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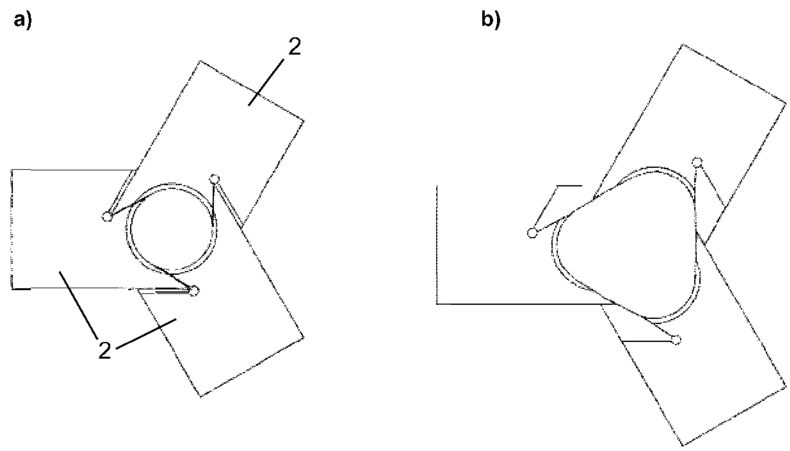


Fig. 3

**(57) Abstract**: The invention relates to processes for the production of capillary dialyzers. The processes involve thermoforming of bundles of hollow fiber membranes. The disclosure also relates to an apparatus for thermoforming bundles of hollow fiber membranes.

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# Thermoforming of fiber bundles

## Technical Field

The present disclosure relates to processes for the production of capillary dialyzers. The processes involve thermoforming of bundles of hollow fiber membranes. The present disclosure also relates to an apparatus for thermoforming bundles of hollow fiber membranes.

## Description of the Related Art

US 4 341 005 A discloses a process for the production of hollow fiber fluid fractionation cells which involves placing a series of half sections of the longitudinal walls of the cell on the periphery of a winding wheel; winding fluid-filled permeable hollow fibers thereabout until the section is full or slightly over-full; placing another mating half shell over each fiber-filled section on the wheel and assembling the cell core; cutting the courses between each section and draining the fluid therefrom; putting an initial fluid potting compound about the courses of fibers and centrifugally casting the potting compound about the fibers at each end of the cell; and cutting the fibers at each end within the area of the potting compound to re-expose the hollow cores thereof.

JP 2003/062433 A discloses a method for manufacturing a hollow fiber membrane module capable of efficiently performing the potting of the end part of a hollow fiber membrane bundle without infiltrating a potting agent into the hollow fiber membranes. In this manufacturing method, the hollow fiber membrane bundle is inserted into the cylindrical case so that the end part thereof protrudes from the cylindrical case; the end part is collapsed and sealed to be potted to the opening of the cylindrical case; and the collapsed and sealed part is subsequently cut off.

Another known process involves feeding hollow fibers to a winding wheel and winding these in sleeve lower parts arranged on the outer circumference of the winding wheel by turning the wheel. As soon as the desired fiber bundle thickness or fiber bundle size has been reached, the winding wheel is stopped and the sleeve upper parts are placed on the sleeve lower parts and fixed there. Subsequently, the hollow fibers are cut between the sleeves; the sleeves are removed from the winding wheel and transferred to an apparatus for taking the finished fiber bundles out of the sleeves and placing them into tubular filter casings. Due to the two-part design of the sleeve, the cross-section of the fiber bundle is not a perfect circle; and some fibers tend to get caught in the fissure between the parts. As a result, kinks and loops are generated in some of the fibers when the bundle is transferred into the filter casing, resulting in scrap.

**Summary**

The present disclosure provides processes for the production of capillary dialyzers comprising a bundle of hollow fiber membranes. The processes involve shaping an end of the fiber bundle to have a circular cross-section and compacting and melting together the fibers on the perime-

ter of the bundle so that a contiguous annular zone on the perimeter of the bundle is formed.

**Brief Description of the Drawings**

Figure 1 shows an embodiment of a two-part thermoforming tool a) in open configuration, and b) in closed configuration;

Figure 2 shows a top view and two side views of an embodiment of an element of a thermoforming tool;

Figure 3 shows a thermoforming tool comprising three elements pictured in Fig.2, a) in closed configuration, and b) in open configuration;

Figure 4 shows a perspective view of another embodiment of an element of a three-part thermoforming tool;

Figure 5 shows another embodiment of a three-part thermoforming tool a) in open configuration, and b) in closed configuration;

Figure 6 schematically shows individual steps of the process of the present disclosure:
a) thermoforming of one end of a fiber bundle;
b) transfer of the fiber bundle into a tubular filter casing;
c) thermoforming of the second end of a fiber bundle;

Figure 7 schematically shows cutting of the ends of the thermoformed fiber bundle.

**Detailed Description**

The process for the production of capillary dialyzers involves feeding dry hollow fibers to a winding wheel and winding these in sleeve lower parts arranged on the outer circumference of the winding wheel by turning the wheel. As soon as the desired fiber bundle thickness or fiber bundle size has been reached, the winding wheel is stopped and the sleeve upper parts are placed on the sleeve lower parts and fixed there. Subsequently, the hollow fibers are cut between the sleeves (11); and the sleeves (11) containing a fiber bundle (10) are removed from the winding wheel.

Prior to transfer of a fiber bundle (10) from a sleeve (11) into a tubular filter casing (15), one end of the fiber bundle (10) is reshaped into a circle and the fibers on the perimeter of the fiber bundle are compacted and melted together (this operation is subsequently referred to as "thermoforming") so that a contiguous annular zone (13) is formed on the perimeter of the fiber bundle (10) (Fig. 6a).

In one embodiment of the process, thermoforming is also performed on the second end of the fiber bundle (10). A thermoforming tool (17) produces a contiguous annular zone (18) on the perimeter of the second end of the fiber bundle (10) (Fig. 6c).

In one embodiment of the process, the diameter of the fiber bundle (10) is reduced to from 70 to 90% of its initial value in the contiguous annular zone (13,18) (the thermoformed zone) during thermoforming.

In one embodiment, the contiguous annular zone (13,18) produced by the thermoforming process has a thickness of 0.1 to less than 1 mm, and a length of 2 to 20 mm in longitudinal direction of the bundle.

In one embodiment of the process, thermoforming is effected by a two-part tool (thermoforming jaws) as shown in Fig. 1. In another embodiment of the process, thermoforming is effected by a three-part tool (thermoforming jaws) as shown in Fig. 3. In still another embodiment of the process, thermoforming is effected by a three-part tool (thermoforming jaws) as shown in Fig. 5.

In one embodiment, the thermoforming tool (12,17) in closed configuration frames a central void having the form of a cylinder with a diameter in the range of from 15 to 40 mm; and a height in the range of from 5 to 20 mm.

Different exemplary embodiments of individual elements (1,2,3,4) of a thermoforming tool (12,17) for use in the process of the present application are shown in Figures 1 to 5.

In one embodiment, the thermoforming tool (12,17) is made of aluminum, and the individual elements (1,2,3,4) are coated with a nonstick coating. In one embodiment, the coating is based on polytetrafluoroethylene (PTFE; Teflon®); in another embodiment, the coating is a silica-based nonstick coating.

The individual elements (1,2,3,4) (also referred to as jaws) of the thermoforming tool (12,17) are heated to a temperature in the range of from about 250°C to about 300°C. Heating can be effected in different ways known in the art. In one embodiment, the individual jaws (1,2,3,4) feature cavities comprising heating cartridges. In another embodiment, heating elements are provided on a surface of each individual jaw (1,2,3,4). In still another embodiment, a hotplate is arranged on a surface of each individual jaw (1,2,3,4).

To perform the thermoforming and form a contiguous annular zone on the perimeter of the fiber bundle, the heated jaws (1,2,3,4) of the thermoforming tool are moved from a starting position in which they are separated from each other (open configuration) into an end position in which the jaws of the tool contact each other and define a cylindrical central void (closed configuration). Examples are shown in Figures 1, 3, and 5. In the closed configuration, the thermoforming tool constricts an end of the fiber bundle (10), shaping its cross-section into a circle with reduced diameter, as compared to the rest of the fiber bundle. The fibers on the perimeter of the fiber bundle (10) are compacted and melted together, thereby forming a contiguous annular zone on the perimeter of the fiber bundle. The jaws (1,2,3,4) remain in their end position for a time in the range of from 3 to 15 seconds, for instance, 5 to 10 seconds, and then are moved back into the starting position.

Thermoforming of a first end of a fiber bundle (10) is schematically shown in Fig. 6a. A thermoforming tool (12) produces a contiguous annular zone (13) on the perimeter of the first end of the fiber bundle (10). The fiber bundle (10) then is transferred into a tubular filter casing (15) (Fig. 6b). In a preferred embodiment, the tubular filter casing (15) is equipped with potting sleeves (16) at both ends. The length of the fiber bundle (10) is greater than the length of the tubular casing (15), so that both ends of the fiber bundle (10) protrude from the tubular casing (15) after the transfer. In particular, the thermoformed zone (13) of the fiber bundle (10) is entirely outside the tubular casing (15).

In one embodiment of the process, the transfer is effected by a transfer tool (14), e.g., a transfer claw, which reaches through the tubular filter casing (15); grabs the thermoformed end (13) of the fiber bundle; and pulls it into the tubular casing (15), continuing to pull until the end of the fiber bundle (10) inclusive of the entire contiguous annular zone (13) protrudes from the tubular casing (15).

The thermoformed end (13) of the fiber bundle (10) simplifies transfer of the fiber bundle (10) into the tubular casing (15). As the position of the fiber ends on the perimeter of the bundle is fixed, and no fibers protrude from the perimeter of the bundle, formation of kinks and loops is avoided. Additionally, the transfer tool (14) does not need to engage all fibers on the perimeter. When the diameter of the thermoformed zone (13) is smaller than the initial diameter of the fiber bundle (10), and also smaller than the inner diameter of the tubular casing (15), the transfer is further facilitated as less force is necessary to pull the fiber bundle (10) into the tubular casing (15). This in turn reduces the risk of fibers rupturing during the transfer of the fiber bundle. Both factors result in reduction of scrap.

In one embodiment of the process, thermoforming is also performed on the second end of the fiber bundle (10) protruding from the tubular casing (15) after transfer of the fiber bundle (10) into the tubular casing (15) (Fig. 6c). A thermoforming tool (17) produces a contiguous annular zone (18) on the perimeter of the second end of the fiber bundle (10).

The portions of the bundle of hollow fiber membranes (10) protruding from the tubular casing (15) are cut off with a cutting tool (19) (Fig. 7) prior to the next stage of the dialyzer production process, which involves the formation of end walls within the tubular casing (15) by embedding the ends of the fiber bundle (10) in a potting material, e.g., polyurethane.

In one embodiment of the process, the end of the fiber bundle (10) is cut off with a blade subsequently to the thermoforming and transfer steps. In another embodiment of the process, the end of the fiber bundle is cut and the fiber ends are heat-sealed with a hot blade or a hot wire subsequently to the thermoforming and transfer steps.

When a thermoformed end of the fiber bundle (10) is cut off, the cut-off forms a contiguous slice, while otherwise a multitude of small fiber pieces is generated. Thus thermoforming also results in less particle generation and less contamination of the workplace and equipment; less maintenance is required in the area where the transfer and cutting steps are performed.

It will be understood that the features mentioned above and those described hereinafter can be used not only in the combination specified but also in other combinations or on their own, without departing from the scope of the present invention.

List of reference signs

| | |
|---|---|
| 1 | first type of element of a thermoforming tool |
| 2 | second type of element of a thermoforming tool |
| 3 | third type of element of a thermoforming tool |
| 4 | fourth type of element of a thermoforming tool |
| 10 | bundle of hollow fiber membranes |
| 11 | sleeve |
| 12 | first thermoforming tool |
| 13 | thermoformed first end of the fiber bundle |
| 14 | transfer tool |
| 15 | tubular filter casing |
| 16 | potting sleeve |
| 17 | second thermoforming tool |
| 18 | thermoformed second end of the fiber bundle |
| 19 | cutting tool (e.g., blade, hot blade, or hot wire) |

## Claims

1. A process for the production of a capillary dialyzer comprising a bundle (10) of hollow fiber membranes disposed within a tubular casing (15), the process comprising forming a contiguous annular zone (13,18) on the perimeter of an end of a bundle (10) of hollow fiber membranes by shaping an end of the bundle (10) to have a circular cross-section; and compacting and melting together the fibers on the perimeter of the bundle (10) of hollow fiber membranes.

2. The process of claim 1, wherein the contiguous annular zone (13,18) has a thickness of 0.1 to less than 1 mm.

3. The process of claims 1 or 2, wherein the contiguous annular zone (13,18) has a length of 2 to 15 mm in longitudinal direction of the bundle (10).

4. The process of any one of claims 1 to 3, wherein the diameter of the fiber bundle (10) is reduced to from 70 to 90% of its initial value in the contiguous annular zone (13,18).

5. The process of any one of claims 1 to 4, wherein a contiguous annular zone (13,18) is formed on the perimeter of each end of the bundle (10) of hollow fiber membranes.

6. The process of any one of claims 1 to 4, wherein the bundle (10) of hollow fiber membranes is transferred into a tubular casing (15) after a contiguous annular zone (13) on

the perimeter of one end of the bundle (10) of hollow fiber membranes has been formed.

7. The process of claim 6, wherein the transfer is effected by a tool (14) reaching through the tubular casing (15); engaging the contiguous annular zone (13) of the bundle (10) of hollow fiber membranes; pulling the bundle (10) of hollow fiber membranes into the tubular casing (15); and continuing to pull until the end of the bundle (10) of hollow fiber membranes inclusive of the entire contiguous annular zone (13) protrudes from the tubular casing (15).

8. The process of claim 7, wherein both ends of the bundle (10) of hollow fiber membranes protrude from the tubular casing (15) after the transfer; and the portions of the bundle (10) of hollow fiber membranes protruding from the tubular casing (15) are subsequently cut off.

9. The process of claim 8, wherein a contiguous annular zone (18) is also formed on the perimeter of the second end of the bundle (10) of hollow fiber membranes before the portions of the bundle (10) of hollow fiber membranes protruding from the tubular casing (15) are cut off.

10. The process of claims 8 or 9, wherein, simultaneously with cutting off the portions of the bundle (10) of hollow fiber membranes protruding from the tubular casing (15), the ends of the fibers of the bundle (10) of hollow fiber membranes are heat-sealed.

11. The process of claim 10, wherein cutting off and heat-sealing are performed with a hot blade or a hot wire.

12. An apparatus (12,17) for forming a contiguous annular zone (13,18) on the perimeter of an end of a bundle (10) of hollow fiber membranes, comprising movable individual ele-

ments (1,2,3,4) which can be arranged into a configuration in which they jointly frame a cylindrical void.

13. The apparatus of claim 12, wherein the cylindrical void is framed by two individual elements (1).

14. The apparatus of claim 12, wherein the cylindrical void is framed by three individual elements (2,3,4).

15. The apparatus of any one of claims 12 to 14, wherein the individual elements (1,2,3,4) feature heating elements.

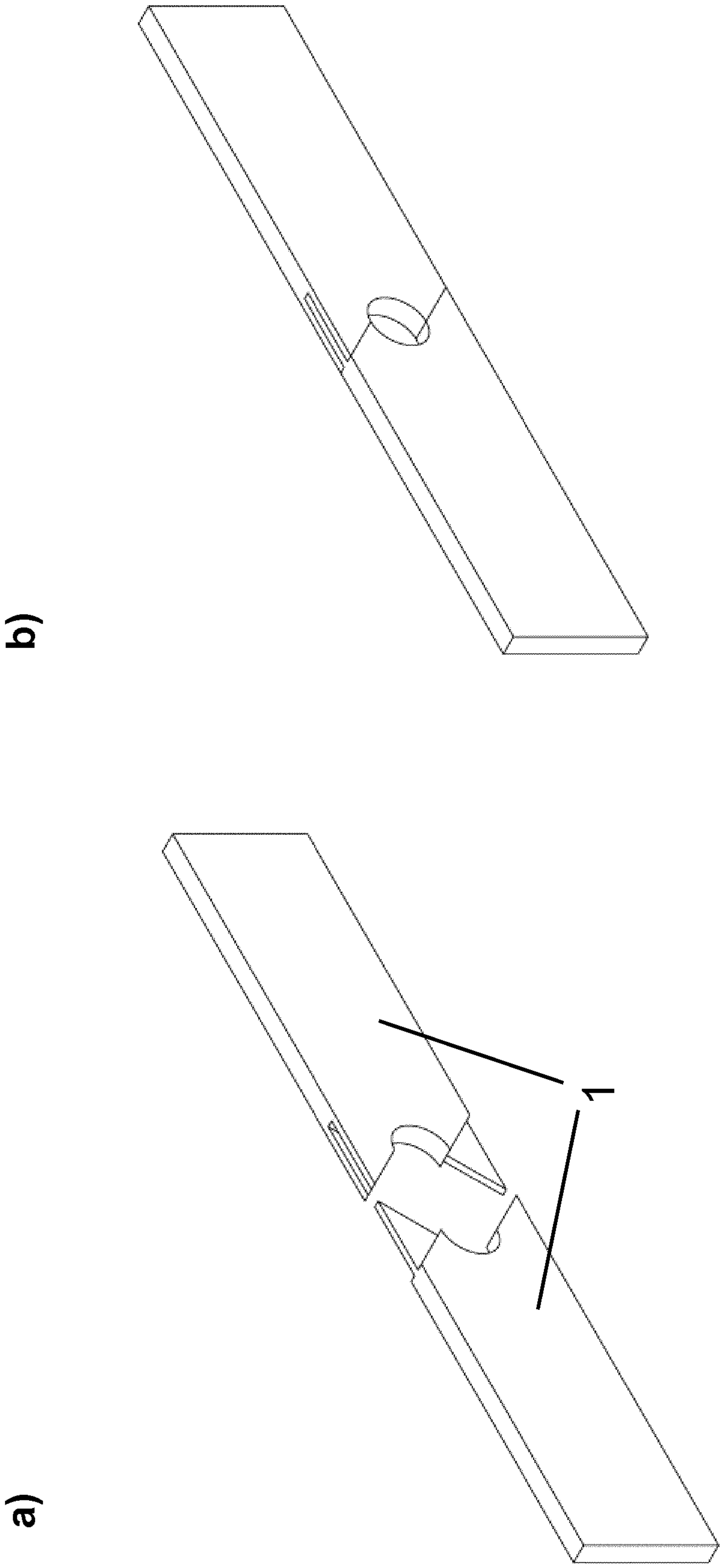


Fig. 1

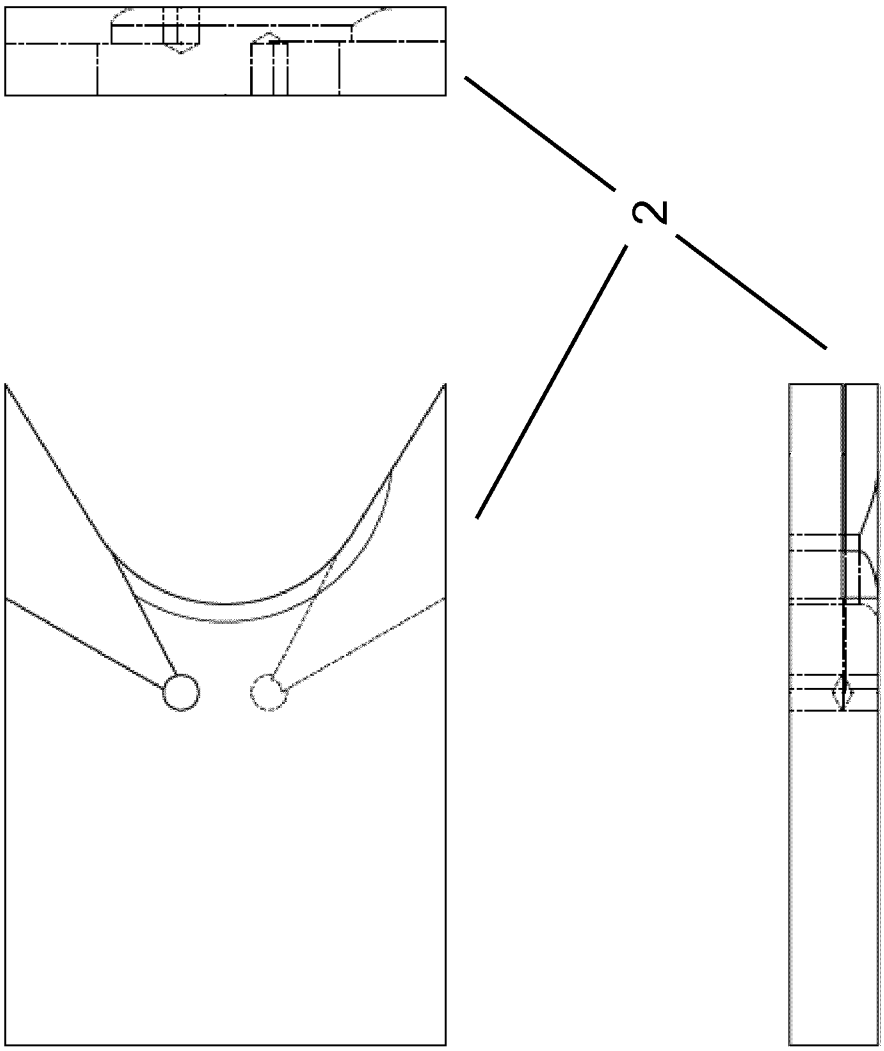


Fig. 2

b)

a)

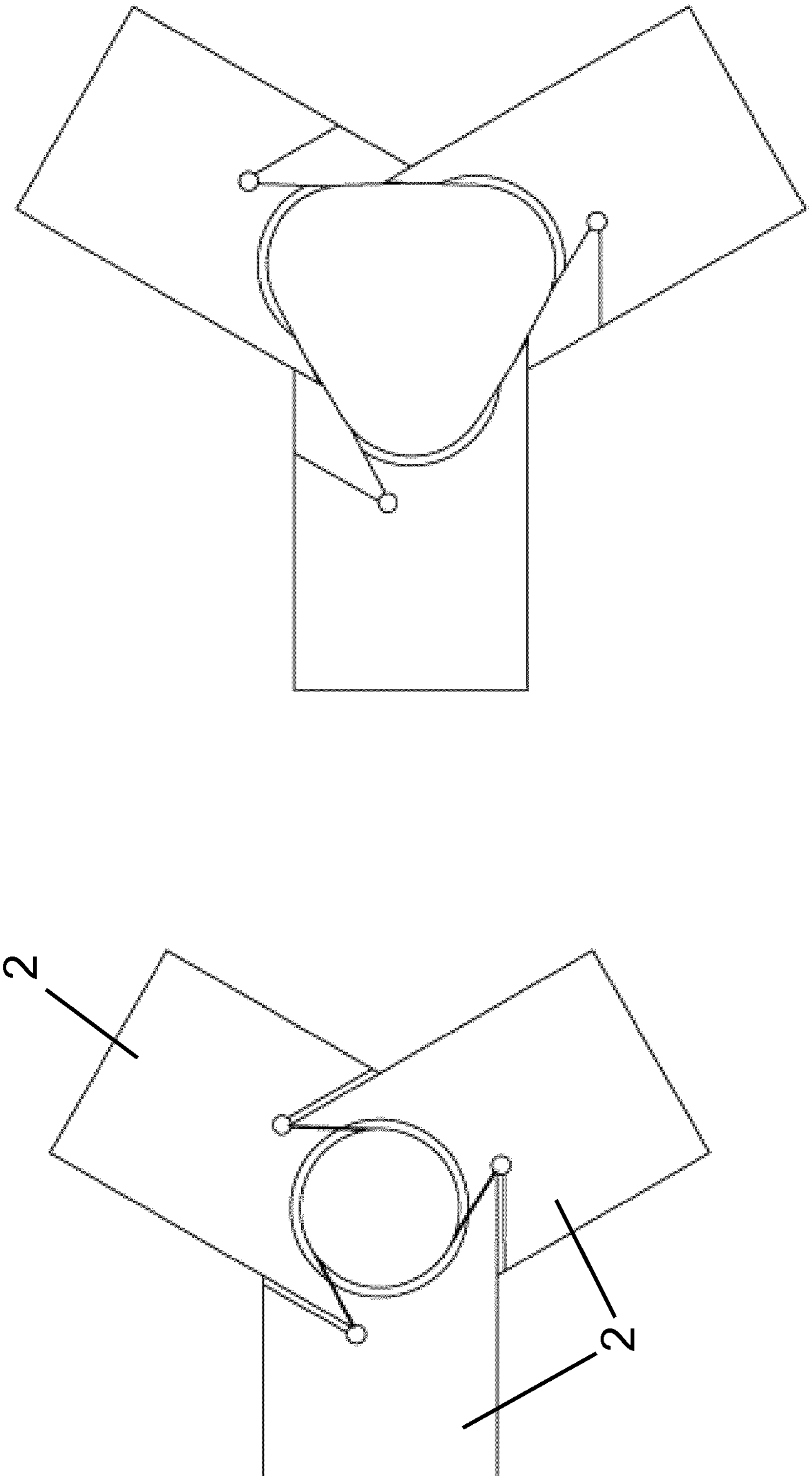


Fig. 3

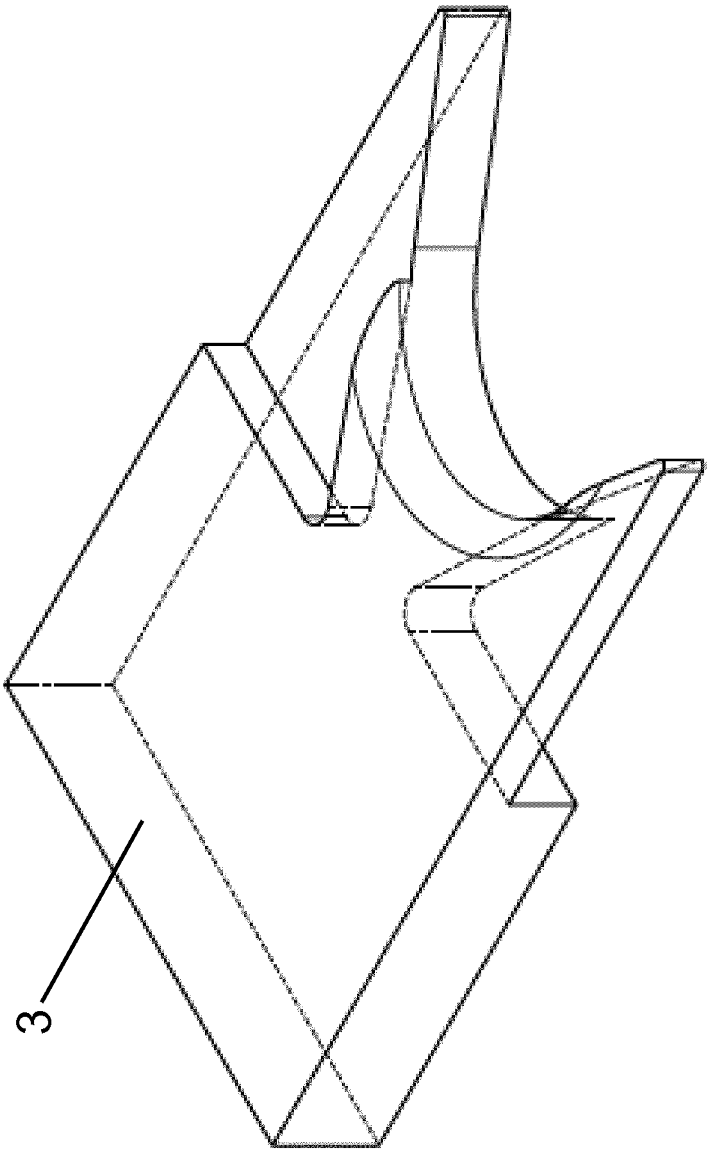


Fig. 4

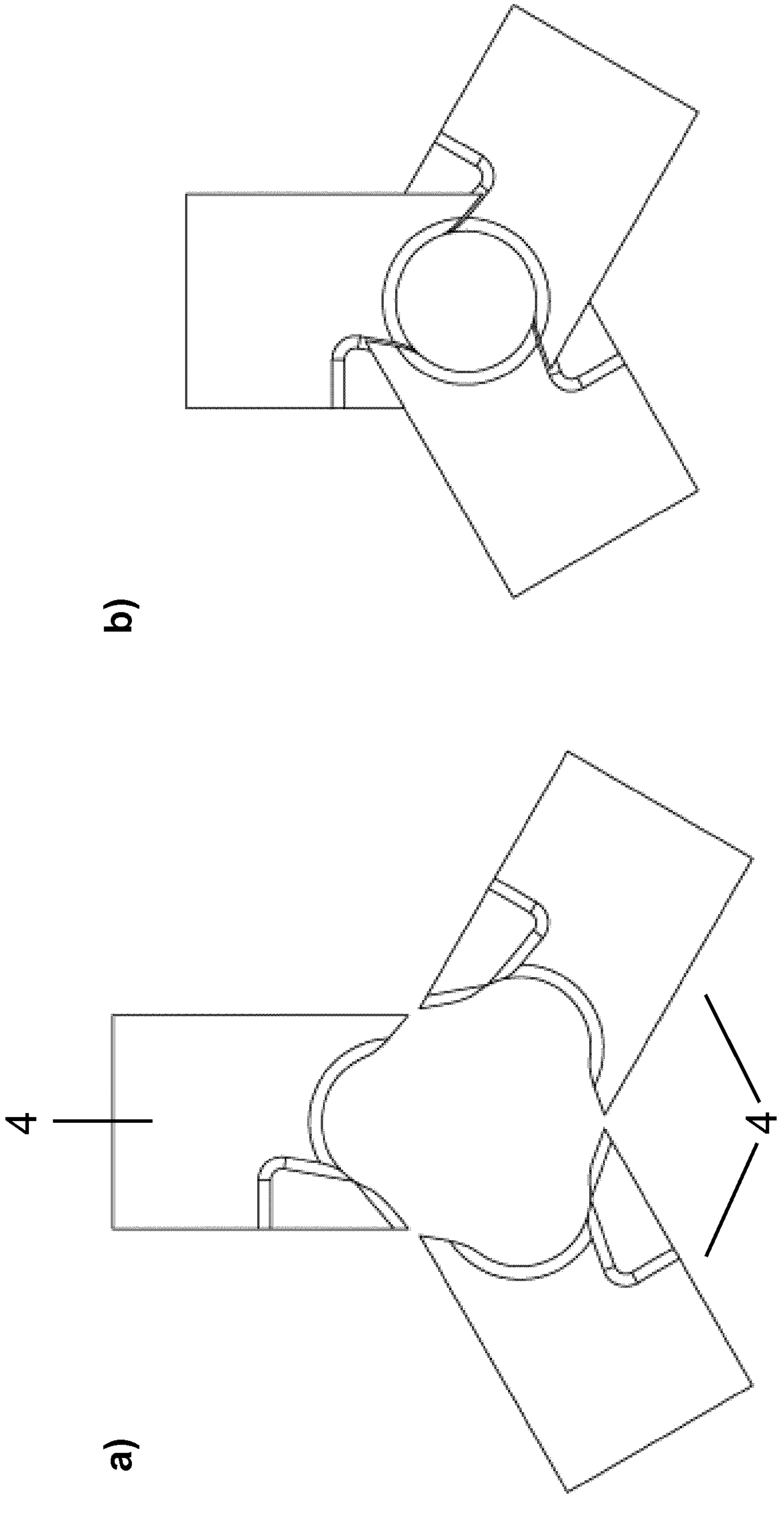


Fig. 5

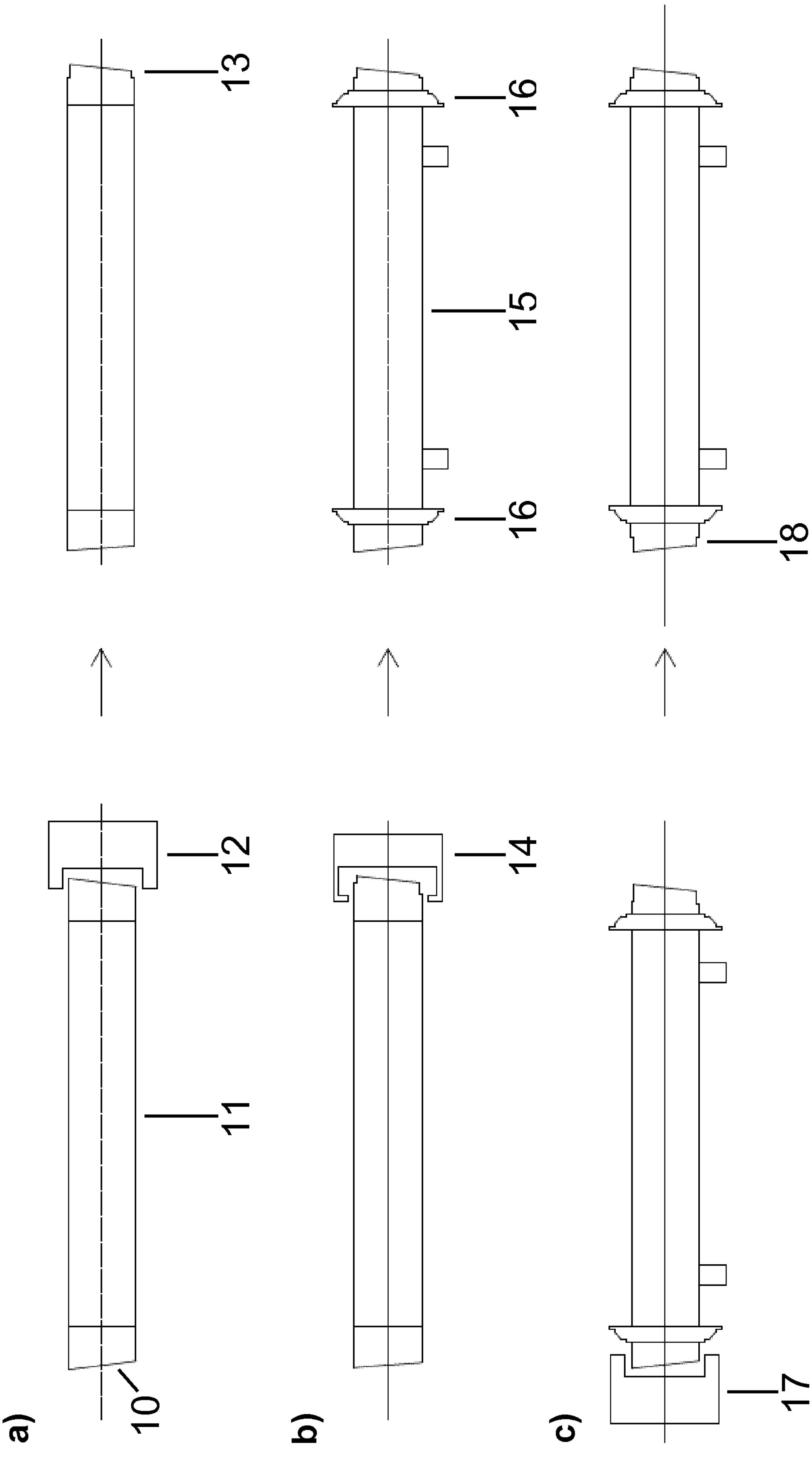


Fig. 6

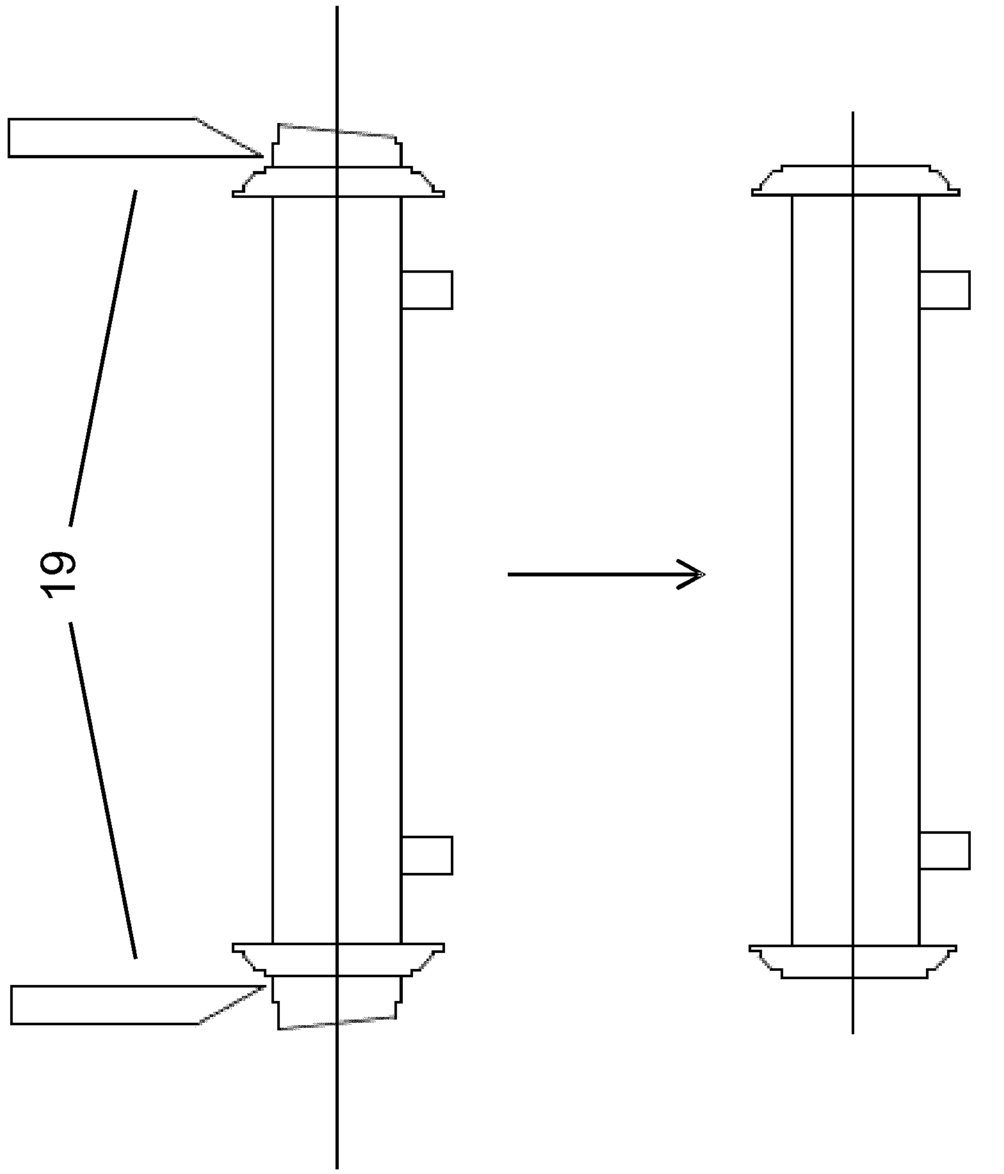


Fig. 7