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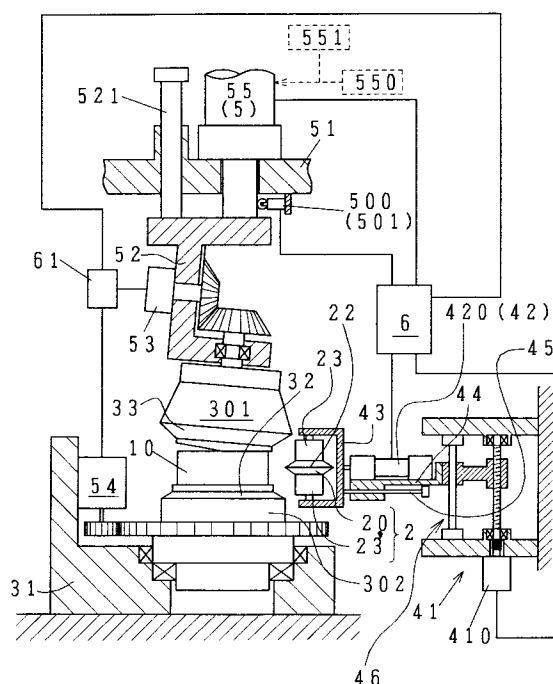
(11) Publication number:

0 672 483 A1

(12)

EUROPEAN PATENT APPLICATION(21) Application number: **94308138.0**(51) Int. Cl.⁶: **B21J 9/02, B21K 1/28,
B21H 1/04**(22) Date of filing: **04.11.94**(30) Priority: **16.03.94 JP 45997/94**(43) Date of publication of application:
20.09.95 Bulletin 95/38(84) Designated Contracting States:
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London WC2A 1JO (GB)(54) **Rotary forging apparatus.**

(57) A rotary forging apparatus has a first rotary ram (301), a second rotary ram (302) facing together in a vertical direction and a shaping roller (2) equipped beside the rams. The apparatus forges a product from a material work (10) by sandwiching the work (10) between the first ram (301) and the second ram (302), pressing the work (10) by the rams, thinning the work (10) into the disc part (1) of a product, pressing the excluded material out of the rams by the shaping roller (2) to the sides of the rams and shaping the rim part. When the apparatus forges a wheel having a V-grooved or U-grooved rim part (11), scars or voids are often generated on the rim part, since the roller (2) does not move in the vertical direction in prior apparatuses. This invention provides the shaping roller (2) with a supporting device, a vertical transference device (41) and a horizontal transference device (42). The roller (2) is moved also in the vertical direction, accompanying the thinning of the work. Vertical movement enables the roller (2) to divide the extruded material in a suitable ratio into two parts. The rim part is immune from scars or voids because of the vertical transference of the roller accompanying the thinning of the work.

FIG. 4

This invention relates to a rotary forging apparatus, in particular, to an apparatus for forming a wheel or the like from a starting material (a workpiece) by sandwiching the workpiece formed for example, of aluminum alloy, magnesium alloy, between an upper ram and a lower ram, forming a disc part by pressing and thinning the central part of the workpiece, pressing the extruded material out of the rams by a roller located in the vicinity of a side of the boundary of the rams and shaping a rim part of a product.

Japanese Patent Laying Open No.61-226132 proposed one of rotary forging apparatuses having two rams and a side roller as mentioned above. Fig.1 shows the prior apparatus. The rotary forging apparatus of Fig.1 presses a workpiece between a bottom surface of a first ram (301) and a top surface of a second ram (302) for shaping a disc part. The apparatus has also a side shaping roller (2) beside the rams and moves the roller (2) horizontally at the height of the boundary of the rams (301) and (302).

The first ram (301) has an umbrella-like bottom i.e. a cone with an obtuse top angle. A supporting device (not shown in figures) supports the conical upper ram (301) in a fixed inclined posture in which the generating line of the bottom cone is horizontal at its lowest point. A generating line is defined as a line of a section of a rotationally symmetric thing taken along a plane including a central axis. A rotationally symmetric body has an infinite number of generating lines on its outer surface. However all the generating lines are geometrically identical because of the rotational symmetry. Since the upper ram (301) is inclined, only a small portion of the conical bottom touches the work along a radius which is just included in the plumb symmetry plane. The other ram (302) has an erect rotary axis.

The forging apparatus synchronously rotates the first ram (301) and the second ram (302) sandwiching workpiece (10), brings the first ram (301) down on the workpiece (10) and presses extruded material by the side roller (2). Finally the workpiece is transformed into a product having a disc part (1) shaped after the bottom and top of the rams and a rim part (11) shaped after the sides of the rams and the shaping roller (2).

If the section of the rim part (11) is a simple rectangle symmetric with regard to the central plane of the disc part (1), the apparatus is capable of finishing well the section of the rim part (11) of the product. Otherwise, if the section of the rim part is an edged V-shape, the shaped rim part (11) is likely to suffer from an accidental occurrence of a void (19) or a scar in the section.

The reason for the occurrence of the void is now explained.

A Λ -edged roller (2) with a suitable section is adopted for forging such a V-shaped rim part. The edged side roller (2) is fixed at a position at which the Λ edge (22) is horizontally coincident with the V-groove of the rim to be shaped from the beginning to the end in the whole forging process. Under this condition, the upper ram (301) rotates and presses down the workpiece gradually against the lower ram (302) whose height is constant. On the contrary, the upper ram (301) is descending for thinning the workpiece (10). Excess material is successively excluded from a space between the upper ram (301) and the lower ram (302). The side roller presses the excluded material from the side into a rim part (11).

However since the roller is fixed at a constant height which is equal to the height of the center plane of the finished rim part, the edge (22) of the roller (2) differs downward from the center plane of the work (10) at the beginning. The distance between the lower ram (302) and the roller (12) is maintained constant. But the distance between the roller (2) and the first, upper ram (301) gradually reduces. At first most of the material is extruded to the space above the edge (22). Little is extruded to the other space lower than the edge (22). The rams asymmetrically exclude the material against the roller (2). As the second ram (301) is lowering and thinning the workpiece (10), the supply to the upper space is reducing and the supply to the lower space is enhancing.

At the final stage, the supply of the material to the lower space becomes tantamount to that for the upper space. While the ram (301) is thinning the workpiece (10) together with the ram (302), some portion of the excluded material must transfer from the upper space to the lower space over the Λ -edge (22) of the roller (2). Nevertheless, the edge itself disturbs the downward transference of the material. Deficiency of the material in the lower space generates the void (19) at the lower side of the V-groove of the rim part (11).

Aiming for solving such a problem, some one may have idea of improving the shaping once the rim portion (11) into a rectangle section by a simple roller such as the example of Fig. 1 and further of shaping the rim part by another Λ -edged roller as shown in Fig.2. This improvement will be immune from the occurrence of a void. But such an improvement suffers from the disadvantage of low productivity because of the inconvenience of having to exchange two rollers every cycle of forging.

The present invention aims at overcoming this difficulty. One object of this invention is to provide an improvement capable of shaping a rim part having a V-section or a U-section without voids by means of a single shaping roller (2) in a rotary forging apparatus which has a first ram (301), a

second ram (302) facing the first ram (301) and a shaping roller (2) installed beside the rams, and forges a wheel from a workpiece by forming the disc by the rams and by shaping the rim part by the roller.

In order to solve the difficulty, this invention proposes a rotary forging apparatus having a second rotary ram (302) which rotates at a constant position, a first rotary ram (301) which can be lifted or lowered by a supporting device, a shaping roller (2) for shaping a rim part, a roller supporting device (4) for sustaining the roller, a generally vertical transferring device (41) for raising or lowering the roller supporting device (4) and a generally horizontal transferring device (42) for feeding the roller supporting device (4) in a horizontal direction.

The function of the rotary forging apparatus of this invention is explained by taking an example of making a wheel having a rim part with a V-shaped section. The apparatus forges an object wheel from a workpiece (starting material) by laying the workpiece on the second ram (302), lowering the first ram (301) onto the workpiece, sandwiching the workpiece by the rams (301) and (302), pressing down the workpiece by the rams (302) and (301), extruding a portion of the material from the outer boundary of the upper ram and the lower ram, pressing the extruded material by the roller which is sustained at a height exactly equal to the middle between the bottom of the upper ram (301) and the top of the lower ram, dividing the side of the workpiece exactly into halves by the edge of the roller from the beginning, lowering the roller in accordance with the descent of the upper ram for keeping the height of the roller at the middle of the surfaces of the rams, extruding the extra material by the rams equally both into the upper space above the edge and the lower space below the edge. Thus the extruded material is divided exactly into halves by the edge of the roller. When the ram (301) forges the disc part together with the ram (302), the roller has shaped the V-shaped rim part (11) from the symmetrically supplied material with the rams.

In other words, the side roller is driven downward at a speed equal to a half of the descending speed of the upper ram (301). The edge of the roller always keeps contact with the middle height of the deforming rim part. The excluded material is divided into halves by the edge.

The advantage of the invention is now explained.

In the case of forging a product having a V-grooved or U-grooved rim part, two parts divided into halves by the edge of the lowering roller are formed into the upper sub-part and the lower sub-part of a rim as it is. No deficiency occurs for the lower space between the edge (22) of the roller

and the lower ram (302). The equivalent partition of material entirely prevents the occurrence of voids or scars in the section of the rim part.

Further, this invention enables a single roller (2), a first ram (301) and a second ram (302) to shape a rim part with a variety of sections in a single step by designing the sections of the roller and ram in accordance with the section of the product.

This invention allows the rotary forging apparatus to make an asymmetric product by selection of the ratio of the material extruded from the rams into two spaces by controlling the ratio of descending speeds between the roller and the upper ram (301). For example, a preset of the roller (2) at a suitable height allows the excluded material between the rams to flow only into either the upper space or the lower space. The asymmetric setting of the side roller is also suitable for making an asymmetric wheel having a rim part (11) bending toward the outer direction from the disc part (1).

This invention has other versions besides the fundamental structure abovementioned. Four typical improvements of this invention will be further explained.

A first version (claims 2 and 3) proposes a rotary forging apparatus further having a ram-driving device (5) for lifting or lowering the first ram (301) by hydraulic pressure (e.g. oil pressure or water pressure), an hydraulic pressure controller (601) for selecting either a low, preset first pressure only for moving the upper (first) ram (301) toward the lower, stable ram (302) or a high, second preset pressure for rotary-forging the objection (workpiece), a zero-point detector (602) for monitoring the zero-point at which the first ram (301) comes into contact with the workpiece by the first preset pressure, wherein the hydraulic pressure controller (601) converts the hydraulic pressure from the first preset pressure to the second preset pressure, when the zero-point detector (602) senses contact of the ram on the workpiece and issues the signal of zero-point detection. The switching of the oil pressure to two stages is an additional characteristic of the version. Thus when the ram (301) contacts the work (10), the ram does not press excessively on the workpiece. The rams may begin rotating either before the first ram (301) attains the zero-point or after the first ram (301) has reached the zero-point.

A second version (claim 6) aims at forming the rim part into a predetermined shape automatically by feeding the roller (20) along a predetermined path. Preliminarily, an end point of an initial forging is defined as the point at which an initial pressing on the workpiece of the ram (301) by a determined pressure has ended.

The second version therefore proposes a rotary forging apparatus further comprising a transference measuring device (501) for monitoring the distance of the transference of the first ram (301) toward the second ram (302) which is fixed at a certain height, a thinning depth calculating device (50) for evaluating the depth of the thinning of the workpiece from the zero-point or from the end point of the initial forging on the basis of the distance signal issued from the transference measuring device (501), a roller controller for issuing a signal for starting the horizontal movement of the roller and for issuing a necessary distance of the vertical movement of the roller determined by the information of the thinning depth calculating device (50), wherein the vertical transference device receives the signal of the necessary distance of the vertical movement and moves the roller supporting device by the distance, and the horizontal transference device receives the signal of the starting the horizontal movement and begins to feed the roller supporting device to the workpiece.

The second version allows the roller controller to determine the timing of the commencement of the horizontal transference and the necessary distance of the vertical transference automatically in accordance with the thinning of the workpiece, namely in accordance with the output of the thinning depth calculating device (50). When extra material of the workpiece is excluded from the space between the first ram (301) and the second ram (302), the roller controller feeds the shaping roller (2) along a predetermined locus according to the amount of the excluded material. The shaping process of the rim portion can also be automated.

A third version (claim 8) aims at rotary forging of a product with a complicated section by enabling synchronous control of the horizontal transference and the vertical transference of the shaping roller (2).

The third version further comprises a transference measuring device (501) for monitoring the distance of the transference of the first ram (301) toward the second ram (302) which is fixed at a certain height, a thinning depth calculating device (50) for reckoning the depth of the thinning of the workpiece from the zero-point or from the end point of the initial forging on the basis of the signal issued from the transference measuring device (501), a roller controller for issuing signals of a necessary horizontal transference distance and the necessary vertical transference distance, wherein the vertical transference device receives the signal of the necessary vertical transference distance and displaces the roller by the designated distance in the vertical direction, and the horizontal transference device receives the signal of the necessary horizontal distance and moves the roller by the

indicated distance in the horizontal direction.

This version enables the shaping roller to move both in the horizontal and vertical directions at the same time along a predetermined path, as the workpiece is being thinned by the cooperation of the rams. Therefore this version succeeds in shaping a product with a rim part having a complicated section by the controlled vertical and horizontal movements of the roller (2). This improvement is, in particular, suitable for automatic forging of such a product with a rim part having a complicated curved section or an asymmetric section to the disc part.

A fourth version aims at shaping rim part of a section further more complicated than the one produced by the third version. The fourth version further requires that the side surfaces of the first rams (301) and (302) and the outer surface of the shaping roller have been designed to coincide in a negative with the section of the rim part of the object product. Namely the side surfaces of the rams have been shaped after the inner surfaces of the rim part. The outer surface of the shaping roller has also been shaped after the outer surface of the rim part. The rams form the inner surface of the rim part by the designed side surfaces and the roller shapes the outer surface of the rim part by displacing by the calculated distances in the horizontal and vertical directions along a determined path. Therefore this improvement enables the formation of a rim part with a more complex section than the former version.

The invention will be more fully understood from the following description given by way of example only with reference to the accompanying drawings in which,

Fig.1 is a partially sectioned view of a prior rotary forging apparatus during the formation of a rim part with a rectangular section.

Fig.2 is a partial section of a prior rotary forging apparatus, while it shapes a rim part with a V-edged section.

Fig.3 is a partial section of the prior rotary forging apparatus of Fig.2, while it starts to divide the extruded material into two parts by the edge of the roller at an intermediate stage.

Fig.4 is a sectioned view of the whole forging apparatus of a first embodiment of this invention.

Fig. 5(a) is a beginning part of a flow chart of a controller of the first embodiment.

Fig. 5(b) is a middle part of a flow chart of the controller of the first embodiment.

Fig.6 is a final part of the flow chart of the controller of the first embodiment.

Fig.7 is a sectional view of a part of the first embodiment showing the relation of a shaping roller and a work at an initial step of the rotary

forging.

Fig.8 is a sectional view of a part of the first embodiment demonstrating the relation of the shaping roller and the work at an intermediate step of the forging.

Fig.9 is a sectional view of a part of the first embodiment designating the relation of the shaping roller to the work at a final step of the forging.

Fig.10 is a partially sectional view of a work, rams and a roller of a second embodiment at an intermediate step.

Fig.11 is a partially sectional view of the work, the rams and the roller of the second embodiment at a final step.

Fig.12 is a front view of the whole of a rotary forging apparatus of the second embodiment.

Fig.13 is a partial front view of a roller supporting device of the second embodiment.

Fig.14 is an explanatory sectional view of rams, a work and a roller of an apparatus of a third embodiment.

Fig.15 is a sectional view of the rams, the roller and the work which is being shaped by the roller and the rams.

Fig.16 is a sectional view of the rams, the roller and the work just before the end of the shaping of the outer rim part.

Fig.17 is a sectional view of the rams, the roller and the work before the end of the whole forging process.

Fig.18 is a section of a finished wheel of an automobile.

Fig.19 is a main portion of a flow chart of a controller of the second embodiment.

As clearly shown by Fig.4, a rotary forging apparatus of a first embodiment has an upper first ram (301) and a lower second ram (302) facing each other in a vertical direction and a shaping roller (2) located beside the boundary of the rams. This apparatus aims at shaping a wheel having a rim part with a V-grooved section, as shown in Fig.9.

The first ram (301) rotates around an axis which is inclined at two degrees to five degrees to a vertical line. The bottom surface of the first ram (301) is a cone with a wide obtuse top angle. The inclination angle of the axis is equal to the difference between 90 degrees and the half top angle of the cone. Thus a generating line of the cone inclines at various angles to the horizontal plane according to the rotation of the ram (301). Every generating line becomes parallel to the horizontal plane once in a rotation when the generating line is just included in a plumb plane containing the rotary axis. Here a generating line is defined as a line of a section along a plane including the symmetry axis of an object having rotational symmetry. All the

generating lines are equivalent owing to the rotational symmetry of the object. The drum part of the upper ram (301) is also a cone with a narrower upper diameter and a wider lower diameter. A rim shaping surface (33) is formed on a side at a certain distance from the bottom. The bottom of the first ram (301) acts as the shaping surface of the upper surface of the disc part (1).

The second ram (302) is a column which is rotatably supported by an erect axis. The top surface of the ram (302) plays the role of the shaping surface of the lower part of the disc part (1). Some region of the side at a certain distance from the top shapes the inner rim part (32).

The first ram (301) is suspended from an output shaft of a first oil pressure cylinder (55) mounted on a yoke (51) of a frame. The first oil pressure cylinder (55) corresponds to the ram-driving device (5) mentioned before. The oil pressure cylinder (55) can raise or lower the first ram (301), maintaining the inclined posture of the ram (301).

In more detail, the output shaft of the oil pressure cylinder (55) supports an intermediate bracket (52) which rotatably maintains the first ram (301). The intermediate bracket (52) has a guide shaft (521) which pierces a hole vertically perforated on the yoke (51). Since the guide shaft (521) is always kept in parallel with the output shaft of the first oil pressure cylinder (55), the intermediate bracket (52) is raised or lowered by the progress of the recession of the oil pressure cylinder (55), keeping the same posture. The intermediate bracket (52) carries a first driving device (53) which is connected to the first ram (301) for transmitting rotational torque to the ram (301).

A base (31) rotatably sustains the second ram (302) in a vertical posture. A second driving device (54) supported on the base (31) gives the second ram (302) a rotation torque via gears. A regulator (61) controls the direction and the speed of rotation of the first driving device (53) and the second driving device (54) for rotating both rams (301) and (302) at the same speed in the same direction synchronously.

The shaping roller (2) is upheld by a vertical transference device (41) and a horizontal transference device (42) in the inclination direction of the inclined axis of the upper ram (301) in the vicinity of the boundary between the upper ram (301) and the lower ram (302). The vertical transference device (41) and the horizontal transference device (42) can move the roller (2) in the vertical direction and in the horizontal direction respectively in a plumb plane including the vertical axis of the ram (302) and the inclined axis of the ram (301).

The roller (2) has an annular ridge (20) at its middle and two columnar parts (23) and (23') on both sides of the ridge (20). The ridge (20) has a

sharp circular edge (22). The roller (2) is rotatably supported in an erect posture by a bracket held at a front end of a rod of the second oil cylinder (420). To keep the erect posture of the roller (2), a guide bar (45) fixed to the back of the bracket (43) slidably pierces a horizontal hole perforated in parallel with the oil cylinder (420) in a stem (44) on which the second oil pressure cylinder (420) is mounted. The horizontal transference device is built with the oil pressure cylinder (420), the stem (44), the guide bar (45) and a block supporting the stem (44).

The vertical transference device (41) of the roller (2) comprises a servo-motor (410) and a feeding screw device (46). The feeding screw device (46) includes a feeder screw and a guide bar. The feeder screw engages a female screw hole of the block. The guide bar penetrates a vertical hole of the block. The guide bar maintains the posture of the vertical transference device in the parallel displacement. The servo-motor (410) is equipped with a driving circuit. The servo-motor (410) rotates by an angle in proportion to the number of pulses input to the driving circuit.

For measuring the movement of the first ram (301), the transference measuring device (501) includes a sensing roller which is kept in contact with the output shaft of the first oil pressure cylinder (55) and is rotated in proportion to the displacement of the output shaft and a pulse encoder (500) which detects the rotation angle of the sensing roller. The pulse encoder is preset to zero, when the intermediate bracket (52) is at the highest position. The pulse encoder (500) outputs the signal designating the descent of the intermediate bracket (52) from the uppermost position.

The signal of the pulse encoder (500) is input to a main controller (6). The main controller (6) controls the motion of the vertical transference device (41) and the horizontal transference device (42). The main controller (6) comprises a hydraulic pressure controller (601), a zero-point detector (602) and a roller controller. Receiving the signal of the movement of the upper ram (301) from the pulse encoder (500), the main controller (6) issues action signals to the first oil cylinder (55), the servo-motor (410), and the second oil cylinder (420). The regulator (61) adjusts the angular velocity of the first ram (301) and the second ram (302). The embodiment employs a microcomputer as the main controller (6). The main controller (6) processes input signals and produces action signals to the active devices in accordance with a flow chart shown in Fig.5(a), Fig. 5(b) and Fig.6.

The flow chart clarifies the series of actions of the devices of the embodiment. At an initial step, the intermediate bracket (52) is raised to its uppermost position. The roller (2) lies at the highest point

distanced farthest from the rams (301) and (302). The first driving device (53) and the second driving device (54) are at rest at the initial step.

5 A disc-like work (10) with a certain thickness is laid on the top surface of the second ram (302). At this time, the bottom of the first ram (301) lies above the top surface of the work (10) with a narrow clearance.

10 Then the main controller (6) starts the forging operations along the flow chart of Fig.5(a), Fig.5(b) and Fig.6. First, the first oil pressure cylinder (55) begins lowering the intermediate bracket (52). The first ram (301) accompanying the first oil pressure cylinder (55) falls and stops on the workpiece at Step 70, as shown in Fig. 4 and Fig.7. In this state, the first oil pressure cylinder (55) only pushes the work down with the first preset pressure which has been determined to be sufficiently low that the rams cannot thin the workpiece (10). The position of the ram (301) is now defined to be a zero-point for the motion of the first ram (301). Namely the zero-point is such a point of the height of the ram (301) which is in contact with the workpiece (10) by the first preset pressure without thinning it at all. 20 Since the zero-point has been detected, the position of the zero-point is input into the apparatus by memorizing the present output (α) of the pulse encoder (500) at Step 71.

30 Whether the fall of the first ram (301) is stopped or not is judged according to whether the pulse encoder (500) changes the output any more or not. Step 70 judges that the first ram (301) has touched the workpiece with a certain pressure, when the output of the encoder (500) changes no more. Step 70 then corresponds to the zero-point detector (602) defined before and described in claims.

40 The rotation regulator (61) is turned on. According to the order of the regulator (61), the first driving device (53) rotates the first, upper ram (301). The second driving device (54) rotates the second ram (302) simultaneously. The regulator (61) synchronizes the rotation of the first ram (301) with the rotation of the second ram (302).

45 The rams (301) and (302) are heavy. Thus the large inertia demands a waiting time till the rams attain the stationary state in which they rotate at a constant angular velocity. Step 72 confirms whether the certain waiting time has passed.

50 When the waiting time lapses, the first oil pressure cylinder (55) pushes the first ram (301) with the second preset pressure which enables the rams to deform the workpiece. Rotating rams (301) and (302) press and thin the workpiece with the second preset pressure. At the initial stage of the forging, the workpiece is still smaller in diameter than the top surface of the ram (302) and the bottom end of the ram (301). As the workpiece is

gradually expanded by the rams, the peripheral part of the workpiece (10) is being excluded from the end surfaces of the rams. The thinning depth soon attains a first preset value $\Delta\alpha_1$, which is easily detected by an increase of the output of the pulse encoder (500) to $(\alpha_0 + \Delta\alpha_1)$. At this time the periphery (101) of the excluded material just coincides with the valley of the section of the rim part (11) of a product to be shaped, as demonstrated in Fig.8.

The first oil pressure cylinder reduces the pressure on the first ram (301) to the first preset pressure at Step 73.

The main controller (6) drives the servo-motor (410) in the forward direction at Step 741. At Step 742, the servo-motor (410) displaces the shaping roller (2) down by an initial descent (β_0) from an initial height which is determined to be the highest position. The initial descent (β_0) is predetermined to be the difference between the initial height and the acting height at which the Λ -edge (22) of the roller (2) coincides with the middle of the excluded material, as shown in Fig.8. The roller (2), thus, moves to the middle height of the extruded material by Step 742.

The second oil pressure cylinder (420) drives forward the roller (2) till the side columns (23) and (23') contact the sides of the rams (301) and (302) at Step 75. The height of the Λ -edge (22) from the side columns (23) is designed to be equal to the depth of the circular groove on the rim part (11) of a finished product. At Step 75, the Λ -edge (22) of the roller (2) touches the middle of the periphery (101) of the material (10) excluded.

The first oil pressure cylinder (55) again applies the higher second preset pressure to the upper ram (301). The rams further thin the workpiece (10).

Then the second oil pressure cylinder (402) pushes the roller (2) to the workpiece (10) with a constant force in the horizontal direction. The servo-motor (410) feeds the roller (2) down in accordance with the state of the workpiece. Namely Step 771 to 775 lowers the roller (2) by half of the descent of the upper ram (301) which is monitored by the output ($\Delta\alpha$) of the pulse encoder (500).

The main controller (6) stores the output (α_i) at different times of the pulse encoder (500) at Step 771. Then the ram (301) continues lowering to press the workpiece further. The extra descent soon becomes a unit depth $\Delta\alpha$. At Step 772 the main controller (6) monitors whether the ram (301) has fallen by the unit depth $\Delta\alpha$ or not. When the main controller (6) confirms the fall of the unit depth $\Delta\alpha$ at Step 773, the main controller (6) forwardly drives the servo-motor (410) till the fall $\Delta\beta$ of the roller becomes half ($\Delta\alpha/2$) of the unit fall $\Delta\alpha$ of the upper ram (301) at Step 774. Steps 771

and 772 processed by the computer correspond to the thinning depth calculating device (50).

Steps 771 to 774 are repeated every unit fall $\Delta\alpha$ of the ram (301) or every unit thinning of the workpiece. During the forging, the main controller (6) always monitors whether the total thinning depth reaches the final, second preset value $\Delta\alpha_2$ or not, at Step 76.

When the total thinning depth attains the second preset value $\Delta\alpha_2$, the first ram (301) lies now at the lowest height. The material sandwiched between the top disc-shaping surface of the second ram (302) and the bottom of the first ram (301) has been shaped into the disc part (1) of the product. The oil pressure of the first cylinder (55) is reduced to the first preset pressure.

The main controller (6) maintains the roller (2) at the height determined by the relation with the second preset value $\Delta\alpha_2$ for a while. The first ram (301) and the second ram (302) are still rotated for a certain time, e.g. ten seconds to one minute at Step 78 of Fig.6. In this state, the roller (2) finishes the rim part (11) into the final shape as shown in Fig. 9.

Throughout the forging, the Λ -edge of the roller (2) exactly faces and touches the middle of the excluded material out of the space between the surfaces of the rams (301) and (302). The equivalence of the upper and the lower thicknesses enables the edge to divide the excluded material into precise halves. The quantity allocated into the upper space than the edge is tantamount to the quantity allotted into the lower space than the edge. The rim part (11) is exactly shaped into the designed section by the cooperation of the outer columnar part of the roller (2) with the rim-shaping portion (33) of the first ram (301) and the side rim-shaping portion (32) of the second ram (302).

When the forging processes have ended, the regulator (61) stops the first driving device (53) and the second driving device (54). The main controller (6) restores the shaping roller (2) to the initial position by the servo-motor (410) and the second oil pressure cylinder (420). Then a reverse movement of the first oil pressure cylinder (55) displaces the intermediate bracket (52) and the first ram (301) to the initial heights. All processes end thus for shaping the wheel having a rim part (11) with a V-grooved section.

In the embodiment, the shaping roller controller in claims corresponds to Steps 741 to 774 for controlling the servo-motor (410) and the second oil pressure cylinder (420).

When the pulse encoder (500) outputs a value $(\alpha_0 + \Delta\alpha_1)$, the first ram (301) just lies at the height below the zero-point by the first preset length $\Delta\alpha_1$ which is equal to the depth of the initial thinning of the workpiece (10). The height is the end point of

the initial forging.

An alternative for controlling the height of the roller is setting the initial height of the roller to be equal to the end point of the upper ram of the initial forging and adjusting the descent of the roller step by step in accordance with the thinning the work from the end point of initial forging as a standard point.

Embodiment 2 aims at forging of products having a rim part (2) asymmetric to the disc part (1), as shown in Fig.11. The main controller (6) controls the movement of the shaping roller (2) both in the vertical direction and in the horizontal direction, as shown in Fig.12 and Fig.13.

As shown in Fig.12, the first driving device (53) is fixed at the yoke (51) in embodiment 2. An expansible joint connects an output shaft of the first driving device (53) by a spline coupling to an input shaft of a bevel gear device of the first ram (301). The second driving device (54) rotates the second ram (302) by a gear engagement in a similar way to embodiment 1.

The shaping roller (2) has an upper, short, narrower column part (231), a middle conical part (24), and a long, wider columnar part (232) in succession from the top to the bottom. The lower columnar part (232) occupies the lower half of the roller. The roller supporter (4) comprises a vertical transference device (41) and a horizontal transference device (42). Both transference devices (41) and (42) are composed of servo-motors (411) and (412) and feeding screws. These servo-motors are similar to the servo-motor (410) of embodiment 1 in their function.

In embodiment 2, too, a microcomputer acts as a main controller (6) and controls the first oil pressure cylinder (55), and servo-motors (411) and (412) on the basis of the signal from the pulse encoder (500). Embodiment 2 practices the same processes as the flow chart of Fig.5 till Step 73 at which the initial forging ends.

Then embodiment 2 then takes different processes represented by another flow chart of Fig.19. The servo-motors (411) and (412) feed the shaping roller (2) from its initial position to a shaping position as shown in Fig.10. At this position the lower columnar part (232) is in contact with the side of the second ram (302). Step 743 to Step 745 maintains the columnar part (232) in contact with the second ram (302).

The first oil pressure cylinder (55) applies the second preset pressure to the ram (301) for thinning the workpiece (10). As the rams presses the workpiece (10) by the second preset pressure, part of the material is being excluded out of the boundary space between the rams. The roller (2) bends the extruded material in the upper direction with the conical part (24) and the narrower cylindrical

part (231). The upper bent portion of the workpiece becomes a part of the upper rim part (111). The greater the thinning depth increases, the wider the rim part grows. When the extension of the rim part (111) attains a preset value, namely the pulse encoder (500) outputs a signal of a third preset value (α_4), the servo-motors (411) and (412) carry the roller (2) to the position at which the lower columnar part (232) is in contact with the outer surface of the extruded material at the boundary between the first ram (301) and the second ram (302). Steps 776 to 778 equalize the gap between the sides of the rams and the columnar part (232) to the current thickness of the upper rim part (111). Then the material extruded from the boundary of the rams (301) and (302) is divided into upper and lower halves. The roller (2) forges the upper flange (111) and the lower flange (112) of the rim part (11) at the same time.

When the first ram (301) falls to its lowest position, the material sandwiched between the first ram (301) and the second ram (302) has been transformed into the disc part (1). At the same time, the extensions of the upper flange (111) and the lower flange (112) attain the preset lengths. At the same moment, the first ram (301) has just fallen by $\Delta\alpha_2$ from the zero-point position. Step 761 confirms the fact. Thus the product shown in Fig.11 has been produced by embodiment 2.

The regulator (61) ends the rotation of the first ram (301) and (302) by stopping the first driving device (53) and the second driving device (54). The main controller (6) lifts up the first ram (301) by driving the first oil pressure cylinder (55) in the reverse direction. The roller (2) is restored to the initial position. Then the product is removed from the second ram (302).

Embodiment 3 aims at forming an automobile wheel shown in in Fig.18. Embodiment 3 is equipped with a first ram (301), a second ram (302) and a auxiliary ram (303) which rotate synchronously, as shown in Fig.14. The end surfaces of the first ram (301) and the second ram (302) have been made after the section of the disc part of an automobile wheel to be produced. The sides of the second ram (302) and the auxiliary ram (303) have been finished after the section of the rim part of the wheel. Further, the shaping roller (2) has been produced after the outer surface of the rim part of the product. Embodiment 3 transforms a workpiece into a product by thinning the workpiece by the rams, pressing the extruded material by the roller which is fed along a predetermined path in accordance with the thinning of the workpiece.

Circumscribing the first ram (301), the auxiliary ram (303) is supported outside the first ram (301) by a vertical, rotary shaft which coincides with the shaft of the second, lower ram (302) at the exten-

sion. The auxiliary ram (303) can rotate with any velocity regardless of the angular velocity of the first ram (301). The auxiliary ram (303) is positioned slightly higher than the drop center (110) of the rim part (11). The outer diameter of the bottom of the auxiliary ram (303) is nearly equal to the outer diameter of the bottom of the first ram (301). The side surface of the auxiliary ram (303) consists of a lower, tapering surface (34) which reduces the diameter downward and an upper, annular flange (35). The forms of the sides of the first ram, the tapering surface (34) and the annular flange (35) coincide with the shape of the inner surface of an inner rim (113) and a flange (13) of the rim part (11).

The shoulder of the second ram (302) has been made after the inner surface of an outer rim (114) and another rim flange (14) of the rim part (11). A circular groove and an annular wall (36) are formed around the shoulder of the ram (302).

The section of the roller (2) exactly coincides with the outer surface of the outer rim (114) and the inner surface of the flange (14) at the tapering bottom. The upper half column of the roller (2) has been shaped after the inner surface of the flange (13) and the tire-seat portion of the inner rim (113).

Embodiment 3 lifts up or brings down the first ram (301) and the auxiliary ram (303) together during the rotary forging. At a former stage of shaping the rim part (11), the roller (2) is positioned at a spot shown by Fig.15. The rams and the roller form annular portions corresponding to the upper flange (13) above the boundary (27) and the lower flange (14) below the same boundary (27) first.

Then the roller (2) is transferred lower and nearer to the rams as demonstrated by Fig.16. The workpiece (10) is being thinned by the rotating rams (301) and (302) and the excluded material fills the quasi-closed space enclosed by the shoulder, the groove and the annular wall of the second ram (302) and the tapering bottom below the boundary (27) of the roller (2). Thus the outer rim part (114) with the flange (14) is shaped in the quasi-closed space. On the contrary, a cylindrical part is extending above the boundary (27).

When the rams press the workpiece (10) further, the extruded material flows down below the boundary (27) no more, since the material has filled the narrow space enclosed by the ram shoulder and the tapering bottom of the roller. All the excluded material then flows upward. The cylindrical part of the material grows upward in the axial direction further. The tapering surface (34) of the auxiliary ram (303) bends outward the top end of the cylindrical material, as demonstrated by a dotted line in Fig.14 or a solid line in Fig.17. Then the cylindrical part becomes a reverse conical drum. The top of the conical drum part has sufficient

thickness to make the upper rim flange (13), because the top has been shaped at the former stage of rim-shaping.

When the first ram (301) attains its lowest position, the disc part (1) is finished between the rams (301) and (302). The bottom flange (14) is also finished at the same time.

The fall of the auxiliary ram (303) is stopped. The first ram (301) and the second ram (302) still rotate synchronously. The main controller (6) lifts up the shaping roller (2) for shaping the tire seat portion of the inner rim (113) with the rim flange (13). Finally the roller (2) presses the top end of the conical material to the flange (35) of the auxiliary ram (303) by the edge of the upper half column. Thus the upper rim flange (13) is shaped. The forging of the rim part (11) is completed then.

Embodiment 2 enjoys the advantage of making thick flanges (13) and (14), since the flanges have been shaped at an early stage of forging as shown in Fig.15, when the rams and the roller still keep a wide clearance therebetween. The advantage is more conspicuous in the case of a wheel having a thin rim part except the flanges (13) and (14).

Embodiment 3 also employs a microcomputer as the regulator (61) and the main controller (6) like embodiment 1. The regulator (61) and the roller controller (6) built by a microcomputer control the rotation of the first ram (301) and the second ram (302), the fall of the first ram (301), and the position of the roller (2) in accordance with the shape of the product. The flow chart of the controlling is substantially the same as embodiment 1. Thus the flow-chart of embodiment 3 is now omitted.

This invention can be practiced by various versions. Embodiments 1 and 2 have adopted the transference measuring device (501) consisting of the pulse encoder (500) which measures the displacement of the output shaft of the first oil pressure cylinder (55). Instead of the pulse encoder, however, a device for measuring the displacement of the ram (301) directly can also be adopted as a transference measuring device (501).

The relation of the first ram (301) and the second ram (302) can be reversed in this invention. Namely the upper ram (301) can be fixed at a certain height, and the lower ram (302) can be lifted up or down in the version.

Embodiment 1 defines the spot to which the first ram (301) has fallen by the first preset value $\Delta\alpha_1$ from the zero point as the end point of the initial forging. Then as the thinning of the work by the ram (301) attains a unit depth $\Delta\alpha$, the roller controller (6) lowers the roller (2) by $\Delta\alpha/2$, a half of the unit depth.

Instead from the end point of the initial forging, a version keeps applying the second preset pressure to the first oil pressure cylinder (55) from the

zero-point to the end of the entire rotary forging throughout and lowers the roller (2) by $\Delta\alpha/2$ at every unit descent $\Delta\alpha$ of the first ram (301).

An alternative of the zero-point detector (602) can be built with a pressure monitor (551) of the ram (301) and a comparator (not shown in figures) for comparing the monitored pressure with a third preset pressure.

The pressure monitor (551) is equipped to the oil piping connecting the first oil pressure cylinder (55) to an oil source (550) as shown by the dotted lines in Fig. 4. The third preset pressure is determined as an intermediate pressure lower than the second preset pressure for forging but higher than the first preset pressure for descending.

The first oil cylinder (55) lowers the first ram (301) with the first preset pressure at first. When the ram (301) comes into contact with the work (10), the pressure monitor (551) finds an increase of the pressure. When the pressure monitor (551) feels the oil pressure exceed the third preset pressure, the comparator issues a signal of zero-point detection.

Another version of this invention begins bringing the roller along a determined path at the end of the initial forging by the rams from the initial position to the forging position at which the roller edge is inserted into the extruded material.

Nevertheless, if the amount of the excluded material is too large, it is difficult to insert the edge of the roller deep into the excluded material later. In such a case, it is desirable to transfer the roller from the initial rest position to the position of forging before the end of the initial forging. Then the main controller (6) should move the roller (2) only in the plumb direction for rotary forging.

Claims

1. A rotary forging apparatus comprising
 - a rotary first ram (301) with a conical bottom end surface which rotates around a inclined axis,
 - a ram-driving device for raising or lowering the first ram (301),
 - a rotary second ram (302) having a top end surface which faces the first ram and rotates around a generally vertical axis at a certain height,
 - a shaping roller (2) positioned beside the end surfaces of the rams (301) and (302),
 - a roller supporter (4) for supporting the shaping roller and allowing the roller to rotate around a generally vertical axis,
 - a vertical transference device (41) for moving the roller supporter in a generally vertical direction and
 - a horizontal transference device for moving

the roller supporter in a generally horizontal direction.

the arrangement being such that, in use, the second ram (302) and the first ram (301) sandwich a workpiece, the rams press and thin the workpiece into a disc part of a product, extruded material is pressed by the shaping roller to the sides of the rams and the rim part is shaped by the sides of the rams and the side of the roller which can move in a vertical direction in proportion to the thinning of the work.

2. A rotary forging apparatus as claimed in claim 1, wherein the ram-driving device (5) is a hydraulic pressure cylinder for raising or lowering the first ram (301).
3. A rotary forging apparatus as claimed in claim 2, further comprising:
 - a hydraulic pressure controller (601) for applying either a first preset pressure for feeding the first ram (301) toward the second ram (302) or a second preset pressure for rotary forging to the ram-driving device, and
 - a zero-point detector (602) for detecting the zero-point of the ram-driving device at which the first ram (301) presses the workpiece down by the first preset pressure to the second ram (302), the zero-point detector (602) issuing a signal of the zero-point detection, when it finds the zero-point,
 - the arrangement being such that the ram-driving device changes the hydraulic pressure from the first preset pressure to the second preset pressure, when the zero-point detector issues a signal indicative of the zero-point detection, after the ram-driving device has begun lowering the first ram (301) from an initial position.
4. A rotary forging apparatus as claimed in claim 3, further comprising:
 - a transference measuring device for measuring the distance of displacement of the first ram (301) to the second ram (302),
 - wherein the zero-point detector (602) issues the signal of zero-point detection when the distance between the rams measured by the transference measuring device changes no more.
5. A rotary forging apparatus as claimed in claim 3, wherein the zero-point detector (602) comprises:
 - a pressure monitor (551) for detecting the hydraulic pressure applied to the ram-driving device (5) and

a comparator for comparing the pressure of the ram-driving device (5) lowering the ram (301) with a third preset pressure which has been defined as a value between the first preset pressure and the second preset pressure and for issuing a signal of zero-point detection, when the pressure of the ram-driving device exceeds the third preset pressure.

6. A rotary forging apparatus as claimed in claim 3, further comprising:

a transference measuring device for measuring the length of displacement of the first ram (301) toward the second ram (302),

a thinning depth calculating device (50) for calculating the thinning depth from the zero-point or the end point of an initial forging of the ram (301), and

a roller controller for issuing a signal of starting a horizontal transference and a signal of the necessary transference in the vertical direction predetermined in accordance with the signal of thinning depth issued from the thinning depth calculating device (50),

wherein the signal of the necessary vertical transference is supplied to the vertical transference device (41), the signal of starting the horizontal transference is input into the horizontal transference device (42), the horizontal transference device starts to move the roller in the horizontal direction to the side of the work and the vertical transference device carries the roller by the designated necessary vertical transference distance in the vertical direction.

7. A rotary forging apparatus as claimed in claim 6, wherein the shaping roller can be displaced in the horizontal direction between a position distanced from the second ram (302) and another position where the roller is in contact with the side of the second ram (302).

8. A rotary forging apparatus as claimed in claim 3, further comprising:

a transference measuring device (501) for measuring the length of displacement of the first ram (301) toward the second ram (302),

a thinning depth calculating device (50) for calculating thinning depth from the zero-point of the ram or the end point of an initial forging, and

a roller controller for issuing a signal of necessary transference in the horizontal direction and a signal of the necessary transference in the vertical direction which are predetermined in accordance with the signal of the thinning depth issued from the thinning depth

calculating device,

wherein the signal of the necessary vertical transference is supplied to the vertical transference device (41), the signal of the necessary horizontal transference is supplied to the horizontal transference device (42), the horizontal transference device moves the roller in the horizontal direction by the designated necessary horizontal transference toward the side of the work and the vertical transference device carries the roller (2) by the designated necessary vertical transference distance in the vertical direction.

9. A rotary forging apparatus as claimed in claim 8, wherein the side surfaces of the first ram (301) and the second ram (302) have been shaped after the inner surface of the rim part of a product to be forged and the side surface of the shaping roller has also been shaped after a part of the outer surface of the rim part of the same product.

10. A rotary forging apparatus as claimed in claim 6, wherein the side surface of the first ram (301) is plane-symmetric with the side surface of the second ram (302) and the necessary vertical transference to be issued from the roller controller is determined to be half of the thinning depth output from the thinning depth calculating device (50).

FIG. 1 (PRIOR ART)

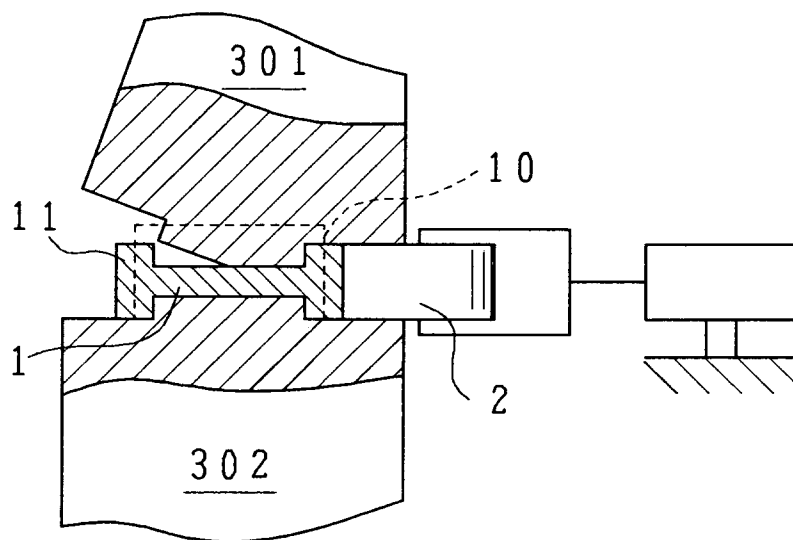


FIG. 2 (PRIOR ART)

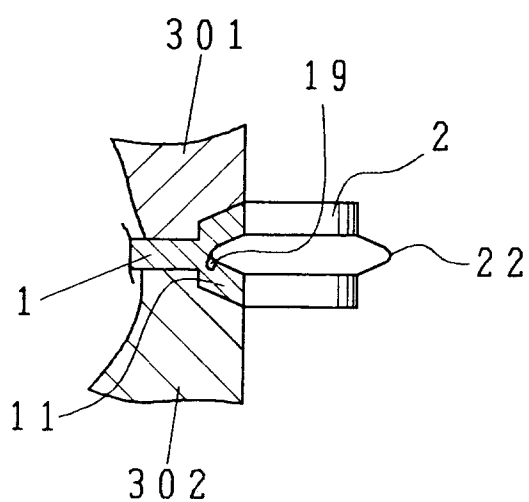


FIG. 3 (PRIOR ART)

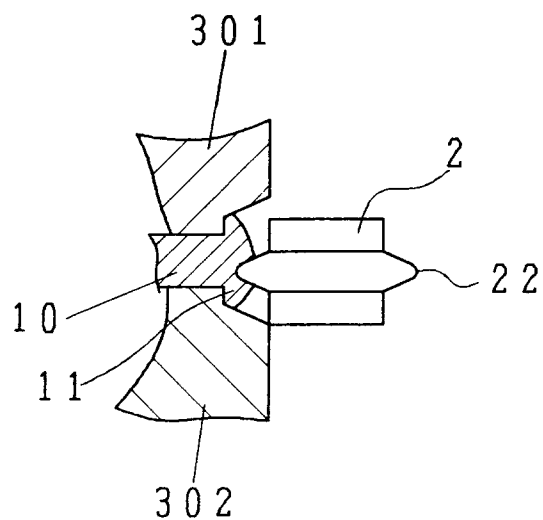


FIG. 4

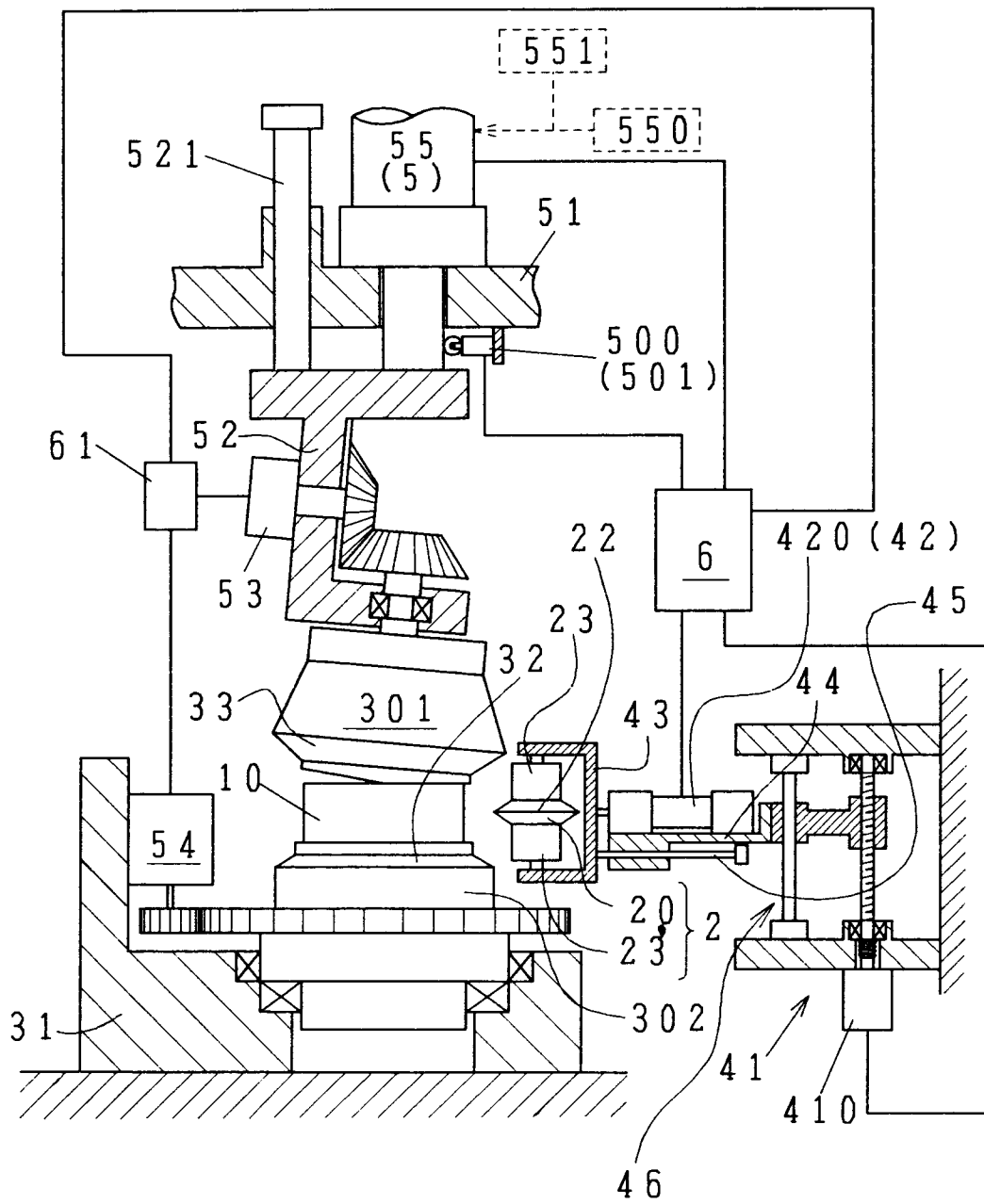


FIG. 5 (a)

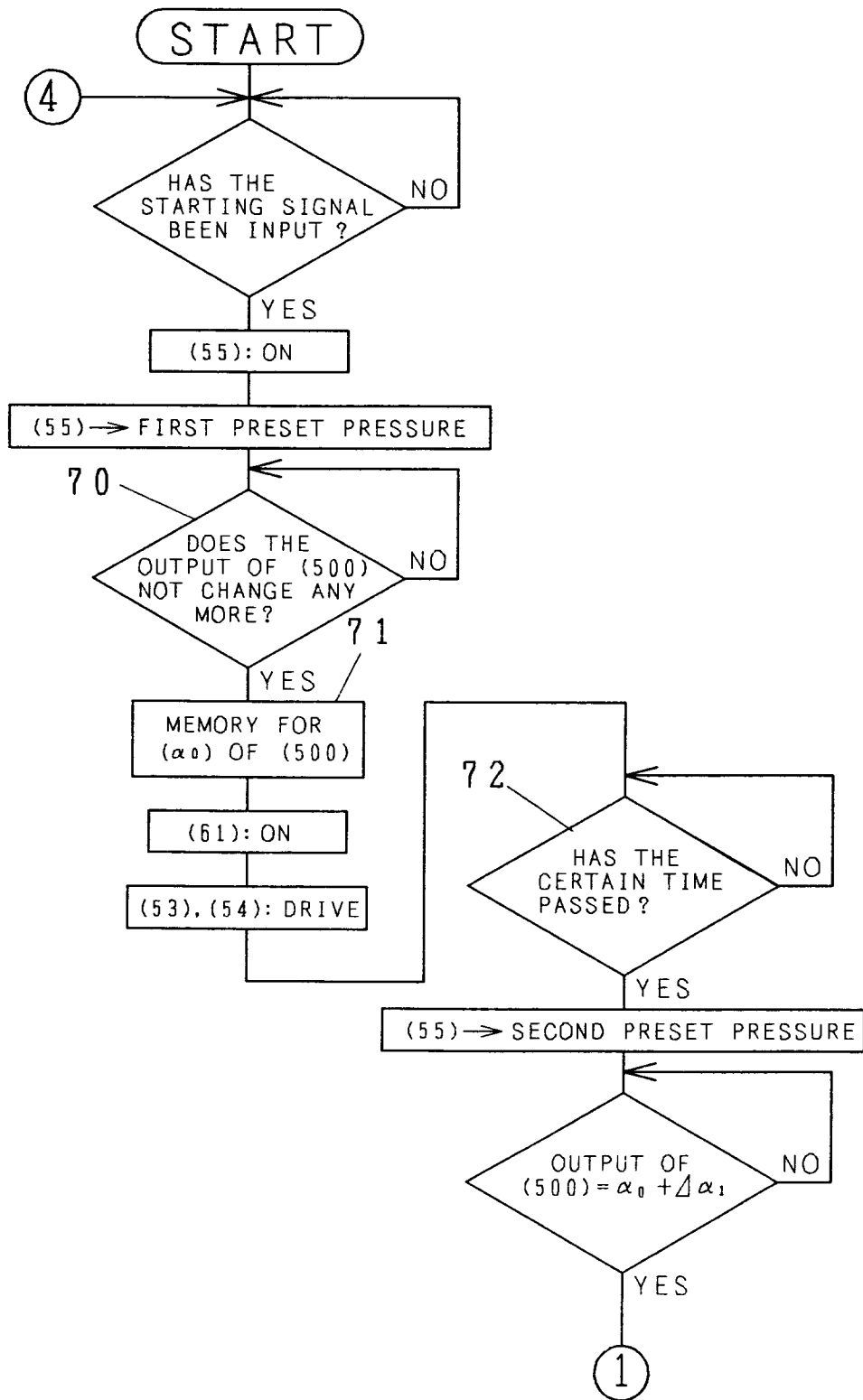


FIG. 5 (b)

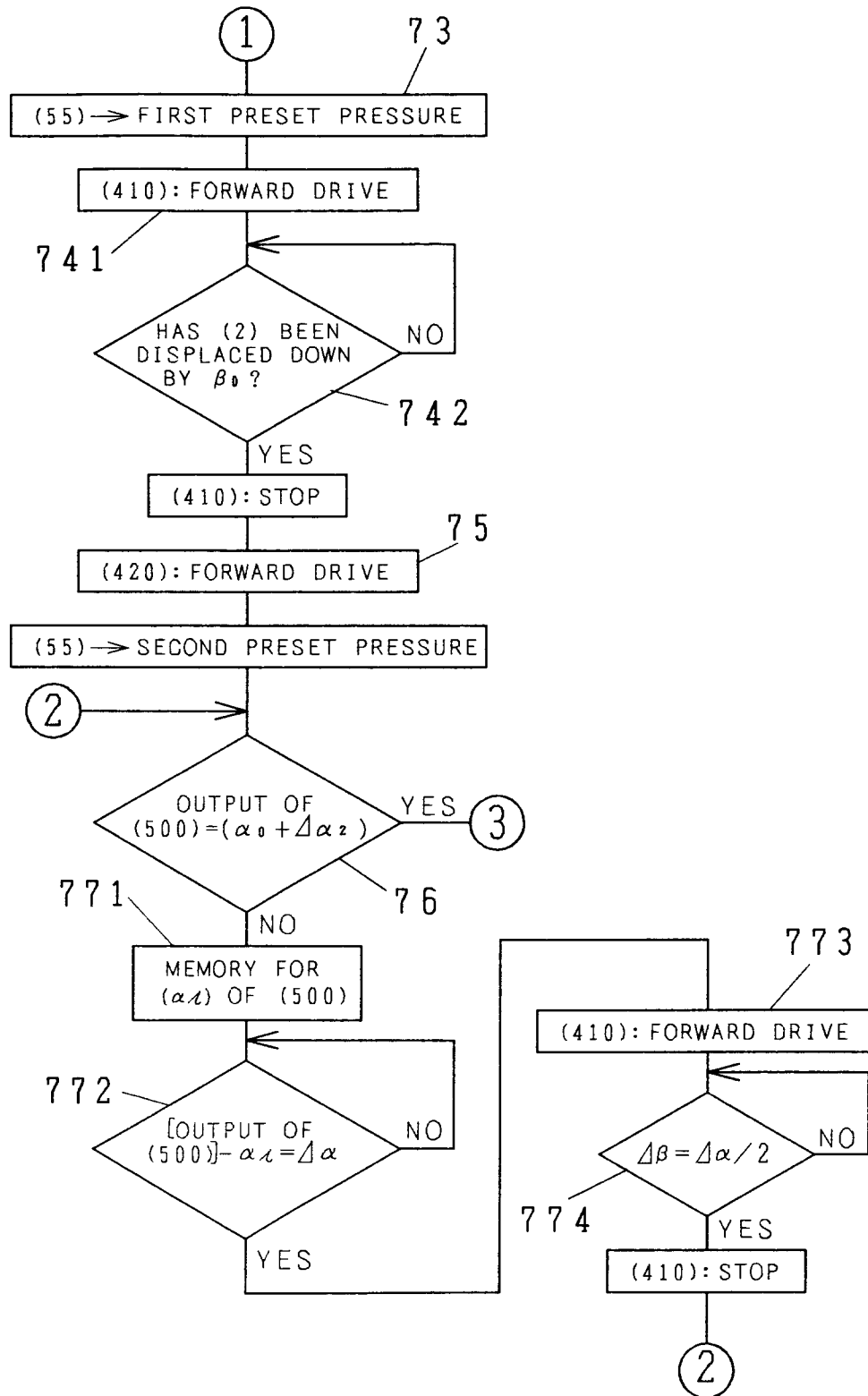


FIG. 6

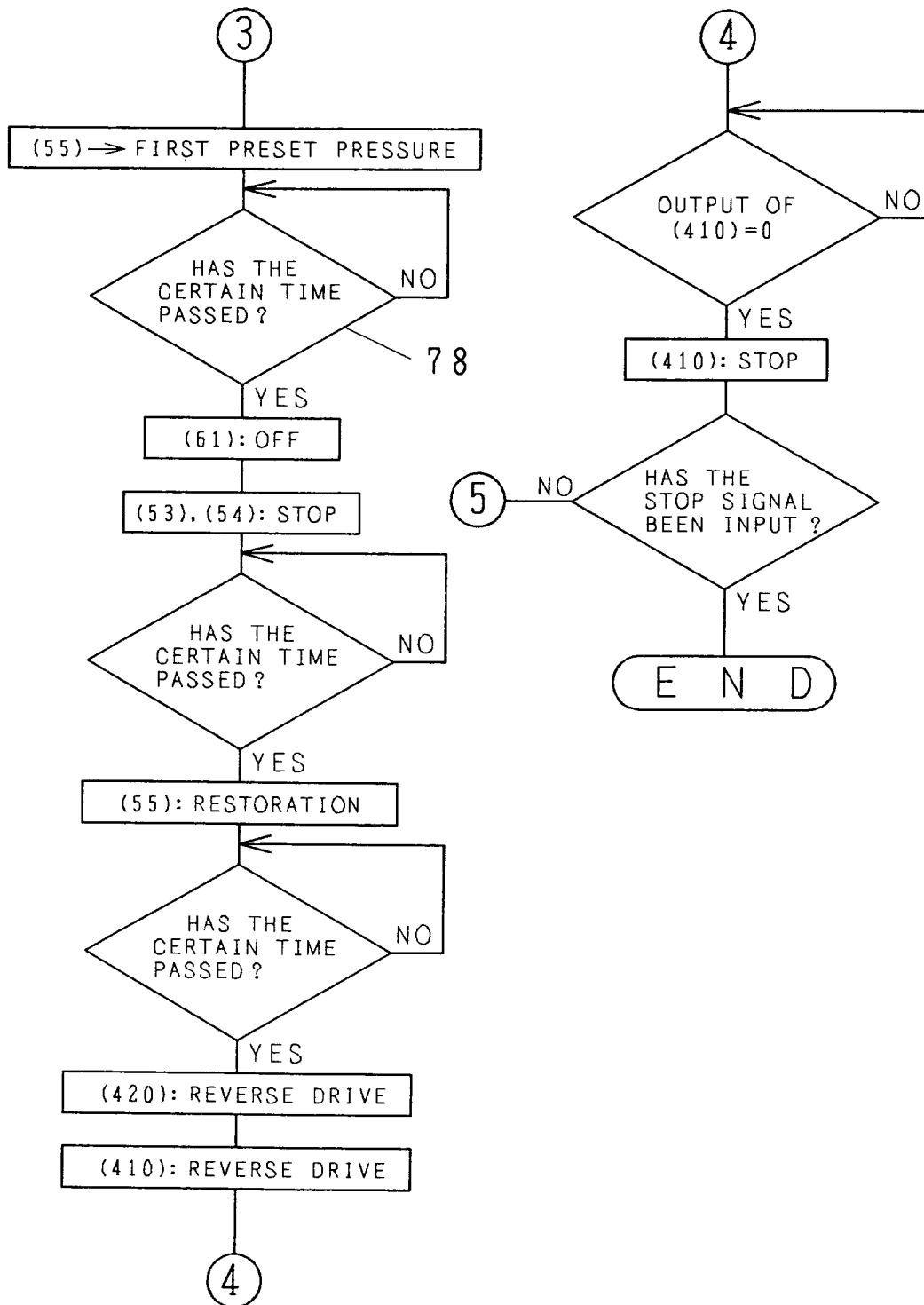


FIG. 7

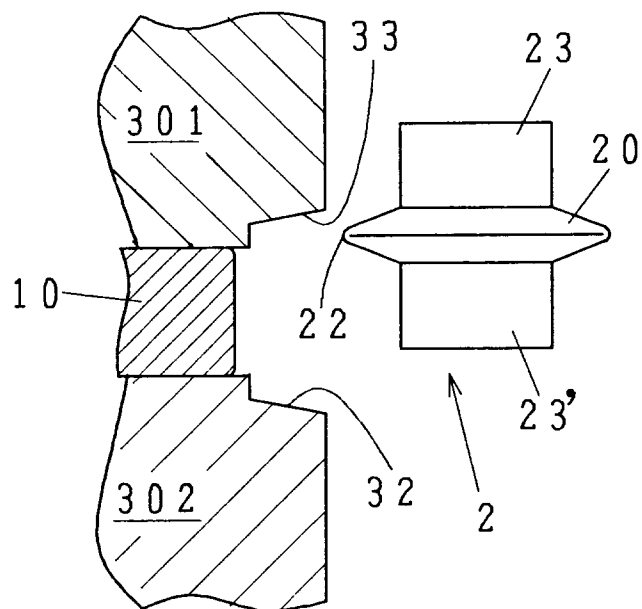


FIG. 8

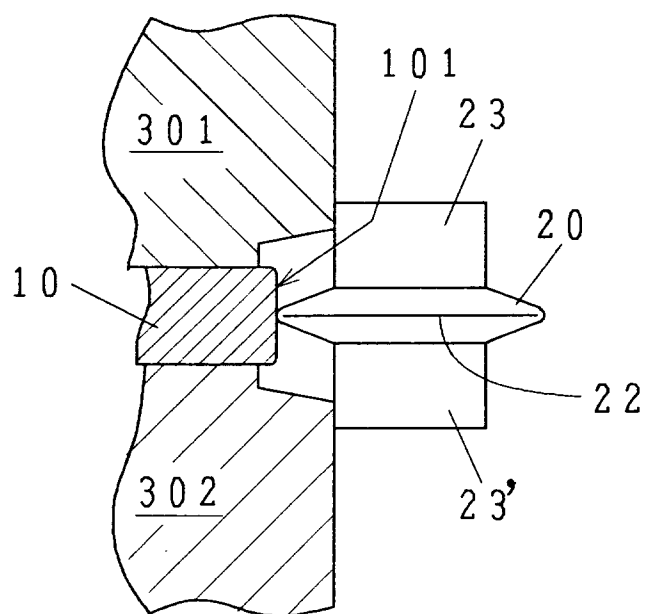


FIG. 9

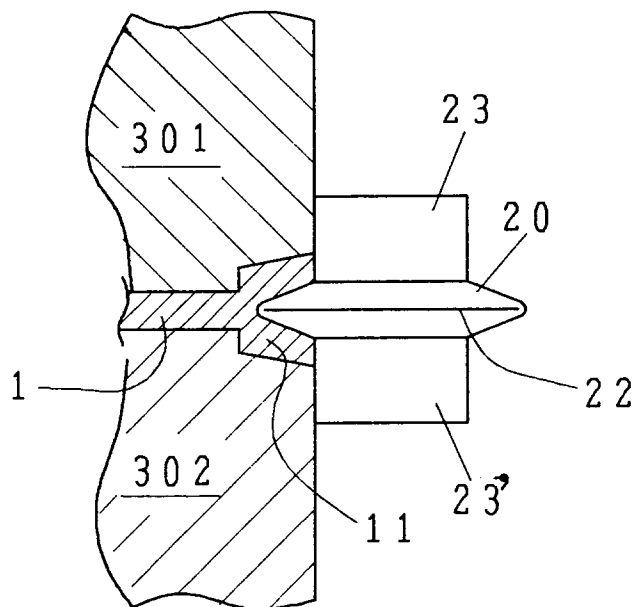


FIG. 10

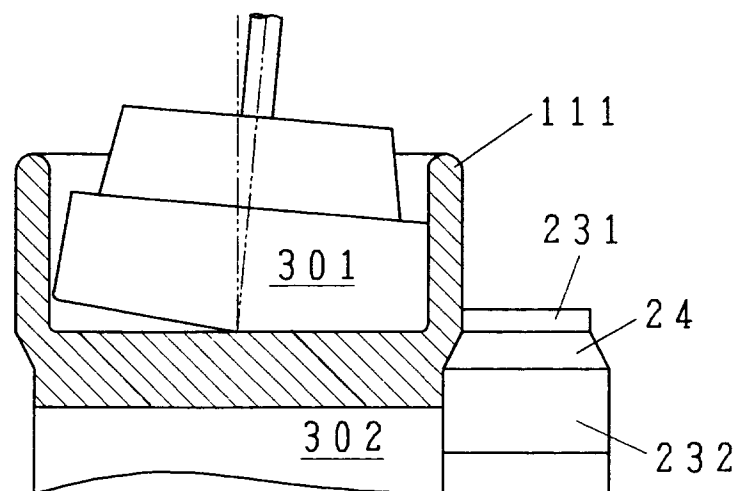


FIG. 11

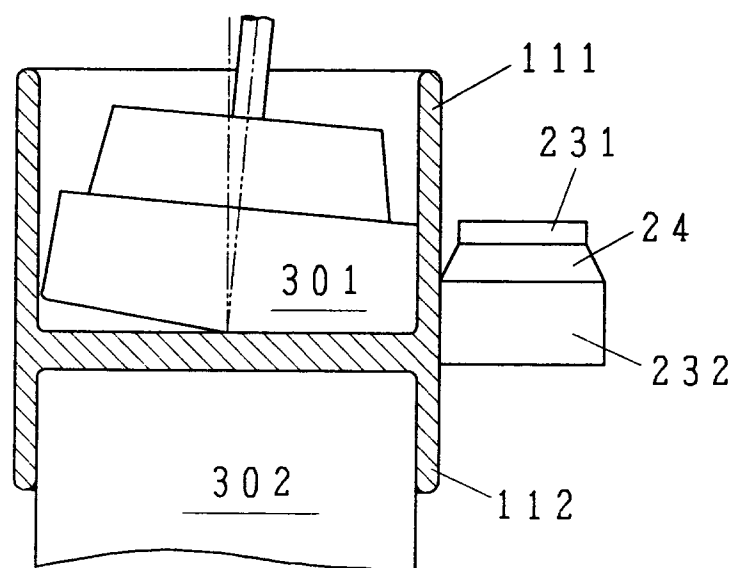


FIG. 12

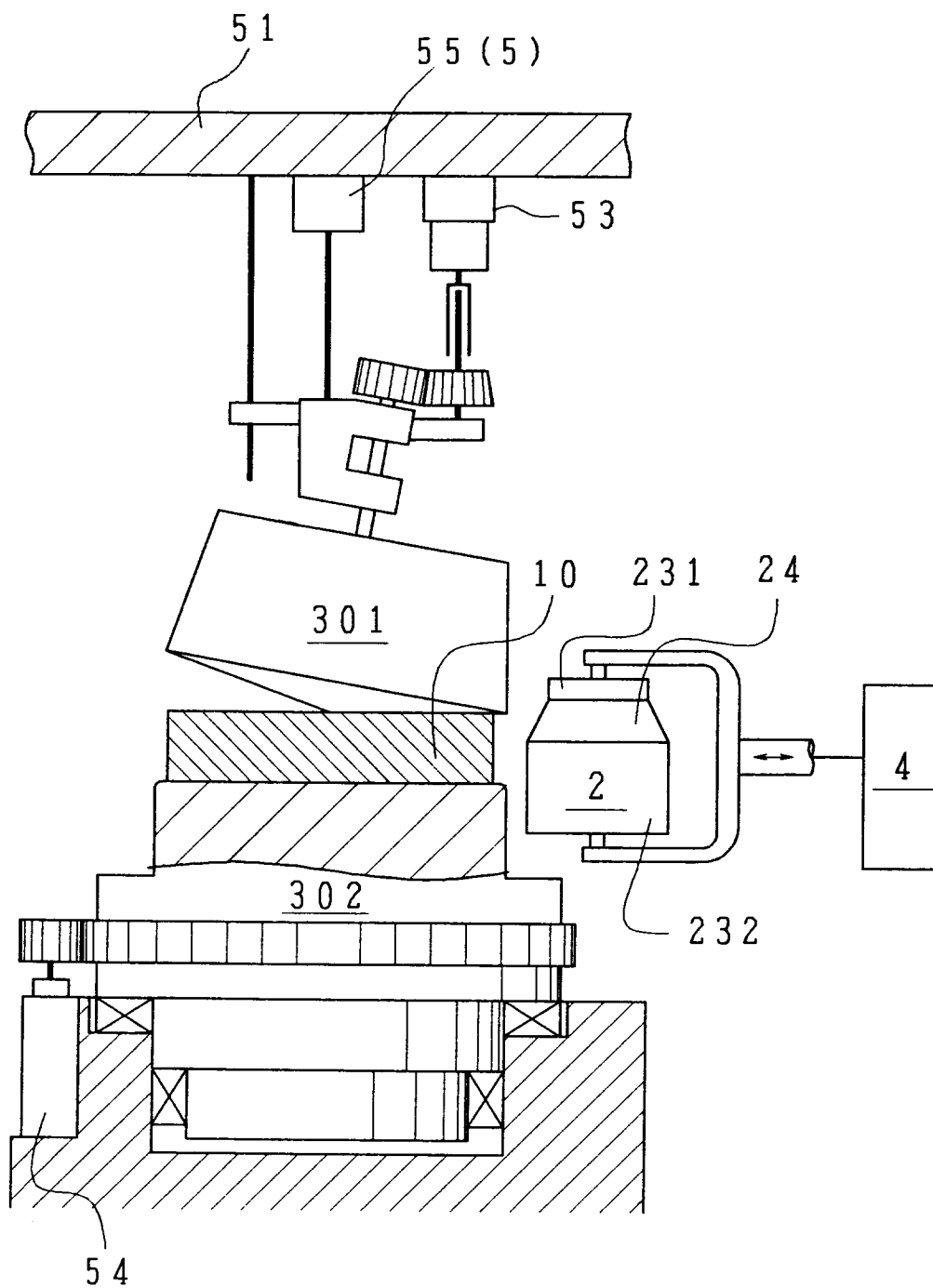


FIG.13

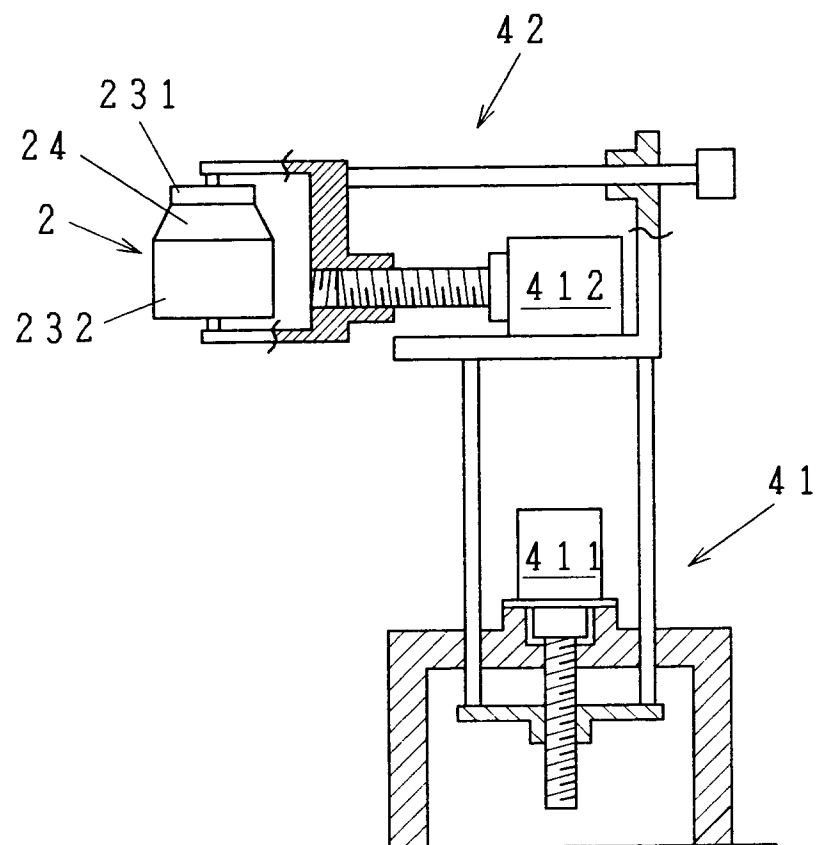


FIG.14

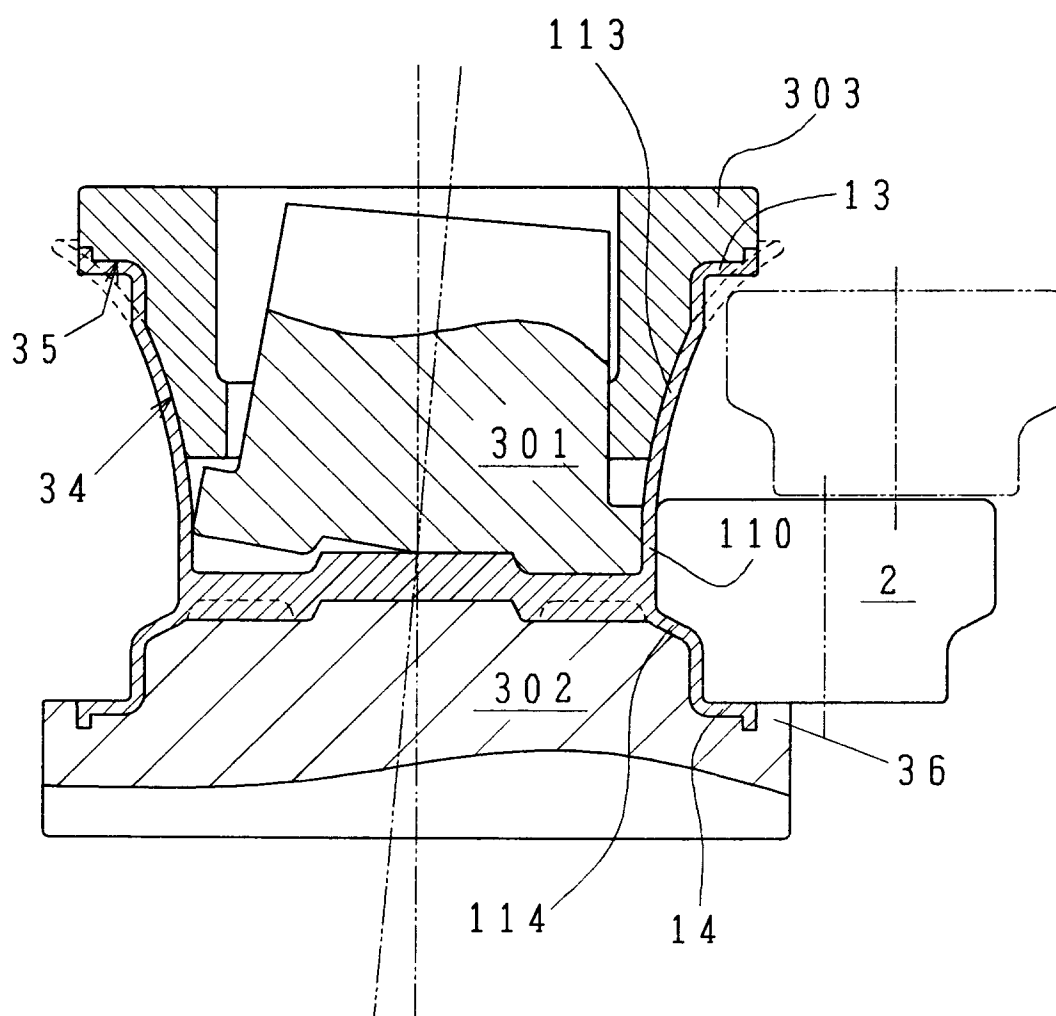


FIG.15

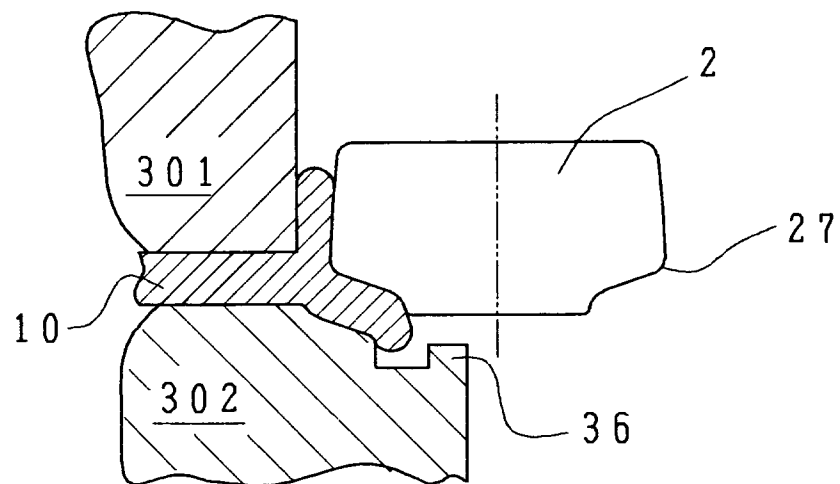


FIG.16

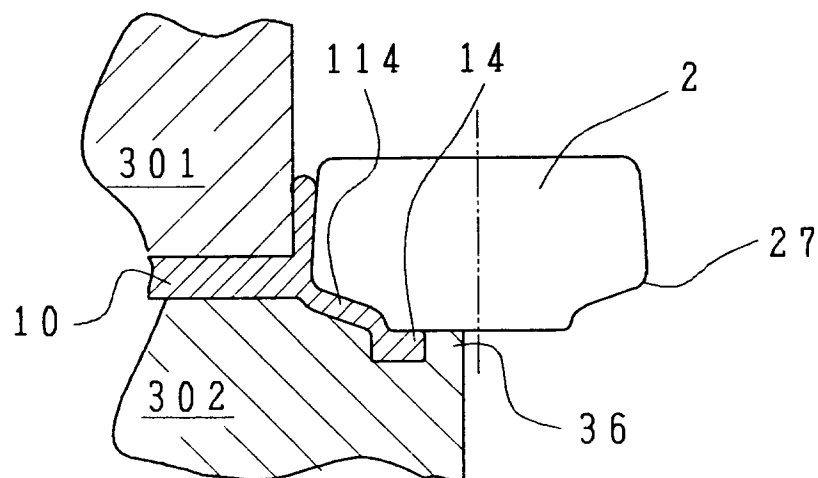


FIG.17

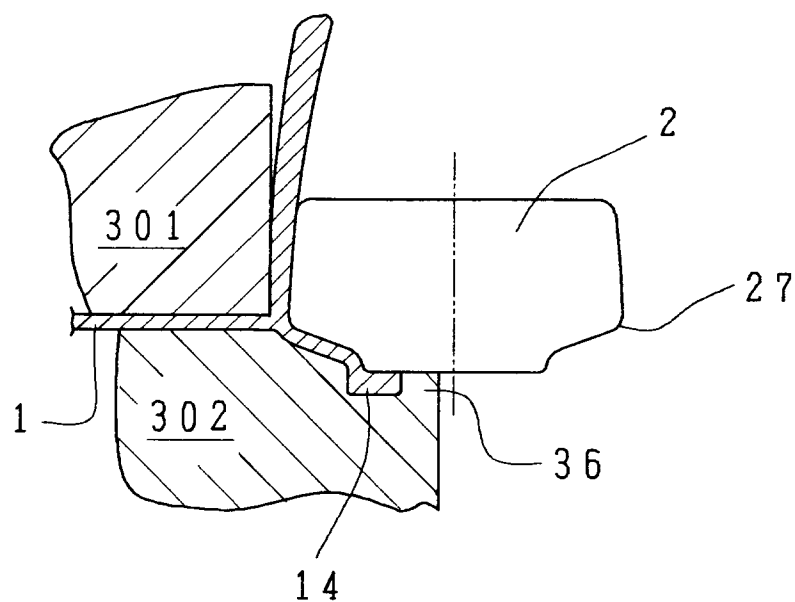


FIG.18

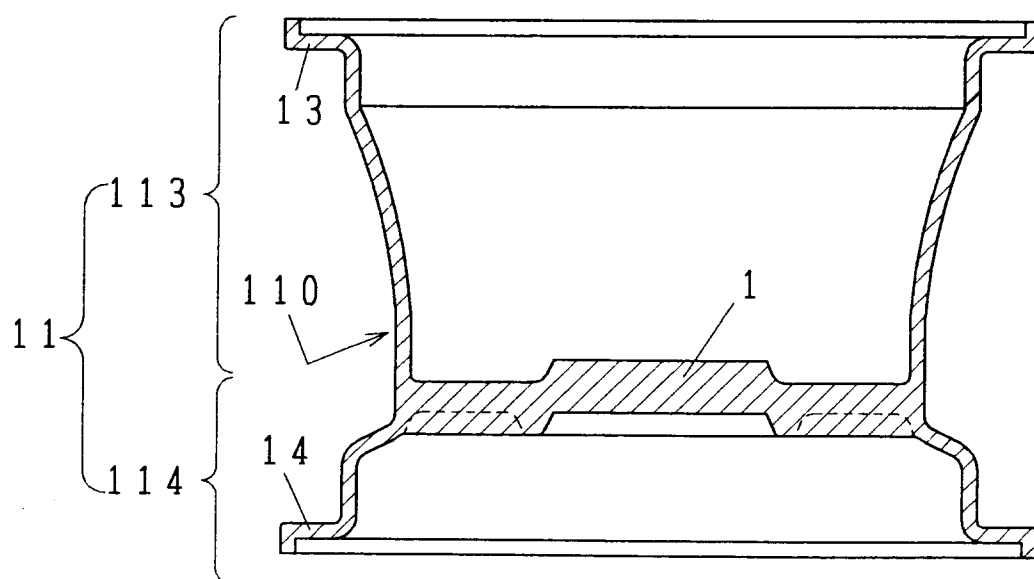
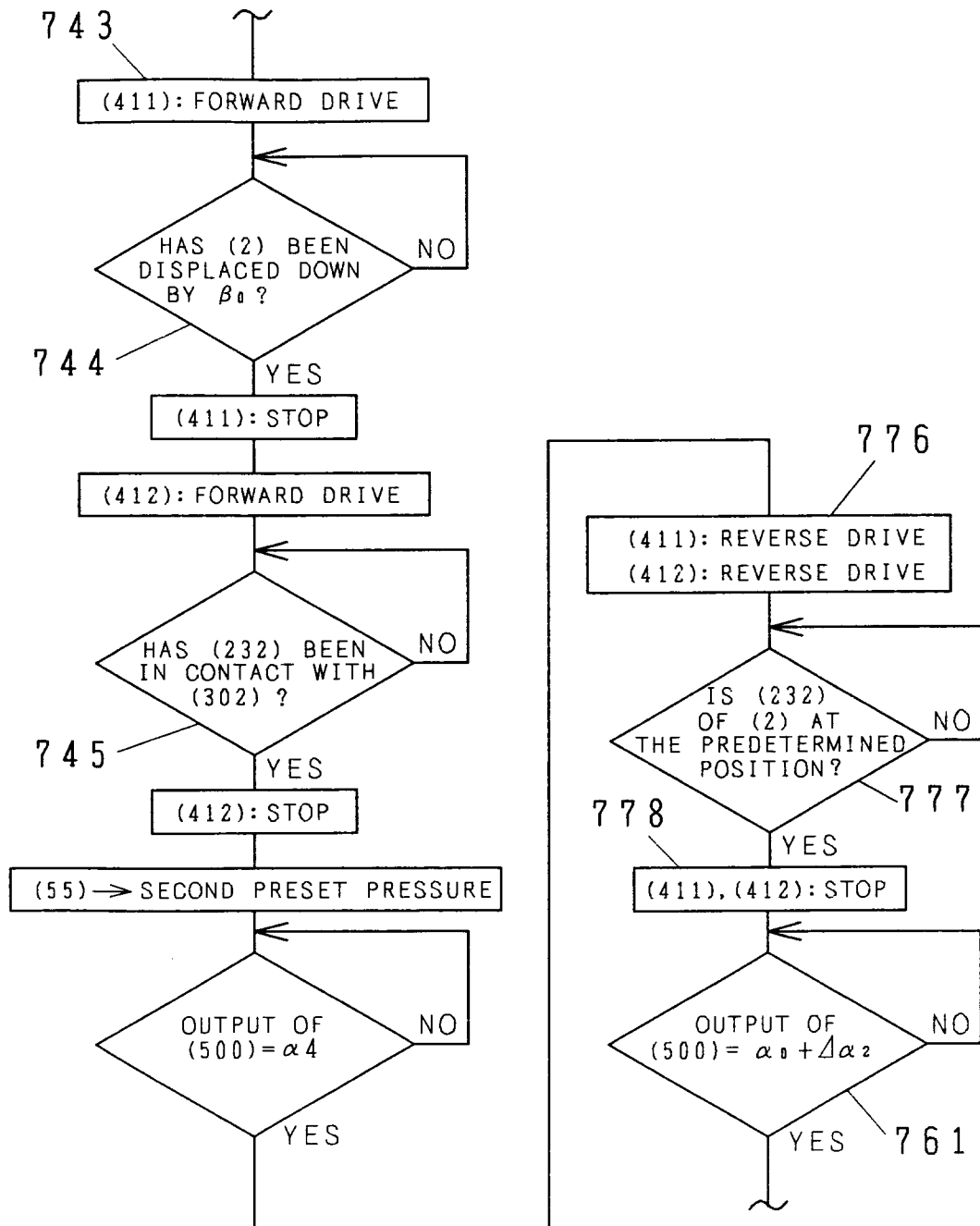


FIG. 19





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 8138

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
P,A	PATENT ABSTRACTS OF JAPAN vol. 18, no. 472 (M-1667) 2 September 1994 & JP-A-06 154 932 (REIZU ENG) 3 June 1994 * abstract *	1-3	B21J9/02 B21K1/28 B21H1/04
T	EP-A-0 652 061 (RAYS ENGINEERING) * column 1 - column 2; figures 1-3 *	1-3	
D,A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 67 (M-566) 28 February 1987 & JP-A-61 226 132 (SUMITOMO METAL IND) 8 October 1986 * abstract *	1	
A	SOVIET INVENTIONS ILLUSTRATED Section PQ, Week 9146, 8 January 1992 Derwent Publications Ltd., London, GB; Class P52, AN 91-337581/46 & SU-A-1 613 221 (GRIGOREV) 15 December 1990 * abstract *	1	
A	US-A-4 523 446 (MÜLLER) -----		TECHNICAL FIELDS SEARCHED (Int.Cl.6) B21D B21H B21J B21K
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 27 June 1995	Examiner Rosenbaum, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			