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(54) SUB-MUFFLER AND MANUFACTURING METHOD OF SUB-MUFFLER

(57) A manufacturing method of a sub-muffler (1, 201) includes a tubular body shaping step (S3), a central part spinning machining step (S5, S7, S26, S27), and a diameter reduction machining step (S8, S28). In the tubular body shaping step (S3), a cylindrical body (2, 202) is formed by rolling a plate material (70). In the central part spinning machining step (S5, S7, S26, S27), the cross-sectional shape of a central part (20, 220) of the cylindrical body (2, 202) is machined into a rectangular shape by performing a spinning machining in which a rotating roller (88) is moved along a rectangular trajectory (T3, T6) while pressing the rotating roller (88) onto the central part (20, 220) of the cylindrical body (2, 208). In the diameter reduction machining step (S8, S28), the diameter of an end (80, 81, 280, 281) of the cylindrical body (2, 208) is reduced.

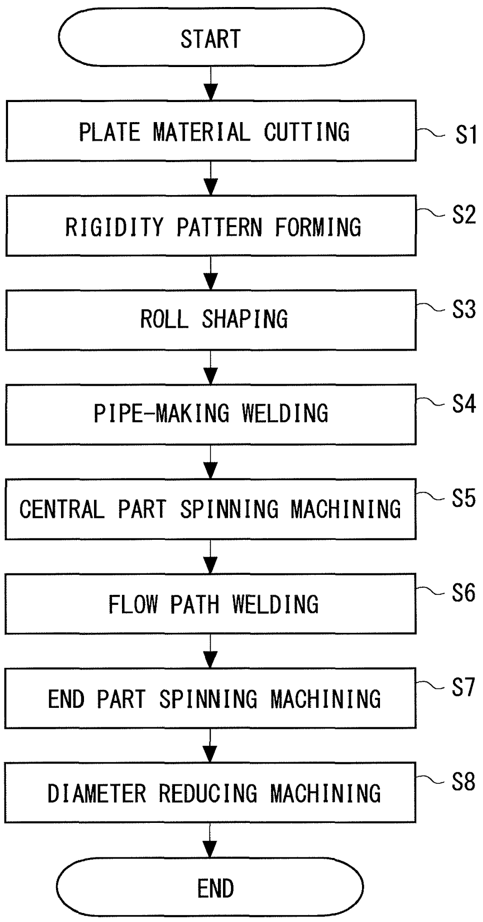

Fig. 5

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a sub-muffler incorporated into an exhaust system of an automobile, and a manufacturing method of such sub-mufflers. In particular, the present invention relates to a sub-muffler including a main body having a rectangular shape in cross section, and a manufacturing method of such sub-mufflers.

2. Description of Related Art

[0002] A sub-muffler integrated into an exhaust system of an automobile is often housed and disposed in a floor tunnel section that is formed so as to extend in the front/back direction of the vehicle (a space recessed in the vehicle interior direction) on the under surface of the floor of the vehicle.

[0003] For example, Japanese Unexamined Patent Application Publication No. 2002-347664 discloses a sub-muffler with a recess formed on the upper side thereof and having curved sides as shown in its Fig. 6. In particular, the sub-muffler is disposed in a recessed space of a floor tunnel section in such a manner that the under surface of the sub-muffler is roughly flush with the under surface of the floor of the vehicle. Further, a recess extending in the vehicle front/back direction is formed at the center in the vehicle width direction on the upper surface of the sub-muffler. Further, a space is formed between the recess and a propeller shaft extending in the front/back direction above the recess and having a circular shape in cross section. This space allows air to flow easily from the front of the vehicle to the back thereof.

SUMMARY OF THE INVENTION

[0004] The present inventors have found the following problem. A sub-muffler is connected to a catalyst converter and/or a main muffler through a pipe having a diameter smaller than that of the sub-muffler.

[0005] The inventors of the present application have examined a method in which a spinning machining is performed on both ends of a sub-muffler to reduce the cross sectional areas thereof and thereby conform the cross section of the ends to those of pipes so that the pipes can be connected to both ends of the sub-muffler. (In this specification, the term "machining" includes "shaping", "deforming", and so on by using a machine.) However, the inventors have found a problem that when a spinning machining is simply performed on the ends of a rectangular sub-muffler (i.e., a sub-muffler having a rectangular shape in cross section) including a main body having a rectangular outer shape in cross section, wrinkling and cracking occur.

[0006] Therefore, the inventors have also examined a method in which, for example, separate connection components such as pressed articles are attached to the ends of a sub-muffler by using a welding process or a crimping process, and the sub-muffler is connected to pipes through the connection components. However, the inventors have found that since this method requires separate connection components, the yield rate is lowered.

[0007] The present invention has been made in view of the above-described circumstances, and an object thereof is to make it possible to manufacture sub-mufflers with a high yield rate.

[0008] A first exemplary aspect of the present invention is a manufacturing method of a sub-muffler including:

a tubular body shaping step of rolling a plate material, and thereby forming a cylindrical body (e.g., a roll shaping step S3, a pipe-making welding step S4);
a central part spinning machining step of performing a rectangular spinning machining in which a rotating roller is moved along a rectangular trajectory while pressing the rotating roller onto a central part of the cylindrical body, and thereby machining the central part so that a cross-sectional shape of the central part becomes a rectangular shape (e.g., a central part spinning machining step S5, S26, an end part spinning machining step S7, S27); and
a diameter reducing step of reducing a diameter of an end of the cylindrical body (e.g., a diameter reduction spinning machining step S8, S28).

[0009] The above-described manufacturing method makes it possible to manufacture sub-mufflers with a high yield rate.

[0010] Further, in the diameter reducing step, the diameter of the end of the cylindrical body may be reduced by performing a circular spinning machining in which the rotating roller is moved along a circular trajectory while pressing the rotating roller onto the end of the cylindrical body. Further, in the central part spinning machining step, the central part may be machined so that the cross-sectional shape of the central part becomes a rectangular shape by performing the rectangular spinning step after performing a circular spinning machining in which the rotating roller is moved along a circular trajectory while pressing the rotating roller onto the central part of the cylindrical body. Further, in the central part spinning machining step, the trajectory of the rotating roller may be gradually changed from the cross-sectional shape of the central part of the cylindrical body into a rectangular shape.

[0011] Another exemplary aspect of the present invention is a sub-muffler manufactured by using the above-described manufacturing method.

[0012] The above-described configuration makes it possible to provide sub-mufflers that can be manufactured with a high yield rate.

[0013] According to the present invention, it is possible to provide a manufacturing method of a sub-muffler that can make it possible to manufacture sub-mufflers with a high yield rate.

[0014] The above and other objects, features and advantages of the present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 is a perspective view of a sub-muffler according to a first exemplary embodiment;
Fig. 2 is a figure showing a disposition of the sub-muffler according to the first exemplary embodiment;
Fig. 3 is a cross section of the sub-muffler and a front floor tunnel section according to the first exemplary embodiment;
Fig. 4 is a graph showing primary sound pressure magnitudes of an exhaust sound with respect to volume ratios of a sub-muffler to the total volume of the sub-muffler and a main muffler;
Fig. 5 is a flowchart showing a manufacturing method according to the first exemplary embodiment;
Fig. 6 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 7 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 8 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 9 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 10 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 11 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 12 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 13 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 14 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 15 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 16 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 17 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 18 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 19 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 20 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 21 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 22 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 23 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 24 is a schematic diagram showing one step in the manufacturing method according to the first exemplary embodiment;
Fig. 25 is a perspective view of a sub-muffler according to a second exemplary embodiment;
Fig. 26 is a flowchart showing a manufacturing method according to the second exemplary embodiment;
Fig. 27 is a schematic diagram showing one step in the manufacturing method according to the second exemplary embodiment; and
Fig. 28 is a schematic diagram showing one step in the manufacturing method according to the second exemplary embodiment.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

First exemplary embodiment

[0016] A sub-muffler according to a first exemplary embodiment is explained with reference to Figs. 1 to 4. Fig. 1 is a perspective view of a sub-muffler. Fig. 2 is a figure partially showing a disposition of the sub-muffler when the sub-muffler is mounted on a vehicle. Fig. 3 is a cross section of the sub-muffler and a front floor tunnel section. Fig. 4 is a graph showing primary sound pressure magnitudes of an exhaust sound with respect to volume ratios of a sub-muffler to the total volume of the sub-muffler and a main muffler (i.e., ratios of the volume of the sub-muffler to the total volume of the sub-muffler and the main muffler).

[0017] As shown in Fig. 1, a sub-muffler 1 includes a tubular body 2, a flow path pipe 3, and a separator 23.

[0018] The tubular body 2 has a roughly trapezoidal shape in cross section. The tubular body 2 is made of, for example, a metal material such as iron, titanium, aluminum, or an alloy thereof. Examples of the alloy include stainless steel. The tubular body 2 has a central axis Y1. The central axis Y1 may pass through the center of gravity in the cross section of the tubular body 2. The tubular body 2 includes a central part 20, an end part 21 extending in one direction from the central part 20, and an end part 22 extending in the other direction.

[0019] The central part 20 has a roughly trapezoidal shape in cross section, and its cross section becomes smaller from the end part 21 toward the end part 22. The diameters of the end parts 21 and 22 of the tubular body 2 are reduced so that they are closely attached to the outer circumferential surface of the flow path pipe 3. The inner diameter of the central part 20 is larger than the outer diameter of the flow path pipe 3. Further, the inner diameter of the parts of the ends parts 21 and 22 that are located closest to their ends is equal to or slightly larger than the outer diameter of the flow path pipe 3. In some cases, a bump-and-recess pattern may be formed on the outer wall surface of the tubular body 2 in order to increase its rigidity. The central part 20 and the end parts 21 and 22 are formed as an integrated article. That is, instead of the boundaries between the central part 20 and the end part 21 and between the central part 20 and the end part 22 being formed by joining two members by welding or crimping, they are formed from one planar raw material by a form-shaping process. The end part 22 has an outlet 33 for discharging exhaust from the tubular body 2, and the outlet 33 is connected to a main muffler or the like located in the downstream side through a pipe of the like.

[0020] The separator 23 is disposed inside the tubular body 2 and divides the space inside the tubular body 2 into two sections, i.e., an expansion chamber on the end part 21 side and another expansion chamber on the end part 22 side. Further, a holding hole 24 is formed in the separator 23. The flow path pipe 3 is inserted into the holding hole 24 and thereby held by the separator 23.

[0021] The flow path pipe 3 includes a suction part 31 that is connected to a catalyst converter or the like, and a straight part 32 extending on a straight line from the suction part 31. Exhaust that has passed through the catalyst converter or the like is guided from the expansion chamber on the end part 21 side to the expansion chamber on the end part 22 side through the straight part 32. The straight part 32 may be a punching pipe in which a plurality of holes are formed. A sound absorption member (not shown) is disposed in the expansion chamber of the tubular body 2 and envelops the outer circumferential surface of the straight part 32. The sound absorption member is a member made of a material capable of absorbing sound energy and thereby absorbing the sound. Examples of the sound absorption member include glass-wool.

[0022] Next, a sub-muffler 1 incorporated into an exhaust system of an automobile is explained.

[0023] As shown in Fig. 2, an exhaust system 50 of an automobile includes a catalyst converter 51, the sub-muffler 1, a pipe 52, and a main muffler 53 connected to the pipe 52. The catalyst converter 51 is connected to an engine (not shown) through an exhaust pipe (not shown). The sub-muffler 1 is incorporated into the exhaust system 50 of the automobile by connecting the suction part 31 to the catalyst converter 51 and connecting the outlet 33 to the pipe 52. Further, the sub-muffler 1 supplements the silencing effect of the main muffler 53.

[0024] Note that the sub-muffler 1 is disposed, for example, directly below a front floor tunnel section 60 of the automobile. As shown in Fig. 3, the front floor tunnel section 60 has a difference in height in the width direction of the automobile (Rh-direction in Fig. 3). That is, a part of the front floor tunnel section 60 is recessed toward the vehicle interior, and hence the front floor tunnel section 60 includes a space 61, i.e., a recessed part having a roughly trapezoidal shape in cross section. Meanwhile, since the tubular body 2 of the sub-muffler 1 is a tubular-shape body having a roughly trapezoidal shape in cross section as described above, the tubular body 2 is housed in the vacant space 61 in such a manner that gaps in the space 61 can be reduced as much as possible while avoiding interference caused by obstacles located in the lower part of the automobile. Therefore, it can be ensured that the sub-muffler 1 has a larger volume compared to that of a typical cylindrical sub-muffler in related art.

[0025] An increase in the total volume of the sub-muffler and the main muffler lowers the exhaust resistance of the engine and hence contributes to an improvement in the engine power and the fuel efficiency. However, there is a limit to the increase in the volume of the main muffler because of the restriction imposed by the vehicle design and a demand that the interior space should be increased as much as possible. Therefore, we have come up with an idea that the volume of the sub-muffler should be increased in the first exemplary embodiment. It is difficult to ensure that there is a large space for mounting the sub-muffler by changing the shape of the front floor tunnel section 60 because of other factors regarding the vehicle design and the design restriction of the unit to be mounted. Therefore, we have decided to effectively use the conventional housing space by changing the outer shape of the sub-muffler as explained above.

[0026] Further, we have conducted experiments for measuring primary sound pressure magnitudes of an exhaust sound with respect to volume ratios of the sub-muffler to the total volume of the sub-muffler and the main muffler. The primary sound pressure magnitude indicates the magnitude of a sound pressure of the exhaust sound. A decrease in the primary sound pressure magnitude means a decrease in the noise caused by the exhaust. As shown in Fig. 4, when the volume ratio is increased from 0.1 to 0.5, the primary sound pressure magnitude gradually decreases until it eventually reaches the minimum value. The volume of a typical sub-muffler is much smaller than that of a main muffler. That is, the volume ratio of a sub-muffler is about 0.2 at the maximum. It is possible to reduce the noise caused by the exhaust by employing the sub-muffler according to this exemplary embodiment and thereby increasing the volume ratio of the sub-muffler.

[0027] Note that although the tubular body 2 has a roughly trapezoidal shape in cross section in the above-described exemplary embodiment, the tubular body 2 may have a rectangular shape other than the trapezoidal shape in cross section in other embodiments. Examples of the rectangular shape include a roughly trapezoidal shape, a roughly quadrangular shape, a roughly rectangular shape, a roughly square shape, and other polygonal shapes. The rectangular shape does not necessarily have to be a perfect rectangular shape. For example, the rectangular shape includes a rectangular shape in which some or all of the four corners are rounded or cut. The tubular body 2 should have a cross section so that it conforms to the shape of the wall surface forming the front floor tunnel section 60 of the automobile in which the sub-muffler 1 is mounted as much as possible.

Manufacturing Method 1

[0028] Next, a manufacturing method of a sub-muffler according to the first exemplary embodiment is explained with reference to Figs. 6 to 24 as well as Fig. 5. Fig. 5 is a flowchart showing a manufacturing process according to the first exemplary embodiment. Figs. 6 to 24 are schematic diagrams for explaining steps in the manufacturing method according to the first exemplary embodiment.

[0029] As shown in Fig. 6, for example, plate materials 70 having a predetermined trapezoidal shape are cut out from a planar raw material made of the same type of material as that of the tubular body 2 (plate material cutting step S1). Fig. 6 shows a state where four plate materials 70 are cut out by punching or the like. Each plate material 70 has edges 73 and 74. The edges 73 and 74 are parts corresponding to a pair of opposite sides extending between the top side and the bottom side in the trapezoidal shape.

[0030] Next, as shown in Fig. 7, for example, a bump-and-recess pattern 76 is formed by using a press die (not shown) in order to increase the rigidity (rigidity pattern shaping step S2). Note that for the sake of easier understanding, the illustration of the bump-and-recess pattern 76 is omitted in Figs. 1 to 6 and Figs. 8 to 28.

[0031] Next, as shown in Figs. 8 to 12, the cut-out plate material 70 is made to pass between a plurality of rollers 85 and thereby rolled. By doing so, the plate material 70 is bending-formed into a ring shape (roll shaping step S3). In particular, as shown in Fig. 9, it is confirmed that the plate material 70 has a planar shape before making the plate material 70 pass between the plurality of rollers 85. As shown in Fig. 10, while the plate material 70 is passing between the plurality of rollers 85, the edge 74 is rolled into an arc shape and then the plate material 70 is gradually rolled from the edge 74 to the edge 73. Finally, as shown in Fig. 11, the plate material 70 is rolled into a ring shape. Further, the end face at the edge 73 gets closer to that of the edge 74 and they are opposed to each other. The plate material 70 is formed into a shape shown in a perspective view of Fig. 12. Note that the end faces of the edges 73 and 74 may be brought into contact with each other.

[0032] Next, as shown in Fig. 12, the edges 73 and 74 are welded in a state where they are in contact with each other by using a welding torch 87 connected to a welding device (not shown) (pipe-making welding step S4). As a result, a perfect tubular body 72 is formed. The roll shaping step S3 and the pipe-making welding step S4 may be collectively called "tubular body shaping step". As shown in Fig. 13, the tubular body 72 (also referred to as "cylindrical body") is a tubular body having a central axis Y0 at its center and roughly a circular shape in cross section. Note that the circular shape may be, for example, a perfect circular shape, a roughly circular shape, or a roughly elliptical shape. Further, assuming that the tubular body 72 consists of a front part 77, a central part 78, and a rear part 79 for the sake of convenience, the front part 77 is a part extending forward from the central part 78 and the rear part 79 is a part extending backward from the central part 78. The end on the front part 77 side is referred to as "front end 80" and the end on the rear part 79 side is referred to as "rear end 81". The central part 78, the front part 77, and the rear part 79 may be inclined with respect to the central axis Y0.

[0033] Next, as shown in Fig. 14, a spinning machining is performed by using a form-shaping rotating roller 88 that can rotate (i.e., rotate on its own axis and revolve around the tubular body 72) and is included in a spinning machining device (not shown) (central part spinning machining step S5). By doing so, the central part 78 of the tubular body 72 is machined (or processed) so that its cross-sectional shape becomes a rectangular shape.

[0034] In particular, as shown in Figs. 13 and 14, firstly, the rotating roller 88 is rotated on its own axis and moved along a circular trajectory T1 while pressing the rotating roller 88 onto the central part 78 of the tubular body 72. Note that the circular trajectory T1 is, for example, a circular trajectory around the central axis Y0 on an imaginary plane ZX perpendicular to the central axis Y0.

[0035] Next, as shown in Figs. 14 to 16, the spinning machining is performed while changing the trajectory of the rotating roller 88 from the circular trajectory T1 to an intermediate trajectory T2, and to a rectangular trajectory T3, i.e., gradually changing the trajectory of the rotating roller 88 from the circular trajectory to a rectangular trajectory. Note that the rectangular trajectory T3 is a rectangular trajectory on the imaginary plane ZX perpendicular to the central axis Y0. This rectangular shape is the shape that the central part 78 is eventually shaped into through the machining. That is, the cross-sectional shape of the central part 20 of the machined tubular body 2 (see Fig. 1) is identical to or similar to this rectangular shape. Further, the trajectory T2 is an intermediate trajectory between the circular trajectory T1 and the rectangular trajectory T3.

[0036] Further, as shown in Fig. 16, the central part 78 is machined into a rectangular shape. Since the trajectory of the rotating roller 88 gradually changes from the circular trajectory to the rectangular trajectory, thickening and wrinkling are less likely to occur in the central part 78. Therefore, it is possible to prevent or reduce the occurrences of cracking due to the thickening and wrinkling.

[0037] Next, as shown in Fig. 17, the flow path pipe 3 and the separator 23 are inserted into the tubular body 72 and the separator 23 is welded to the central part 78 (flow path pipe welding step S6). Note that the flow path pipe 3 may be disposed so as to pass through the separator 23.

[0038] Next, as shown in Fig. 18, a spinning machining is performed for a predetermined width A1 in the end part on the central part 78 side of the front part 77, and then a spinning machining is performed for a predetermined width B1 in the end part on the central part 78 side of the rear part 79 (end part spinning machining step S7). The end part spinning machining step S7 may also be referred to as "central part spinning machining step".

[0039] In particular, as shown in Fig. 19, firstly, the rotating roller 88 is rotated on its own axis and moved along a circular trajectory T4 while pressing the rotating roller 88 onto the front part 77.

[0040] Next, as shown in Fig. 20, the spinning machining is performed while reducing the diameter of the circular trajectory of the rotating roller 88 so that the diameter of the front part 77 is reduced.

[0041] Further, as shown in Fig. 21, the spinning machining is performed while gradually changing the trajectory of the rotating roller 88 from the circular trajectory T4 to a rectangular trajectory T6. As a result, the front part 77 is machined into a rectangular shape. Since, similarly to the central part spinning machining step S5, the trajectory of the rotating roller 88 gradually changes from the circular trajectory to the rectangular trajectory, thickening and wrinkling are less likely to occur in the front part 77. Therefore, it is possible to prevent or reduce the occurrences of cracking due to the thickening and wrinkling. Through a similar procedure, the above-described spinning machining is also performed on the rear part 79.

[0042] Finally, as shown in Figs. 22 to 24, the diameters of the front end 80 and the rear end 81 are reduced by performing a spinning machining (diameter reduction spinning machining step S8). The diameter reduction spinning machining step S8 may also be referred to as "diameter reduction machining step". In particular, a spinning machining is performed by rotating the rotating roller 88 on its own axis and moving the rotating roller 88 along a circular trajectory while pressing the rotating roller 88 onto the front end 80. Similarly, a spinning machining is also performed on the rear end 81 so that the diameter of the rear end 81 is reduced. The diameters of the front end 80 and the rear end 81 are preferably reduced so that they are closely attached to the outer circumferential surface of the flow path pipe 3. Through the above-described procedure, the outer shape of the sub-muffler 1 can be shaped into the shape shown in Fig. 1.

[0043] Note that if necessary, an inspection may be performed after the diameter reduction spinning machining step S8. Further, the rigidity pattern shaping step S2 may be performed after the central part spinning machining step S5.

[0044] As stated above, according to the above-described Manufacturing Method 1, a sub-muffler can be manufactured from one plate material and the manufactured sub-muffler can be directly connected to a pipe(s). That is, there is no need to separately manufacture a separate connection component(s) in addition to the tubular body of the sub-muffler, thus making it possible to manufacture sub-mufflers with a high yield rate.

[0045] Further, according to the above-described Manufacturing Method 1, in a tubular body having a circular shape in cross section, its central part is machined into a rectangular shape by a spinning machining, and then the diameter of its end(s) having a circular shape in cross section is reduced by a spinning machining. That is, since the end part(s) has a circular shape in cross section while the central part has a rectangular shape in cross section, wrinkling and cracking are less likely to occur even when the diameter of the end part(s) is reduced, thus making it possible to obtain a sub-muffler having a rectangular shape in cross section.

[0046] Further, according to the above-described Manufacturing Method 1, in the end part spinning machining step, the diameter of the end part(s) of the tubular body is reduced by performing a spinning machining in which a rotating roller is moved along a circular trajectory while pressing the rotating roller onto the end part(s) of the tubular body. This makes it possible to perform the above-described process by continuously using the same spinning machining device as that used in the preceding step, thus eliminating the need for another machining device different from the spinning machining device used in the preceding step. That is, a sub-muffler can be manufactured at a lower cost.

[0047] Further, according to the above-described Manufacturing Method 1, in the central part spinning machining step, the central part is machined so that its cross-sectional shape becomes a rectangular shape by performing a rectangular spinning machining after reducing the diameter of the central part by performing a circular spinning machining in which a rotating roller is moved along a circular trajectory while pressing the rotating roller onto the central part of the tubular body.

[0048] Further, in the central part spinning machining step, the trajectory of the rotating roller gradually changes from the cross-sectional shape of the central part of the tubular body into a rectangular shape.

[0049] According to these processes, thickening and wrinkling are less likely to occur in the central part. Therefore, it is possible to manufacture a sub-muffler while preventing or reducing the occurrences of cracking due to the thickening and wrinkling.

Second exemplary embodiment

[0050] A sub-muffler according to a second exemplary embodiment is explained with reference to Fig. 25. Fig. 25 is a perspective view of a sub-muffler.

[0051] As shown in Fig. 25, a sub-muffler 201 includes a tubular body 202 and a flow path pipe 203

[0052] The tubular body 202 has a roughly trapezoidal shape in cross section. The tubular body 202 is made of, for example, a metal material such as iron, titanium, aluminum, or an alloy thereof. The tubular body 202 has a central axis Y21. The central axis Y21 may pass through the center of gravity in the cross section of the tubular body 202. The tubular body 202 includes a central part 220, an end part 221 extending from one side of the central part 220, and an end part 222 extending from other side of the central part 220. The central part 220 has a roughly trapezoidal shape in cross section, and its cross section is unchanged from the end part 21 to the end part 22. The central part 220 has a space inside thereof and this space functions as an expansion chamber. The diameters of the end parts 221 and 222 of the tubular body 202 are reduced so that they are closely attached to the outer circumferential surface of the flow path pipe 203. In some cases, a bump-and-recess pattern (not shown) may be formed on the outer wall surface of the tubular body 202 in order to increase its rigidity.

[0053] The central part 220 and the end parts 221 and 222 are formed as an integrated article. That is, the boundaries between the central part 220 and the end part 221 and between the central part 220 and the end part 222 are not formed by joining two members by welding or crimping, but are formed from one planar raw material by a form-shaping process.

[0054] The flow path pipe 203 is a roughly straight pipe including a suction part 231 that is connected to a catalyst converter or the like, a straight part 232 extending on a straight line from the suction part 231, and an outlet 233 connected to a main muffler or the like through a pipe or the like.. Exhaust that has passed through the catalyst converter or the like is guided to the expansion chamber through the suction part 231 and the straight part 232. The exhaust guided into the expansion chamber is discharged to the outside of the tubular body 202 from the outlet 233. The straight part 232 may be a punching pipe in which a plurality of holes are formed. A sound absorption member (not shown) is disposed in the expansion chamber of the tubular body 202 and envelops the outer circumferential surface of the straight part 232. The sound absorption member is a member made of a material capable of absorbing sound energy and thereby absorbing the sound. Examples of the sound absorption member include glass-wool.

[0055] Similarly to the sub-muffler 1 according to the first exemplary embodiment (see Fig. 1), the sub-muffler 201 is incorporated into an exhaust system 50 (see Fig. 2) of an automobile and supplements the silencing effect of a main muffler 53.

[0056] Further, since, similarly to the sub-muffler 1, the sub-muffler 201 has a roughly trapezoidal shape in cross section, the sub-muffler 201 can be housed in a vacant space 61 (see

[0057] Fig. 2) in such a manner that gaps in the space 61 can be reduced more effectively while avoiding interferences caused by obstacles located in the lower part of the automobile. Therefore, it can be ensured that the sub-muffler 201 has a larger volume compared to that of a typical sub-muffler having a circular shape in cross section in related art.

[0058] Further, similarly to the sub-muffler 1, the sub-muffler 201 can effectively use the conventional sub-muffler housing space.

[0059] Further, similarly to the sub-muffler 1, it is possible to increase the volume ratio of the sub-muffler, reduce the primary sound pressure magnitude, and reduce the noise caused by the exhaust by employing the sub-muffler according to the second exemplary embodiment.

Manufacturing Method 2

[0060] Next, a manufacturing method of a sub-muffler according to the second exemplary embodiment is explained with reference to Figs. 27 and 28 as well as Fig. 26. Fig. 26 is a flowchart showing a manufacturing process according to the second exemplary embodiment. Figs. 27 and 28 are schematic diagrams for explaining steps in the manufacturing method according to the second exemplary embodiment.

[0061] Firstly, similarly to the manufacturing method according to the first exemplary embodiment, a tubular body 272 is formed through the plate material cutting step S 1 to the pipe-making welding step S4 (see Figs. 5 to 12). Similarly to the tubular body 72 (see Fig. 12), the tubular body 272 is a pipe having a central axis Y20 at its center and roughly a circular shape in cross section as shown in Fig. 27. Note that the circular shape may be, for example, a perfect circular shape, a roughly circular shape, or a roughly elliptical shape. Further, assuming that the tubular body 272 consists of a front part 277, a central part 278, and a rear part 279 for the sake of convenience, the front part 277 is a part extending forward from the central part 278 and the rear part 279 is a part extending backward from the central part 278. Further, the end on the front part 277 side is referred to as "front end 280" and the end on the rear part 279 side is referred to as "rear end 281".

[0062] Next, the flow path pipe 203 is inserted into the tubular body 272 (flow path pipe inserting step S25). The position of the flow path pipe 203 with respect to the tubular body 272 is preferably fixed.

[0063] Next, as shown in Fig. 28, a spinning machining is performed by using a rotating roller 88 (see Fig. 14) (central part spinning machining step S26) and the central part 278 of the tubular body 272 is thereby machined so that its cross-sectional shape becomes a rectangular shape. In the central part spinning machining step S26, the spinning machining is performed in a manner similar to that performed in the central part spinning machining step S5 (see Figs. 14 to 16).

[0064] Next, a spinning machining is performed for a predetermined width A21 on the central part 278 side of the front part 277, and then a spinning machining is performed for a predetermined width B21 on the central part 278 side of the rear part 279 (end part spinning machining step S27). In the end part spinning machining step S27, the spinning machining is performed in a manner similar to that performed in the end part spinning machining step S7 (see Figs. 19 to 21). The end part spinning machining step S27 may also be referred to as "central part spinning machining step".

[0065] Finally, a spinning machining is performed while reducing the diameter of the circular trajectory of the rotating roller 88 so that the diameter of the front end 280 and the rear end 281 is reduced (diameter reduction spinning machining step S28). In particular, the spinning machining is performed on the front end 280 and the rear end 281 in a manner similar to that in the diameter reduction spinning machining step S8. Both of the front end 280 and the rear end 281 are preferably closely attached to the outer circumferential surface of the flow path pipe 203. The diameter reduction spinning machining step S28 may also be referred to as "diameter reduction machining step".

[0066] Finally, the flow path pipe 203 is welded to the tubular body 202 (flow path pipe welding step S29). Note that if necessary, an inspection may be performed after the flow path pipe welding step S29.

[0067] As stated above, according to the above-described Manufacturing Method 2, a sub-muffler can be manufactured from one plate material and the manufactured sub-muffler can be directly connected to a pipe(s) as in the case of the Manufacturing Method 1. That is, there is no need to separately manufacture a separate connection component(s) in addition to the tubular body of the sub-muffler, thus making it possible to manufacture sub-mufflers with a high yield rate.

[0068] Further, according to the above-described Manufacturing Method 2, since the end part(s) of the tubular body has a circular shape in cross section while the central part has a rectangular shape in cross section, wrinkling and cracking are less likely to occur in the sub-muffler having a rectangular shape in cross section even when the diameter of the end part(s) is reduced as in the case of the Manufacturing Method 1.

[0069] Further, according to the above-described Manufacturing Method 2, in the end part spinning machining step, the diameter of the end part(s) of the tubular body is reduced by performing a spinning machining in which a rotating roller is moved along a circular trajectory while pressing the rotating roller onto the central part of the tubular body as in the case of the Manufacturing Method 1. This makes it possible to perform the above-described process by continuously using the same spinning machining device as that used in the preceding step, thus eliminating the need for another machining device different from the spinning machining device used in the preceding step. That is, a sub-muffler can be manufactured at a lower cost.

[0070] Further, according to the above-described Manufacturing Method 2, in the central part spinning machining step, the central part is machined so that its cross-sectional shape becomes a rectangular shape by performing a rectangular spinning machining after reducing the diameter of the central part by performing a circular spinning machining in which a rotating roller is moved along a circular trajectory while pressing the rotating roller onto the central part of the tubular body as in the case of the Manufacturing Method 1.

[0071] Further, in the central part spinning machining step, the trajectory of the rotating roller gradually changes from the cross-sectional shape of the central part of the tubular body into a rectangular shape.

[0072] According to these processes, thickening and wrinkling are less likely to occur in the central part. Therefore, it is possible to manufacture a sub-muffler while preventing or reducing the occurrences of cracking due to the thickening and wrinkling.

[0073] Note that if necessary, the rigidity pattern shaping step S2 may be performed after the central part spinning machining step S26 or the end part spinning machining step S27 in the above-described Manufacturing Method 2.

[0074] Note that although the diameter of the ends are reduced by a spinning machining in the diameter reduction spinning machining steps S8 and S28 in the above-described manufacturing methods 1 and 2, a diameter reduction machining method other than the spinning machining may be used to reduce the diameter of the ends in other embodiments. Examples of such diameter reduction machining methods include a drawing process and an extrusion process using dies, a press forming, and a swaging machining.

[0075] Note that the present invention is not limited to the above-described exemplary embodiments, and modifications, improvements, and so on in which the object of the present invention can be achieved are also included in the scope of the present invention. For example, although the sub-muffler according to the first exemplary embodiment includes a separator, the sub-muffler may include a flow path pipe for guiding an exhaust gas from one end of the tubular body to the other end, such as the flow path pipe 203 (see Fig. 25). In contrast to this, the sub-muffler 201 according to the second exemplary embodiment includes a flow path pipe for guiding an exhaust gas from one end of the tubular body to the other end, the sub-muffler 201 may include a separator for dividing the inner space of the tubular body into a plurality of sections, such as a separator 23 (see Fig. 1). Further, although the tubular body includes a front part, a front end, a rear part, and a rear end in the manufacturing methods, these parts may be disposed in a reversed fashion in the front/back direction.

[0076] From the invention thus described, it will be obvious that the embodiments of the invention may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

[0077] A manufacturing method of a sub-muffler (1, 201) includes a tubular body shaping step (S3), a central part spinning machining step (S5, S7, S26, S27), and a diameter reduction machining step (S8, S28). In the tubular body shaping step (S3), a cylindrical body (2, 202) is formed by rolling a plate material (70). In the central part spinning machining step (S5, S7, S26, S27), the cross-sectional shape of a central part (20, 220) of the cylindrical body (2, 202) is machined into a rectangular shape by performing a spinning machining in which a rotating roller (88) is moved along a rectangular trajectory (T3, T6) while pressing the rotating roller (88) onto the central part (20, 220) of the cylindrical body (2, 208). In the diameter reduction machining step (S8, S28), the diameter of an end (80, 81, 280, 281) of the cylindrical body (2, 208) is reduced.

Claims

1. A manufacturing method of a sub-muffler comprising:

    a tubular body shaping step of rolling a plate material, and thereby forming a cylindrical body;
    a central part spinning machining step of performing a rectangular spinning machining in which a rotating roller is moved along a rectangular trajectory while pressing the rotating roller onto a central part of the cylindrical body, and thereby machining the central part so that a cross-sectional shape of the central part becomes a rectangular shape; and
    a diameter reducing step of reducing a diameter of an end of the cylindrical body.

2. The manufacturing method of a sub-muffler according to Claim 1, wherein in the diameter reducing step, the diameter of the end of the cylindrical body is reduced by performing a circular spinning machining in which the rotating roller is moved along a circular trajectory while pressing the rotating roller onto the end of the cylindrical body.

3. The manufacturing method of a sub-muffler according to Claim 1 or 2, wherein in the central part spinning machining step, the central part is machined so that the cross-sectional shape of the central part becomes a rectangular shape by performing the rectangular spinning step after performing a circular spinning machining in which the rotating roller is moved along a circular trajectory while pressing the rotating roller onto the central part of the cylindrical body.

4. The manufacturing method of a sub-muffler according to any one of Claims 1 to 3, wherein in the central part spinning machining step, the trajectory of the rotating roller is gradually changed from the cross-sectional shape of the central part of the cylindrical body into a rectangular shape.

5. A sub-muffler manufactured by using a manufacturing method of a sub-muffler according to any one of Claims 1 to 4.

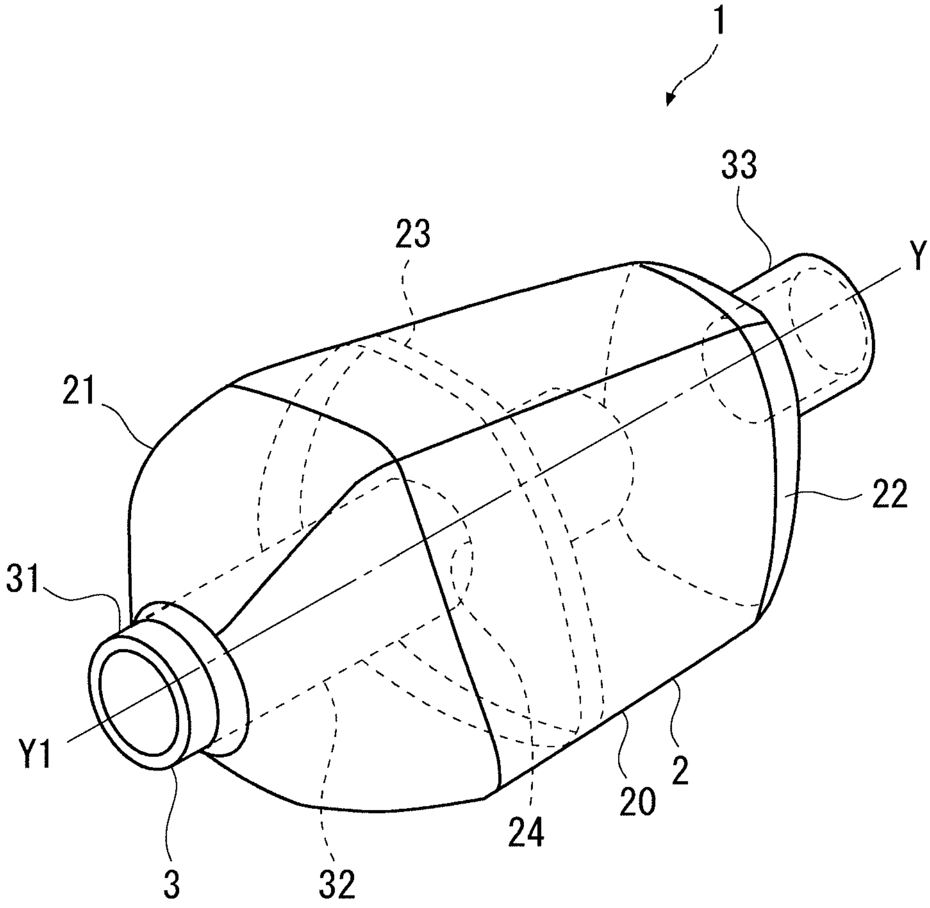
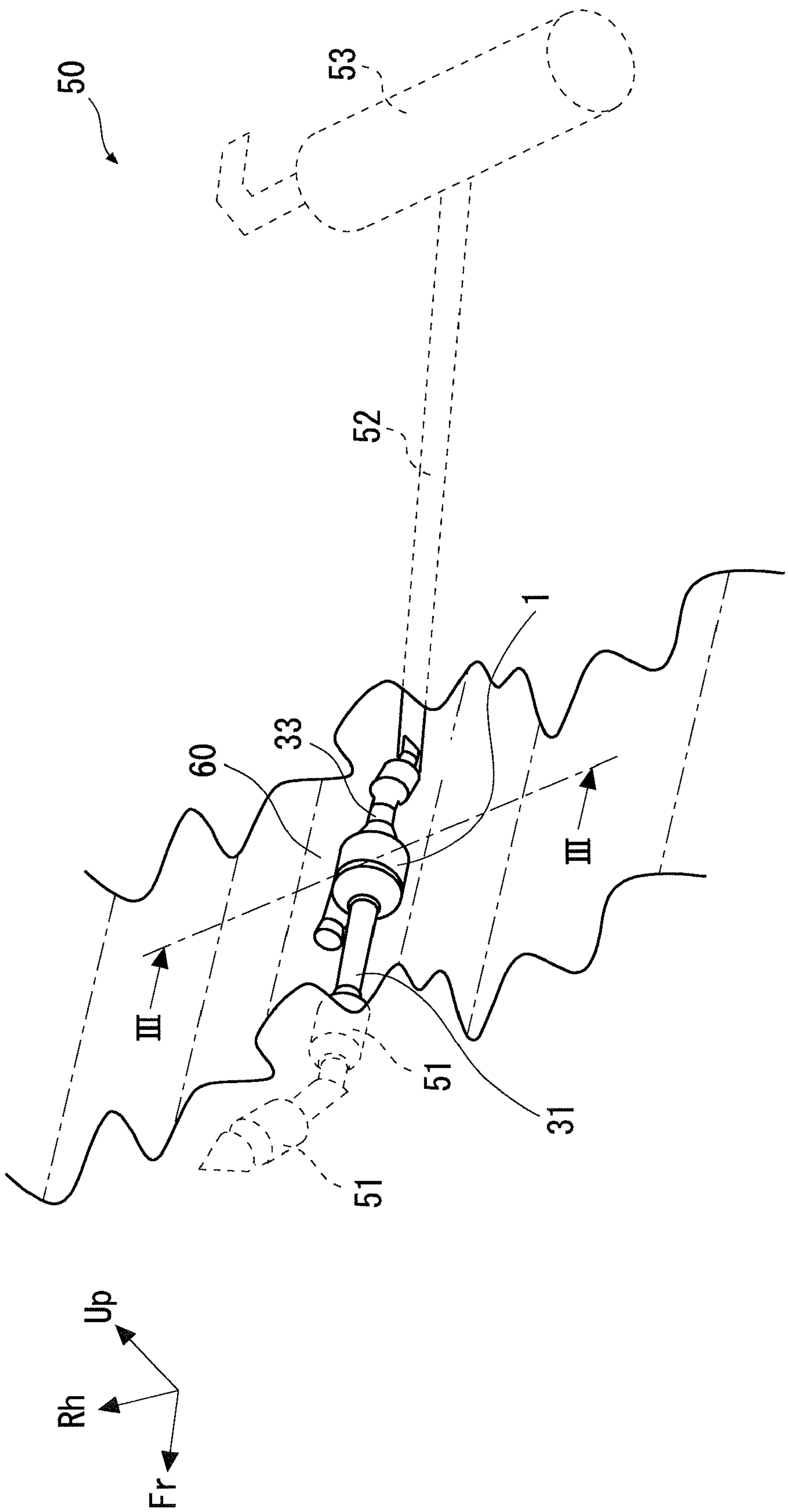


Fig. 1

Fig. 2



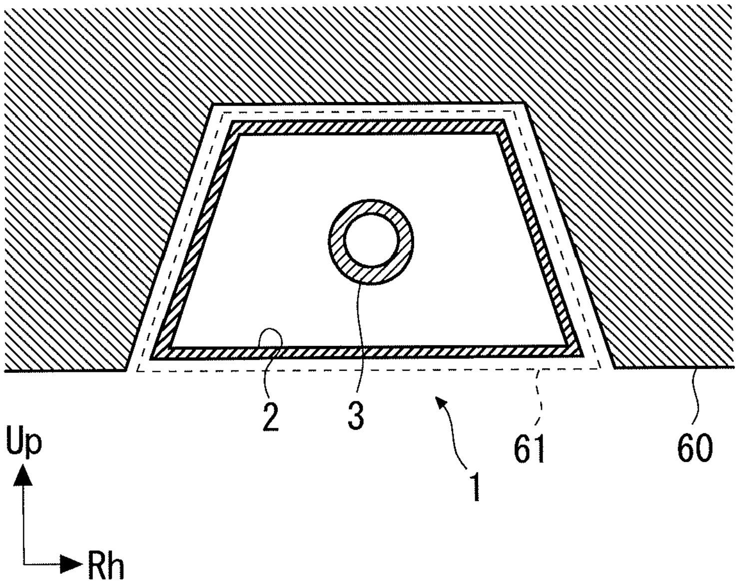


Fig. 3

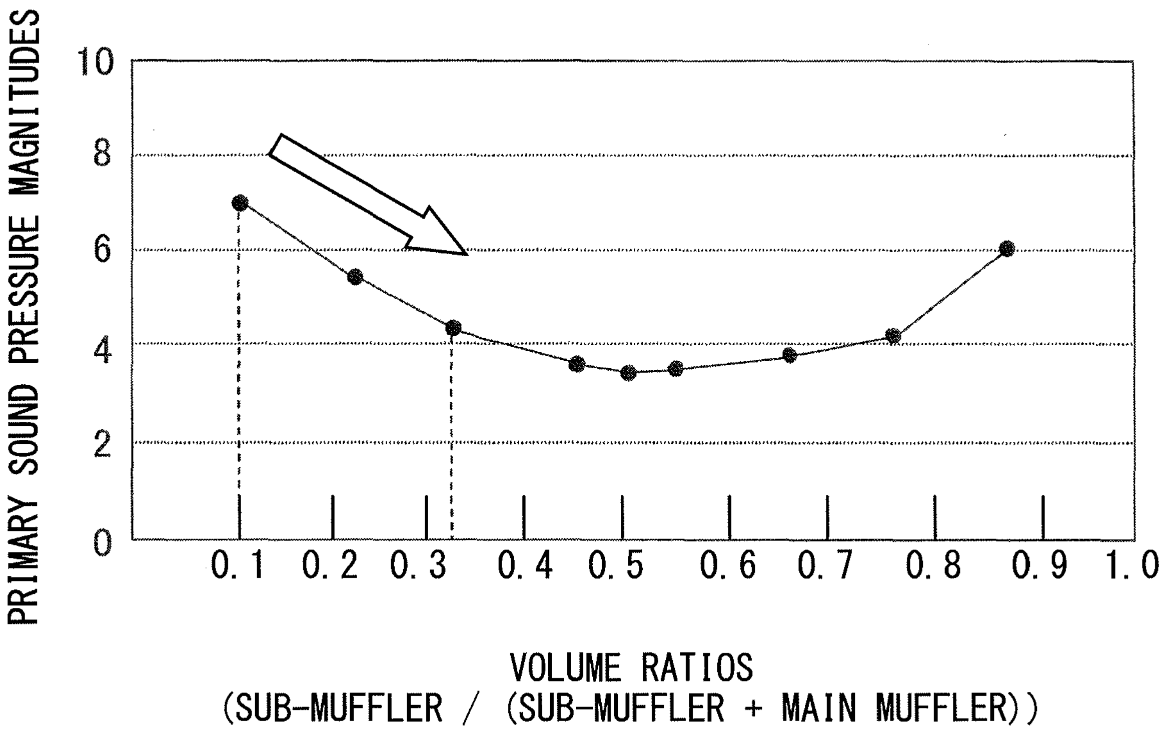
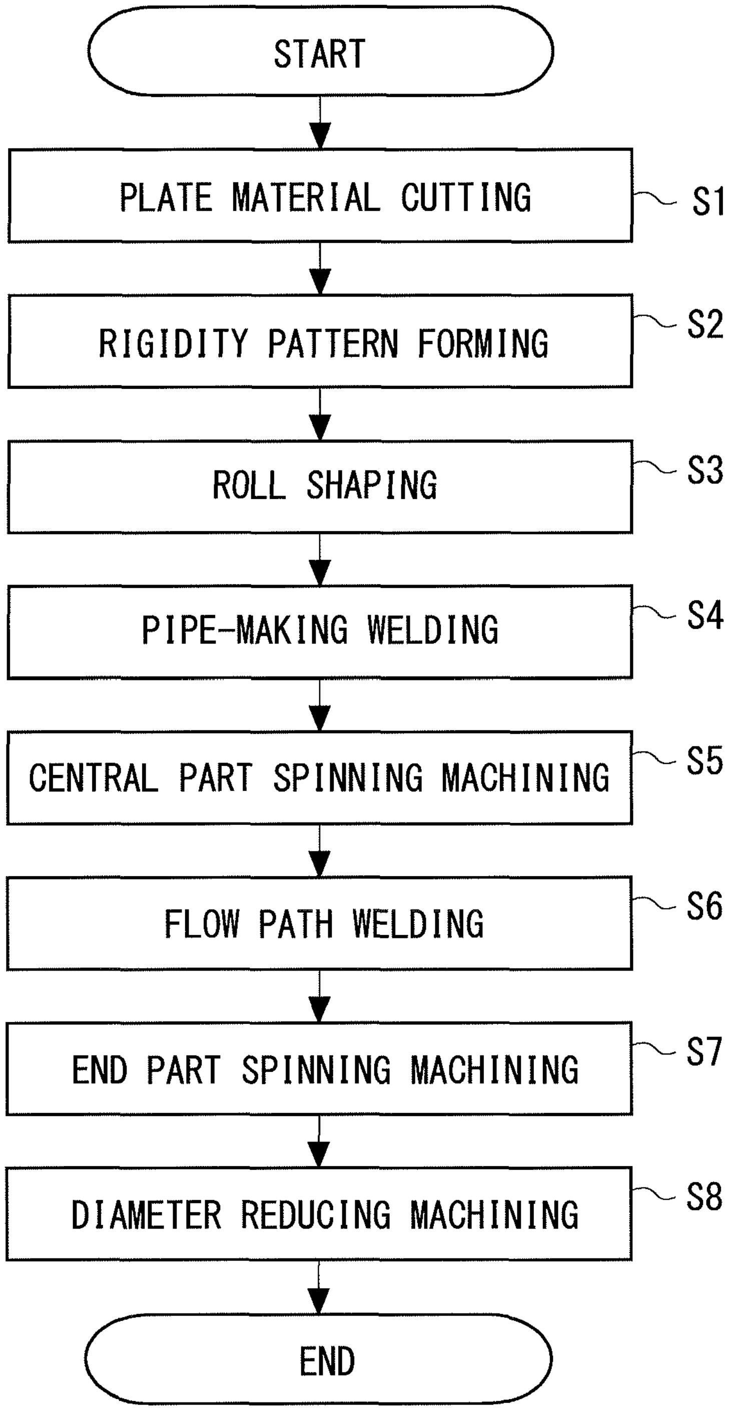

PRIMARY SOUND PRESSURE MAGNITUDES
10
8
6
4
2
0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
VOLUME RATIOS
(SUB-MUFFLER / (SUB-MUFFLER + MAIN MUFFLER))

Fig. 4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S2
ROLL SHAPING
S3
PIPE-MAKING WELDING
S4
CENTRAL PART SPINNING MACHINING
S5
FLOW PATH WELDING
S6
END PART SPINNING MACHINING
S7
DIAMETER REDUCING MACHINING
S8
END

Fig. 5

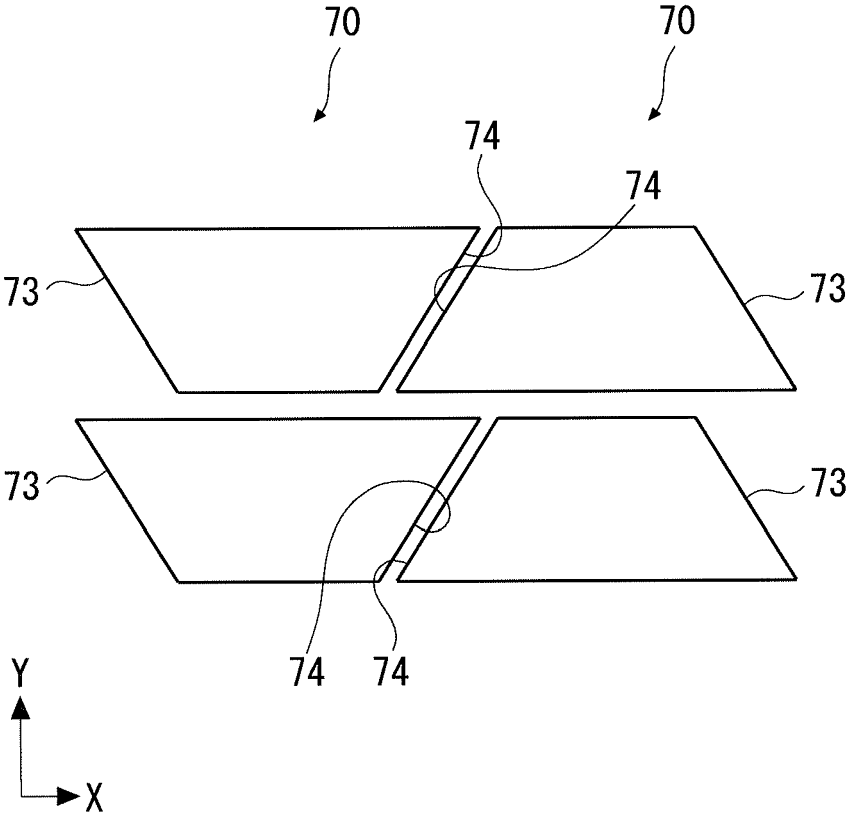


Fig. 6

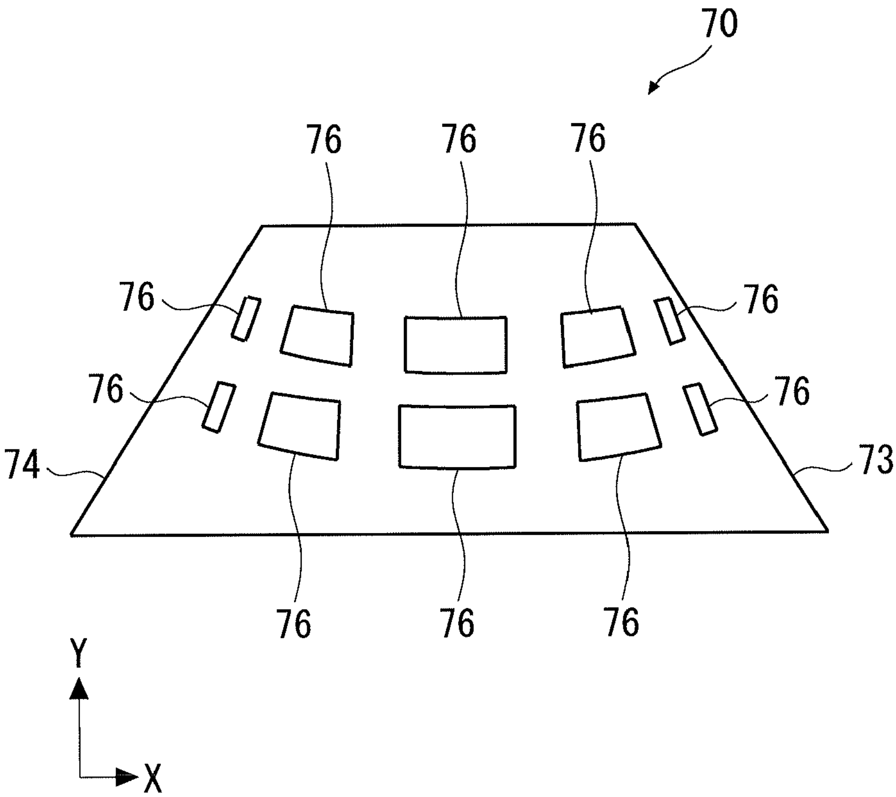
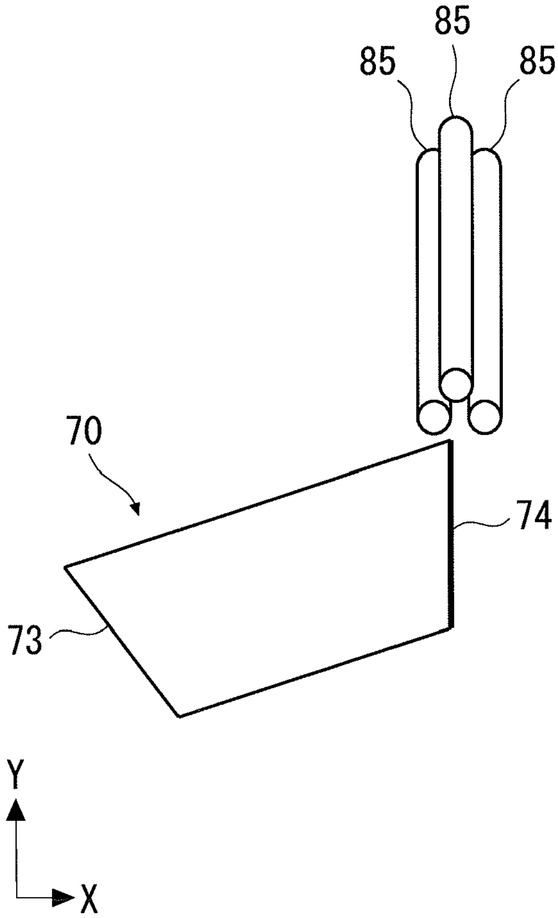


Fig. 7



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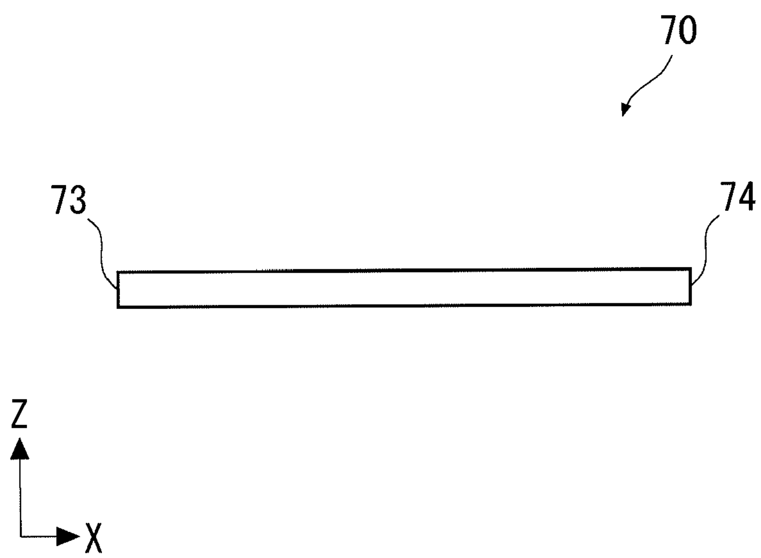

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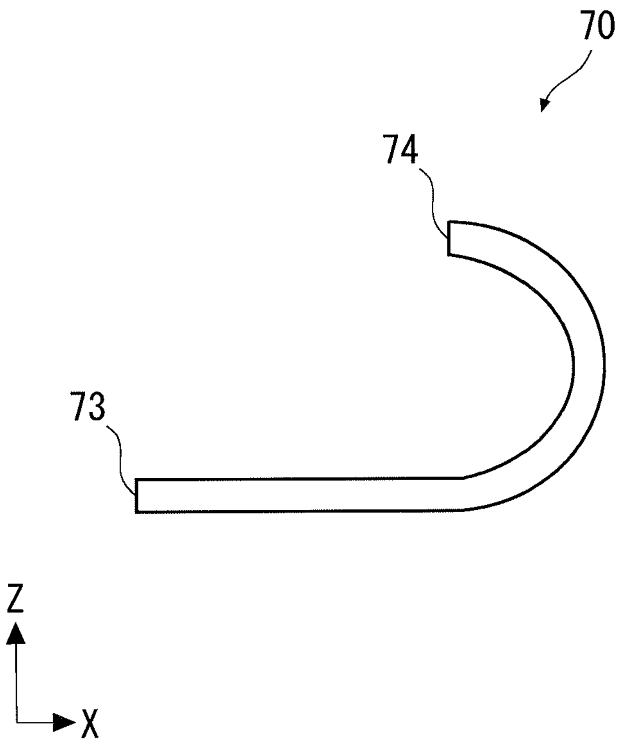
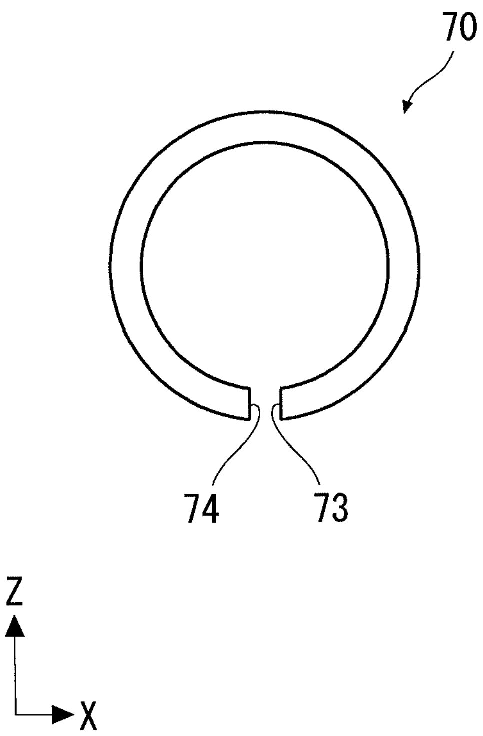


Fig. 10



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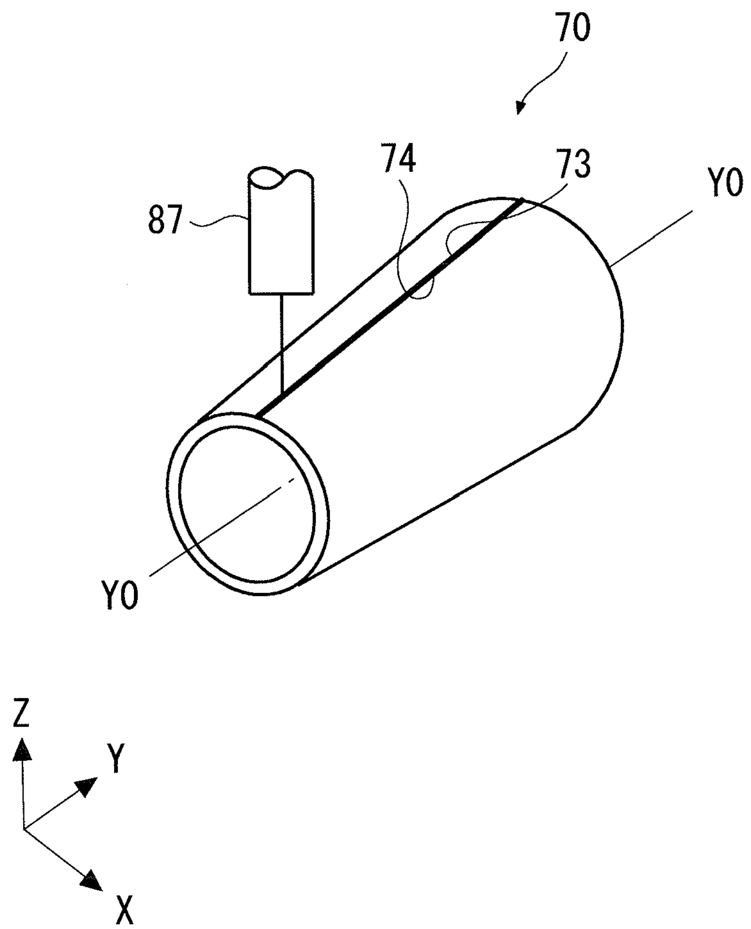

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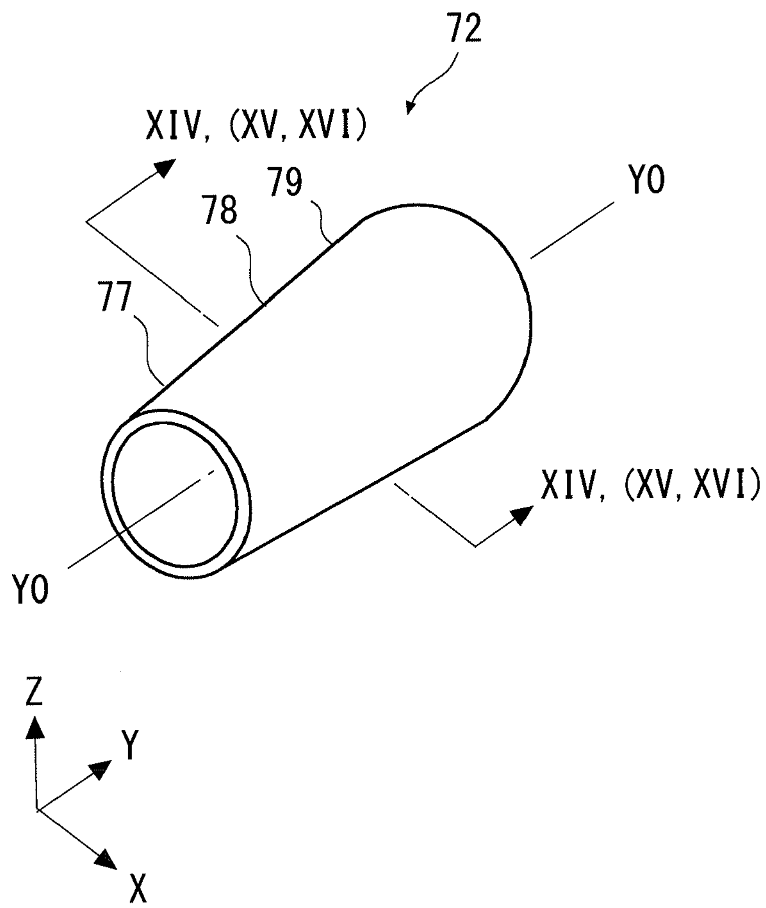


Fig. 13

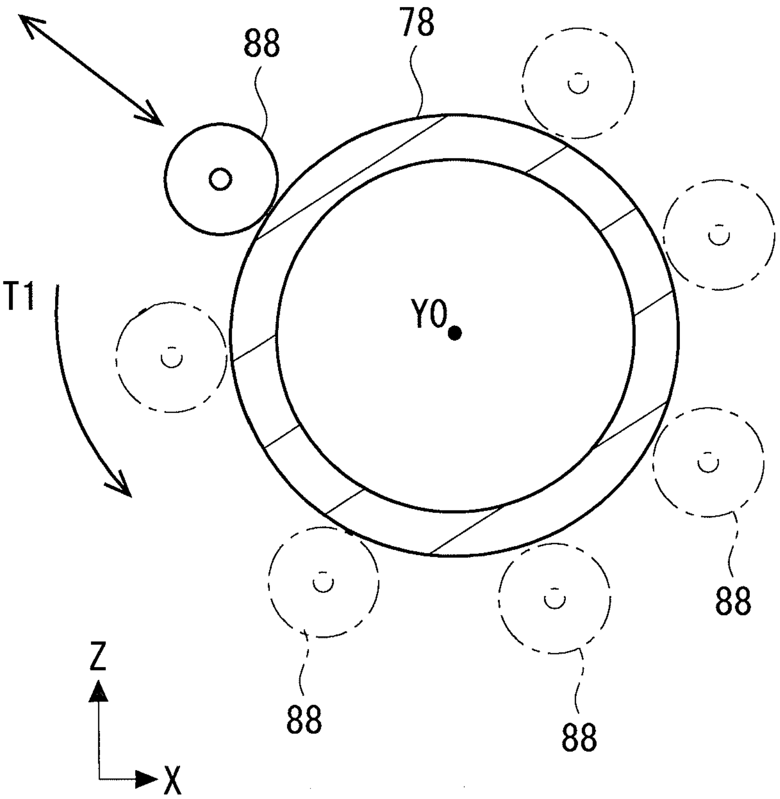
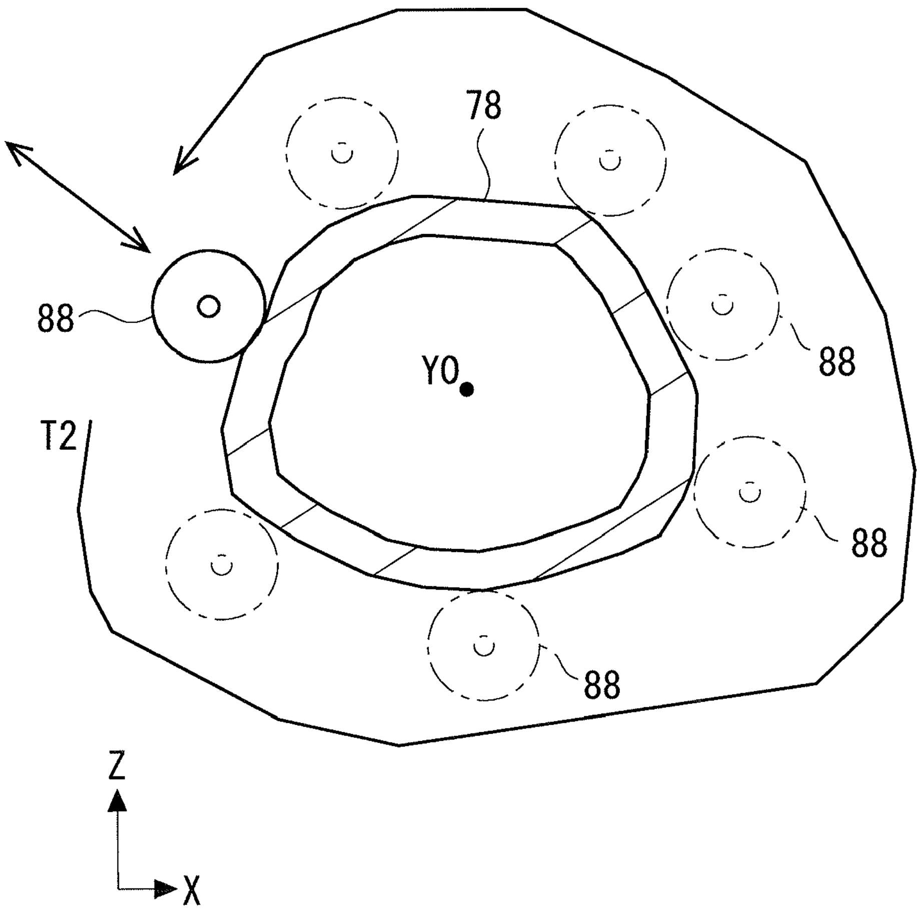


Fig. 14



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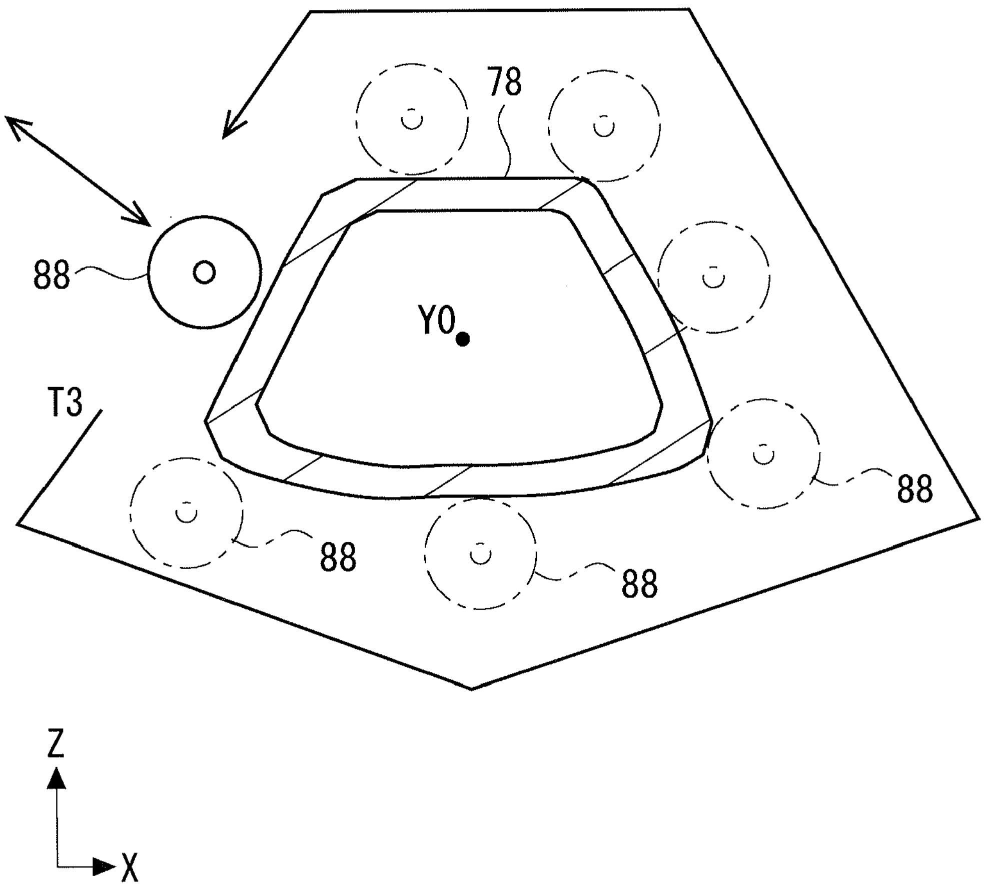
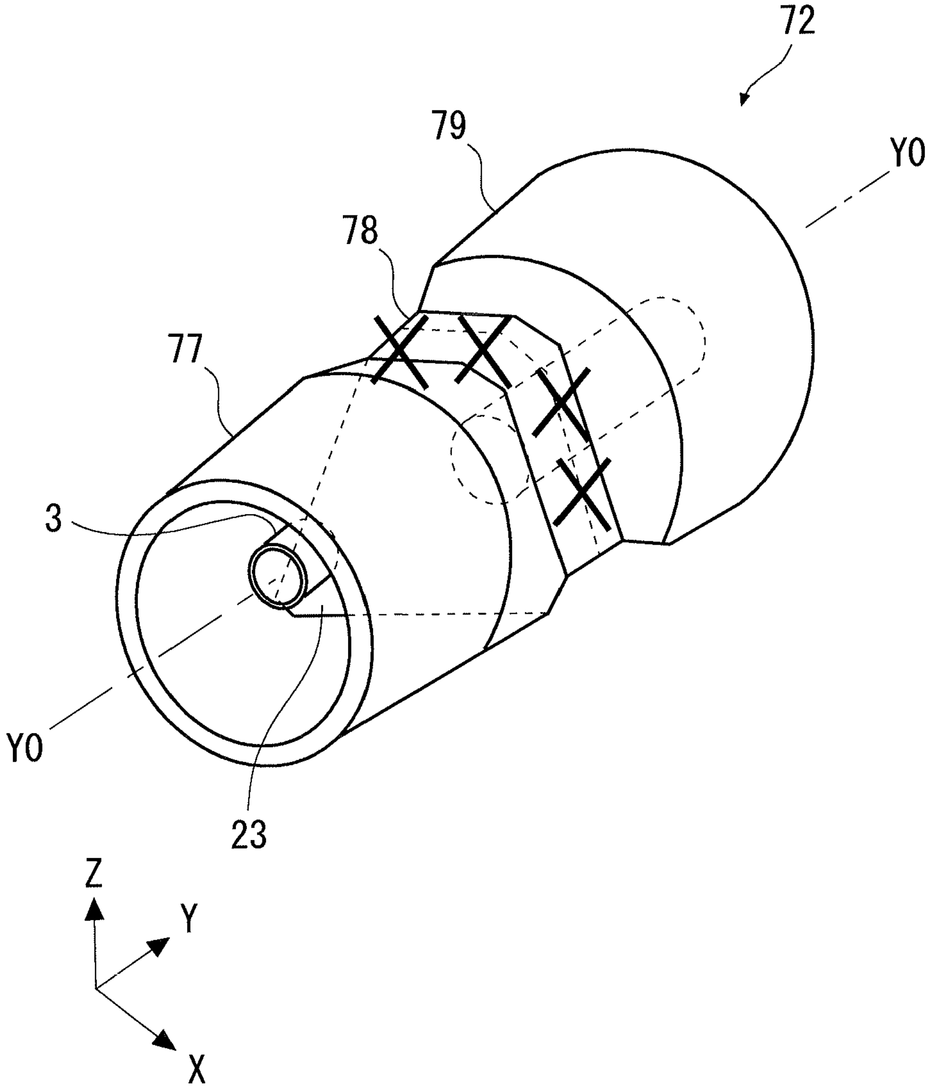


Fig. 16



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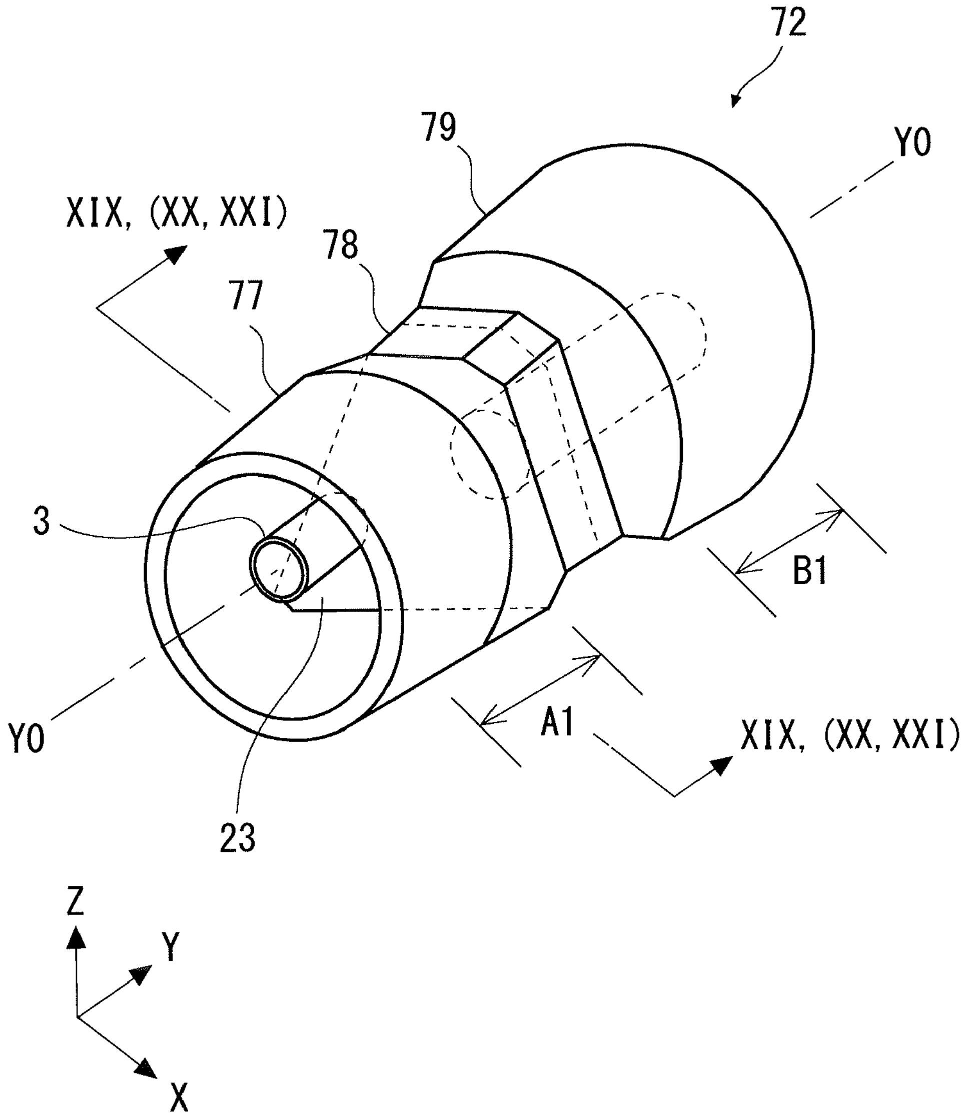

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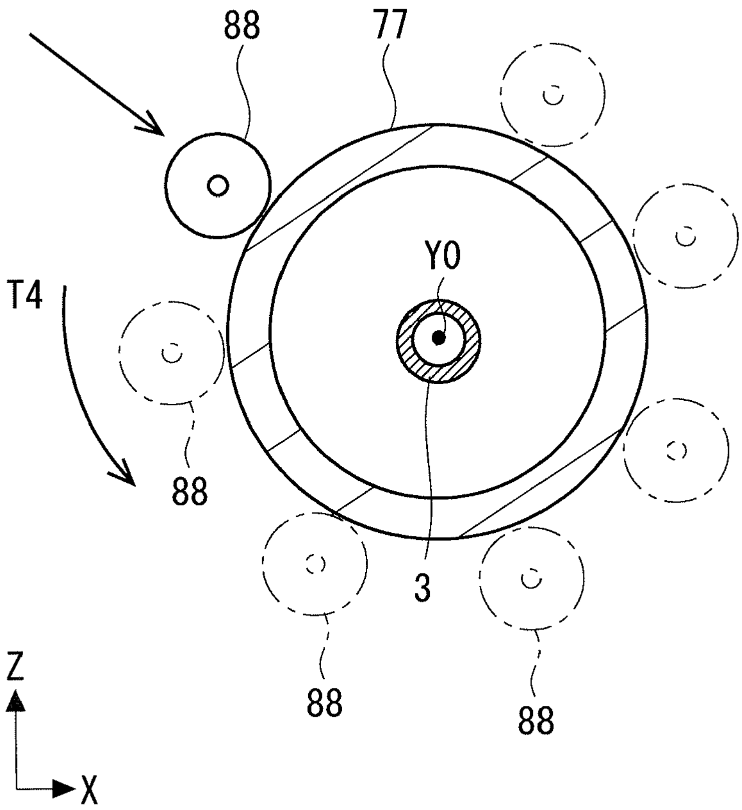

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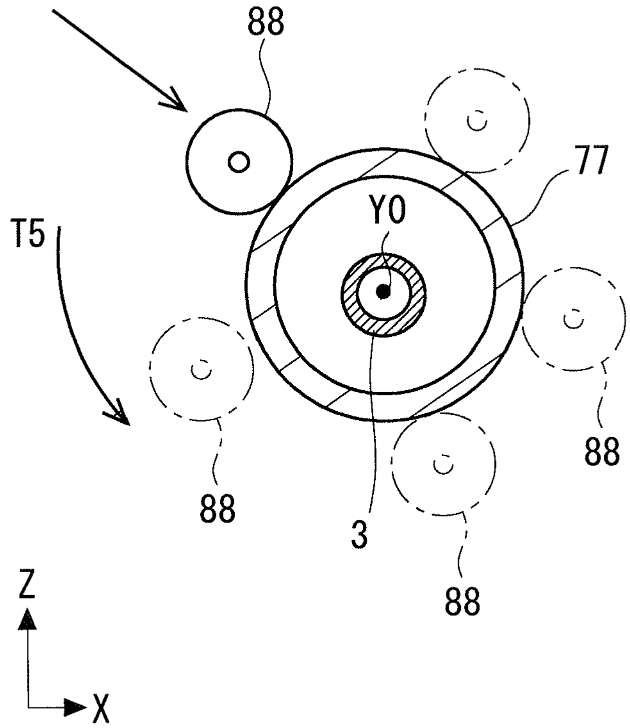
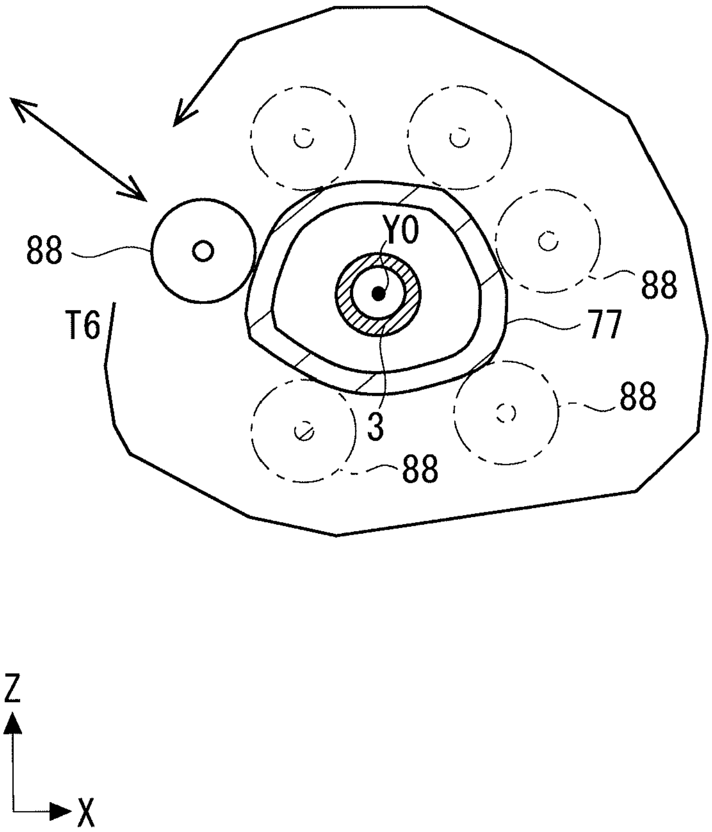


Fig. 20



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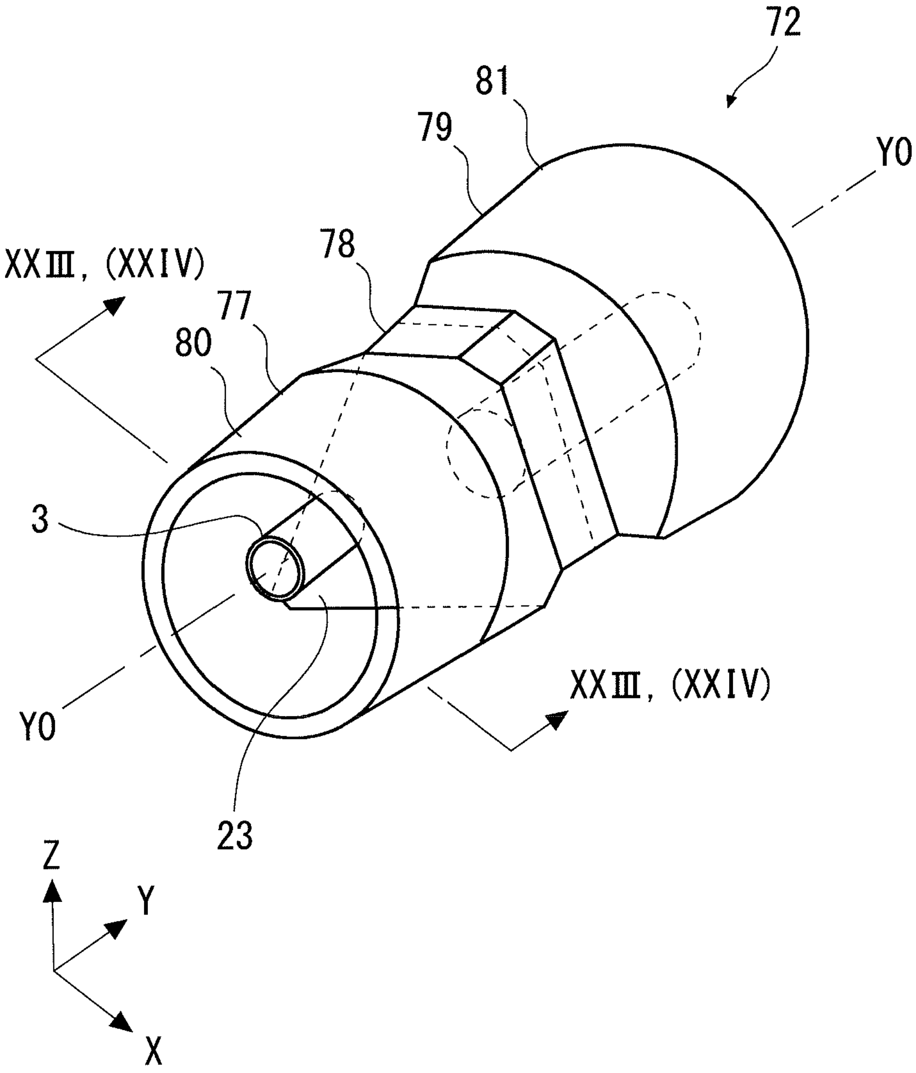

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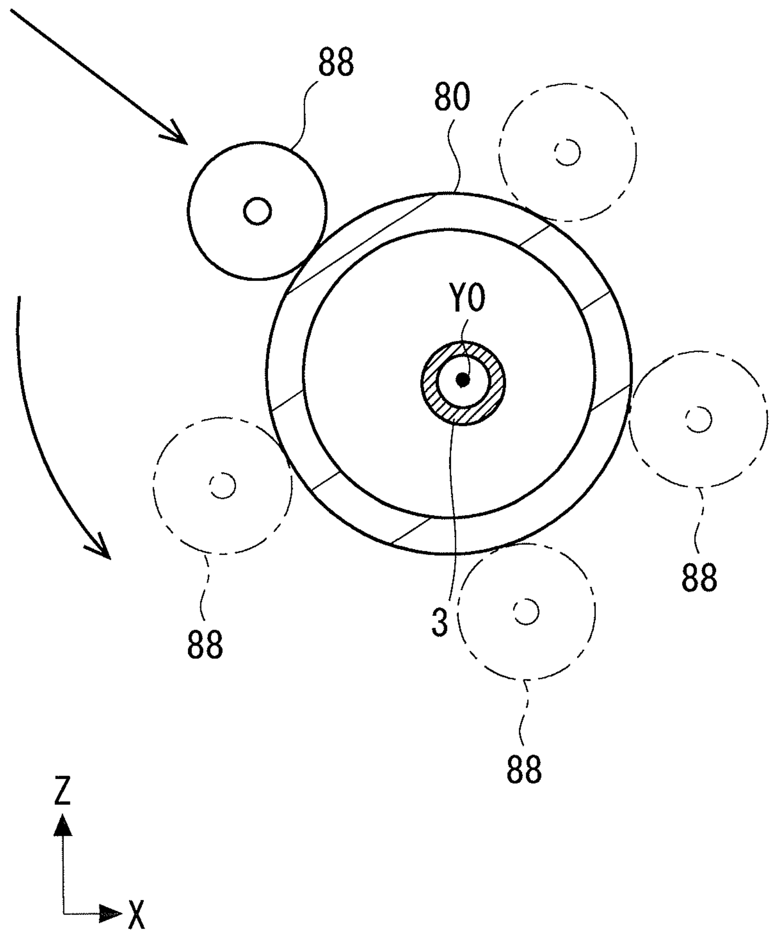


Fig. 23

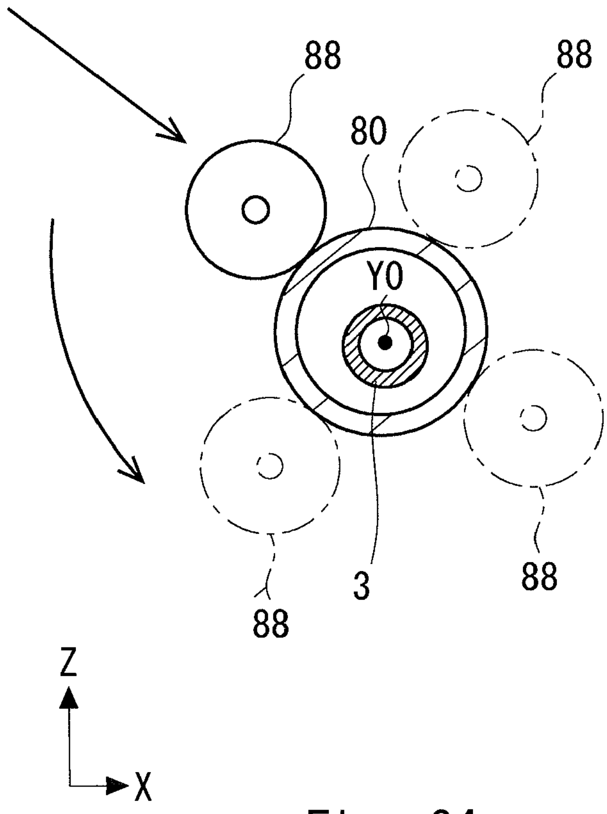


Fig. 24

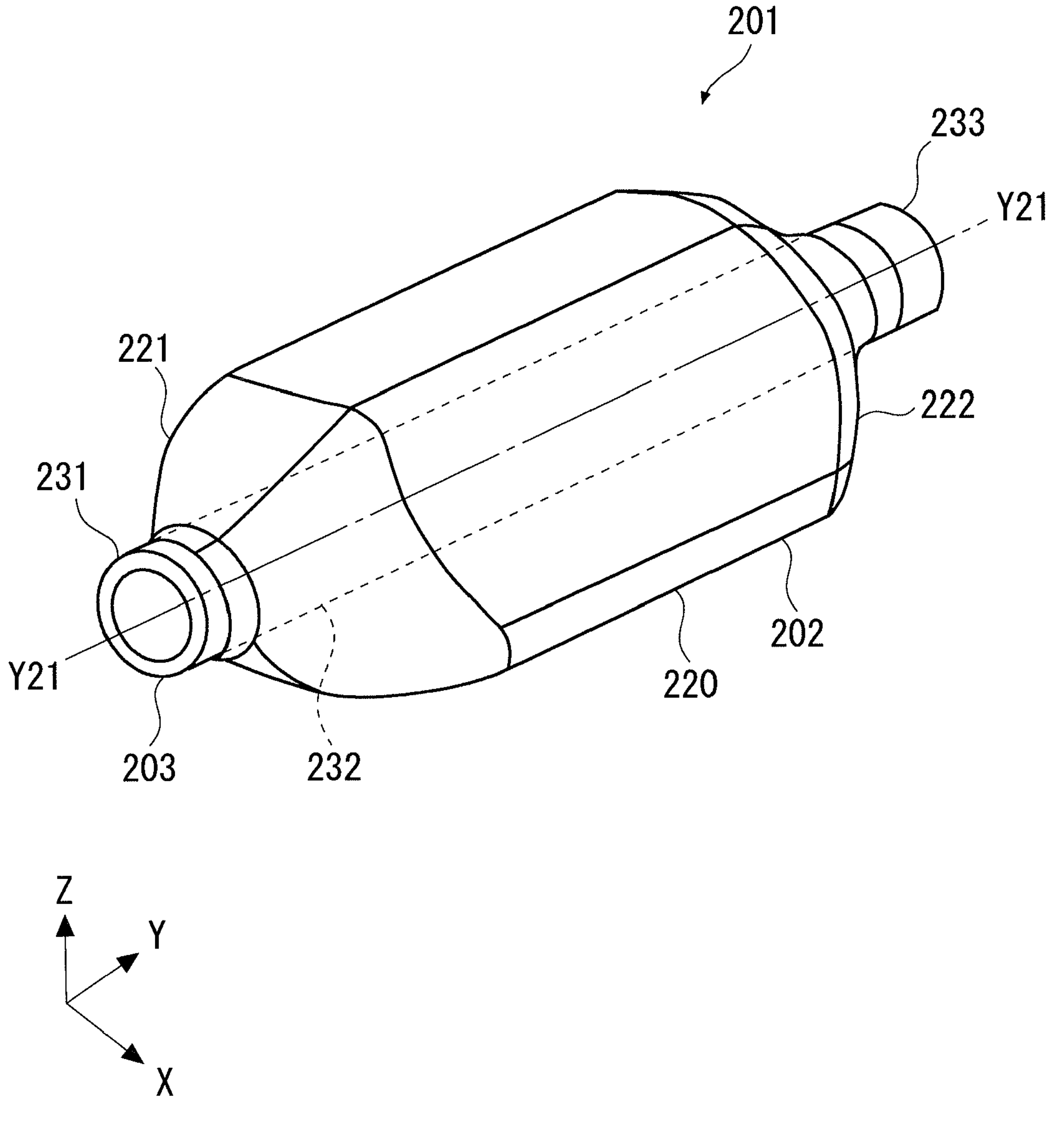
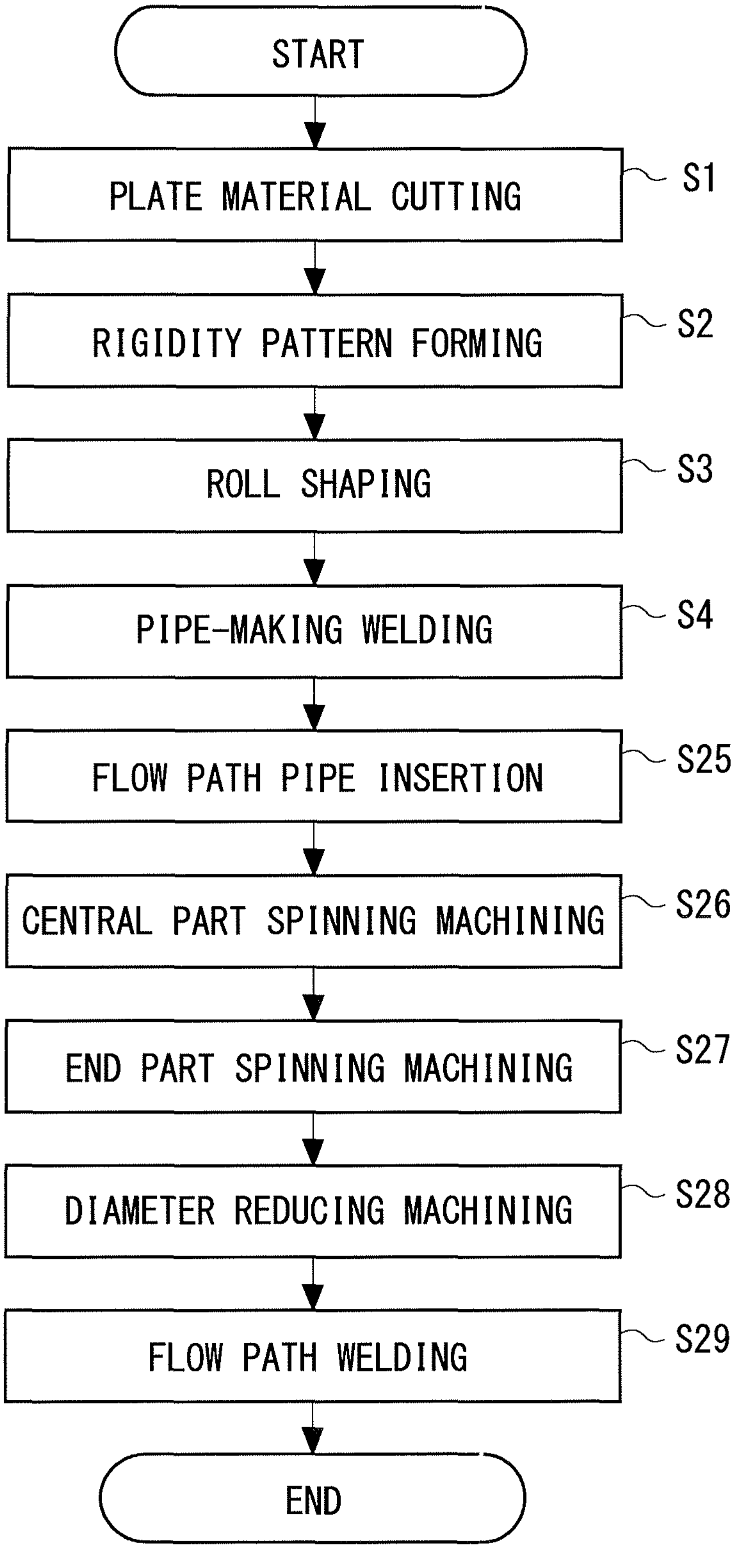


Fig. 25


START
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S1
RIGIDITY PATTERN FORMING
S2
ROLL SHAPING
S3
PIPE-MAKING WELDING
S4
FLOW PATH PIPE INSERTION
S25
CENTRAL PART SPINNING MACHINING
S26
END PART SPINNING MACHINING
S27
DIAMETER REDUCING MACHINING
S28
FLOW PATH WELDING
S29
END

Fig. 26

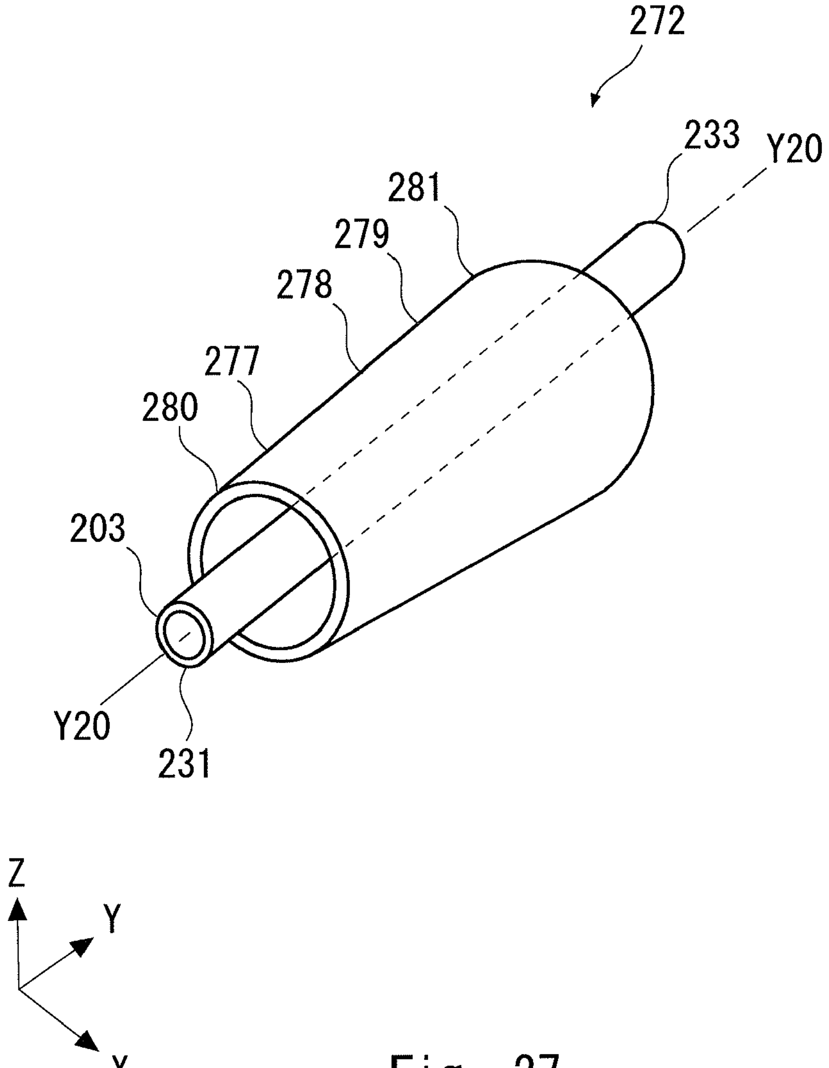

Fig. 27

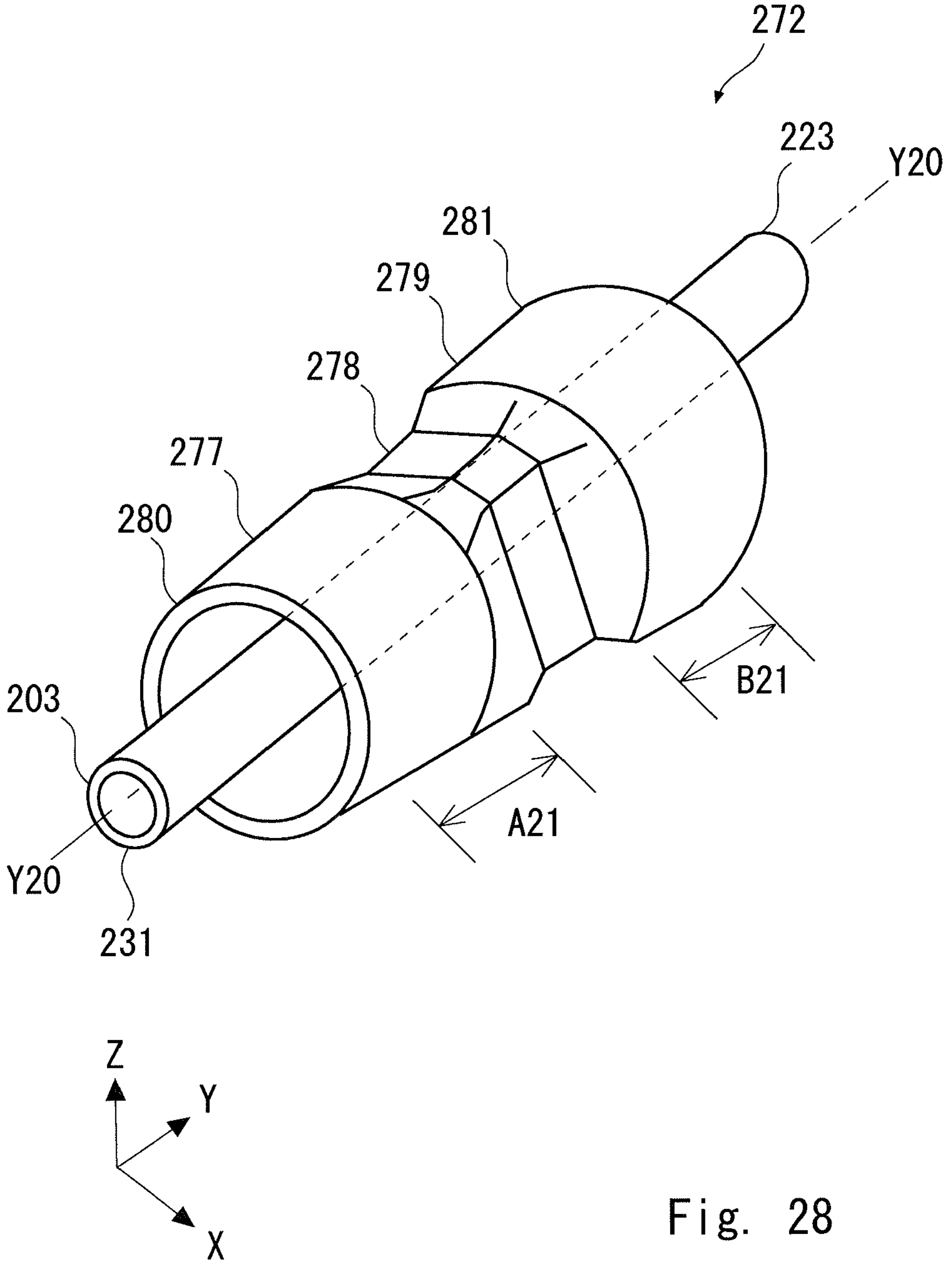

Fig. 28

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EUROPEAN SEARCH REPORT

Application Number
EP 15 16 6590

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 1 245 303 A2 (SAKAMOTO IND CO LTD [JP]) 2 October 2002 (2002-10-02) * paragraphs [0002] - [0006]; figures 1,2 * * paragraph [0018]; figures 3,6 * -----	1-5	INV. B21D22/14
Y	JP 2004 243354 A (JFE STEEL KK; SANGO CO LTD) 2 September 2004 (2004-09-02) * paragraphs [0001], [0014], [0015]; figures 2,3,4 * -----	1-5	

TECHNICAL FIELDS SEARCHED (IPC)

F01N
B21D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 September 2015	Kolland, Ulrich

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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15-09-2015

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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