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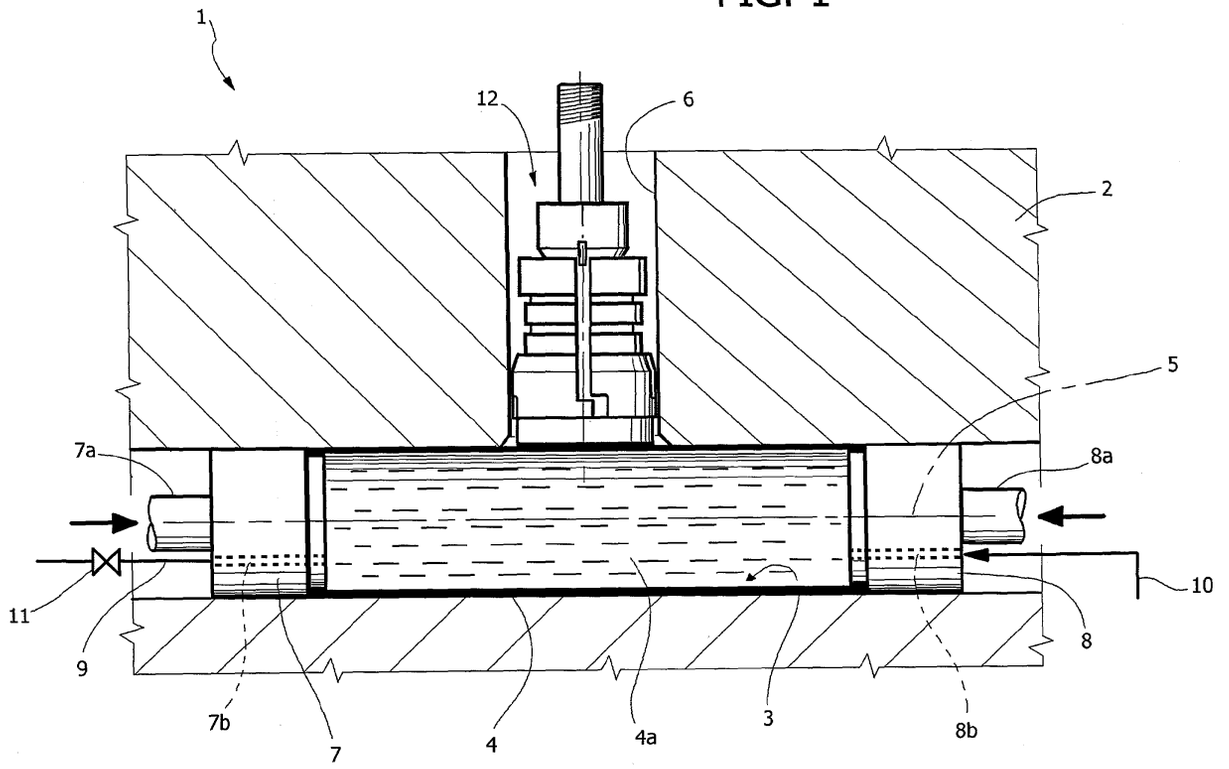
(54) Method for hydroforming a hollow body having at least a branch portion, and apparatus used for carrying out this method

(57) A method and an apparatus for hydroforming a hollow body (4) with at least a branch portion (24) includes a step of hydroforming a protrusion on a wall of a hollow body, which protrusion is for defining the branch portion, a step of shearing the end wall (22a) of the protrusion (22) and a step of outwardly deforming the circumferential edge of the opening (22b) formed by the shearing step, all the above mentioned steps being performed within a hydroforming die.

FIG. 1



EP 1 579 931 A1

Description

[0001] The present invention relates to methods for hydroforming hollow bodies. Such methods have been known and used since long. They provide hydroforming of hollow bodies, such as tubular elements of metal material, within a cavity of a hydroforming die, by applying a fluid (for example water) under pressure within the hollow body, in order to expand the body wall outwardly against the surface of the die cavity.

[0002] A typical application of hydroforming methods is that of the manufacture of metal tubular elements for exhaust pipes of motor-vehicle engines. Among the different solutions known, it has already been proposed in the past to form, for instance, a metal tubular element having any desired configuration (for instance a straight, curved or S-shape configuration) with a branch portion extending from the tubular body. Structures of this type are for instance required to form the exhaust manifold of the engine of a motor-vehicle. By obtaining a one-piece tubular element with a branch portion, it is possible to avoid welding operations which are difficult to carry out and involve losses in time and manufacturing costs.

[0003] Therefore, it has already been proposed in the art to carry out a method for hydroforming a hollow body with at least a branch portion, wherein a hydroforming die is provided, having a forming cavity. A hollow blank body, originally lacking of the branch portion, is placed within the die cavity and pressurized fluid is fed within the hollow blank body in order to cause formation of a blind bottomed protrusion on awall of the hollow body, which protrusion is expanding in a corresponding portion of the die cavity. At the end of the hydroforming method, the hollow body is extracted from the hydroforming die and subjected to a separated shearing operation of the blind bottom in order to obtain an opening at the end of the protrusion.

[0004] It is also known in the art to provide a metal tubular body with a lateral opening, by carrying out a shearing operation in the wall of the tubular body, which is required to obtain the above mentioned lateral opening, within a hydroforming die (US 6 305 201 B1). In this known solution, the pressure of the fluid within the tubular body during the hydroforming process is used to promote the shearing operation which is carried out by a punching member slidably mounted in the hydroforming die and radially pushed towards the wall to be sheared. In this known solution, the shearing operation performed by this punching member causes the formation of a neck portion around the lateral opening, extending inwardly of the tubular element, and constituting thereby an obstacle to the flow which is to run through the tubular body during its future use.

[0005] The main purpose of the present invention is to propose a new method for forming a hollow body provided with a branch portion, which is simpler, easier to carry out and quicker than the methods proposed in the known art.

[0006] In view of achieving this purpose, the object of the invention is a method for hydroforming a hollow body with at least one branch portion, wherein:

- a hydroforming die is provided, having a forming cavity,
- a hollow blank body, originally lacking of the branch portion, is arranged within the die cavity,
- fluid under pressure is fed within the hollow blank body, so as to cause formation of an outwardly extending protrusion on a wall of the hollow body, which protrusion expands in a corresponding portion of the die cavity, said method being characterized in that:

- within said portion of the die cavity where said protrusion expands, a plunger is slidably mounted which defines a front wall against which said protrusion is pressed and which is moved backwardly during the forming process of the protrusion by applying a controlled pressure thereon,
- the aforesaid plunger is shaped so as to perform also the function of a shearing punching member,
- once the aforesaid protrusion has been formed until a blind bottomed branch portion is defined, the above-said plunger-punching member is pushed radially against it in order to shear said bottom obtaining thereby an opening at the end of the branch portion.

[0007] Therefore, in the method according to the invention, the shearing operation required for removing the blind bottom of the protrusion formed by hydroforming, is carried out within the hydroforming die. For this reason, it is not necessary to remove the formed piece from the die to carry out the shearing operation in a different place and with a different tool. This makes the operations necessary to obtain the end piece simpler and easier, considerably reducing manufacturing times. At the same time, since said plunger-punching member acts on the bottom wall of a protrusion extending outwardly of the body, the drawback found in the solution of US 6 305 201 B1 does not occur.

[0008] It is to be considered that during the end step of the method according to the invention, in which the plunger/punching member causes the shearing of the end wall of the protrusion, the circumferential edge of the opening which is thereby defined usually results radially deformed inwardly, whereby it requires an end operation for deformingit radially outwardly, in order to give the component the desired geometry, within the required manufacturing tolerances.

[0009] Preferably, according to the invention, also such end step for outwardly deforming the edge of the opening of the branch portion of the hollow body and for calibrating the opening dimension is carried out within the same hydroforming die. For this purpose, according to the invention, said plunger/punching member, once

its shearing stroke towards the interior of the hollow body is completed, is moved in the opposite direction and used as a chuck for radially deforming the opening edge outwardly and press it against the wall of the die cavity.

[0010] Still according to a preferred feature, in order to ensure the optimal execution of this end processing step, the plunger/punching member has a radially extendable section and actuating means are provided to cause this expansion at the end of the shearing stroke of the plunger/punching member inwardly of the hollow body, and prior to the return stroke of the plunger/punching member, which causes expansion and calibration of the opening edge of the branch portion.

[0011] Due to this feature, the portion of the plunger/punching member which causes the outwardly deformation of the opening edge is in a retracted, non operating condition during the shearing stroke and it moves into its operating expanded configuration just before the start of the return stroke. Thanks to such return stroke, the branch portion is calibrated in order to have a diameter precisely corresponding to that of the corresponding portion of the die cavity.

[0012] It is also a subject of the invention the apparatus used for carrying out the above described method and the plunger/punching member with an expandable section which is used therein.

[0013] A further feature of the invention consists in that the above plunger/punching member has a magnetic or magnetizable front head, in order to retain on it the shearing operation scrap.

[0014] Further features and advantages of the invention will be clear from the following description, with reference to the enclosed drawings which are given as not limitative example, wherein:

figure 1 is a sectional diagrammatic view of a hydroforming die for carrying out the method according to the invention,

figures 2-5 show a detail of figure 1 in different stages of the method according to the invention, and

figures 6, 7 are an exploded perspective view and a sectional view of one embodiment of the plunger/punching member used in the method according to the invention.

[0015] In figure 1, numeral 1 generally designates the apparatus used for carrying out the hydroforming method according to the invention. Numeral 2 is a hydroforming die illustrated only diagrammatically in the drawings. The die 2 includes a cavity 3 wherein a tubular steel element 4 is placed, originally having a cross-section of constant shape and size along the full-length of the tubular element 4.

[0016] Constructive details of the die 2 are not illustrated, as they can be carried out in any known way. Such details, taken alone, do not lie within the scope of the present invention and their elimination from the drawings makes these latter of prompt and easy understanding. Obviously, according to the conventional art, the die 2 consists in at least two parts that can be opened among them to allow the introduction and the extraction of the tubular element within the die.

[0017] The cavity 3 of the hydroforming die 2 show a cylindrical main portion, which axis is indicated by 5, and an additional portion 6 constituted by a cylindrical cavity radially branching with respect to the axis 5 from the cylindrical main portion of the cavity 3. The portion 6 of the hydroforming cavity 3 is for allowing a radial protrusion to form on the wall of the tubular element 4. Of course, although the drawings, show a tubular element 4 in form of a straight cylinder by way of example, it would be equally possible to provide a tubular element 4 and correspondingly a cavity 3 having a complex form, for example a configuration with one or more curves.

[0018] Within the cylindrical cavity 3 of the die, two opposite plungers 7, 8, which are schematically illustrated in the drawings, are slidably mounted, whose stems 7a, 8a are driven through actuating means of any type (usually fluid actuator means) in order to subject the tubular element 4 to a mechanical compression in the direction of its main axis 5. For this purpose, plungers 7, 8 are in front contact with the end surfaces of the tubular element 4.

[0019] Moreover, the two plungers 7,8 have axial passages 7b,8b which put in communication the space 4a inside the tubular element 4 respectively with an outlet pipe 9 for enabling the hydroforming liquid (for example water) to leave space 4a and an inlet pipe 10 (only diagrammatically illustrated) for feeding the pressurized fluid required for carrying out the hydroforming operation within the space 4a. In the outlet pipe 9 a valve 11 is interposed.

[0020] Within the portion 6 of the hydroforming cavity 3 a third plunger 12 is further slidably mounted, which structure and function will be described in more detail in the following. Plunger 12 is also subjected to actuator means of any known type (typically fluid means) which are able to drive it in any one of its two moving directions, by applying a predetermined force. Preferably, the actuating means of the two plungers 7, 8 and of the third plunger 12 are controlled by an electronic control circuit according to a predetermined program, in order to carry out the operation cycle that will be described in more detail in the following.

[0021] Referring now to figures 6,7 the third plunger body 12 consists in four angular sectors 13 defining at their ends two conical surfaces 14, 15 in contact with a conical surface 16 and a conical surface 17 respectively of two end elements 18, 19 of the plunger 12. The end element 18 is rigidly connected with a stem 19 which axially passes through the four sectors 14 and has a threaded end on which the annular body of the end element 19 is screwed. Actuator means of any type (not shown) are contemplated to give a rotation motion to stem 20 with respect to the end element 19, in order to

cause the two end elements 18, 19 to move towards each other. Due to the mutual engagement among the conical surfaces 14, 16 and 15, 17, this movement, causes an outward radial movement of the fours sectors 13, which determines an expansion of the plunger portion 12 interposed among the two end elements 18 and 19.

[0022] Figure 7 illustrates the assembly in the expanded condition.

[0023] At the plunger 12, spring means are further provided for pushing sectors 13 towards their radially inward position, corresponding to the minimum diameter configuration of the plunger 12. These spring means may consist, for example, in one or more elastic rings 21 placed around the four sectors 13.

[0024] Thanks to the above-described structure, the plunger 12 is capable to assume a smaller diameter configuration or an expanded diameter configuration.

[0025] A further important feature of the plunger 12 resides in that the front circumferential edge 18a of the end element 18 is shaped like a cutting edge, in such a way that the plunger 12 may also function as a shearing punching member to make a circular opening in the metal body wall 4.

[0026] In the following, the different steps of the method according to the invention will be now described.

[0027] In the initial condition, the tubular element 4 has, as already indicated, a tubular conformation with a section of constant shape and size along the full-length thereof. The tubular element 4 is placed within the hydroforming die 2 in the condition illustrated in figure 1.

[0028] The plunger 12 is arranged with its front end surface in contact with the tubular element wall 4, as illustrated in figure 1. As from this condition, the hydroforming method is started by feeding a high pressure fluid (water) within the space 4a. At the same time of the water action, an axial mechanical compression, as already indicated, is also applied to the tubular element 4 by the two opposite plungers 7, 8 which are driven to move one towards the other.

[0029] The joined action of the two plungers 7, 8 and of the pressurized water within the space 4a upon the tubular element wall 4 causes the forming of a protrusion 22 (figure 2) on the tubular element wall 4 expanding outwardly in the portion 6 of the hydroforming cavity. During this step, the third plunger 12 is progressively moved backwardly, that is e moved away from the main portion of the hydroforming cavity 3, to allow the formation of the protrusion 22. The moving back of the plunger 12 is however performed by applying to such plunger a controlled pressure in order to provide a resistance to the growing of the protrusion 22 sufficient to form at last a desired configuration (illustrated in the figure 3) with a bottom wall 22a which is substantially planar.

[0030] The above mentioned backward movement of the plunger 12 takes place with the plunger 12 in its minimum diameter configuration.

[0031] Once the protrusion 22 has been formed as illustrated in figure 3, thanks to the joined action of the hydroforming water and opposite plungers 7, 8, and thanks to the controlled resistance offered by plunger 12, this latter is advanced in the direction of wall 22a, by keeping it in its minimum diameter configuration. In this step, the plunger 12 is used as a shearing punching member. The pressure exerted by plunger 12 against the wall 22a, together with the backpressure exerted by the hydroforming water against the internal surface of the protrusion 22, allows the shear edge 18a of the punching member to cut-off the wall 22a by obtaining a circular opening 22b (figure 3). The wall portion 22a thus removed remains adherent to the front surface of the plunger/punching member 12, because the end portion of the plunger 12 comprises a permanent magnet or a portion magnetizable by a solenoid (not illustrated). Therefore, the scrap does not fall freely inside the tubular element, but remains adherent to the plunger 12.

[0032] Once the shearing operation has been carried out, the plunger 12 is brought in its expanded diameter configuration and then moved again in a radially outward direction. In this step, a portion 23 (figures 6, 7) of the external surface of the plunger/punching member 12 comes into contact with the internal surface of the circumferential edge of the opening 22b by pressing it again against the portion 6 of the cavity 3, in order to obtain the forming of a tubular portion 34 branching from the tubular element 4, with a regular cylindrical configuration, with the desired size.

[0033] Therefore, thanks to the method according to the invention, when the hydroforming die is finally opened, the element obtained is a finished hollow body, such as the tubular element of the illustrated example,, with a branch tubular portion already having its end opening 22b and with a geometry corresponding to the requirements. It is not then necessary to subject the element coming out from the hydroforming die to further operations or processes.

[0034] It is therefore apparent that by the method and the apparatus according to the invention, within the same hydroforming die, the hydroforming of the component as well as the shearing of the end wall of the branch portion, as well as the calibration of the opening obtained in the branch portion can be carried out. This means that, thanks to the invention, a ready for the assembly component may be provided with a single operation.

[0035] Naturally, without prejudice to the principle of the invention, constructive details and embodiments could broadly change with respect to what has been discussed and illustrated by way of example.

[0036] It is especially apparent that the hollow body configuration may be of any type, and in particular may be a complex configuration other than the one of the cylindrical tubular element here illustrated by way of example. Moreover, also the branch portion configuration may be different and may include, for instance, a curved portion. Further, the invention is also applicable when

multiple branch portions have to be formed on a same hollow body, in which case it is necessary to provide a plunger/punching member for each of these portions within the hydroforming die.

Claims

1. Method for hydroforming a hollow body (4) with at least one branch portion (24), wherein:

   - a hydroforming die (2) is provided, having a forming cavity (3),
   - a hollow blank body (4), originally lacking of the branch portion (24), is arranged within the die cavity (3),
   - fluid under pressure is fed within the hollow blank body (4), so as to cause formation of an outwardly extending protrusion (22) on a wall of the hollow body (4), which protrusion expands in a corresponding portion (6) of the die cavity (3), said method being **characterized in that**:

   - within said portion (6) of the die cavity (3) where said protrusion (22) expands, a plunger (12) is slidably mounted which defines a front wall against which said protrusion (22) is pressed and which is moved backwardly during the forming process of the protrusion by applying a controlled pressure thereon,
   - the aforesaid plunger (12) is shaped so as to perform also the function of a shearing punching member,
   - once the aforesaid protrusion (22) has been formed until a blind bottomed branch portion is defined, the above-said plunger-punching member (12) is pushed radially against it in order to shear said bottom obtaining thereby an opening (22b) at the end of the branch portion (24).

2. Method according to claim 1, **characterized in that** once said plunger (12) has performed said shearing operation, it is driven in the opposite direction, so that the circumferential edge of said opening (22b) is deformed outwardly and against the wall of said portion (6) of the die cavity (3).

3. Method according to claim 2, **characterized in that** said plunger/punching member has at least an intermediate portion with an extending diameter, means being provided for driving an expansion of said portion towards a larger diameter configuration immediately before said return stroke is performed to deform outwardly the circumferential edge of the opening (22b).

4. Method according to any one of the preceding claims, **characterized in that** along with the application of pressurized fluid within the hollow body (4), during the forming operation of said protrusion (22), said hollow body (4) is subjected to a mechanical compression in the direction of a main axis (5) thereof.

5. Apparatus for hydroforming a hollow body (4) with at least a branch portion (24), including:

   - a hydroforming die (2), having a forming cavity (3) for receiving a hollow blank body (4) originally lacking of the branch portion (24),
   - means for feeding pressurized fluid within the hollow blank body (4), so that a protrusion (22) is formed on a wall of the hollow body and expands in a corresponding portion (6) of the die cavity (3),
   - a plunger (12) movably mounted within said portion (6) of the die cavity (3) where the above-said protrusion (22) expands,
   - **characterized in that** means for moving backwardly said plunger (12) during forming of said protrusion (22) are provided, and that said plunger (12) has a front surface with a cutting edge (18a), whereby said plunger (12) acts also as a shearing punching member, and **in that** said apparatus also includes means for pushing said plunger/punching member (12) against the end wall (22a) of said protrusion (22) after this has been formed, in order to shear it by obtaining an opening (22b) therein.

6. Apparatus according to claim 5, **characterized in that** means are provided for moving back said plunger/punching member (12) outwardly, after it has completed its stroke to perform said shearing operation, in order to radially deform the circumferential edge of said opening (22b) outwardly against the wall of said portion (6) of the hydroforming die.

7. Apparatus according to claim 6, **characterized in that** said plunger/punching member (12) has at least an expandable intermediate portion, actuating means being provided for bringing said portion in its expanded diameter configuration before said plunger/punching member performs the above-said return stroke in order to radially deform the circumferential edge of the opening (22b) outwardly.

8. Apparatus according to any one of the claims 5-7, **characterized in that** it includes a pair of additional plungers (7, 8) opposite to each other, movably mounted in the forming cavity (3) to apply a compression to the hollow body (4) in the direction of its main axis (5).

9. Apparatus according to claim 8, **characterized in that** said additional plungers (7, 8) have respective axial passages (7b, 8b) for the connection of the space (4a) within the hollow body (4) to a discharge line (9) for the hydroforming fluid and a feed line (10) for the hydroforming fluid, respectively.

10. Apparatus according to any one of claims 5-9, **characterized in that** said plunger/punching member (12) has an intermediate portion comprising a plurality of circumferentially distributed sectors (13), defining two conical end surfaces (14,15) which are in engagement with corresponding conical surfaces (16,17) of two end bodies (18, 19), one of said end bodies (18) being rigidly connected to a stem (20) having a threaded portion on which the other end body (19) is screwed, actuator means being provided for applying a rotation to said stem (20) with respect to said end body (19) screwed thereon, in such a way that a variation of the mutual axial distance among said end bodies is generated, spring means (21) being further provided for radially pushing said sectors (13) inwardly.

11. Apparatus according to any one of the claims 5-10, **characterized in that** said plunger/punching member (12) has a magnetic or magnetizable front head to hold the sheared portion of the end wall (22a) of said protrusion (22) thereon.

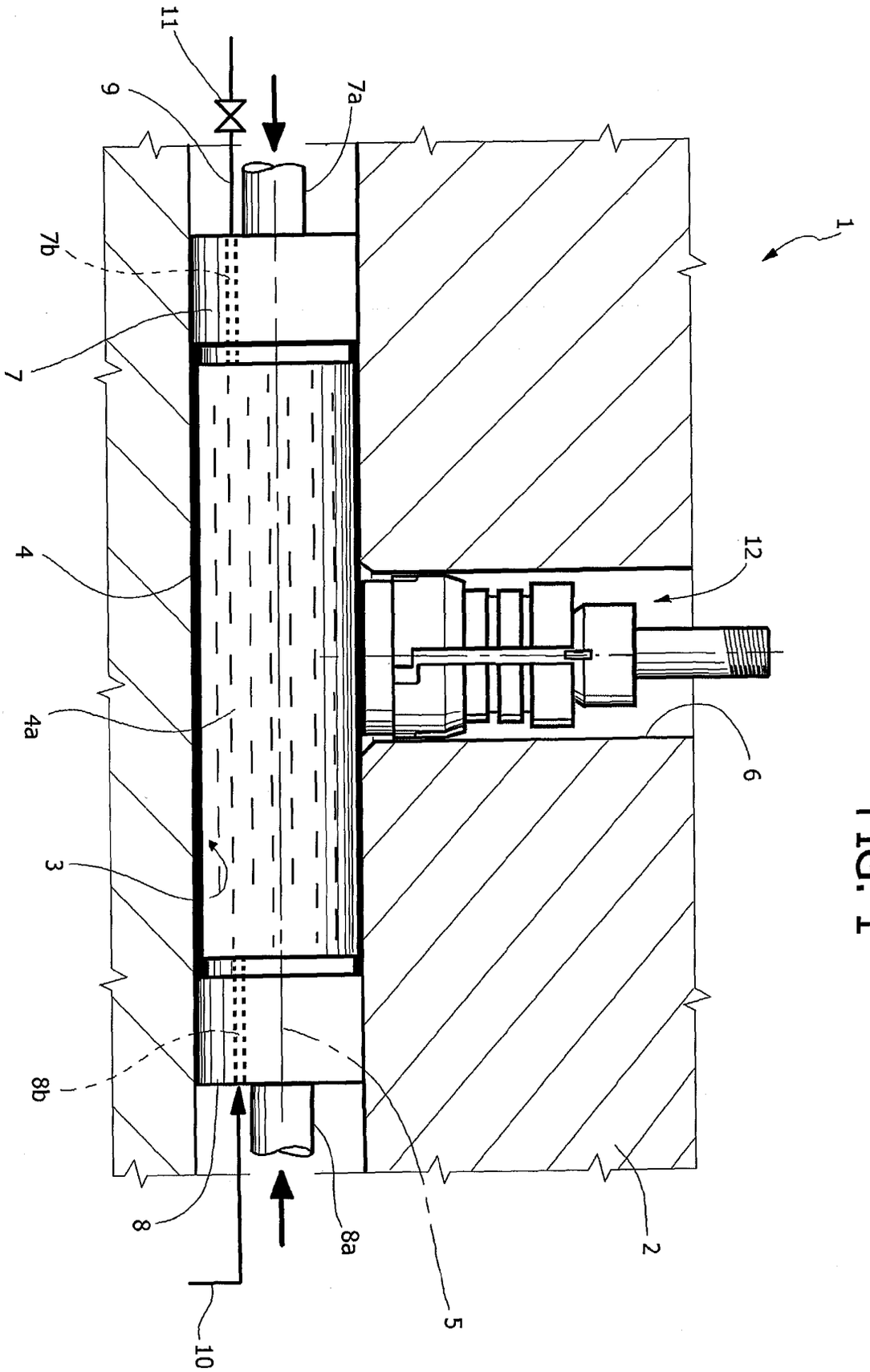


FIG. 1

FIG. 2

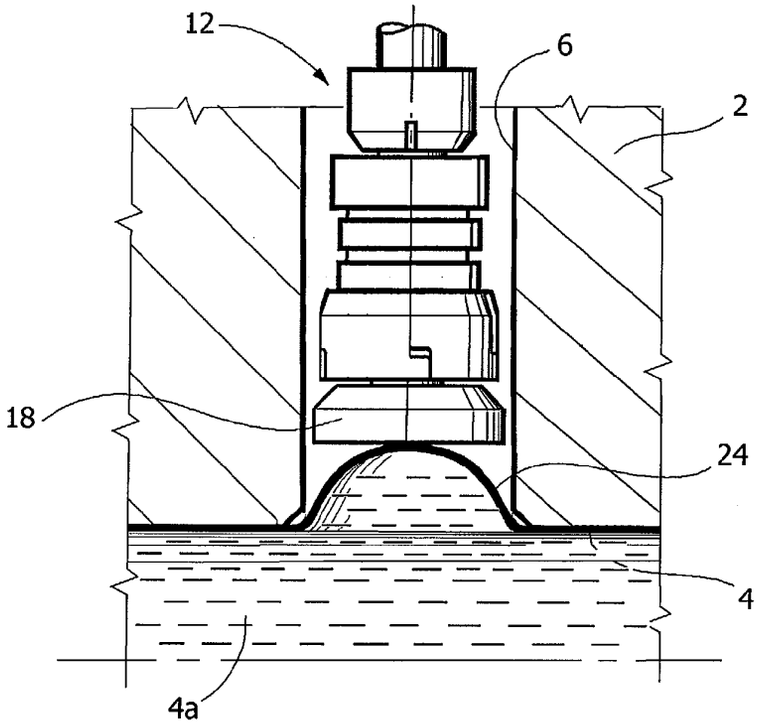


FIG. 3

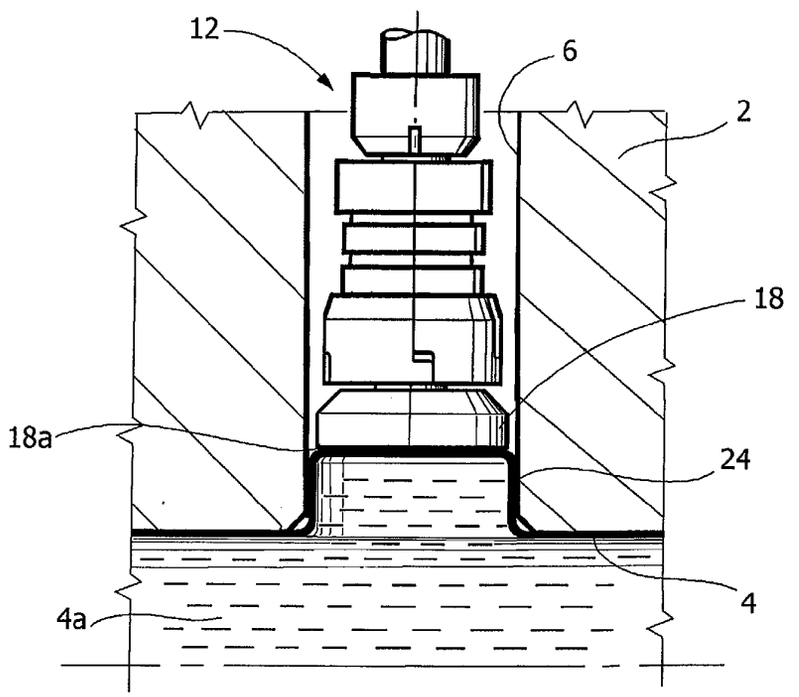


FIG.4

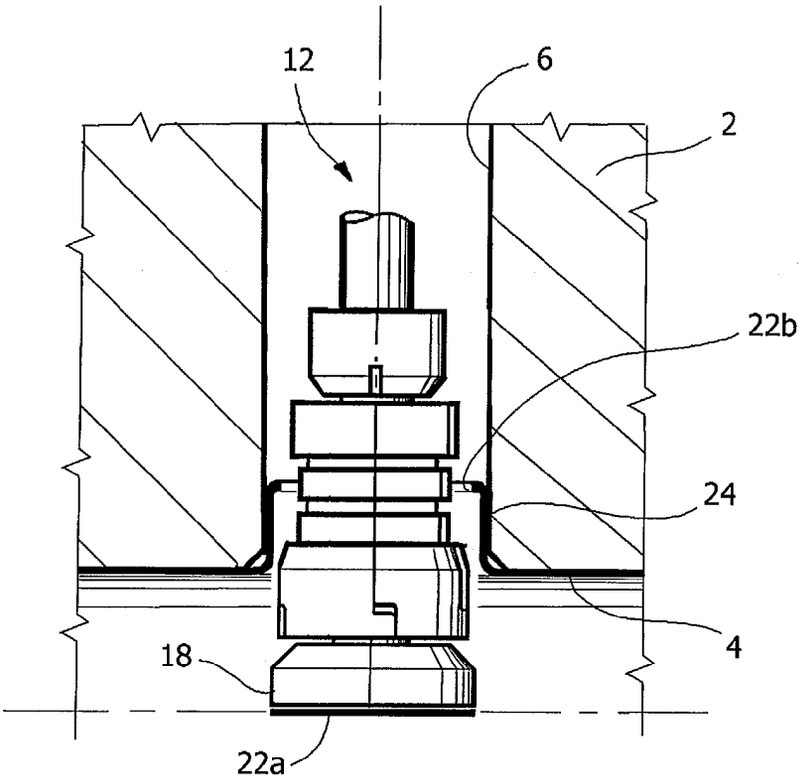


FIG. 5

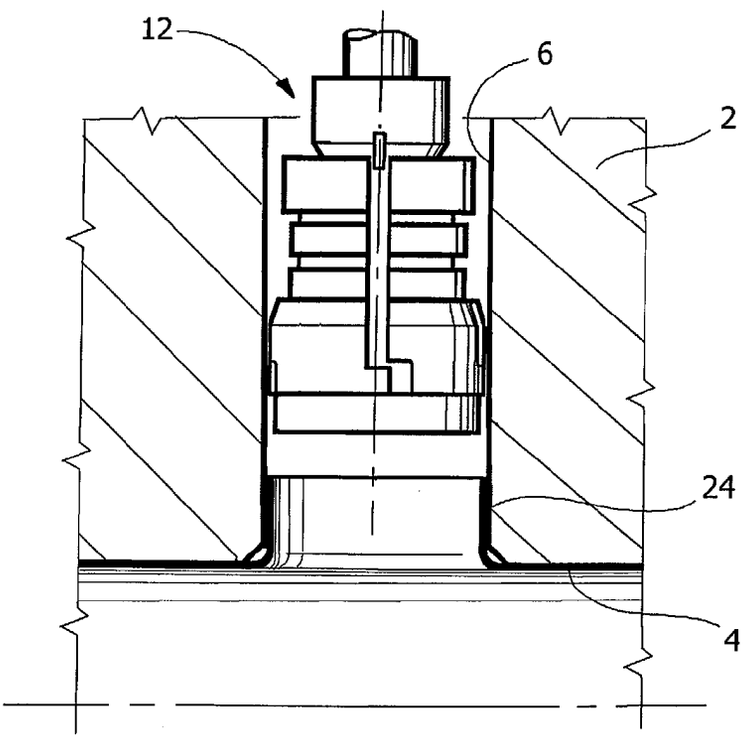


FIG. 6

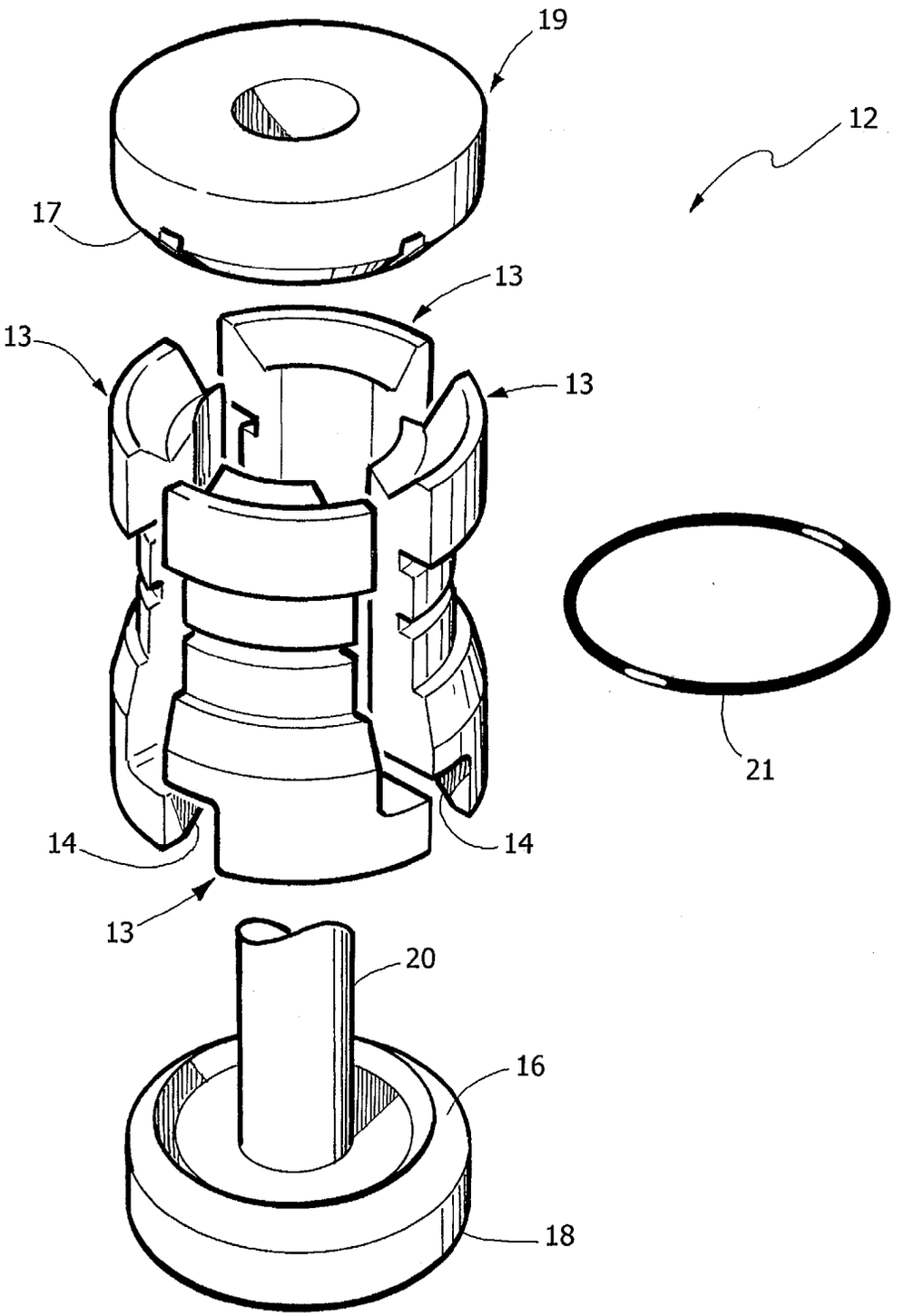
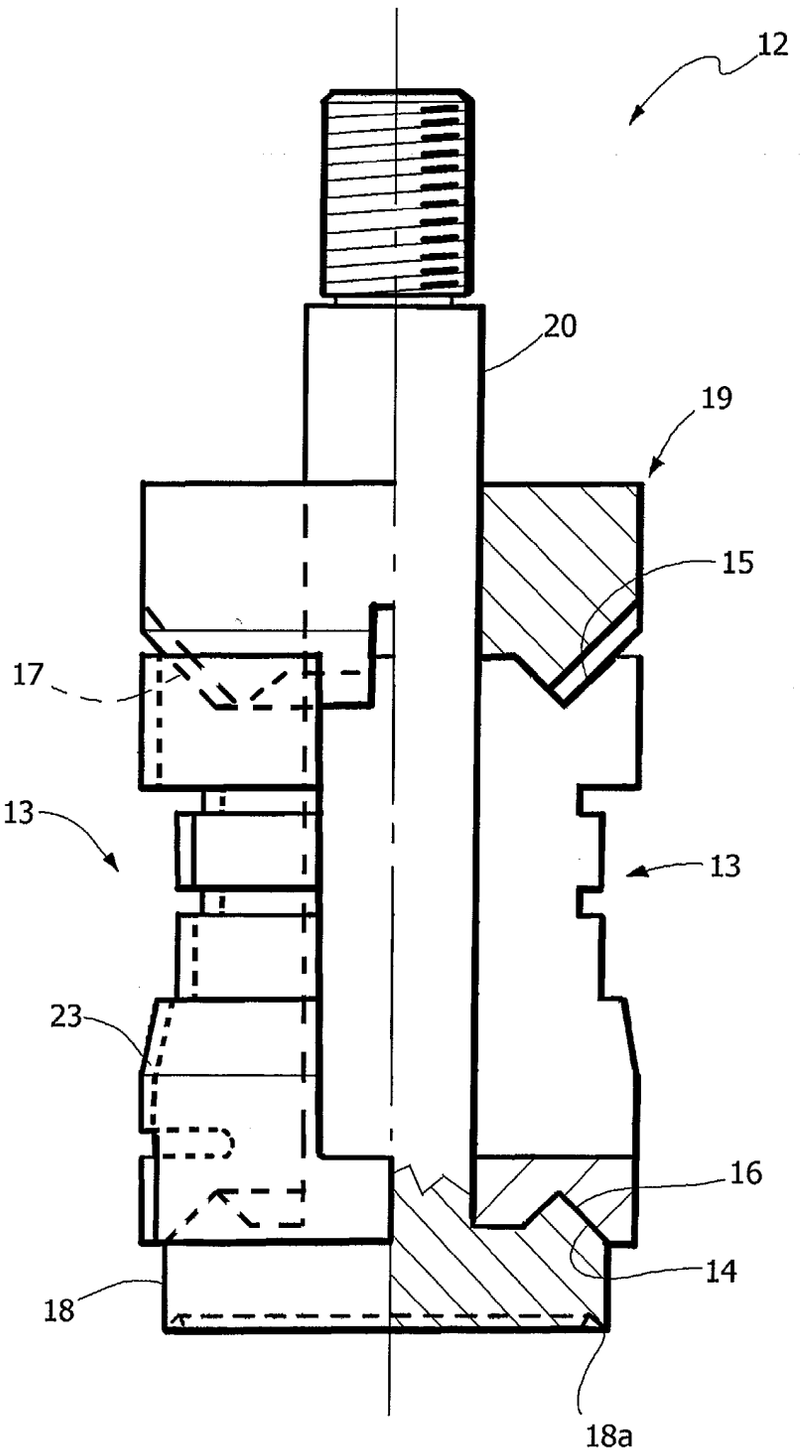


FIG. 7



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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	7 January 2005	Vinci, V

CATEGORY OF CITED DOCUMENTS

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