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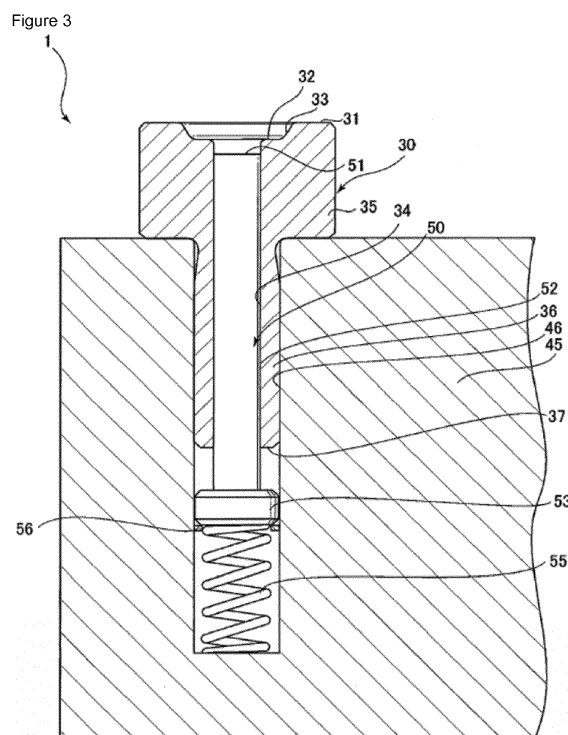
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(54) **SELF-PIERCING RIVET APPARATUS**

(57) A self-piercing rivet fastening apparatus (1) drives a self-piercing rivet (10) having a large-diameter head portion (11) and a hollow leg portion (12) into member to be fastened (41, 42), and fastens it. The die is equipped with a die body (30) and a center pin (50). The die body (30) has an upper surface (31), a recessed portion formed inside the upper surface and a center pin hole (34) which passes from the center portion of the concave portion to the lower end portion (37). The center

pin (50) is axially movably supported in the center pin hole and has a shaft portion (52). It is possible to have a pin flange (53) at one end portion of the shaft portion. A spring (55) pushes the center pin upward. When fastening the self-piercing rivet, the member to be fastened pushes the center pin and enters the center pin hole. After fastening, the center pin pushes out the member to be fastened.



Description

[0001] The present invention relates to a self-piercing rivet fastening apparatus for fastening a plurality of members to be fastened by using a self-piercing rivet having a large-diameter head portion and a hollow leg portion hanging from the head portion. More particularly, it relates to a self-piercing rivet fastening apparatus for use in fastening a member to be fastened made of a material with poor spreadability, such as a die cast material.

[0002] The self-piercing rivet has the advantage wherein a plurality of members to be fastened can be easily fastened simply by driving a rivet without processing a hole for allowing passage of a bolt or the like for fastening to the member to be fastened.

[0003] Self-piercing rivets are suitable for connecting aluminum body panels, which are unsuitable for welding. The weight of automobile bodies has been reduced, aluminum bodies have also been adopted, and the demand for self-piercing rivets is increasing. In particular, although such self-piercing rivets are driven so that they penetrate the upper (punch side) member to be fastened, they remain within the member to be fastened on the lower side (receiving side) adjacent to the die without penetration, so that a rivet through hole is not formed on the surface of the receiving side member to be fastened. Therefore, there is an advantage wherein the sealing property of the member to be fastened of the receiving side is not impaired and the appearance thereof is maintained without its deterioration.

[0004] When members to be fastened, such as die cast materials with poor spreadability, are fastened using a self-piercing rivet fastening apparatus using conventional die, when the tip of the leg portion of the self-piercing rivet is driven by the punch into the member to be fastened and the member to be fastened is deformed by the recessed portion of the die, the member to be fastened is not able to withstand plastic deformation, and cracks occur in some cases. In particular, cracking often occurs in the lower member to be fastened.

[0005] EP2872270 discloses a punch rivet setting die equipped with a base body for a punch (self-piercing type) rivet setting tool. The recessed portion formed in the base body has a base portion on the bottom surface and an annular wall around the base portion. An annular ridge is provided in the center region of the base of the recessed portion to limit the material flow exiting radially outward from the inner region. Alternatively, instead of an annular ridge, a cavity is provided in the center of the base of the recessed portion to limit the material flow exiting radially outward. The subject matter of Patent Document EP2872270 restricts the material flow in the radial direction relative to the center region, so that after the punch rivet is fastened, the lowest member to be fastened is retained to a sufficiently thick level and cracks are unlikely to occur in the lowermost member to be fastened. However, the shape of the cavity of the mounting die of Patent Document 1 does not change even when

fastened. Also, since the annular protuberance of the mounting metal die has a short axial length, its effect has been limited.

[0006] WO03/061869 discloses a die for an automatic piercing rivet fastening apparatus. The die has a center pin for receiving the center portion of the leg of the automatic piercing rivet and a die body formed with a recessed portion for guiding the leg tip of the self-piercing rivet to deform radially outward. A disc spring for pressing the die body against the punch side is provided.

[0007] When the automatic piercing rivet is pushed by the punch and driven into the member to be fastened and the leading end of the leg portion begins to pass through the receiving side member to be fastened, the disc spring shrinks, the die body moves downward, the center pin moves relatively upward with respect to the die body, and the center pin abuts against the lower surface of the receiving side member to be fastened.

[0008] In WO03/061869, since the center pin is at the center position of the leg portion of the automatic piercing rivet, the tip of the leg portion of the automatic piercing rivet widens largely in the radial direction and is fastened. Therefore, the member to be fastened can be fastened with sufficient coupling force.

[0009] However, with the automatic piercing rivet fastening apparatus of WO03/061869, when fastening an automatic piercing rivet, the center pin pushes up the lower surface of the receiving side member to be fastened at the center of the leg tip end of the automatic piercing rivet so that the leg of the automatic piercing rivet opens. If the member to be fastened is made of a material with poor spreadability, cracks may occur in the member to be fastened on the receiving side.

[0010] Therefore, there is a need for a self-piercing rivet fastening apparatus that prevents the occurrence of cracks in the member to be fastened, even when the member to be fastened with poor spreadability is fastened by self-piercing rivets.

[0011] An object of the present invention is to provide a self-piercing rivet fastening apparatus capable of fastening a member to be fastened with poor spreadability by self-piercing rivet so that cracks do not occur.

[0012] To achieve this object, the die of a self-piercing rivet fastening apparatus of the present invention is equipped with a die body, and a center pin capable of moving in the axial direction the inside of a center pin hole formed in the axial direction of the die body. The self-piercing rivet fastening apparatus is equipped with a pressing apparatus that pushes the center pin upward. When a self-piercing rivet is driven into a member to be fastened by a punch and fastened, the material of the member to be fastened pushes the center pin downward, and the material of the member to be fastened enters the center pin hole after the center pin has moved. The member to be fastened is not expanded more than necessary, and it is difficult to crack. Also, after the fastening is completed, the pressing apparatus can push the center pin upward and push the member to be fastened to the inside

of the hole.

[0013] A self-piercing rivet fastening apparatus characterized by a first embodiment of the present invention is a self-piercing rivet fastening apparatus for driving a self-piercing rivet having a large-diameter head portion and a hollow leg portion hanging from the head portion by driving it into a member to be fastened and fastening it;

a punch for driving the self-piercing rivet into the member to be fastened, and
 a die for receiving the member to be fastened;
 wherein the die is equipped with die body having an upper surface and a recessed portion formed inside the upper surface wherein a center pin hole is formed therethrough downward from a center portion of the recessed portion, and
 a center pin supported in the center pin hole of the die body so as to be movable in the axial direction;
 the center pin has a cylindrical shaft portion having an outer diameter matching the inner diameter of the center pin hole, and
 the self-piercing rivet fastening apparatus is further equipped with a pressing apparatus for axially pressing the center pin.

[0014] When the self-piercing rivet fastening apparatus is equipped with a pressing apparatus for axially pressing the center pin, the center pin can be held pressed upward in the center pin hole of the die body, and when a large force is applied to the upper surface of the center pin, the center pin can move downward.

[0015] Preferably, the upper surface of the center pin is movable from a position below the bottom surface of the recessed portion of the die body to a position above the bottom surface of the recess.

[0016] When the center pin can be moved downward until the upper surface of the center pin comes to a position below the bottom surface of the recessed portion of the die body, the center pin moves downward, whereby the material of the member to be fastened below the self-piercing rivet can enter the center pin hole.

[0017] When the center pin can be moved upward until the upper surface of the center pin comes to a position above the bottom surface of the recessed portion, the center pin moves upward, whereby the member to be fastened that has been fastened is pushed out from the die body.

[0018] The pressing apparatus is a spring disposed below the center pin; it is preferable that when the spring applies an upward pressing force to the center pin and a downward pressing force stronger than the pressing force of the spring to the upper surface of the center pin, the upper surface moves downward until comes to a position below the bottom of the recessed portion, and when the downward pressing force is not applied to the upper surface of the center pin, the center pin is pushed by the pressing force of the spring, and the center pin moves upward until the upper surface is positioned above

the bottom surface of the recessed portion.

[0019] If the pressing apparatus is a spring provided at the lower side of the center pin, the center pin can be easily pressed upward, and when a punching stress is applied by the punch to the self-piercing rivet, the spring shrinks and the center pin can move downward.

[0020] When the member to be fastened is pushed by the self-piercing rivet and the upper surface of the center pin is pressed, the center pin moves downward, and the member to be fastened can enter the center pin hole after the center pin has moved. When the fastening of the self-piercing rivet is completed, the center pin is pushed upward by the pressing force of the spring, and the member to be fastened that has been fastened can be pushed out from the die body.

[0021] In further embodiments or additional embodiments, the pressing apparatus can be a hydraulic apparatus, a pneumatic apparatus or an electric apparatus that is attached to the frame and that presses the center pin.

[0022] If the pressing apparatus is a hydraulic apparatus, a pneumatic apparatus or an electric apparatus, such as a motor, oil or air can be supplied to the cylinder connected to the center pin, or the center pin can be moved in the axial direction by force of a motor or the like. When the center pin is pressed by hydraulic pressure, pneumatic pressure or electric apparatus, the movement of the center pin can be controlled to a more finite degree.

[0023] A fastening method characterized by a second embodiment of the present invention is a fastening method for fastening a self-piercing rivet,

wherein the self-piercing rivet fastening apparatus is equipped with a nose for pressing the member to be fastened,

a punch for driving the self-piercing rivet into the member to be fastened, and
 a die for receiving the member to be fastened;
 the die is equipped with die body having an upper surface and a recessed portion formed inside the upper surface wherein a center pin hole is formed therethrough downward from a center portion of the recessed portion, and

a center pin supported in the center pin hole of the die body so as to be movable in the axial direction;
 the self-piercing rivet fastening apparatus is further equipped with a pressing apparatus for axially pressing the center pin; wherein the fastening method is equipped with the following steps:

- (a) a step of positioning the member to be fastened on the upper surface of the die body,
- (b) a step of pressing the member to be fastened by the nose,
- (c) a step of arranging the self-piercing rivet between the punch and the member to be fastened,
- (d) a step of lowering the punch to press the self-

piercing rivet against the member to be fastened so that the member to be fastened moves downward, and the distal end of the leg portion of the self-piercing rivet passes through the member to be fastened, and

(e) a step wherein the material of the member to be fastened penetrates the center pin hole, and the center pin descends against the pressing force of the pressing apparatus until the upper surface of the center pin is positioned lower than the bottom surface of the recessed portion of the die body, thereby completing fastening.

[0024] When the punch presses the self-piercing rivet and the self-piercing rivet pushes the material of the member to be fastened downward, the material of the member to be fastened enters the recessed portion of the die body, the center pin is pushed further downward and enters the pin hole. The upper surface of the center pin descends to a position lower than the bottom surface of the recessed portion of the die body. The self-piercing rivet is not expanded radially outward beyond what is required. Therefore, cracking of the member to be fastened can be prevented.

(f) After the engagement is completed, the center pin rises in the center pin hole by the pressing force of the pressing apparatus, and the member to be fastened located inside the center pin hole can be pushed out.

[0025] After the engagement is completed, the center pin is pressed upward by the pressing force of the pressing apparatus in the center pin hole and is raised, and when the member to be fastened located inside the center pin hole is pushed out, the member to be fastened is automatically removed from the fastening apparatus.

[0026] When the self-piercing rivet is fastened by the self-piercing rivet fastening apparatus of the present invention, the deformation of the member to be fastened can be reduced, and cracks can be reduced even when a member to be fastened that has poor spreadability is fastened.

[0027] As a result, it is possible to provide a self-piercing rivet fastening apparatus capable of fastening a member to be fastened that has poor spreadability, so that it does not crack.

[0028] In addition, it is possible to adjust the opening direction of the legs of the self-piercing rivet by adjusting the pressing force and the distance at the time of descent of the center pin, and it is possible to provide the fastening of members to be fastened of various thicknesses and materials with a small number of dies.

[0029] Other characteristics and advantages of the invention will readily appear from the following description of embodiments, provided as non-limitative examples, in reference to the accompanying drawings.

[0030] In the drawings: [0026]

FIG. 1 is an enlarged view of a portion for fastening a self-piercing rivet of a conventional self-piercing rivet fastening apparatus.

FIG. 2 is an enlarged cross-sectional view after a member to be fastened has been fastened with a self-piercing rivet using a conventional die.

FIG. 3 is a cross-sectional view of a portion of a self-piercing rivet fastening apparatus according to a first embodiment of the present invention.

FIG. 4 is a perspective view in which a portion of the die of FIG. 3 is sectioned.

FIG. 5 is a cross-sectional view before a member to be fastened is fastened by a self-piercing rivet using the die of FIG. 4.

FIG. 6 is a cross-sectional view showing a stage in which the punch slightly pushes the head of the self-piercing rivet downward from the stage of FIG. 5.

FIG. 7 is a cross-sectional view showing a stage in which the punch pushes the head of the self-piercing rivet further downward from the stage of FIG. 6.

FIG. 8 is a cross-sectional view showing a stage in which the punch pushes the head of the self-piercing rivet further downward from the stage of FIG. 7.

FIG. 9 is a cross-sectional view showing a stage in which the punch pushes the head of the self-piercing rivet further downward from the stage of FIG. 8.

FIG. 10 is a cross-sectional view showing a stage in which fastening of a self-piercing rivet is completed.

FIG. 11 is a cross-sectional view of a portion of a self-piercing rivet fastening apparatus according to a second embodiment.

FIG. 12 is a simulation of a force applied to a self-piercing rivet and a member to be fastened at a stage in which a fastening operation is completed using a conventional die.

FIG. 13 is a simulation of a force applied to a self-piercing rivet and a member to be fastened at a stage in which the fastening operation is completed using the die of FIG. 4.

[0031] Hereinafter, an embodiment of a die used in a self-piercing rivet fastening apparatus according to the present invention will be described in comparison to a conventional die with reference to the drawings. FIG. 1 is an enlarged view of a portion for fastening a self-piercing rivet of a conventional self-piercing rivet fastening apparatus. The self-piercing rivet fastening apparatus 1 is equipped with a C-shaped frame (not shown), and a conventional die 20 is fixed to the C-shaped frame. A vertically movable nose 3 is attached to the C-shaped frame, and a punch 4 for driving a self-piercing rivet 10 is attached. The member to be fastened 41, 42 can be clamped between the upper surface of the die 20 and the lower surface of the nose 3.

[0032] The self-piercing rivet 10 has a large-diameter head portion 11 and a cylindrical leg portion 12 hanging from the head portion 11. The lower end portion of the leg portion 12 is a leg portion tip 13 with a narrowed width.

[0033] The die 20 has a short cylinder-shaped large-diameter portion 24 and a cylindrical-shaped small-diameter portion 26 thereunder. An upper end portion of the large-diameter portion 24 is a flat upper surface 21, and a recessed portion for deforming the leg portion 12 of the self-piercing rivet 10 is formed in the center portion of the upper surface 21. The recessed portion consists of a bottom surface 22 of a circular plane at the center portion and a curved surface 23 around the bottom surface 22.

[0034] When the members to be fastened 41, 42 are disposed on the die 20 and the self-piercing rivet 10 is driven by the punch 4 from above the members to be fastened 41, 42, the tip of the leg portion 13 of the self-piercing rivet 10 passes through the member to be fastened 41 on the punch side and does not pass through member to be fastened 42 on the receiving side adjacent to the die 20 but remains therein. The tip of the leg portion 12 of the self-piercing rivet 10 is deformed so as to expand radially outward by the die 20. The members to be fastened 41 and 42 are connected to each other by the leg portion 12 and the head portion 11 which are opened in the member to be fastened 42.

[0035] FIG. 2 is an enlarged cross-sectional view after a member to be fastened is fastened with a self-piercing rivet using a conventional die. Nose 3 and punch 4 move upward. When the self-piercing rivet 10 is driven by the punch 4, the leg portion 12 passes through the member to be fastened 41 on the punch side by the punch 4 and plastically deforms the member to be fastened 42 of the receiving side. The member to be fastened 42 is projected downward by the leg portion 12, the projected portion of the member to be fastened 42 is received in the recessed portion, and the lower surface of the member to be fastened 42 hits against the bottom surface 22 of the recessed portion. Since the member to be fastened 42 cannot move downward when it hits against the bottom surface 22, the leg portion 12 of the self-piercing rivet 10 pushes the member to be fastened 42 outward in the radial direction so as to expand radially outward. The leg portion tip 13 remains in the member to be fastened 42 on the receiving side adjacent to the die 20 without penetrating therethrough. The members to be fastened 41 and 42 are connected to each other by the leg portion 12 and the head portion 11, the diameter of which is enlarged in the member to be fastened 42.

[0036] The member to be fastened 42 is pushed outward in the radial direction by the enlarged leg portion 12. In the case where the member to be fastened 42 is made of a material with poor spreadability, cracks tend to occur near the curved surface 23 of the die 20.

(First Embodiment)

[0037] FIG. 3 is a cross-sectional view showing a portion of a C-shaped frame 45 supporting a die and a die of a self-piercing rivet fastening apparatus 1 according to the first embodiment of the present invention. In the self-piercing rivet fastening apparatus 1, a C-shaped

frame 45 is used. In the C-shaped frame 45, an upper horizontal arm portion, an abdominal arm portion and a lower horizontal arm portion are integrated. In FIG. 3, only the lower horizontal arm portion is shown. A fastening mechanism is attached to the upper horizontal arm portion. A die is attached to the lower horizontal arm portion of the C-shaped frame 45.

[0038] The fastening mechanism attached to the upper horizontal arm part has a nose 3 so that the member to be fastened can be pressed onto the die. Further, it has a punch 4 so that the self-piercing rivet 10 can be driven into the member to be fastened that is disposed on the die. In FIG. 3, the nose 3 and the punch 4 are not shown.

[0039] The self-piercing rivet 10 has a large-diameter head portion 11 and a cylindrical leg portion 12 hanging from the head portion 11. The lower end portion of the leg portion 12 is a leg portion tip 13 with a narrowed width. The material of the self-piercing rivet 10 is selected according to the material of the member to be fastened, and an aluminum, an aluminum alloy, steel, stainless steel, or the like is used therefor.

[0040] Figure 4 is a perspective view of a portion of the die of the self-piercing rivet fastening apparatus 1 of the present invention of FIG. 3, taken in cross section. Hereinafter, the die will be described in detail with reference to FIGS. 3 and 4. The die is equipped with a die body 30 and a center pin 50 slidably received in the center pin hole 34 of the die body 30. The die body 30 has a large-diameter portion 35 and a small-diameter portion 36 having a smaller diameter than the substantially cylindrical large-diameter portion 35 below the large-diameter portion 35.

[0041] The large-diameter portion 35 is made of a hard material, such as a high-speed steel material, so that the leg portion 12 of the rivet 10 can be deformed. The large-diameter portion 35 of the die body 30 is axially symmetrical around the center axis. The upper end portion is a flat upper surface 31, and a recessed portion for deforming the leg portion 12 of the self-piercing rivet 10 is formed in the center portion of the upper surface 31. The recessed portion consists of a center circular plane bottom surface 32 and a curved surface 33 curved around the bottom surface 32. The recessed portion can take various shapes other than this.

[0042] A die body hole 46 having a circular cross section is formed in the lower horizontal arm portion of the C-shaped frame 45. A small-diameter portion 36 of the die body 30 is accommodated in the die body hole 46, and the large-diameter portion 35 protrudes above the die body hole 46. The inner diameter of the die body hole 46 is equal to or slightly larger than the outer diameter of the small-diameter portion 36 of the die body 30. The small-diameter portion 36 of the die body 30 is accommodated in the die body hole 46 and is fixed so as not to move relative to the C-shaped frame 45 by screws (not shown), or the like.

[0043] The small-diameter portion 36 of the die body 30 is substantially cylindrical, and the lower end portion

37 is flat. A center pin hole 34 having a circular cross section is formed at the center portion of the bottom surface 32 of the upper surface of the die body 30. The center pin hole 34 penetrates from the upper surface 31 of the die 30 to the lower end portion 37.

[0044] In the center pin hole 34, the center pin 50 is disposed so as to be slidable in the axial direction. The center pin 50 has a cylindrical shaft portion 52 and a pin flange 53 having a larger diameter than the shaft portion 52 formed at one end portion of the shaft portion 52. The pin flange 53 may be omitted. The upper end portion of the shaft portion 52 of the center pin 50 is a flat upper surface 51. The outer diameter of the pin flange 53 is larger than the inner diameter of the center pin hole 34. When the center pin 50 is slid in the center pin hole 34, the pin flange 53 of the center pin 50 comes into contact with the lower end portion 37 of the die body 30 and stops.

[0045] A spring 55 is disposed between the bottom portion of the die body hole 46 of the C-shaped frame 45 and the lower surface of the pin flange 53 of the center pin 50, and an upward force is applied to the center pin 50. In the absence of the pin flange 53 of the center pin 50, the upper end portion of the spring 55 abuts against the lower end portion of the center pin 50. A stopper 56 is formed in the lower portion of the center pin 50 so that the center pin 50 cannot move further downward when the pin flange 53 abuts against the stopper 56. The stopper 56 may be omitted. In FIGS. 3 and 4, the center pin 50 is in the lowered downward position. In the lowered position, the upper surface 51 of the center pin 50 is disposed lower than the bottom surface 32 of the recessed portion of the die body 30, and there is a gap between the pin flange 53 and the lower end portion 37 of the die body 30.

[0046] As the center pin 50 is moved upward in the center pin hole 34, the upper surface of the pin flange 53 abuts against the lower end portion 37 of the die body 30, so that the center pin 50 stops. This position is set as the home position of the center pin 50. If there is no pin flange 53 on the center pin 50, the upper end portion of the spring 55 abuts against the lower end portion 37 of the die body 30, and the center pin 50 stops.

[0047] More preferably, the length of the shaft portion 52 of the center pin 50 is equal to the length from the upper surface 31 to the lower end portion 37 of the die body 30. Therefore, at the home position (or rest position) of the center pin 50, the upper surface 51 of the center pin 50 is flush with the upper surface 31 of the die body 30. When the members to be fastened 41, 42 are disposed on the die body 30 in a state where the center pin 50 is in the home position, it is convenient that the members to be fastened 41, 42 not be deflected.

[0048] Before tightening the self-piercing rivet 10, the spring force of the spring 55 causes the center pin 50 to be raised to the home position. When the self-piercing rivet 10 is fastened, as the self-piercing rivet 10 pierces into the members to be fastened 41, 42, the material of the members to be fastened 41, 42 moves downward,

enters the recessed portion, further pushes the upper surface 51 of the center pin 50, and the center pin 50 descends (or moves down) within the center pin hole 34. At the stage where the fastening is completed, the center pin 50 descends to or near the lowered position. When conditions such as the material and size of the self-piercing rivet 10 and conditions such as the material and thickness of the member to be fastened 41, 42 are modified, the spring force of the spring 55 is adjusted. Before engagement, the center pin 50 is pushed by the spring 55 and is positioned at the home position; at the time of fastening, the center pin 50 descends to the lowered position against the pressing force of the spring 55, and after fastening, the center pin 50 pushes out the member to be fastened 41, 42 inside the center pin hole 34 by the pressing force of the spring 55.

[0049] With reference to FIGS. 5 to 10, a process is described of driving the self-piercing rivet 10 into the members to be fastened 41 and 42 using the self-piercing rivet fastening apparatus according to the first embodiment of the present invention. In FIG. 5, the members to be fastened 41, 42 are placed on the upper surface 31 of the die body 30 with the center pin 50 in the home position.

[0050] In the illustrated example, the member to be fastened 42 on the receiving side is thicker than the member to be fastened 41 on the punch side. The member to be fastened 41 and the member to be fastened 42 are made of a soft material such as aluminum, or a hard material such as steel. The member to be fastened 41 on the punch side may be made of a material such as a carbon, a resin, or the like. Even if the member to be fastened 42 on the receiving side is made of a hard material having poor spreadability, thickening of the member to be fastened 42 and using the die of the present invention allows fastening without occurrence of cracks. The members to be fastened 41, 42 are pressed by the nose 3, the self-piercing rivet 10 is disposed on the member to be fastened 41 in the opening of the nozzle 3, and the punch 4 is disposed on the member to be fastened 41.

[0051] The upper surface 31 of the die body 30 and the upper surface 51 of the shaft portion 52 of the center pin 50 are preferably flush with each other. The upper surface 31 of the die body 30 and the upper surface 51 of the center pin 50 both abut the lower surface of the lower member to be fastened 42. The upper surface 51 of the shaft portion 52 of the center pin 50 may be located lower than the upper surface of the die body 30. In such case, the upper surface 51 of the shaft portion 52 of the center pin 50 does not support the lower surface of the member to be fastened 42. In FIG. 5, the lower portion of the center pin 50 is not shown, but the center pin 50 is in the home position.

[0052] FIG. 6 shows the stage in which the punch 4 slightly pushes the head 10 of the self-piercing rivet 10 downward. Spring 55 (not shown) is slightly bent. The leg portion tip 13 of the self-piercing rivet 10 enters the upper member to be fastened 41. The portion under the

self-piercing rivet 10 of the members to be fastened 41, 42 moves slightly downward. The lower surface of the member to be fastened 42 is kept in contact with the upper surface 51 of the center pin 50. The center pin 50 is pushed downward by the member to be fastened 42 and moves slightly downward. There is still space between the lower surface of the member to be fastened 42, and the curved surface 33 and the bottom surface 32 of the die body 30. The pin flange 53 of the center pin 50 is slightly separated from the lower end portion 37 of the die body 30.

[0053] FIG. 7 shows the stage in which the punch 4 pushes the head portion 11 of the self-piercing rivet 10 further downward. The self-piercing rivet 10 enters the member to be fastened 41 right before the leg portion tip 13 of the self-piercing rivet 10 penetrates the upper member to be fastened 41. The leg portion tip 13 extends slightly outward. The portions of the members to be fastened 41 and 42 under the self-piercing rivet 10 are further moved downward. The lower surface of the member to be fastened 42 pushes the center pin 50 further downward while abutting against the upper surface 51 of the center pin 50. The upper surface 51 of the shaft portion 52 of the center pin 50 descends to the same plane as the bottom surface 32 of the die body 30. The lower surface portion of the member to be fastened 42 is in contact with the bottom surface 32 of the die body 30. There is still a space between the lower surface of the member to be fastened 42 and the curved surface 33 of the die body 30.

[0054] FIG. 8 shows the stage when the punch 4 pushes the head 11 of the self-piercing rivet 10 further downward. The leg portion tip 13 passes through the upper member to be fastened 41 and the inner portion of the leg portion tip 13 of the member to be fastened 41 is cut into a circular cross section. The parts under the self-piercing rivet 10 of the members to be fastened 41, 42 are further moved downward. The leg portion tip 13 has not yet entered the member to be fastened 42. The center pin 50 is pushed further downward and moves downward. The upper surface 51 of the shaft portion 52 of the center pin 50 is located lower than the bottom surface 32 of the die body 30.

[0055] The lower surface of the member to be fastened 42 is in contact with the bottom surface 32 of the die body 30. There is still a space between the lower surface of the member to be fastened 42 and the curved surface 33 of the die body 30. In the stage of FIG. 8, the punch 4 has moved considerably downward from the stage of FIG. 7, but the leg portion tip 13 of the self-piercing rivet 10 does not enter the lower member to be fastened 42. With the self-piercing rivet 10, the center pin 50 is pushed downward, and a part of the material of the member to be fastened 42 pushes down the center pin 50 and enters into the center pin hole 34. Therefore, the material of the member to be fastened 42 does not move much in the lateral direction.

[0056] FIG. 9 shows the stage in which the punch 4

further pushes the head portion 11 of the self-piercing rivet 10 downward. Leg portion tip 13 breaks through member to be fastened 41 on the punch side, and enters the member to be fastened 42 on the receiving side.

[0057] At this stage, since the bottom surface 32 of the die body 30 is present via the thin portion of the member to be fastened 41 at the lower portion of the leg portion tip 13, the leg portion 12 cannot move downward to a great degree. Therefore, the leg portion tip 13 expands radially outward. The center pin 50 has not moved too far downward from the stage of FIG. 8.

[0058] The bottom surface 32 of the die body 30 is in contact with the lower surface of the member to be fastened 42. A small space remains between the lower surface of the member to be fastened 42 and the curved surface 33 of the die body 30.

[0059] FIG. 10 shows the stage in which fastening of the self-piercing rivet 10 is completed. The lower surface of the pin flange 53 is in contact with a stopper 56, and the center pin 50 is in the lowered position. The position in the axial direction of the self-piercing rivet 10 is not so different from the stage in FIG. 9, but the punch 4 pushes the head portion 11 of the self-piercing rivet 10 further downward. The upper surface of the head portion 11 of the self-piercing rivet 10 is substantially flush with the upper surface of the member to be fastened 41.

[0060] Inside the leg portion 12 of the self-piercing rivet 10, there is a space between the lower surface of the head portion 11 and the upper surface of the member to be fastened 41.

[0061] When the member to be fastened 41 is made of a thick and soft metallic material, this space tends to be small.

[0062] Leg portion tip 13 of the self-piercing rivet 10 is further spread radially outward, and the member to be fastened 42 is fastened to the member to be fastened 41.

[0063] After fastening the self-piercing rivet 10, the punch 4 moves upward, and the nose 3 holding the members to be fastened 41, 42 also moves upward. When there is no force to press the members to be fastened 41, 42 from above, the spring 55 presses the center pin 50 upward. The center pin 50 pushes up the member to be fastened 42 in the center pin hole 34. The members to be fastened 41 and 42 that have been fastened are pushed out to the upper side of the die body 30.

[0064] In the first embodiment, when fastening the self-piercing rivet 10, the center pin 50 moves downward, and the member to be fastened 42 on the receiving side enters the portion of the center pin hole 34. Therefore, the member to be fastened 42 does not largely expand radially outward. The leg portion 12 of the self-piercing rivet 10 expands to a smaller diameter than in the case of using the conventional die 20. The embodiment is set so that a strong tensile stress is not generated in the member to be fastened 42. Therefore, even if the member to be fastened 42 on the receiving side is made of a hard material, cracking is unlikely to occur.

[0065] Next, a second embodiment of the present in-

vention will be described. FIG. 11 is a cross-sectional view showing a die and a portion of a C-shaped frame 45 supporting a die of a self-piercing rivet fastening apparatus according to a second embodiment of the present invention. In the second embodiment, as in the first, the die has a die body 30 and a center pin 50 movably supported in the center pin hole 34 of the die body 30. In the first embodiment, the center pin 50 is pressed upward by the spring 55. In the second embodiment, oil is supplied by a pump 58 to the space between the bottom portion of the die body hole 46 and the lower surface of the pin flange 53, and the pin flange 53 of the center pin 50 is pushed upward by oil pressure. Alternatively, it is also possible to supply air instead of oil by a pump and push up the pin flange 53 of the center pin 50 by air pressure. In the second embodiment, since oil or air is supplied to the space sealed by the die body hole 46 and the pin flange 53, the pin flange 53 is necessary. Alternatively, the center pin 50 can be moved up and down by using an electric apparatus such as a motor instead of a hydraulic apparatus or a pneumatic apparatus.

[0066] In the second embodiment, oil is supplied to the space between the bottom portion of the die body hole 46 and the lower surface of the pin flange 53 before the punch 4 is driven, and the center pin 50 is located at the raised home position. In order to drive the self-piercing rivet 10, as the punch 4 is lowered, the oil is drained so that the center pin 50 falls to the lowered position.

[0067] When fastening the self-piercing rivet 10, the pump 58 can be controlled so that the center pin 50 descends at a constant speed to the lowered position.

[0068] Alternatively, the center pin 50 is controlled to descend at a programmed speed, the descent distance of the center pin is decreased at the initial stage of fastening, and at the stage when deformation of the member to be fastened 42 becomes large in the latter half period, it is also possible to increase the descent distance of the center pin.

[0069] Alternatively, the center pin 50 may be lowered before driving the self-piercing rivet 10.

[0070] After fastening the self-piercing rivet 10, oil or air is supplied to the space between the bottom portion of the die body hole 46 and the lower surface of the pin flange 53 to raise the center pin 50, and member to be fastened 42 can also be pushed out from the center pin hole 34.

[0071] In the second embodiment, the movement of the center pin 50 can be controlled independently of the pressure applied to the upper surface of the center pin 50.

[0072] Further, as compared with the first embodiment in which the center pin 50 is pushed down against the pressing force of the spring 55, the movement of the center pin 50 can be more precisely controlled.

[0073] Also in the second embodiment of the present invention, when fastening the self-piercing rivet 10, the center pin 50 moves downward, and the member to be fastened 42 on the receiving side enters the center pin hole 34. Therefore, the member to be fastened 42 does

not deform largely radially outward, and strong tensile stress is not generated in the member to be fastened 42. Consequently, cracks are unlikely to occur in the member to be fastened 42 on the receiving side.

[0074] With respect to the case in which the members to be fastened 41, 42 are fastened using the conventional die and the case in which the members to be fastened 41, 42 are fastened using the die of the first embodiment of the present invention, the results of simulating the internal stress of the self-piercing rivet 10 and the member to be fastened 41 and 42 will be described.

[0075] FIG. 12 shows the result of simulating the internal stress of the self-piercing rivet 10 and the members to be fastened 41, 42 when fastening the members to be fastened 41, 42 using the conventional die 20 (FIG. 1).

[0076] FIG. 13 shows the results of simulating the internal stress of the self-piercing rivet 10 and the members to be fastened 41 and 42 in the case in which the members to be fastened 41, 42 are fastened by using a die in which the die body 30 and the center pin 50 are combined according to the first embodiment of the present invention.

[0077] The member to be fastened 42 on the receiving side is thicker than the member to be fastened 41 on the punch-side.

[0078] The white part indicates that the internal stress is large. The darker black part indicates that the internal stress is negative and the absolute value is large. The intermediate gray portion represents that the internal stress is positive or negative and small.

[0079] FIG. 12 is a simulation at the stage where the members to be fastened 41, 42 are arranged on the conventional die 20 shown in FIG. 1, and the members to be fastened 41, 42 are fastened by the self-piercing rivet 10. Nose 3 and punch 4 are indicated by double-dashed lines.

[0080] When the self-piercing rivet 10 is driven by the punch 4, the leg portion 12 breaks the member to be fastened 41 on the upper side and enters into the member to be fastened 42 on the receiving side. The member to be fastened 42 is pushed downward, and the portion pushed downward of the member to be fastened 42 enters the recessed portion of the die 20. When the member to be fastened 42 hits against the bottom surface 22, it cannot move downward. Since the leg portion 12 cannot move downward, it expands radially outward. Therefore, the member to be fastened 42 also spreads radially outward.

[0081] After fastening the self-piercing rivet 10, both the head portion 11 and the leg portion 12 of the self-piercing rivet 10 have a very high level of internal stress. The leg portion 12 has high overall level of internal stress.

[0082] The member to be fastened 41 on the punch side is pulled by the self-piercing rivet 10 near the fastening portion and is a negative internal stress. The rounded portion that is cut off by the leg portion 12 of the member to be fastened 41 on the punch side and entered into the leg portion 12 is pulled outward in the radial di-

rection by the enlarged leg portion 12 and is a negative internal stress.

[0083] With the member to be fastened 42 on the receiving side, under the leg portion tip 13 of the self-piercing rivet 10, a strong pressure is applied from the leg portion tip 13, and the level of internal stress is high.

[0084] A negative internal stress is applied to the portion that contacts the curved surface 23 of the fastened portion 42.

[0085] Since the member to be fastened 42 cannot move too far downward, a high level of internal stress is applied to the leg portion 12 of the self-piercing rivet 10. Therefore, a high level of internal stress is generated in the portion of the member to be fastened 42 at the tip of the leg portion tip 13, which may cause cracks in the member to be fastened 42.

[0086] FIG. 13 is a simulation at the stage when self-piercing rivet 10 is driven into members to be fastened 41, 42 using the die according to the first embodiment of the present invention and fastening is completed.

[0087] In the first embodiment, a die consisting of a die body 30 and a center pin 50 is used. When the self-piercing rivet 10 is driven into the members to be fastened 41, 42, the center pin 50 moves downward in the center pin hole 34, and the member to be fastened 42 on the receiving side enters the upper portion of the center pin hole 34.

[0088] In the first embodiment, the internal stress of the head portion 11 of the self-piercing rivet 10 is lower than in the case of using the conventional die 20 of FIG. 12. In the case of using the conventional die 20, while the internal stress of the leg portion 12 has been high, in the first embodiment, the internal stress of the leg portion 12 is only partially high.

[0089] The member to be fastened 41 on the punch side is pulled by the self-piercing rivet 10 near the fastening portion and is negative internal stress. The rounded portion which is cut off by the leg portion 12 of the member to be fastened 41 on the punch side and enters into the leg portion 12 is pulled outward in the radial direction by the enlarged leg portion 12, and a negative internal stress is generated; however, the portion where the negative internal stress is larger than that of the conventional case is narrowed.

[0090] Regarding the member to be fastened 42 on the receiving side, the internal stress is lower in the portion under the leg portion tip 13 of the self-piercing rivet 10 than in the conventional case in FIG. 12.

[0091] In the first embodiment, when the self-piercing rivet 10 is driven into the member to be fastened 41, 42 and fastened, the center pin 50 moves downward and the material of the member to be fastened 42 moves to the portion of the center pin hole 34 after the center pin 50 has moved. The material of the member to be fastened 42 does not spread outward in the radial direction to a great degree. The material inside the leg portion 12 of the self-piercing rivet 10 is not pulled radially outward, and the internal stress is not increased. The leg portion

12 is not expanded radially outward beyond what is necessary. The internal stress of the portion of the member to be fastened 42 under the leg portion tip 13 is reduced, and cracks are less likely to occur in the member to be fastened 42 on the lower side.

[0092] Summarizing the simulation results, when the conventional die 20 of FIG. 12 is used, a strong stress is generated in the head portion 11 and the leg portion 12 of the self-piercing rivet 10, and a strong negative stress is generated to the member to be fastened 42 on the receiving side. On the other hand, when the die of the first embodiment shown in FIG. 13 is used, the portion where the strong stress is generated in the head portion 11 and the leg portion 12 of the self-piercing rivet 10 becomes small, and there is almost no portion where a strong negative stress is generated in the member to be fastened 42 on the receiving side. As described above, by simulation, in the first embodiment, it was confirmed that the leg portion 12 is not expanded radially outward more than necessary, the internal stress of the leg portion tip 13 is lowered, and cracks are unlikely to occur in the member to be fastened 42 on the lower side. The same effect can also be obtained in the second embodiment.

Nomenclature:

[0093]

1	Self-piercing rivet fastening apparatus
3	Nose
4	Punch
10	Self-piercing rivet 11 head portion
12	leg portion
13	Leg portion tip
20	Die (conventional)
21	Upper surface
22	Bottom surface
23	Curved surface
24	Large-diameter portion
26	Small-diameter portion
30	Die body
31	Upper surface
32	Bottom surface
33	Curved surface
34	Center pin hole
35	Large-diameter portion
36	Lower end portion
37	Lower end portion
41	Member to be fastened (punch side)
42	Member to be fastened (receiving side)
45	C-shaped frame
46	Die body hole
50	Center pin
51	Upper surface
52	Shaft portion
53	Pin flange
55	Spring
56	Stopper

58 Pump

Claims

1. Self-piercing rivet fastening apparatus (1) for driving a self-piercing rivet (10) having a large-diameter head portion (11) and a hollow leg portion (12) hanging from the head portion by driving it into a member to be fastened and fastening it; equipped with a nose (3) for pressing the member to be fastened, a punch (4) for driving the self-piercing rivet into the member to be fastened, and a die for receiving the member to be fastened; wherein the die is equipped with a die body (30) having an upper surface (31) and a recessed portion formed inside the upper surface (31) wherein a center pin hole (34) is formed therethrough downward from a center portion of the recessed portion, and a center pin (50) supported in the center pin hole (34) of the die body so as to be movable in the axial direction; the center pin (50) has a cylindrical shaft portion having an outer diameter matching the inner diameter of the center pin hole, and the self-piercing rivet fastening apparatus (1) is further equipped with a pressing apparatus for axially pressing the center pin.
2. Self-piercing rivet fastening apparatus (1) according to claim 1, wherein the center pin (50) is movable from a position below the bottom surface (32) of the recessed portion of the die body to a position above the bottom surface (32) of the recessed portion.
3. Self-piercing rivet fastening apparatus (1) according to claim 1 or 2, wherein the pressing apparatus is a spring (55) disposed below the center pin (50), the spring (55) applies an upward pressing force to the center pin, when a downward pressing force stronger than the pressing force of the spring (55) is applied to the upper surface of the center pin (50), the center pin (50) moves downward until the upper surface is positioned below the bottom surface (32) of the recessed portion, and when a downward pressing force is not applied to the upper surface of the center pin, the center pin (50) is pushed by the pressing force of the spring (55) so that the center pin moves upward until the upper surface is positioned above the bottom surface (32) of the recessed portion.
4. The self-piercing rivet fastening apparatus (1) according to claim 1 or 2, wherein the pressing apparatus is a hydraulic apparatus, a pneumatic apparatus or an electric apparatus that presses the center pin (50) upward.

5. A fastening method for driving a self-piercing rivet (10) with a self-piercing rivet fastening apparatus (1) equipped with a nose (3) for pressing a member to be fastened, a punch (4) for driving the self-piercing rivet (10) into the member to be fastened, and a die for receiving the member to be fastened; wherein the die is equipped with a die body (30) having an upper surface (31) and a recessed portion formed inside the upper surface wherein a center pin hole (34) is formed therethrough downward from a center portion of the recessed portion, and a center pin (50) supported in the center pin hole (34) of the die body so as to be movable in the axial direction; the self-piercing rivet fastening apparatus (1) is further equipped with a pressing apparatus for axially pressing the center pin (50); wherein the fastening method comprises the following steps:

- (a) positioning the member to be fastened on the upper surface (31) of the die body (30),
- (b) pressing the member to be fastened by the nose (3),
- (c) arranging a self-piercing rivet (10) between the punch (3) and the member to be fastened,
- (d) lowering the punch (3) to press the self-piercing rivet (10) against the member to be fastened so that the member to be fastened moves downward and the distal end of a leg portion of the self-piercing rivet passes through the member to be fastened, and

the method further comprises a step(e) wherein the material of the member to be fastened penetrates the center pin hole (34), and the center pin (50) descends against the pressing force of the pressing apparatus until the upper surface of the center pin (50) is positioned lower than the bottom surface (32) of the recessed portion of the die body (30), thereby completing fastening.

6. The fastening method according to claim 5, further comprising the following step, (f) after the completion of fastening, the center pin rises in the center pin hole by the pressing force of the pressing apparatus to push out the member to be fastened in the center pin hole.

Figure 1

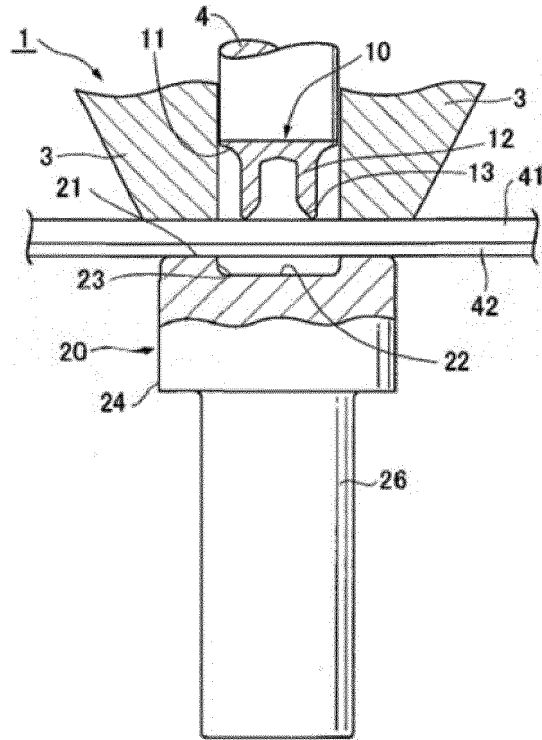


Figure 2

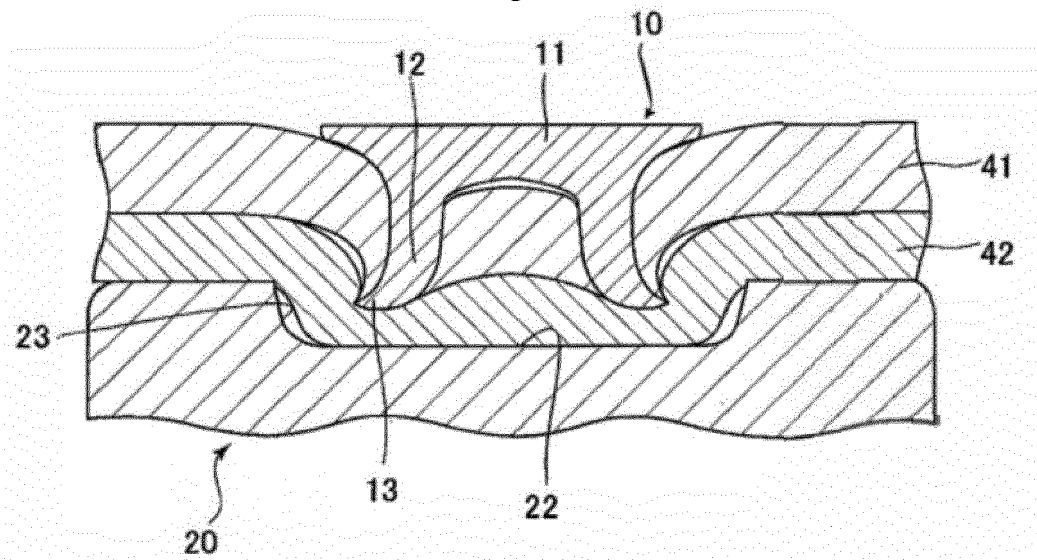


Figure 3

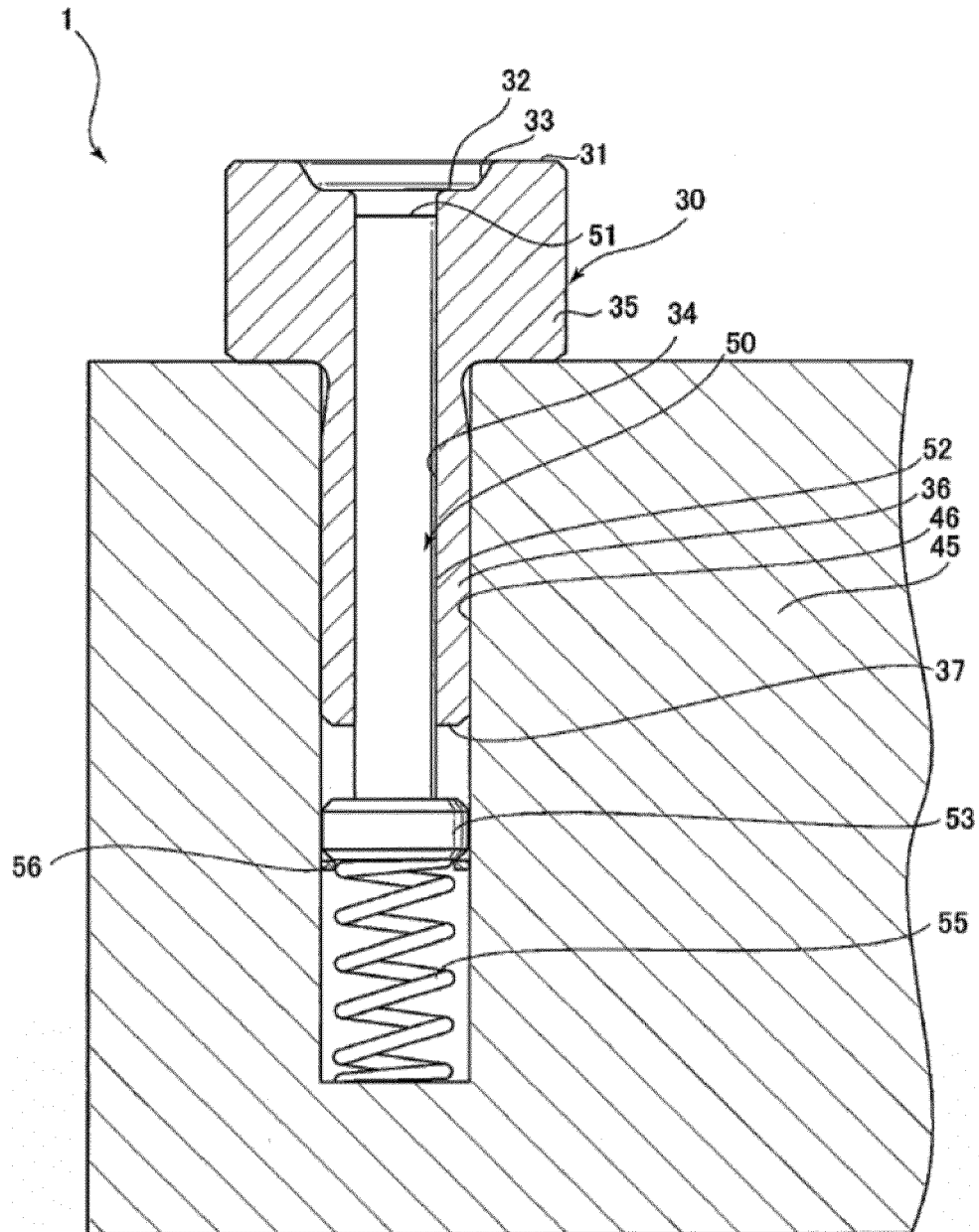


Figure 4

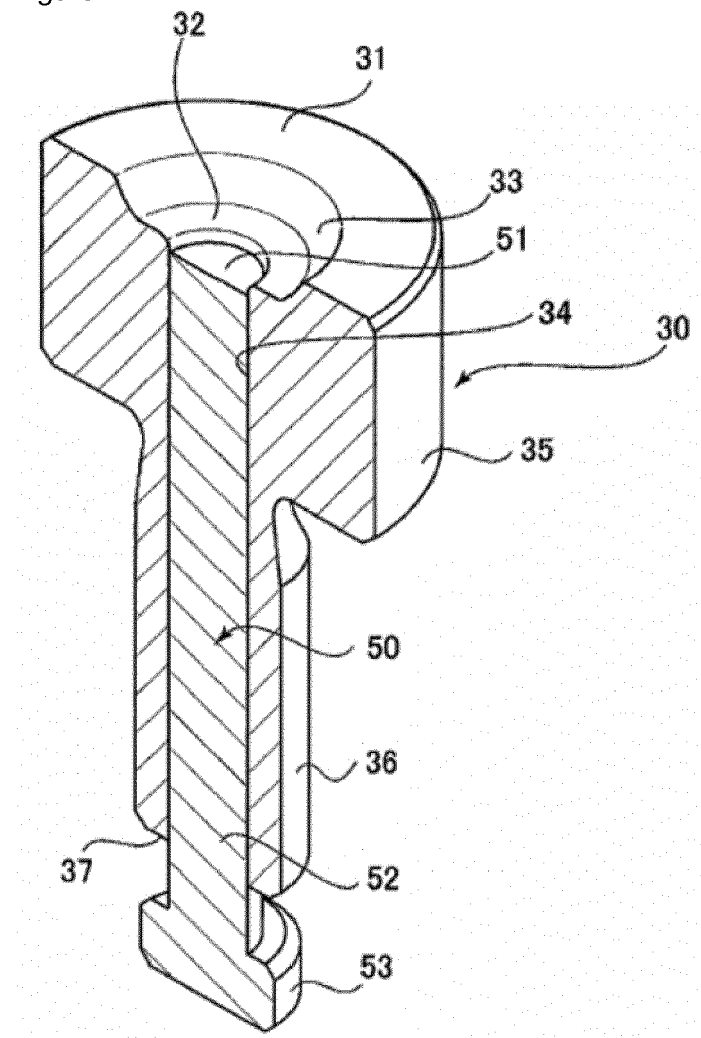


Figure 5

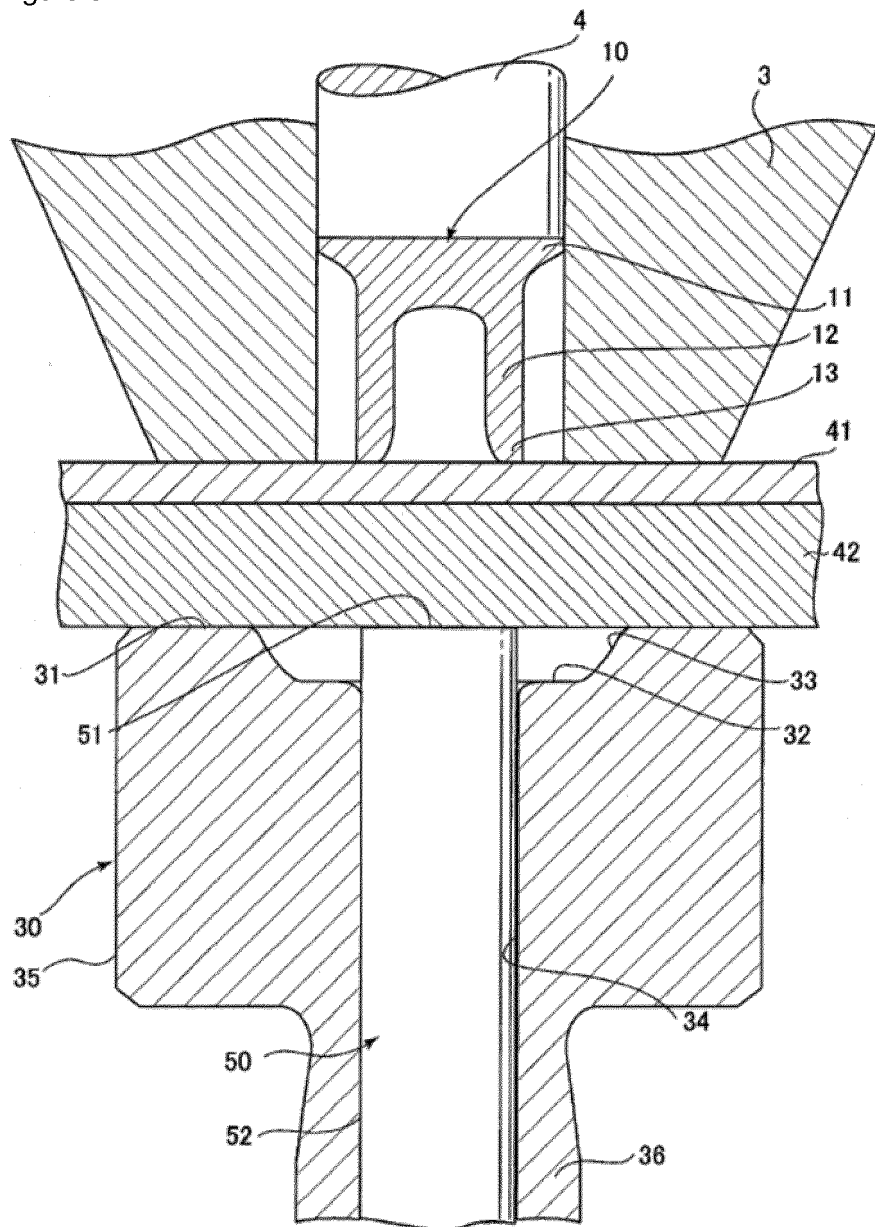


Figure 6

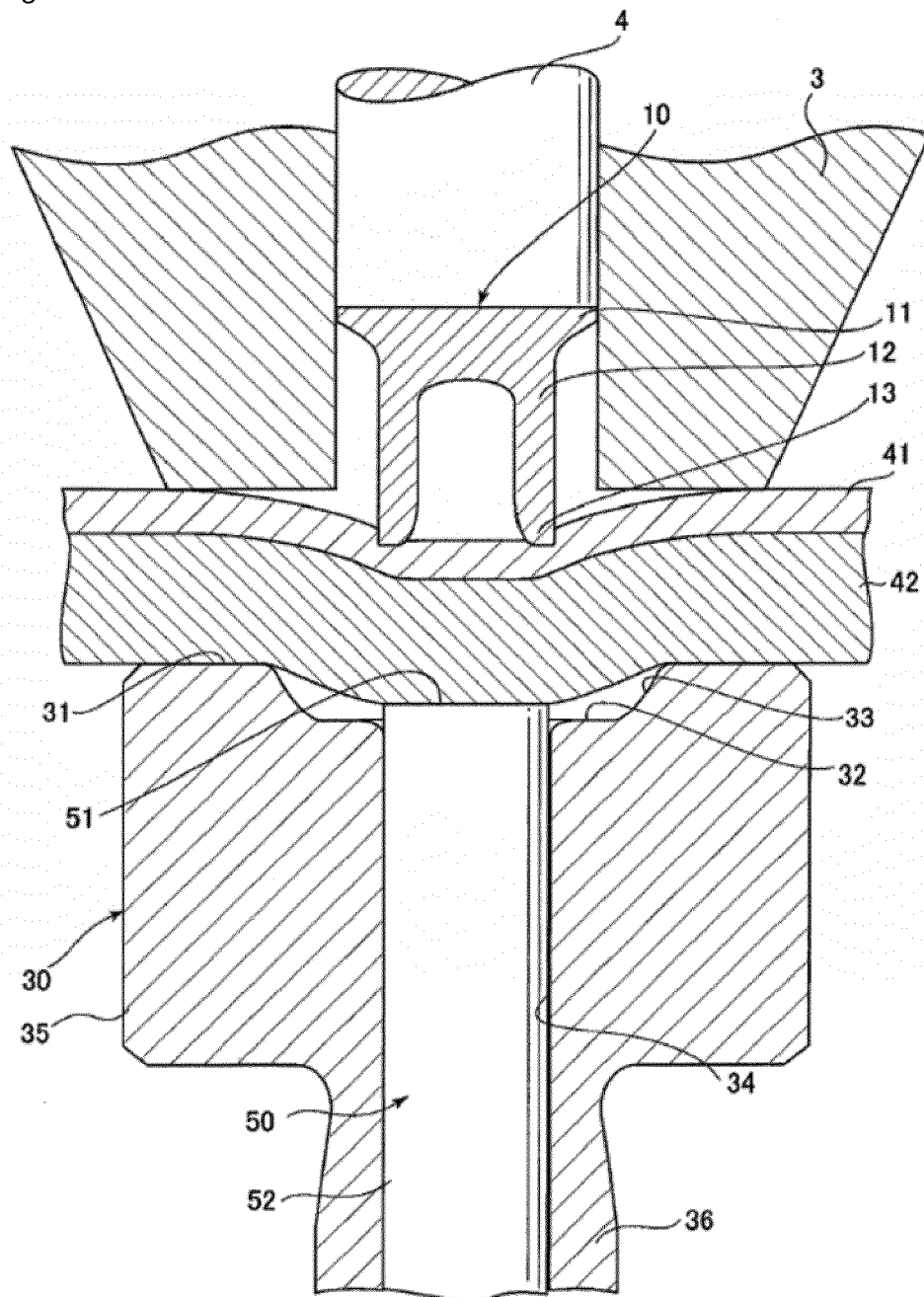


Figure 7

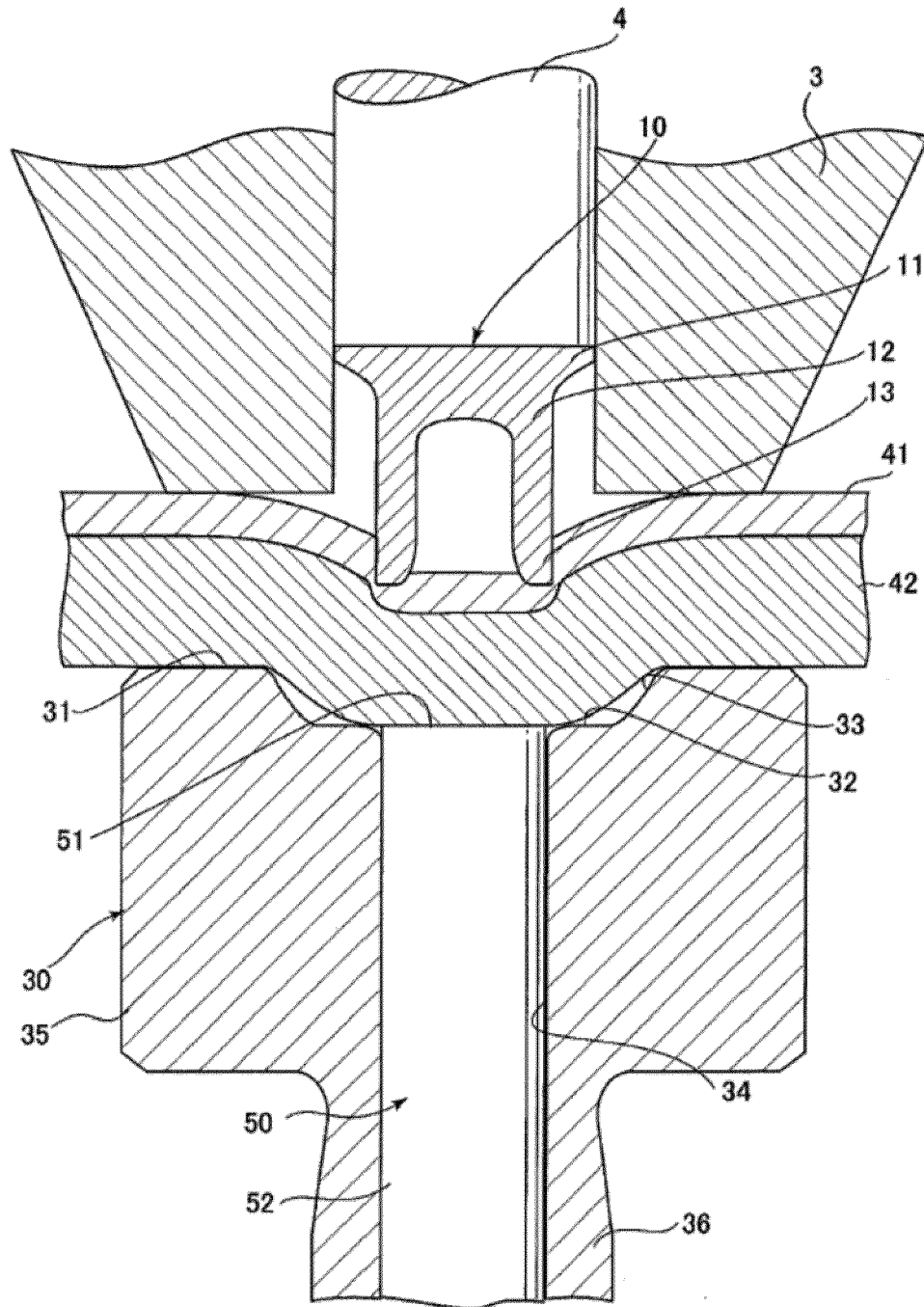


Figure 8

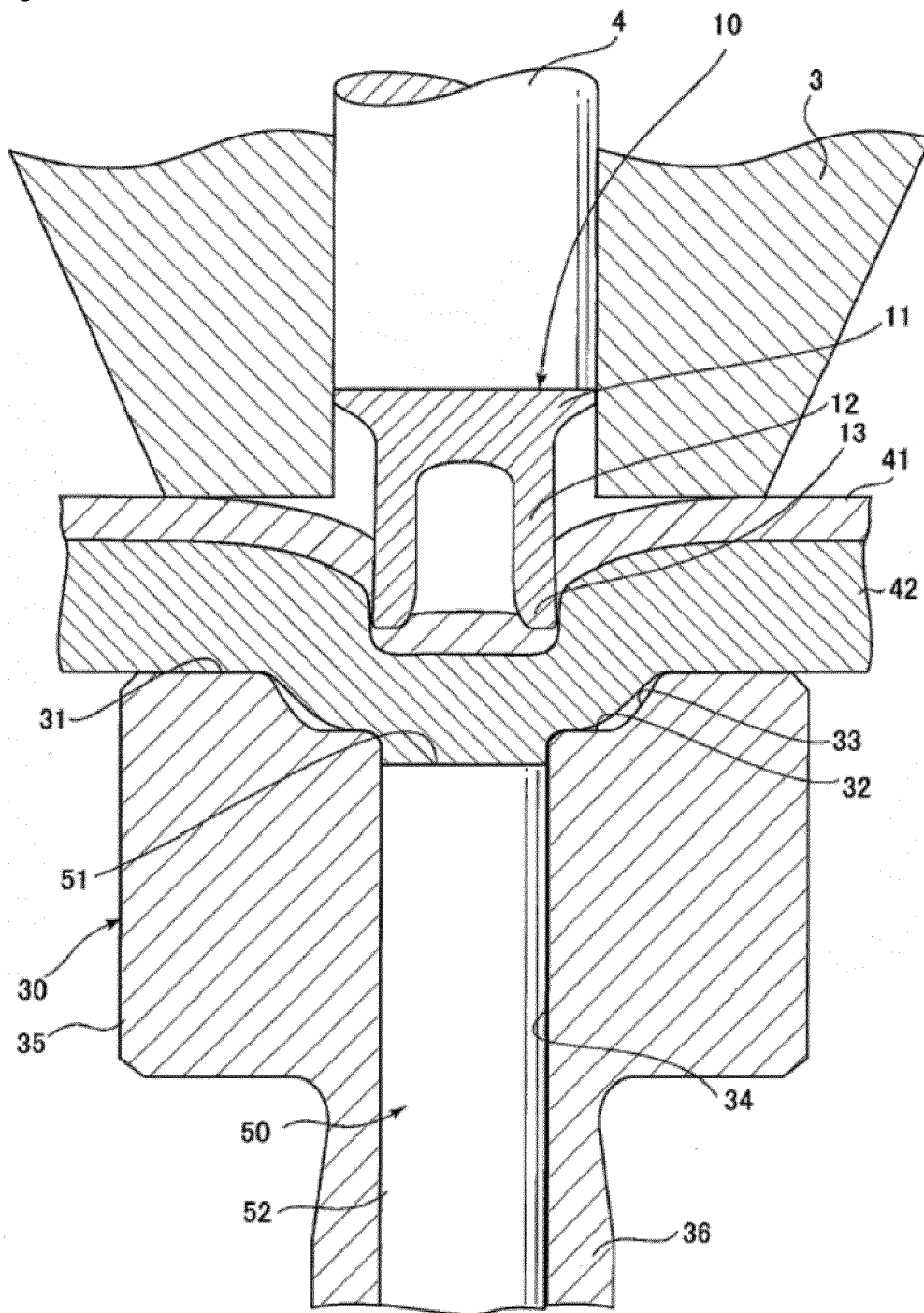


Figure 9

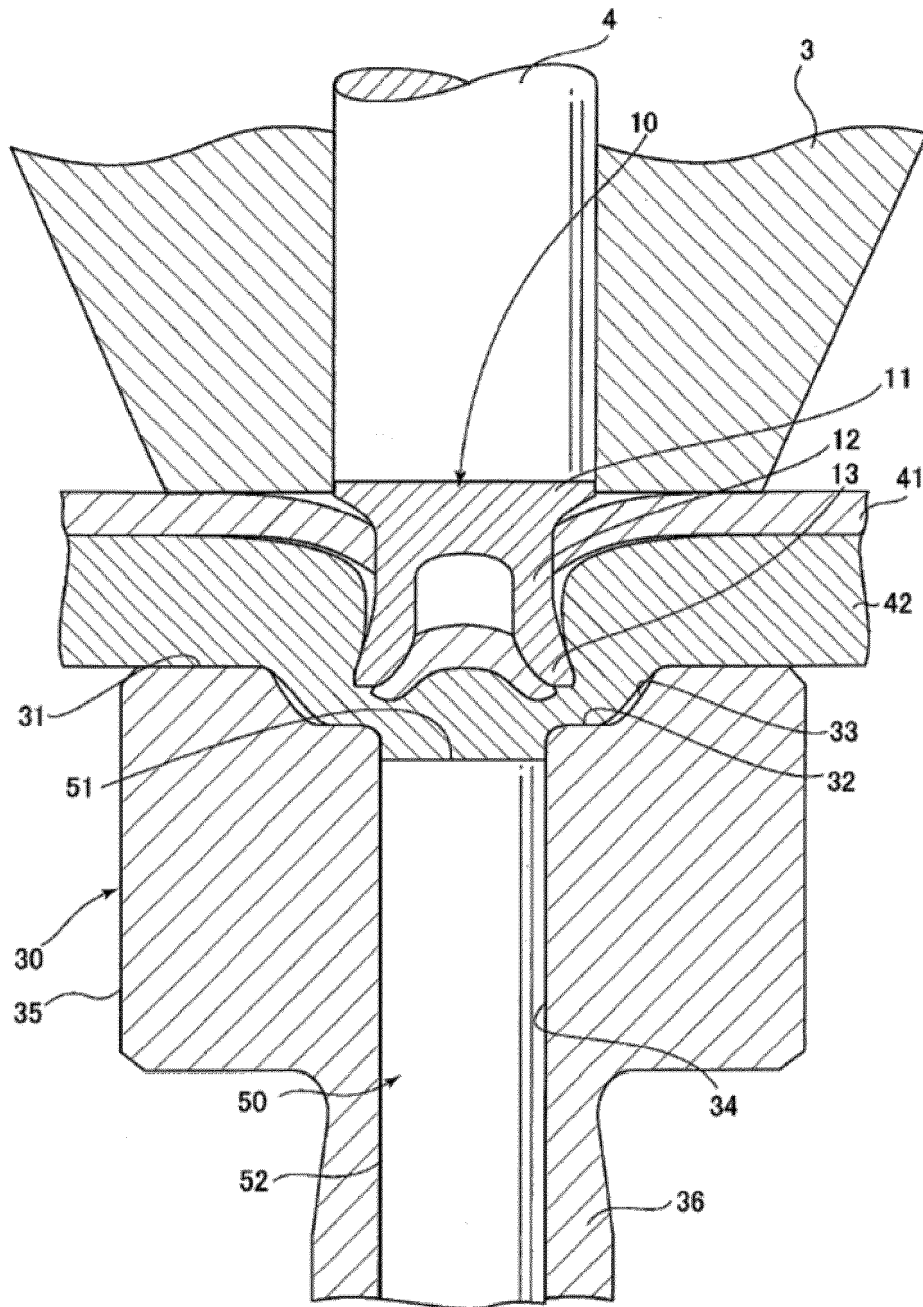


Figure 10

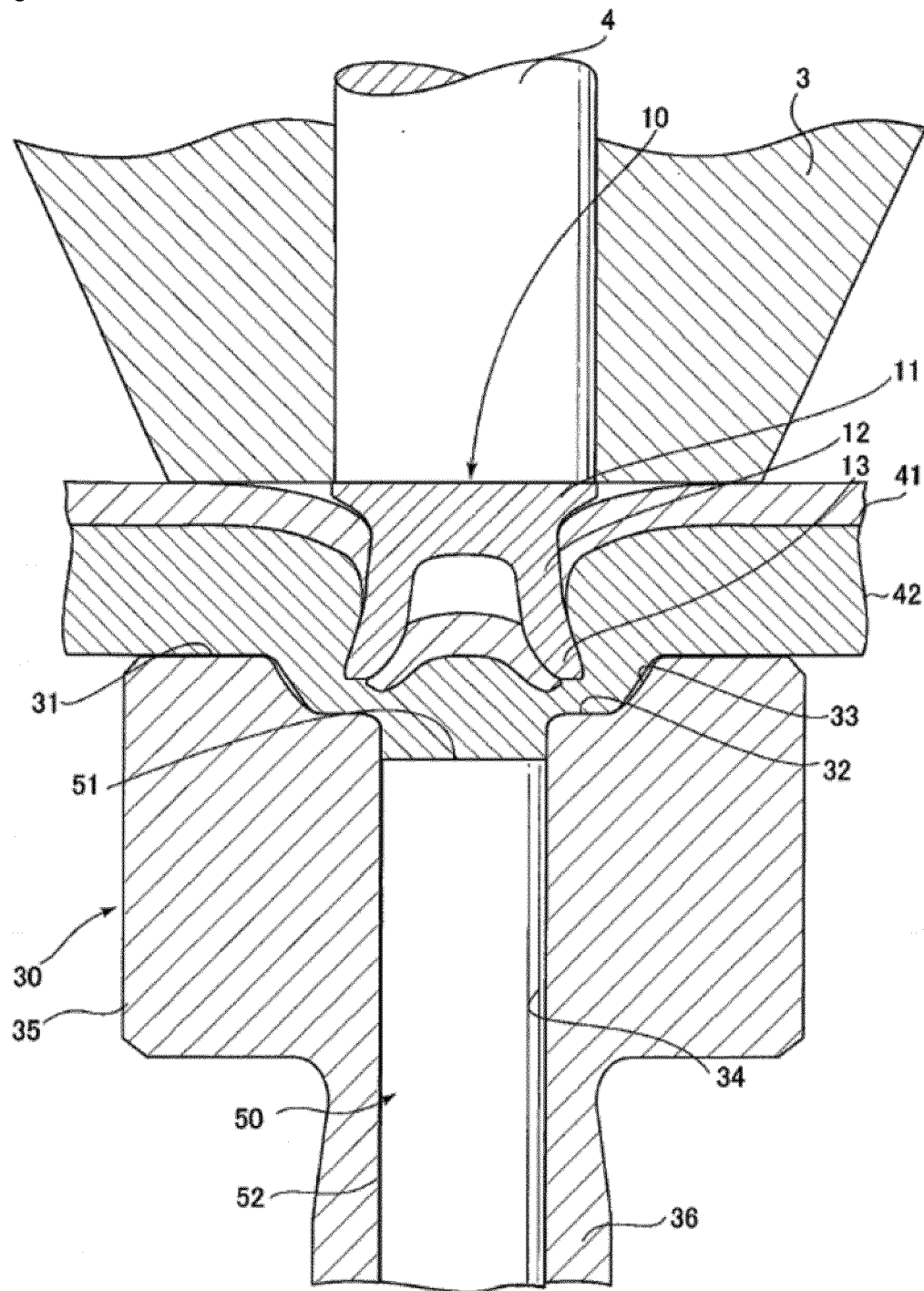


Figure 11

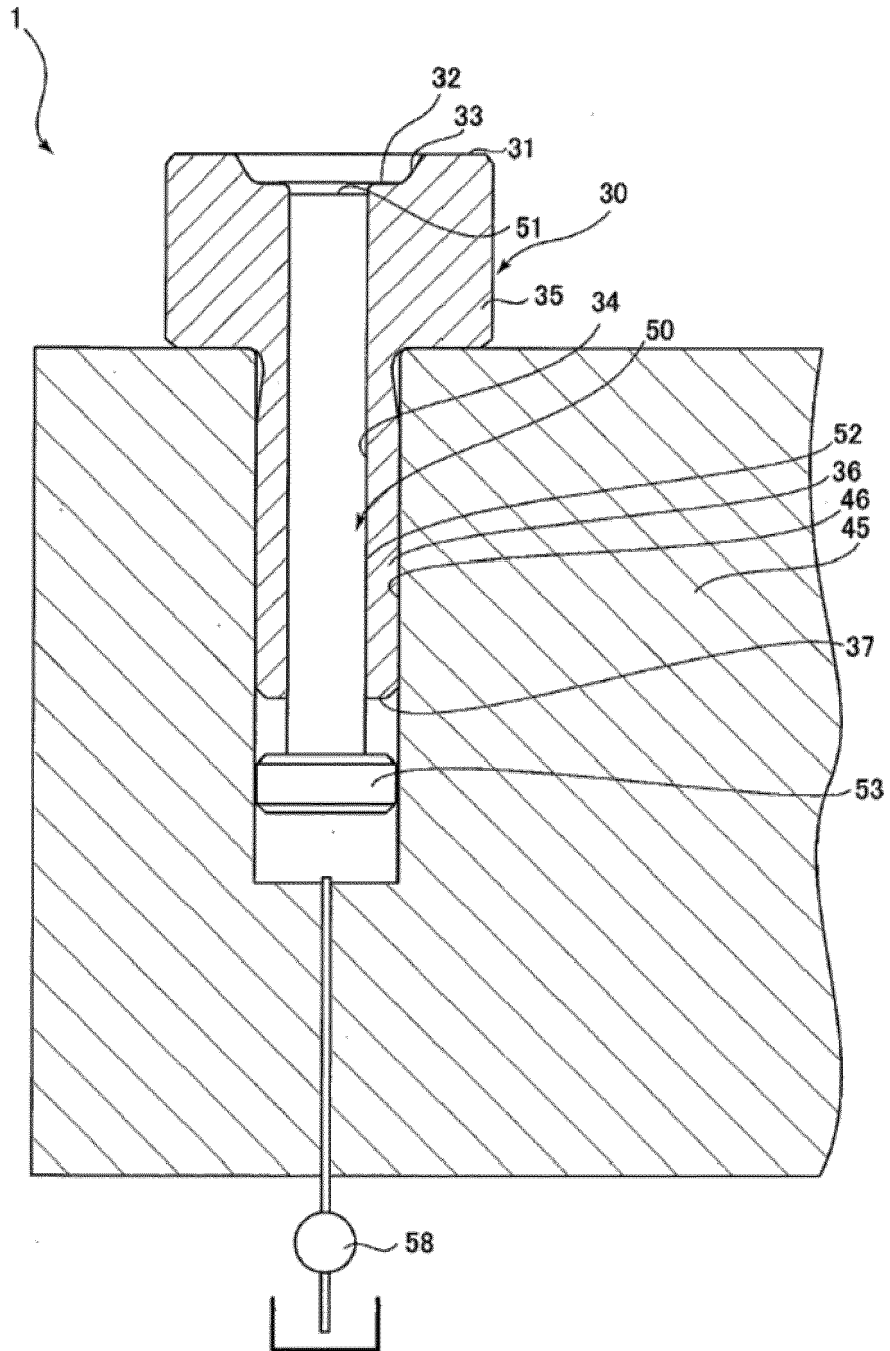


Figure 12

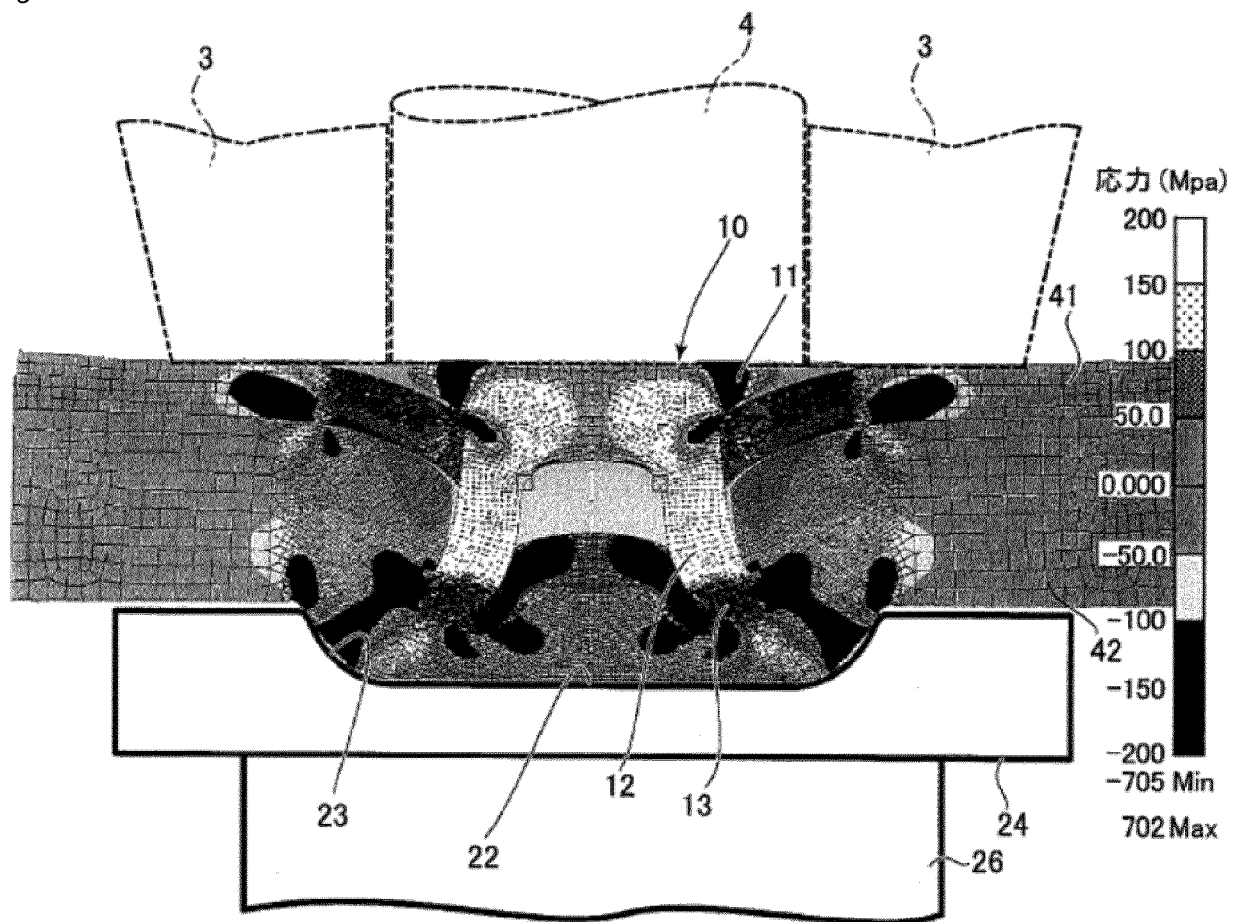
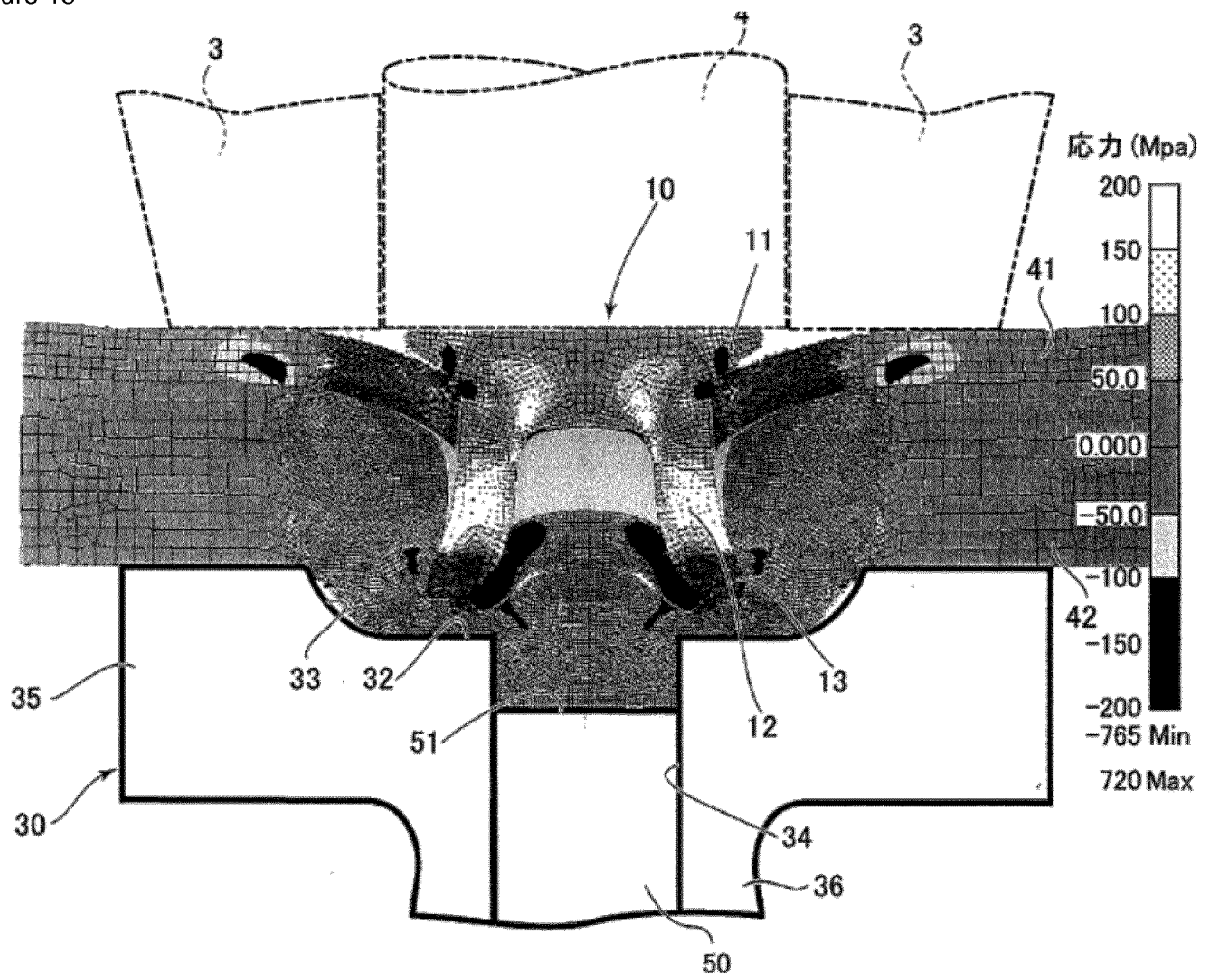


Figure 13





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 EP 18 18 0266

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			B21J
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Place of search Munich		Date of completion of the search 23 November 2018	Examiner Charvet, Pierre
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