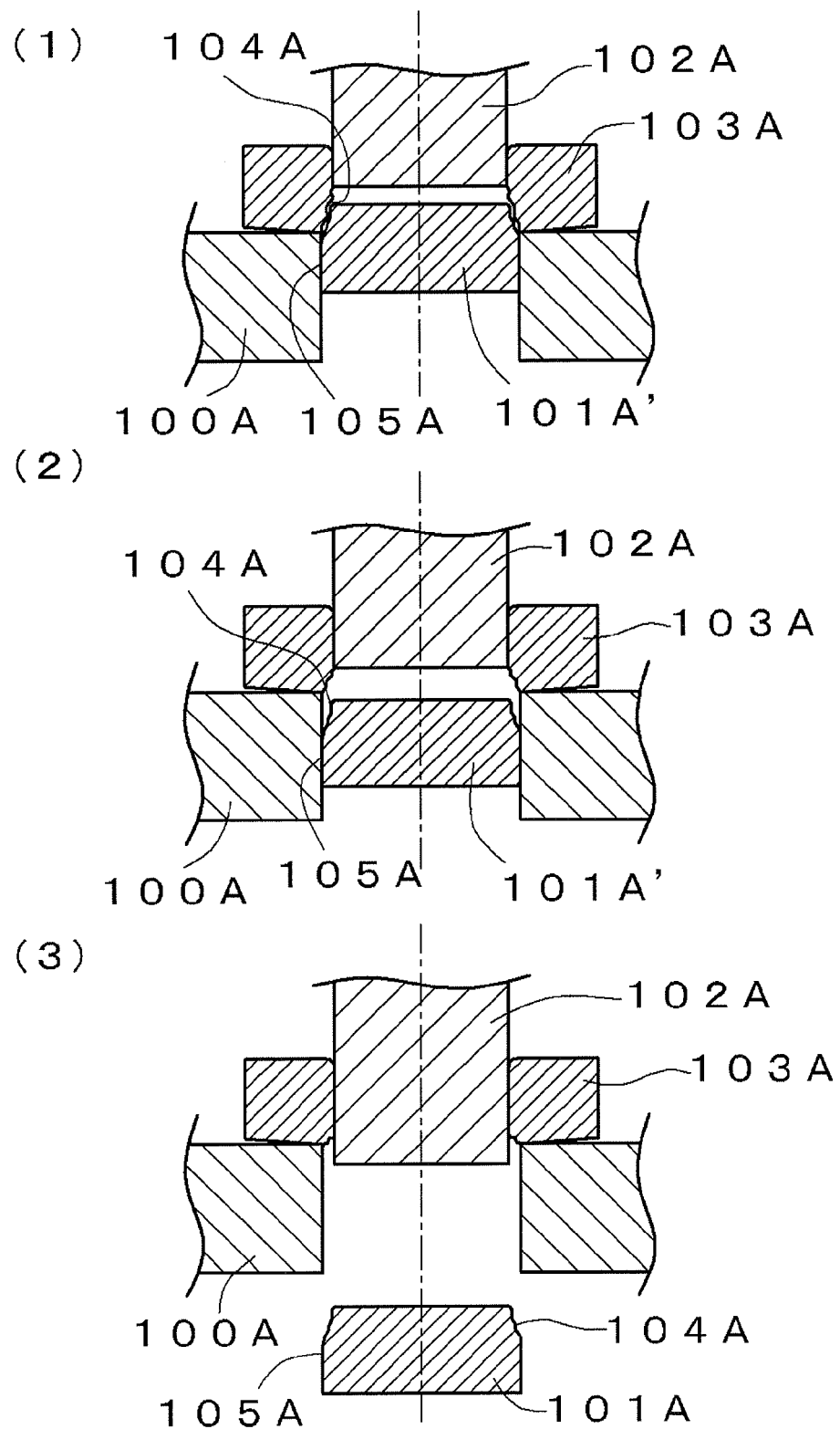


FIG.28



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002206563 A [0005] [0006]