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(54) Benævnelse: **FUNDERINGSPÆL TIL ET VINDENERGIANLÆG**

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FOUNDATION PILE FOR A WIND TURBINE

The invention relates to a foundation pile with at least two foundation pile segments, the longitudinal axes of which are substantially collinear with one another. The present invention relates to a foundation pile for wind turbines, which are designed in particular for offshore use and are known per se, for example, from EP 2 824 257 A1.

It is known from the prior art to construct foundation piles from foundation pile segments. The respective foundation pile segments are assembled from so-called pipe sections. Each pipe section is in turn made from a sheet of metal which is bent according to the shape of the foundation pile to be produced in such a way that the material or sheet metal edges which are opposite one another in the bent state can be welded together. The opposite sheet metal edges are welded by means of a longitudinal weld seam. The foundation pile is then assembled from a number of correspondingly formed pipe sections by connecting adjacent pipe sections by means of a circular weld in such a way that the respective longitudinal axes of the pipe sections extend in a collinear manner relative to one another.

Consequently, a large number of weld seams with a large overall length are required to produce a corresponding foundation pile, as a result of which the manufacture of the foundation pile is complex and expensive. For example, for the production of two foundation pile segments, each with a height of three metres and a diameter of seven metres, and for their connection, weld seams with a total length of 28 metres are necessary, specifically two times three metres of longitudinal weld seam each to connect the opposing side edges or material edges of the individual pipe sections and 22 metres of circular weld seam to connect the two foundation pile segments.

The present invention is based on the task of providing a foundation pile which can be manufactured in a shorter time, which is more cost-effective, and which also has improved flow properties by a fluid (air or water).

The object of the present invention is achieved by a foundation pile having the features of the independent claim. Advantageous embodiments are described in the dependent claims.

More precisely, the object on which the present invention is based is achieved by a foundation pile comprising at least two foundation pile segments which are connected to one another in such a way that the longitudinal axes thereof extend substantially collinearly to one another, wherein at least two of the foundation pile segments each have a through-opening in their jacket walls.

In this context, a recess in a jacket wall of the foundation pile segment is to be understood as a through-opening in the jacket wall. For the purposes of the present invention, collinear longitudinal axes mean that the longitudinal axes are substantially coincident with each other, i.e., that they are not laterally offset from one another. The individual foundation pile segments are connected in particular by welding the end edges of the foundation pile segments together.

The foundation pile according to the invention offers the advantage that fewer longitudinal weld seams and circular weld seams are necessary for its production. This is because the opposing side edges or material edges or sheet metal edges of the respective foundation pile segments do not have to be joined together by means of a longitudinal weld seam. Furthermore, the circular weld seam by means of which adjacent foundation pile segments are welded together does not have to be continuously formed, i.e., the circular weld seam does not have to extend around the entire circumference of the foundation pile segments. When connecting two foundation pile segments, each of which has a diameter of seven metres and a height of three metres, wherein each of the foundation pile segments has a recess which runs over the entire height of the foundation pile segment and has a width of one metre, weld seams with a total length of eight metres can be saved in this manner if the foundation pile segments are connected to each other at an offset angle in such a way that the recesses of the foundation pile segments are also arranged at an offset angle to each other in such a way that they do not merge. This is because three metres of longitudinal weld seam are saved for each foundation pile segment (two times three metres), and the circular weld seam does not have to be continuously formed, but can have a gap of one metre in the region of each recess.

Consequently, the foundation pile according to the invention has a shortened production time. Furthermore, the foundation pile according to the invention is less complex and less cost-intensive to produce than foundation piles known from the prior art, since fewer weld seams are required for its production. Furthermore, the foundation pile according to the invention offers fluidic advantages, because the recesses in the respective foundation pile segments can be arranged in such a way that it is easier for a fluid, i.e., air or water (the latter in offshore use), to enter the foundation pile as well as for the fluid to leave the foundation pile so that the foundation pile offers a reduced contact surface for air and/or water. Another advantage of the foundation pile according to the invention is that a cathodic corrosion protection can act both inside the foundation pile and on the outside of the foundation pile so that only one corrosion protection system needs to be used. Furthermore, the foundation pile according to the invention offers the advantage of

improved driving progress since the foundation pile has a lower axial stiffness.

The foundation pile is preferably designed in such a way that at least one of the foundation pile segments has at least two recesses which are arranged at an angle to one another.

The two recesses are preferably offset at an angle to one another by 180°. This offers the advantage that a fluid flowing around the foundation pile, i.e., air and/or water, can enter the foundation pile through a recess and exit the foundation pile through the recess opposite this recess. The correspondingly formed foundation pile consequently has a reduced contact surface and a reduced resistance for air and/or water.

For offshore use, the recesses can advantageously be arranged at the height of the foundation pile at which the water edge runs. Waves can thus enter the foundation pile via a recess and exit the foundation pile via the opposite recess.

According to the invention, the foundation pile is designed in such a way that, in at least one foundation pile segment, the at least one recess extends to both end faces of the foundation pile segment. Preferably, in all foundation pile segments having a recess, the respective recesses extend to both end faces of the foundation pile segment having the recess.

If the recess/recesses extend(s) to both end faces of the foundation pile segment, then the foundation pile segment has a C-shaped cross-section.

The foundation pile is preferably designed in such a way that two adjacent foundation pile segments are connected to each other in such a way that the recess/recesses is/are closed or delimited at the end face by the axially adjacent foundation pile segment.

The correspondingly formed foundation pile offers the advantage that adjacent foundation pile segments do not have to be welded together over their entire circumferential length, so that the total weld length for producing the foundation pile is reduced. Furthermore, a correspondingly formed foundation pile has increased stability because the individual recesses of the foundation pile segment do not merge into one another. The correspondingly formed foundation pile has increased bending stiffness and increased torsional stiffness compared to an open C-profile.

Preferably, the foundation pile is designed in such a way that the two adjacent foundation pile segments each have at least one recess, the foundation pile segments being connected to one another at an offset angle in such a way that the recess/recesses is/are closed at the end by the axially adjacent foundation pile segment.

A corresponding formation of the foundation pile increases its stability, in particular its torsional stiffness and bending stiffness. The interconnected foundation pile segments

are preferably angled at 180° or 90° to one another with respect to the longitudinal axes of the foundation pile segments, so that the recesses of the foundation pile segments are arranged opposite each other. A correspondingly angularly offset arrangement of the recesses reduces the flow resistance of the foundation pile, as air and/or water can penetrate the foundation pile and partially escape from it again without transferring an impulse to the foundation pile.

The foundation pile is advantageously designed in such a way that a foundation pile segment having a recess is connected to a foundation pile segment without recesses, preferably to two foundation pile segments without recesses. Furthermore, foundation pile segments each having recesses can also be connected to one another, wherein the foundation pile segments are offset at an angle to one another, for example 90°, so that the respective recesses are each axially closed by the adjacent foundation pile segments. In the case where the recessed foundation pile segment is connected to two foundation pile segments without recesses, the foundation pile segment with a recess is sandwiched between the two foundation pile segments without a recess.

A corresponding formation of the foundation pile increases its stability, in particular its torsional stiffness and bending stiffness.

The foundation pile is preferably designed in such a way that the opposing side edges of the foundation pile segment with the recess are connected to each other. A connection of the side edges can be realised for example by bonding the side edges together. For example, an ACX adhesive can be used for bonding. The connection of the side edges improves the dimensional stability of the individual foundation pile segments, especially when not connected to another foundation pile segment, so that the connection/welding of adjacent foundation pile segments is simplified.

Preferably, the foundation pile comprises at least one holding device by means of which opposite side edges of a foundation pile segment are connected to each other.

The holding device can be designed as a holding clamp, in particular as a vice-shaped holding device or as a magnetic holding device. Further, the holding device may be designed as a temporary holding device by means of which opposite side edges of the foundation pile segment are connected to each other in a state in which the foundation pile segment is not welded to another foundation pile segment, wherein the holding device is removed after welding of the foundation pile segment to another foundation pile segment. However, the holding device can also be designed as a permanent holding device that remains connected to another foundation pile segment with the opposite side edges after the foundation pile segment has been welded. The connection of the holding

clamp to the opposing edges of the foundation pile segment can be realised by welding and/or riveting and/or bolting and/or screwing and/or bonding. Furthermore, the foundation pile can have several holding devices by means of which the side edges of a foundation pile segment are connected to each other. For example, opposing side edges of a foundation pile segment can be connected by means of two holding devices arranged in the region of the end faces of the foundation pile segment.

Preferably, the foundation pile is designed in such a manner that the holding device has an arc-shaped or semicircular outer contour, wherein the holding device connects opposing side edges of a foundation pile segment such that the arc-shaped or semicircular outer contour is oriented towards and delimits the recess.

With an appropriate formation of the foundation pile/foundation pile segments and the holding devices, stresses are transferred into the walls of the foundation pile in an improved manner.

Preferably, the foundation pile is designed in such a way that the side edges laterally delimiting the recess in the region of at least one end face are directed toward one another, and preferably extend substantially parallel to the end face. The side edges meet in a central region of the recess and run parallel or approximately parallel to the end face(s) of the foundation pile segment.

Through an appropriate formation of the foundation pile, stresses generated in the foundation pile due to loads are transferred to the walls of the foundation pile in an improved manner without the need for holding devices to connect the side edges of a foundation pile segment.

Further advantages, details and features of the invention arise below from the explained exemplary embodiments. In the figures:

Figure 1: shows a schematic view of a foundation pile according to the invention, comprising four foundation pile segments;

Figure 2: shows a schematic view of a foundation pile segment which is part of a foundation pile according to the invention;

Figure 3: shows a schematic view of a foundation pile according to a further embodiment of the present invention;

Figure 4: shows a schematic view of a foundation pile according to the invention in accordance with a further embodiment of the present invention; and

Figure 5: shows a schematic view of a foundation pile segment comprising two holding devices delimiting a recess.

In the following description, identical reference signs denote identical components or

identical features, so a description provided in relation to one figure also applies to other figures with respect to the components in order to avoid repetition in the description. Furthermore, individual features described in connection with one embodiment can also be used separately in other embodiments.

Figure 1 schematically shows a foundation pile 1 according to a first embodiment of the present invention, comprising several axially interconnected foundation pile segments 10. Figure 1 is to be understood in such a way that not necessarily the entire foundation pile 1 is shown, but that only a partial area of the foundation pile 1 is shown, so that further foundation pile segments 10 can be axially connected to the foundation pile segments 10 shown in Figure 1. In the exemplary embodiment shown, foundation pile 1 comprises four interconnected foundation pile segments 10. The foundation pile segments 10 are connected to each other such that their respective longitudinal axes 17 are collinear with each other and also collinear with a longitudinal axis 17 of the foundation pile 1.

The foundation pile 1 shown in Figure 1 is composed of four foundation pile segments 10, wherein Figure 2 shows a single foundation pile segment 10 not connected to other foundation pile segments 10. The foundation pile segment 10 has a jacket wall 11 delimited at the end face by an end edge 12 shown at the top of Figure 2 and an end edge 13 shown at the bottom of Figure 2. Further, the foundation pile segment 10 has a recess 16 enclosed by two side edges 14, 15 of the foundation pile segment 10. In the exemplary embodiment of the foundation pile segment 10 shown, the recess 16 extends to the end edge 12 or end face 12 shown in Figure 2 at the top and also to the end edge 13 or end face 13 shown in Figure 2 at the bottom.

The foundation pile segment 10 is usually bent from a steel sheet into the cylindrical or part-cylindrical shape shown in Figure 2. The foundation pile segment 10 can be connected to a further foundation pile segment 10 by connecting, in particular welding, the end edge 12 shown in Figure 2 at the top to an end edge 13 of a further foundation pile segment 10.

In the exemplary embodiment of the foundation pile 1 shown in Figure 1, the foundation pile segments 10 are connected to each other in such a way that the respective recesses 16 of the foundation pile segments 16 are closed at the end faces by axially adjacent foundation pile segments 10. This is achieved by the individual foundation pile segments 10 being connected to each other at an offset angle with respect to the longitudinal axes 17 in such a way that the recesses 16 are closed at the end face by the axially adjacent foundation pile segment 10 or by the axially adjacent foundation pile segments 10.

Consequently, the individual recesses 16 do not merge into one another so that the

stability, in particular the torsional stiffness and the bending stiffness of the correspondingly formed foundation pile 1, is increased.

Figure 3 shows a foundation pile 1 according to a further embodiment of the present invention. The axially adjacent foundation pile segments 10 are offset at an angle to one another by 180° here, so that the recesses 16 of the axially adjacent foundation pile segments 10 are arranged opposite one another. The correspondingly formed foundation pile 1 also has a high stability, in particular a high torsional stiffness and a high bending stiffness, as the individual recesses 16 do not merge into one another. Furthermore, the foundation pile 1 shown in Figure 3 offers the advantage that a fluid, for example air or water, can enter the foundation pile via a recess 16 and exit the foundation pile 1 via the recess 16 opposite this recess 16 without necessarily transferring an impulse to the foundation pile 1.

In the offshore use of the foundation pile 1 shown in Figure 3, the recesses 16 can be arranged, for example, in the region of the water's edge so that waves travelling in the direction of a straight connecting line of the opposing recesses 16 can enter the foundation pile 1 via one recess 16 and exit the foundation pile 1 via the opposing recess 16, wherein a reduced transmission of impulses to the foundation pile 1 occurs due to the waves.

Figure 4 shows a foundation pile 1 according to yet another embodiment of the present invention. Here, foundation pile segments 10, each having two recesses 16 arranged opposite one another, are sandwiched by two foundation pile segments 10 each, which have no recesses. Of course, it would also be possible for foundation pile segments 10 having only a single recess 16 to be axially sandwiched between and connected to two foundation pile segments 10 having no recesses.

Figure 5 shows a foundation pile segment 10 in which the recess 16 is delimited by two holding devices 20 in the form of holding clamps 20. The holding devices 20 connect the side edges 14, 15 arranged opposite one another to one another. In particular, the holding devices 20 are welded to the side edges 14, 15. The holding devices 20 each have an arc-shaped or semicircular outer contour or outer edge 21. The arc-shaped outer side 21, which can also be referred to as the first outer edge 21, is oriented in the direction of the recess 16 and delimits the recess 16. The holding device 10 also has a second outer edge 22 which may be designed to be semicircular in plan view, so that the plan view of the foundation pile segment 10 shown in Figure 5 is a continuous circle. The holding device 20 shown in Figure 5 above completes the end edge 12, and the holding device 20 shown in Figure 5 at the bottom completes the end edges 13 of the foundation

pile segment 10.

The shape of the holding devices 20 allows stresses to be dissipated more effectively into the side edges 12, 13 of the foundation pile segment 10 via the holding devices 20.

List of reference signs

1	Foundation pile
10	Foundation pile segment
11	Jacket wall (of the foundation pile segment)
12, 13	End face/end edge (of the foundation pile segment)
14, 15	Sheet edge/material edge/side edge (of the foundation pile segment)
16	Recess/material recess/opening (of the foundation pile segment)
17	Longitudinal axis (of the foundation pile segment)
20	Holding device/holding clamp
21	Arc-shaped or semicircular outer contour/first outer edge (of the holding device)
22	Second outer edge (of the holding device)

FUNDERINGSPÆL TIL ET VINDENERGIANLÆG

Patentkrav

1. Funderingspæl til vindenergianlæg (1) med mindst to funderingspælssegmenter (10), som er forbundet med hinanden på en sådan måde, at deres længdeakser (17) forløber i det væsentlige på linje med hinanden, hvor mindst to af funderingspælssegmenterne (10) i deres kappevægge (11) hver har mindst én udsparing (16), **kendetegnet ved,** at der i mindst et funderingspælssegment (10) strækker sig mindst én udsparing (16) frem til begge endeflader (12, 13) af funderingspælssegmentet (10), og at denne udsparing er en gennemgående åbning i kappevæggen.

2. Funderingspæl (1) ifølge krav 1, **kendetegnet ved,** at mindst et af funderingspælssegmenterne (10) har mindst to udsparinger (16), som er anbragt vinkelforskudt i forhold til hinanden.

3. Funderingspæl (1) ifølge et af de foregående krav, **kendetegnet ved,** at to tilstødende funderingspælssegmenter (10) er forbundet med hinanden på en sådan måde, at udsparingen (16) / udsparingerne (16) er lukket ved endefladen via det aksialt tilstødende funderingspælssegment (10).

4. Funderingspæl (1) ifølge krav 3, **kendetegnet ved,** at de to tilstødende funderingspælssegmenter (10) hver har mindst én udsparing (16), hvor funderingspælssegmenterne (10) er vinkelforskudt forbundet med hinanden på en sådan måde, at udsparingen (16) / udsparingerne (16) er lukket ved endefladen via det aksialt tilstødende funderingspælssegment (10).

5. Funderingspæl (1) ifølge krav 3 eller 4, **kendetegnet ved,** at et funderingspælssegment (10) med en udsparing (16) er forbundet med et funderingspælssegment (10) uden udsparinger (16), fortrinsvis med to funderingspælssegmenter (10) uden udsparinger (16).

6. Funderingspæl (1) ifølge et af de foregående krav, **kendetegnet ved,** at ved funderingspælssegmentet (10) med udsparingen (16) er indbyrdes modstående sidekanter (14, 15) forbundet med hinanden.

7. Funderingspæl (1) ifølge et af de foregående krav, **kendetegnet ved,** at funderingspælen (1) omfatter mindst en holdeindretning (20), ved hjælp af hvilken modstående sidekanter (14, 15) af et funderingspælssegment (10) er forbundet med hinanden.

8. Funderingspæl (1) ifølge krav 7, **kendetegnet ved,** at holdeindretningen (20) har en bueformet, fortrinsvis halvcirkelformet, ydre kontur (21), hvor holdeindretningen (20) er forbundet med indbyrdes modstående sidekanter af et funderingspælssegment (10) på en sådan måde, at den bueformede eller halvcirkelformede ydre kontur (21) er orienteret mod udsparingen (16) og afgrænser denne.

9. Funderingspæl (1) ifølge et af de foregående krav, **kendetegnet ved,** at sidekanterne (14, 15), der lateralt afgrænser udsparingen (16), i området med mindst en endeflade (12, 13) er rettet mod hinanden og fortrinsvis i det væsentlige forløber parallelt med endefladen (12, 13).

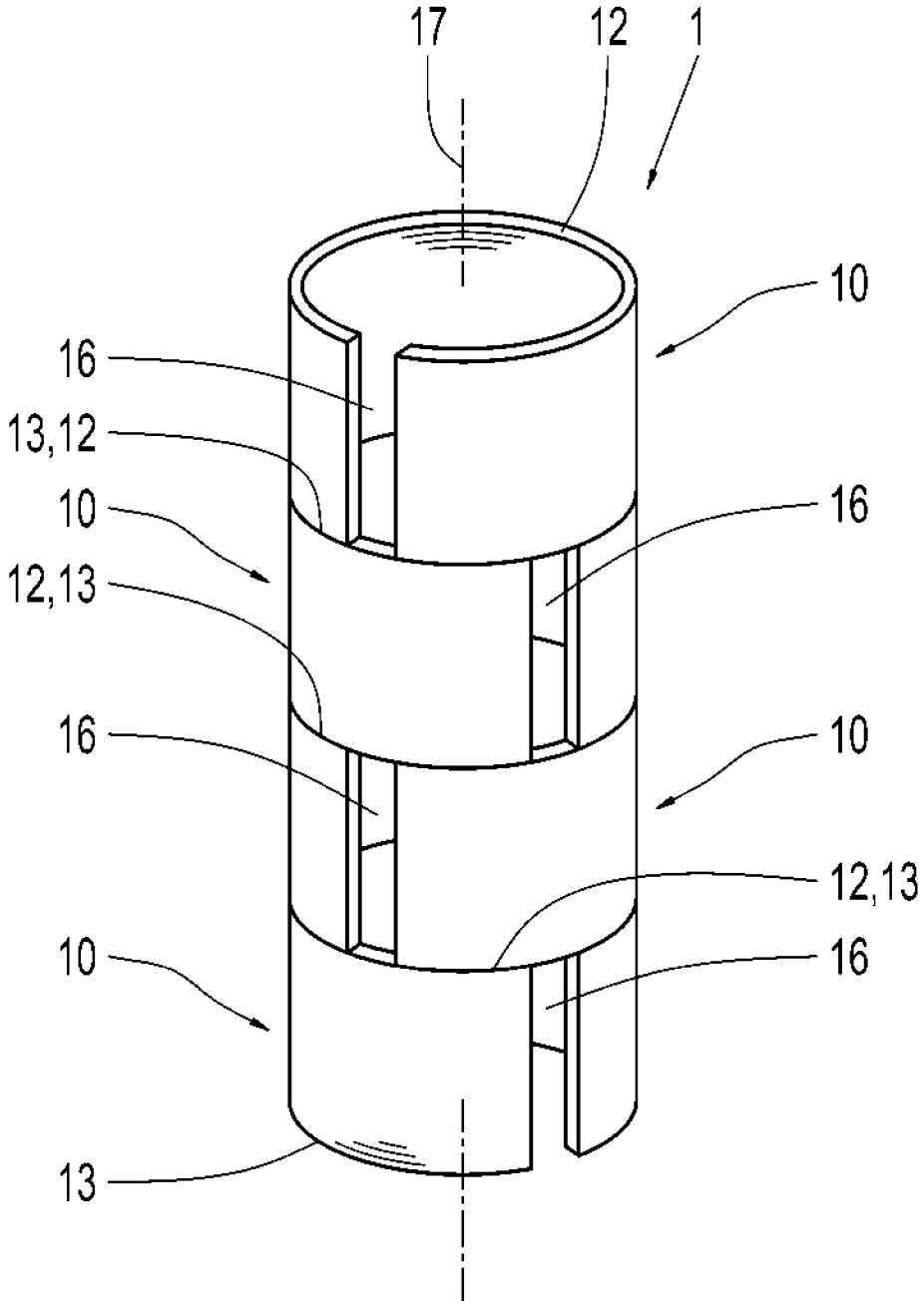

Fig. 1

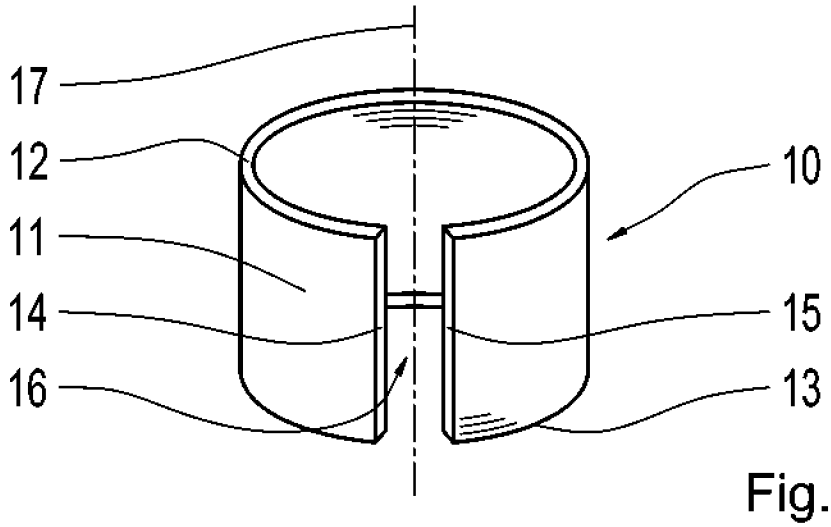

Fig. 2

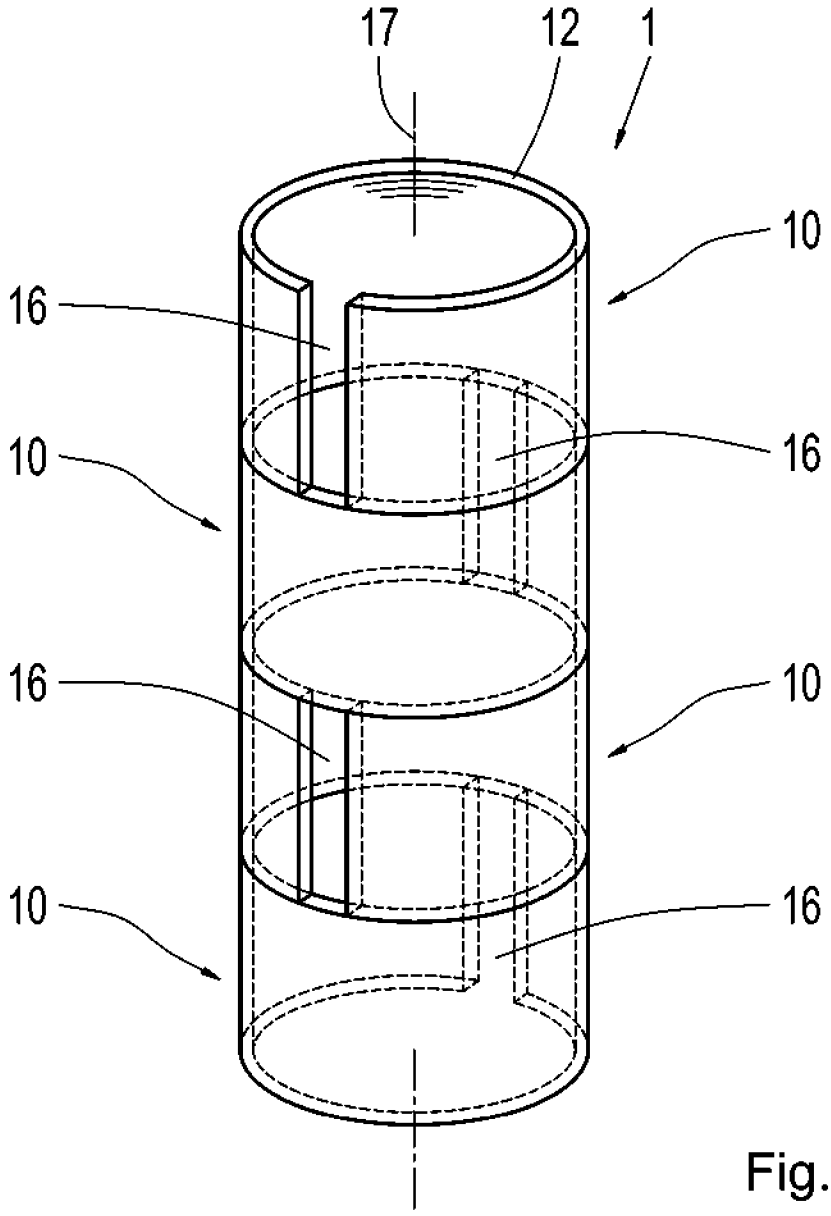

Fig. 3

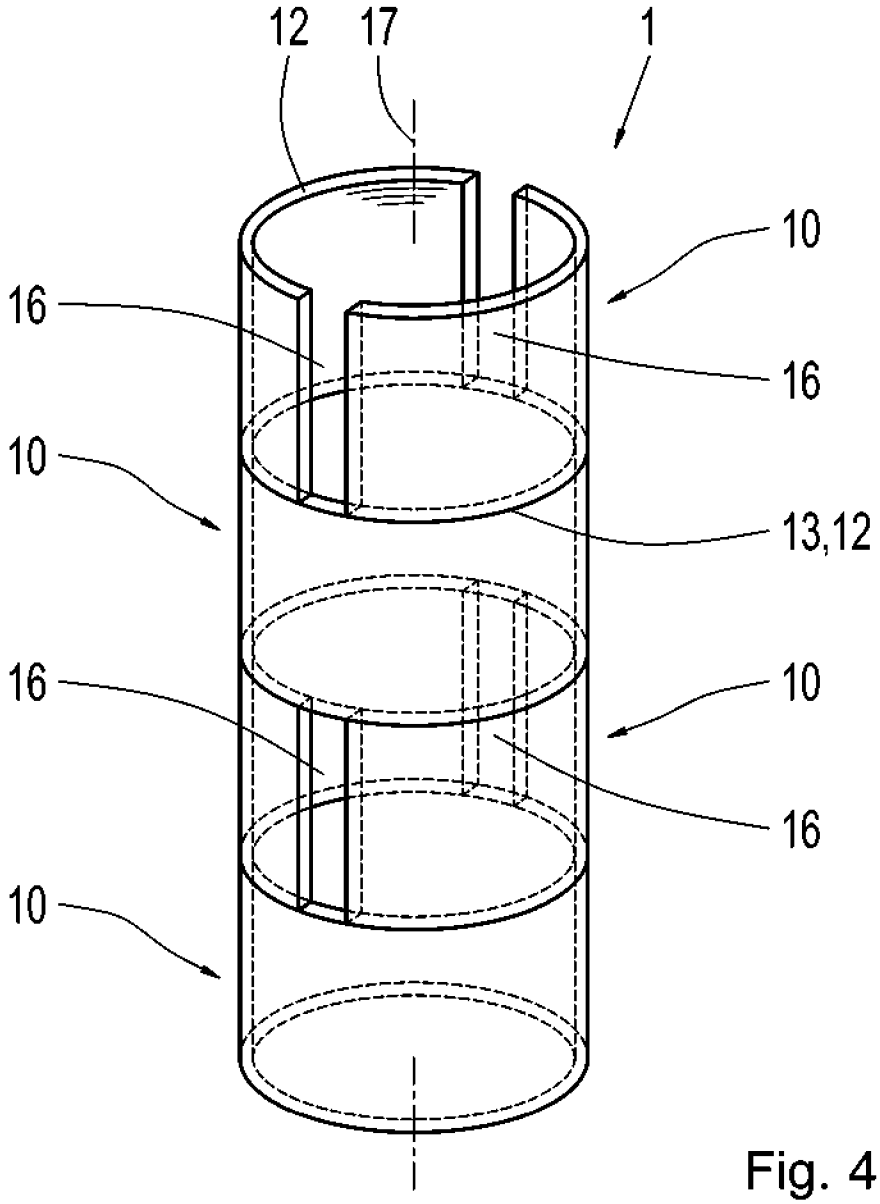

Fig. 4

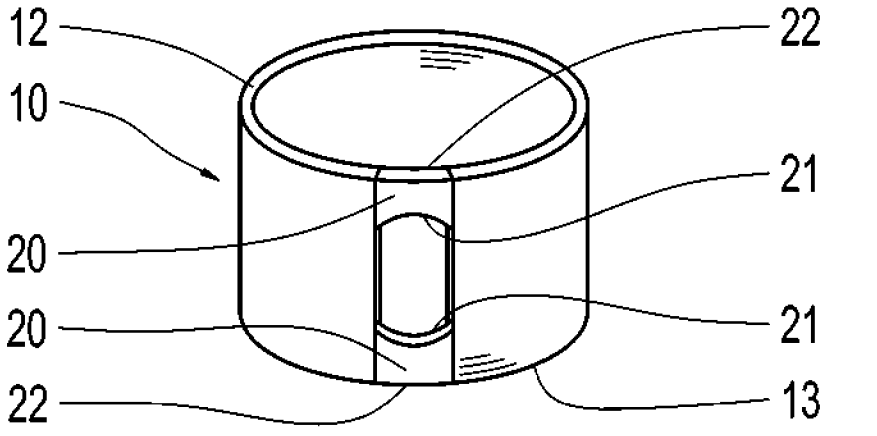

Fig. 5