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(54) **POSITIVE DISPLACEMENT VANE PUMP**

VERDRÄNGERFLÜGELZELLENPUMPE

POMPE À DÉPLACEMENT POSITIF À PALETTES

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(73) Proprietor: **VHIT S.p.A.**
26010 Offanengo (IT)

(72) Inventor: **GALLI, Giancarlo**
26010 Offanengo (Cremona) (IT)

(74) Representative: **Bee, Joachim**
Robert Bosch GmbH, C/IPE
P.O. Box 30 02 20
70442 Stuttgart (DE)

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Description

DE489322, WO2011/086013, US2013/266466, EP2886795.

Technical field

[0001] The present invention relates to a variable volume positive displacement vane pump.

[0002] The variable volume enables the flow rate of a fluid crossing the pump to be regulated, optimising it according to the actual operating requirements. Vane pumps are known comprising a rotor that can rotate about an axis of rotation.

Background art

[0003] Such rotor comprises an impeller in which radial slots are afforded in which the vanes are inserted.

[0004] The pump also comprises a stator which internally defines a chamber in which the rotor can rotate about its own axis of rotation. The vanes are slidable along the slots and project radially until they come into contact with the chamber of the stator.

[0005] The pump comprises a centring ring that abuts a radially more internal end of all the vanes. Such centring ring in combination with the chamber of the stator guides the radial sliding of the vanes along the slot. In particular, the centring ring limits the radial return of the vanes into the slots. Furthermore, the centring ring may be drawn in rotation by the vanes together with the rotor.

[0006] The variation of the pump volume determines the movement of the stator with respect to the axis of rotation of the rotor. This is also associated with a movement of the centring ring.

[0007] Examples of the prior art described above are shown in the following patent documents: US2633805 and WO2007098595.

[0008] Some drawbacks of this construction solution are as follows:

- assembly difficulties, due to the need to keep all the vanes in contact with the chamber both on one side and the other of the rotor;
- lack of stable support for the vanes at the pump chamber, in particular in the zones in which separating the suction and delivery steps is required, with the consequent loss of performance;
- noise caused by beating due to the radial thrusts of the vanes during their functional dynamics;
- abnormal wear on the centring rings of the vanes and the pump chamber, due to the radial stress caused by the functional dynamics, where the vanes in opposition, bouncing against the rings, recover functional clearance, triggering a "hammering" causing wear and noise, with a consequent reduction in performance, both volumetric and mechanical;
- difficulty controlling the presence of the centring ring covered by the rotor. Known pumps are also disclosed by DE102012213847, DE492322,

Object of the invention

[0009] In this context, the technical task underpinning the present invention is to propose a pump which enables obviating the drawbacks described above. In particular, an object of the present invention is to propose a pump that allows the wear and noise to be reduced.

[0010] A further object of the present invention is also to improve performance. The stated technical task and specified objects are substantially achieved by a pump comprising the technical features disclosed in one or more of the appended claims.

Brief description of drawings

[0011] Further features and advantages of the present invention will become more apparent from the following indicative, and hence non-limiting, description of a preferred, but not exclusive, embodiment of a pump as illustrated in the appended drawings, in which:

- figures 1-4 illustrate an exploded view of pumps according to the present invention;
- figures 5a and 5b show two configurations of the same pump according to the present invention;
- figures 6a and 6b show two configurations of the same pump according to the present invention;
- figures 7a and 7b show a view of a component of a pump according to the present invention and a section according to the plane C-C thereof;
- figures 8a-8c show a particular configuration of a component of a pump according to the present invention;
- figures 9a-9c show an exploded view of a particular configuration of a component of a pump according to the present invention;
- figures 10a-10d show four views of a component of a pump according to the present invention;
- figures 11a-11d show four views of a component of a pump according to the present invention;
- figures 12a-12d show four views of a component of a pump according to the present invention;
- figures 13a-13c show sectional views of a pump according to the present invention;
- figures 14a-14c show sectional views of a further embodiment of a pump according to the present invention;
- figures 15a-15c show sectional views of a further embodiment of a pump according to the present invention;
- figures 16a and 16b show the same detail of figures 15a-15c;
- figures 17a-17c show sectional views of a further embodiment of a pump according to the present invention.

Detailed description of preferred embodiments of the invention

[0012] In the appended figures, reference number 1 indicates a variable volume positive displacement vane pump.

[0013] The pump 1 comprises a rotor 2. The rotor 2 can rotate about an axis 20 of rotation. The rotor 2 comprises a plurality of vanes 23.

[0014] They are designed to interact with the fluid whose pressure is to be increased. Appropriately they have a substantially radial extension. In any case, examples of positive displacement vane pumps are well known in the technical sector.

[0015] Appropriately the rotor 2 comprises slots 22 for at least partially housing the vanes 23. The slots 22 cross the rotor 2 along a parallel direction to that of the axis of rotation. The slots 22 therefore have an axial through arrangement along the rotor 2. The slots 22 appropriately have a spoke arrangement. Appropriately also such slots 22 extend radially.

[0016] The pump 1 comprises a shaft 3 for activating the rotor 2. The rotor 2 and the shaft 3 may be two distinct assembled elements, or a single piece. In a particular non-limiting solution, the rotor 2 may surround the shaft 3 at least for a predetermined axial length.

[0017] This facilitates the transmission of the required torque.

[0018] The pump 1 further comprises a stator 4. The relative position between the stator 4 and the axis 20 of rotation of the rotor 2 is adjustable to allow a variation of the volume of the pump 1. Usually the stator 4 is movable while the axis 20 of rotation of the rotor 2 is kept stationary.

[0019] For example, in an exemplified solution shown in figures 5a-5b the stator 4 can translate with respect to the axis 20 of rotation to change the volume of the pump 1. In an alternative solution the stator 4 can rotate to change the volume (see figures 6a-6b in which 46 indicates a joint zone that allows a rotation).

[0020] Appropriately, the pump 1 comprises a regulation means 400 for regulating the volume which may comprise:

- a chamber 401 suitable to contain a pressurised fluid that exerts a thrust on the stator 4;
- elastic means 402 that oppose said thrust.

[0021] The stator 4 internally defines a chamber 40 in which the rotor 2 can rotate about its own axis 20 of rotation.

[0022] Typically, such chamber 40 comprises a lateral surface which is substantially cylindrical, but which could also be shaped like the lateral surface of a prism with an oval or elliptical base. The pump 1 comprises a centring means 5 for centring the vanes. The centring means 5 contributes to the correct positioning of the vanes 23 in an operating zone. The centring means 5 is a means that

contrasts the return of the vanes into the slots 22.

[0023] The centring means 5 comprises a first gudgeon 41 solidly constrained to the stator 4. The first gudgeon 41 is therefore not drawn in rotation by the rotor 2.

[0024] At every volume change of the pump 1, the movement of the stator 4 with respect to the axis 20 of rotation takes place in unison with the first gudgeon 41. Advantageously, the first gudgeon 41 projects in a cantilever fashion appropriately within the rotor 2. In particular, as shown for example in figure 14b, it could project in a cantilever fashion towards the shaft 3. Appropriately (with reference to figures 13b and 14b) the first gudgeon 41 extends axially along a different length (in particular shorter) with respect to the height of the chamber 40 (i. e. at the extension of the chamber 40 along the axis 20 of rotation of the rotor 2). In fact, at the vanes 23 the chamber 40 has a length, measured along the direction of the axis 20 of rotation, which is constant and predetermined. It is specified that in this document the expression "direction of the axis 20 of rotation" means a parallel direction to that of the axis 20 of rotation. In the preferred embodiment the first gudgeon 41 extends along the direction of the axis 20 of rotation for a different length 30 with respect to said predetermined length of the chamber 40.

[0025] The stator 4 comprises a wall 45 which surrounds the axis 20 of rotation and which contributes to delimiting the chamber 40. The wall 45 surrounds the chamber 40.

[0026] The wall 45 is curved, preferably cylindrical, but it could, for example, be oval shaped.

[0027] In an embodiment shown by way of example, for example, in figures 10b, 11b, 12b the first gudgeon 41 has a through hole 410 for the passage of the shaft 3.

[0028] Preferably the first gudgeon 41 is coaxial with the wall 45. In a particular embodiment the centring means 5 comprises a swivel ring 24 that can rotate and that is radially interposed between the first gudgeon 41 and the vanes 23.

[0029] The vanes 23 comprise a radially more internal side 231 and a radially more external side 232.

[0030] The radially more internal side 231 extends parallel to the axis 20 of rotation of the rotor 2. The radially more external side 232 extends parallel to the axis 20 of rotation of the rotor 2. Advantageously each vane 23 extends like a parallelepiped.

[0031] The radially more internal sides 231 of a plurality of said vanes 23 may be in contact with said first gudgeon 41 directly or through the interposition of the swivel ring 24 which surrounds said first gudgeon 41.

[0032] Figures 3 and 4 show a solution in which the first gudgeon 41 is placed in direct contact with the more radially internal sides 231 of the vanes.

[0033] Figures 1 and 2 show a solution in which between the first gudgeon 41 and the more radially internal sides 231 of the vanes 23 said swivel ring 24 is interposed. The purpose of the swivel ring 24 is to optimise the friction between the vanes 23 and the first gudgeon

41. Appropriately the swivel ring 24 is annular. It may surround the first gudgeon 41 for the entire length of the first gudgeon 41. In an alternative solution the axial length of the swivel ring 24 may be shorter or however different with respect to the axial length of the first gudgeon 41.

[0034] As illustrated, for example, in figures 1 and 3, the centring means 5 may also comprise a ring 50 for centring the vanes.

[0035] The rotor 2 would therefore be at least partially interposed (axially) between the first gudgeon 41 and the centring ring 50. The first gudgeon 41 and the centring ring 50 would therefore be located on two opposite sides of said rotor 2. The combination of the first gudgeon 41 and the centring ring 50 allows the vanes 23 to be guided at two opposite ends of the radially most internal side 231 of the vanes 23.

[0036] The stator 4 comprises a structure 43 that delimits at least partially the chamber 40 completely surrounding at least a portion of the rotor 2. The structure 43 integrates (possibly coincide with) said wall 45.

[0037] The first gudgeon 41 is solidly constrained to the structure 43. In particular it is connected to the structure 43. This could take place through an unremovable connection, for example the first gudgeon 41 and the structure 43 could be a single monolithic body (see figures 10b, 11b, 12b) or however constrained together, for example, by interference.

[0038] In that case the first gudgeon 41 could be afforded in a bridge 44 that connects two distinct edges of the structure 43 (preferably the two distinct edges are diametrically opposite with respect to the chamber 40). The bridge 44 and the first gudgeon 41 are therefore a monolithic body with the structure 43. The bridge 44 appropriately contributes to delimiting the chamber 40.

[0039] Alternatively, the connection of the first gudgeon 41 with the structure 43 could be removable (see for example figures 8a-8c and 9a-9c better described below).

[0040] Also in that case the first gudgeon 41 could be afforded in a bridge 44 (see in particular the exemplary figures 8a and 9a) that connects the two distinct edges of the structure 43. Advantageously these two distinct edges are located in diametrically opposite positions (with respect to the chamber 40) of the structure 43.

[0041] The bridge 44 could be detachable with respect to the structure 43. For example, the bridge 44 could be constrained by means of threaded elements (see figures 8a-8c) or by pressure. Alternatively the bridge 44 could be inserted at least in part in specific seats 440 afforded in the structure 43 able to lock at least in part the degrees of freedom of said bridge 44 (see figures 9a-9c).

[0042] In general, the first gudgeon 41 could be afforded in a single monolithic body with remaining parts of the bridge 44 or be assembled thereto.

[0043] Appropriately the centring means 5 for centring the vanes 23 comprises a second gudgeon 42 solidly constrained to the structure 43 (see for example figures 15b, 16b, 17b). Advantageously the second gudgeon 42

projects in a cantilever fashion in the opposite direction with respect to the first gudgeon 41. The second gudgeon 42 projects advantageously towards the inside of the rotor 2 or however towards the shaft 3. The second gudgeon 42 is therefore not drawn in rotation by the rotor 2.

[0044] The combination of the first and the second gudgeon 41, 42 allows the vanes 23 to be guided at two opposite ends of the radially most internal side 231 of the vanes 23. In other words, the vanes 23 could be guided by both sides of the stator 4.

[0045] The vanes 23 extend radially between the second gudgeon 42 and the wall 45 which: is afforded in the structure 43, surrounds at least in part said chamber 40, surrounds said axis 20 of rotation. One or more of the features previously described for the first gudgeon 41 could also be repeated for the second gudgeon 42.

[0046] The structure 43 may possibly completely house the rotor 2 within it (see figures 1-4). The second gudgeon 42 could possibly be integrated into a lid for closing a side of the structure 43.

[0047] In a particularly advantageous solution the shaft 3 crosses the rotor 2, the first and the second gudgeon 41, 42 (see for example figure 15b). Alternatively the shaft 3 may be projecting in a cantilever fashion and could cross the first gudgeon 41 without crossing the second gudgeon 42 (see for example figure 13b or 17b).

[0048] In that case the second gudgeon 42 could be a solid body free from through holes.

[0049] The invention thus conceived makes it possible to achieve multiple advantages.

[0050] In particular by making the first gudgeon solidly constrained to the stator, radial clearance and wear are reduced, as well as the noise associated therewith.

[0051] Furthermore, also the assembly of the pump and quality control are quicker. The invention as it is conceived is susceptible to numerous modifications and variants, all falling within the scope of the appended claims. In practice, all the materials used, as well as the dimensions, can be any according to requirements.

Claims

1. A variable volume positive displacement vane pump comprising:

- a rotor (2) that can turn about an axis (20) of rotation and that comprises slots (22) for at least partially housing vanes (23), said slots (22) passing through the rotor (2) from one end to the other along a direction parallel to that of the axis (20) of rotation;
- a stator (4), the relative position between the stator (4) and the axis (20) of rotation of the rotor (2) being adjustable so as to permit variation in the volume of the pump (1); the stator (4) having an internal chamber (40), wherein the rotor (2) can turn about its own axis (20) of rotation; the

stator (4) comprising a wall (45) that at least partly encloses said chamber (40);
 - centring means (5) for centring the vanes, said centring means (5) comprising a first gudgeon (41) that is solidly constrained to the stator (4) and cannot be drawn into rotation by the rotor (2);

the stator (4) comprising a structure (43) that integrates said wall (45) and that at least partially delimits the chamber (40), completely enclosing at least a portion of the rotor (2); the first gudgeon (41) being solidly constrained to the structure (43).

2. The pump according to claim 1 **characterized in that** it comprises a drive shaft (3) for driving the rotor (2); the first gudgeon (41) having a through hole (410) for passage of the shaft (3).

3. The pump according to claim 1 or 2, **characterized in that** said stator wall (45) is circular, said wall (45) and the first gudgeon (41) being coaxial.

4. The pump according to any one of the preceding claims, **characterized in that** the centring means (5) comprises a swivel ring (24) that is radially interposed between the first gudgeon (41) and the vanes (23).

5. The pump according to any one of the preceding claims, **characterized in that** the centring means (5) for centring the vanes comprises a second gudgeon (42) that is solidly constrained to the structure (43); said vanes (23) extending radially between the second gudgeon (42) and the wall (45) that delimits said chamber (40), surrounding said axis (20) of rotation; said rotor (2) being at least partly interposed between the first and the second gudgeon (41, 42).

6. The pump according to claim 5, when directly or indirectly dependent upon claim 2, **characterized in that** said shaft (3) is solidly constrained to the rotor (2) and passes through the rotor (2), and the first and second gudgeons (41, 42).

7. The pump according to any one of the preceding claims, **characterized in that** the stator (4) comprises a bridge (44) that contributes to delimiting the chamber (40) and that connects two distinct edges of the structure (43); the first gudgeon (41) being afforded in the bridge (44) and said bridge (44) being detachable with respect to said structure (43).

8. The pump according to any one of the preceding claims, **characterized in that** the stator (4) comprises a bridge (44) that contributes to delimiting the chamber (40) and that connects two distinct edges of the structure (43); the first gudgeon (41) being

afforded in the bridge (44), and said bridge (44) and said first gudgeon (41) constituting a monolithic body with said structure (43).

9. The pump according to any one of the preceding claims, **characterized in that** the first gudgeon (41) projects in a cantilever fashion in the rotor (2).

10. The pump according to any one of the preceding claims, **characterized in that** at the vanes (23), the chamber (40) is of a constant, predetermined length, as measured along the direction of the axis (20) of rotation; the first gudgeon (41) extending along said direction of the axis (20) of rotation for a length that differs with respect to said predetermined length of the chamber (40).

Patentansprüche

1. Verdrängerflügelpumpe mit variablem Volumen, die Folgendes umfasst:

- einen Rotor (2), der sich um eine Drehachse (20) drehen kann und der Schlitz (22) zur zumindest teilweisen Unterbringung von Flügeln (23) umfasst, wobei die Schlitz (22) von einem Ende zu dem anderen in einer parallel zu jener der Drehachse (20) verlaufenden Richtung durch den Rotor (2) hindurchgehen;
- einen Stator (4), wobei die Relativposition zwischen dem Stator (4) und der Drehachse (20) des Rotors (2) dahingehend einstellbar ist, eine variierende des Volumens der Pumpe (1) zu gestatten; wobei der Stator (4) eine Innenkammer (40) aufweist, wobei sich der Rotor (2) um seine eigene Drehachse (20) drehen kann; wobei der Stator (4) eine Wand (45) umfasst, die die Kammer (40) zumindest zum Teil umschließt;
- ein Zentrierungsmittel (5) zur Zentrierung der Flügel, wobei das Zentrierungsmittel (5) einen ersten Zapfen (41) umfasst, der fest an dem Stator (4) beschränkt ist und nicht in eine Drehung von dem Rotor (2) verwickelt werden kann;

wobei der Stator (4) eine Struktur (43) umfasst, die die Wand (45) integriert und die die Kammer (40) zumindest zum Teil begrenzt und zumindest einen Teil des Rotors (2) komplett umschließt; wobei der erste Zapfen (41) fest an der Struktur (43) beschränkt ist.

2. Pumpe nach Anspruch 1, **dadurch gekennzeichnet, dass** sie eine Antriebswelle (3) zum Antrieb des Rotors (2) umfasst; wobei der erste Zapfen (41) eine Durchgangsbohrung (410) zum Hindurchgehen der Welle (3) aufweist.

3. Pumpe nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die Statorwand (45) kreisförmig ist, wobei die Wand (45) und der erste Zapfen (41) koaxial sind. 5
4. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Zentrierungsmittel (5) einen Schwenkring (24) umfasst, der radial zwischen dem ersten Zapfen (41) und den Flügeln (23) angeordnet ist. 10
5. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Zentrierungsmittel (5) zur Zentrierung der Flügel einen zweiten Zapfen (42) umfasst, der fest an der Struktur (43) beschränkt ist; wobei sich die Flügel (23) radial zwischen dem zweiten Zapfen (42) und der Wand (45), die die Kammer (40) begrenzt und die Drehachse (20) umgibt, erstrecken; wobei der Rotor (2) zumindest zum Teil zwischen dem ersten und dem zweiten Zapfen (41, 42) angeordnet ist. 15 20
6. Pumpe nach Anspruch 5, insofern direkt oder indirekt abhängig von Anspruch 2, **dadurch gekennzeichnet, dass** die Welle (3) fest an dem Rotor (2) beschränkt ist und durch den Rotor (2) und den ersten und den zweiten Zapfen (41, 42) hindurchgeht. 25
7. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Stator (4) eine Brücke (44) umfasst, die zur Begrenzung der Kammer (40) beiträgt und die zwei individuelle Ränder der Struktur (43) verbindet; wobei der erste Zapfen (41) in der Brücke (44) vorgesehen ist und die Brücke (44) bezüglich der Struktur (43) lösbar ist. 30 35
8. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Stator (4) eine Brücke (44) umfasst, die zur Begrenzung der Kammer (40) beiträgt und die zwei individuelle Ränder der Struktur (43) verbindet; wobei der erste Zapfen (41) in der Brücke (44) vorgesehen ist und die Brücke (44) und der erste Zapfen (41) einen monolithischen Körper mit der Struktur (43) bilden. 40
9. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der erste Zapfen (41) vorkragend in den Rotor (2) vorragt. 45
10. Pumpe nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** an den Flügeln (23) die Kammer (40) eine konstante vorbestimmte Länge, gemessen in der Richtung der Drehachse (20), aufweist; wobei sich der erste Zapfen (41) in der Richtung der Drehachse (20) in einer Länge, die sich von der vorbestimmten Länge der Kammer (40) unterscheidet, erstreckt. 50 55

Revendications

1. Pompe à ailettes à déplacement positif de volume variable, comprenant :

- un rotor (2) qui peut tourner autour d'un axe (20) de rotation et qui comprend des fentes (22) pour recevoir au moins en partie des ailettes (23), lesdites fentes (22) passant à travers le rotor (2) d'une extrémité à l'autre le long d'une direction parallèle à celle de l'axe (20) de rotation ;
- un stator (4), la position relative entre le stator (4) et l'axe (20) de rotation du rotor (2) pouvant être ajustée de manière à permettre une variation de volume de la pompe (1) ; le stator (4) ayant une chambre intérieure (40), le rotor (2) pouvant tourner autour de son propre axe (20) de rotation ; le stator (4) comprenant une paroi (45) qui entoure au moins en partie ladite chambre (40) ;
- un moyen de centrage (5) pour centrer les ailettes, ledit moyen de centrage (5) comprenant un premier goujon (41) qui est fixé solidement au stator (4) et qui ne peut pas être entraîné en rotation par le rotor (2) ;

le stator (4) comprenant une structure (43) qui intègre ladite paroi (45) et qui délimite au moins en partie la chambre (40), renfermant complètement au moins une portion du rotor (2) ; le premier goujon (41) étant fixé solidement à la structure (43).

2. Pompe selon la revendication 1, **caractérisée en ce qu'elle** comprend un arbre d'entraînement (3) pour entraîner le rotor (2) ; le premier goujon (41) ayant un trou traversant (410) pour le passage de l'arbre (3) . 35
3. Pompe selon la revendication 1 ou 2, **caractérisée en ce que** ladite paroi (45) de stator est circulaire, ladite paroi (45) et le premier goujon (41) étant coaxiaux. 40
4. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce que** le moyen de centrage (5) comprend une bague pivotante (24) qui est interposée radialement entre le premier goujon (41) et les ailettes (23). 45
5. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce que** le moyen de centrage (5) pour centrer les ailettes comprend un deuxième goujon (42) qui est fixé solidement à la structure (43) ; lesdites ailettes (23) s'étendant radialement entre le deuxième goujon (42) et la paroi (45) qui délimite ladite chambre (40), entourant ledit axe (20) de rotation ; ledit rotor (2) étant au moins 50 55

en partie interposé entre le premier et le deuxième goujon (41, 42) .

6. Pompe selon la revendication 5 lorsqu'elle dépend directement ou indirectement de la revendication 2, **caractérisée en ce que** ledit arbre (3) est fixé solidement au rotor (2) et passe à travers le rotor (2), et les premier et deuxième goujons (41, 42). 5

7. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce que** le stator (4) comprend un pont (44) qui contribue à délimiter la chambre (40) et qui relie deux bords distincts de la structure (43) ; le premier goujon (41) étant réalisé dans le pont (44) et ledit pont (44) pouvant être détaché de ladite structure (43). 10 15

8. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce que** le stator (4) comprend un pont (44) qui contribue à délimiter la chambre (40) et qui relie deux bords distincts de la structure (43) ; le premier goujon (41) étant réalisé dans le pont (44) et ledit pont (44) et ledit premier goujon (41) constituant un corps monolithique avec ladite structure (43). 20 25

9. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce que** le premier goujon (41) fait saillie en porte-à-faux dans le rotor (2). 30

10. Pompe selon l'une quelconque des revendications précédentes, **caractérisée en ce qu'**au niveau des ailettes (23), la chambre (40) présente une longueur constante prédéterminée mesurée le long de la direction de l'axe (20) de rotation ; 35
le premier goujon (41) s'étendant le long de ladite direction de l'axe (20) de rotation sur une longueur différente par rapport à ladite longueur prédéterminée de la chambre (40). 40

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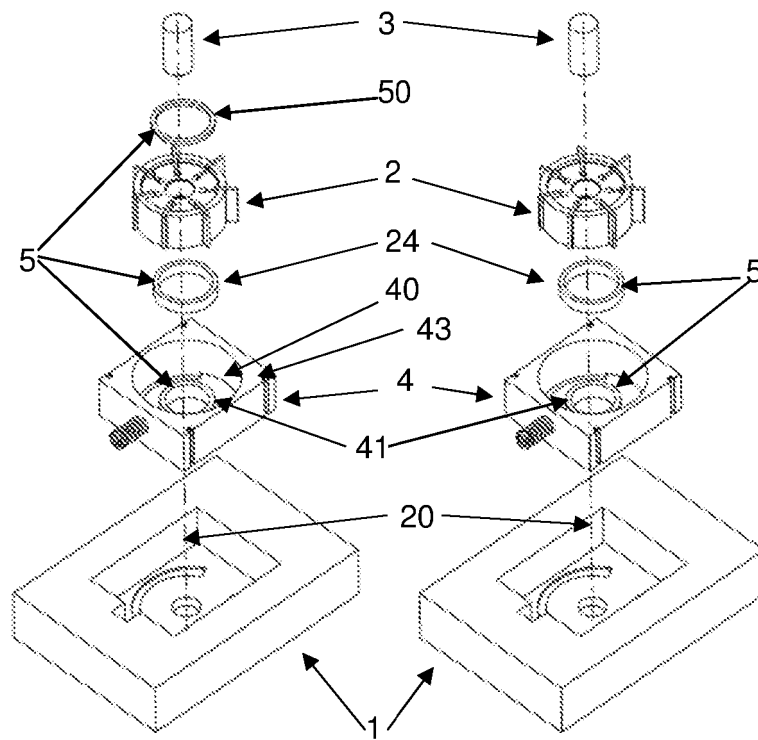


Fig. 1

Fig. 2

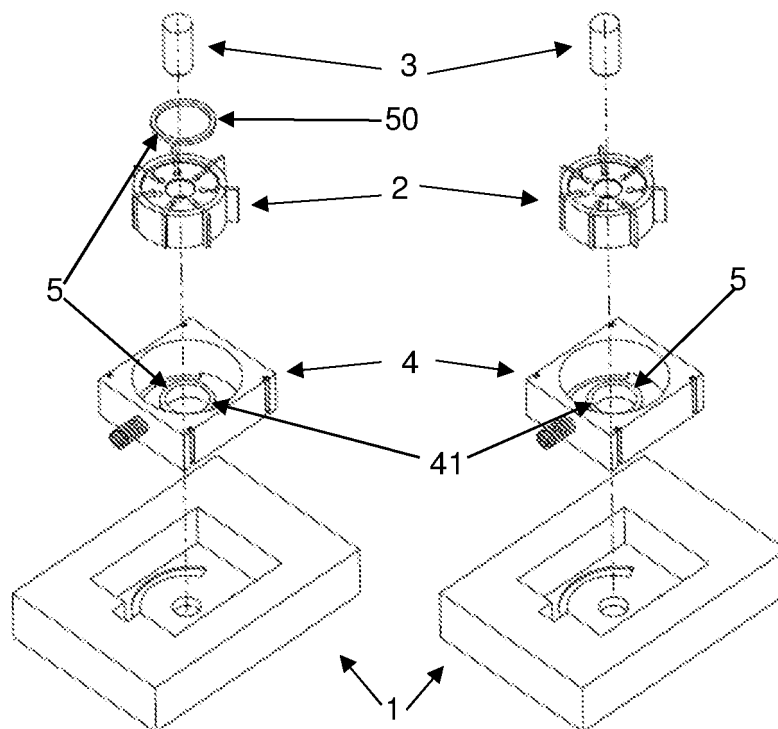


Fig. 3

Fig. 4

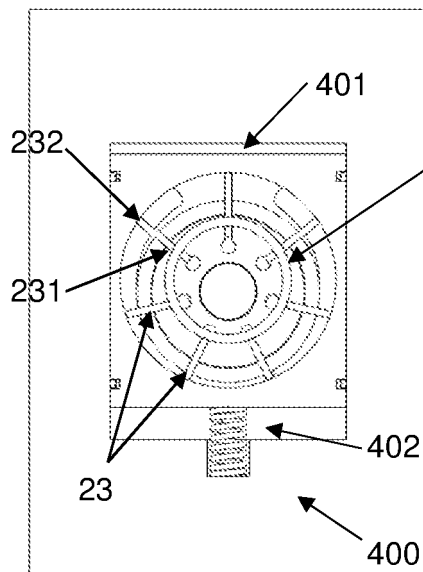


Fig. 5a

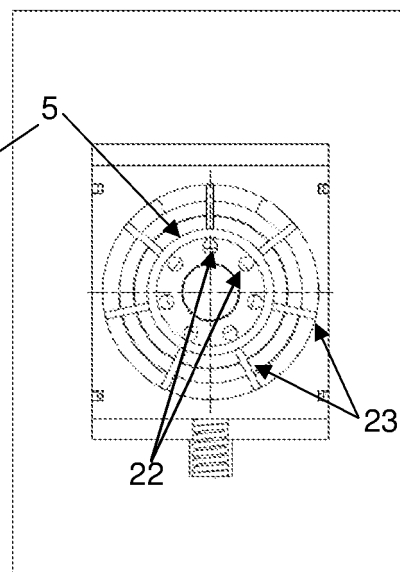


Fig. 5b

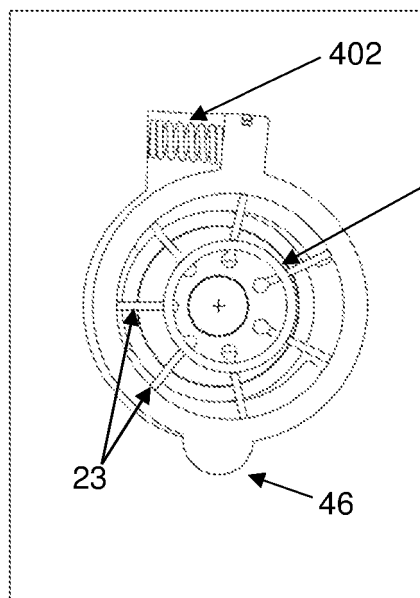


Fig. 6a

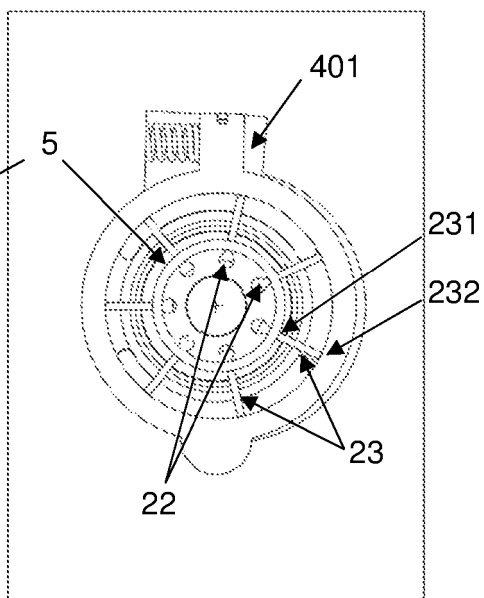


Fig. 6b

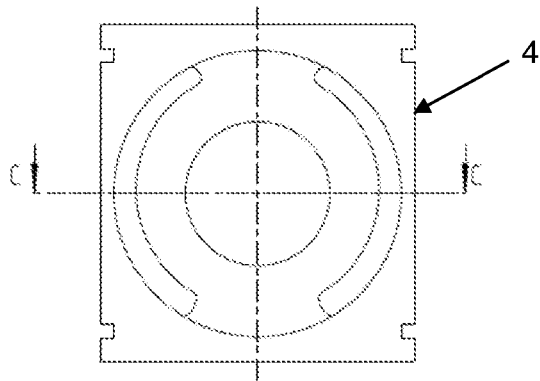


Fig. 7a

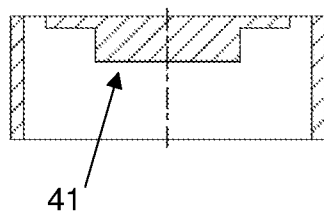


Fig. 7b

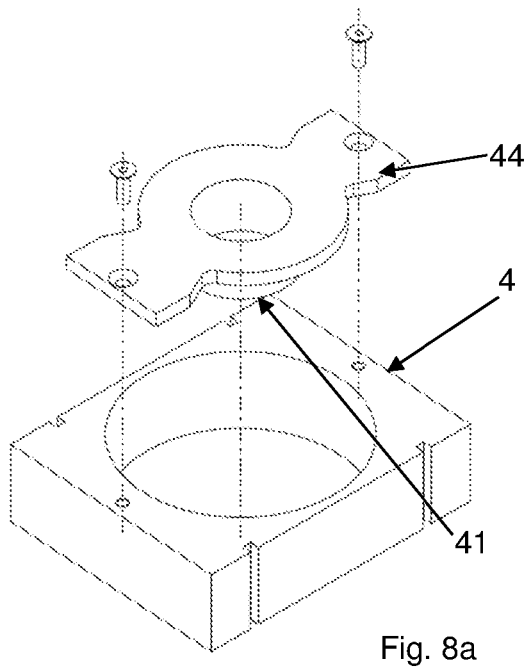


Fig. 8a

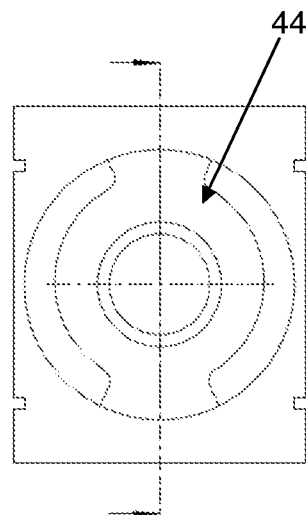


Fig. 8b

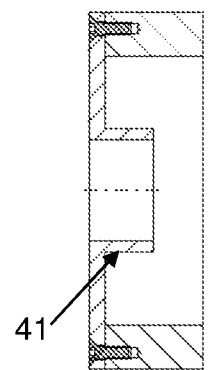


Fig. 8c

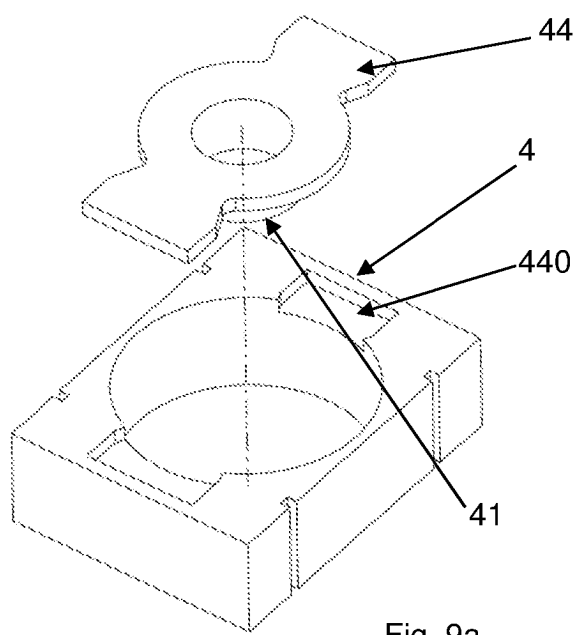


Fig. 9a

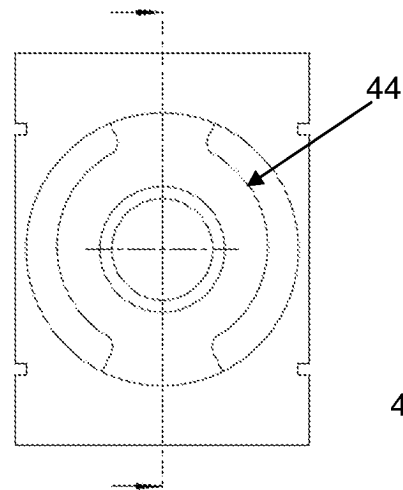


Fig. 9b

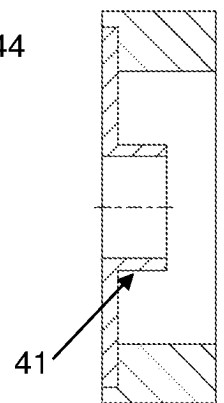
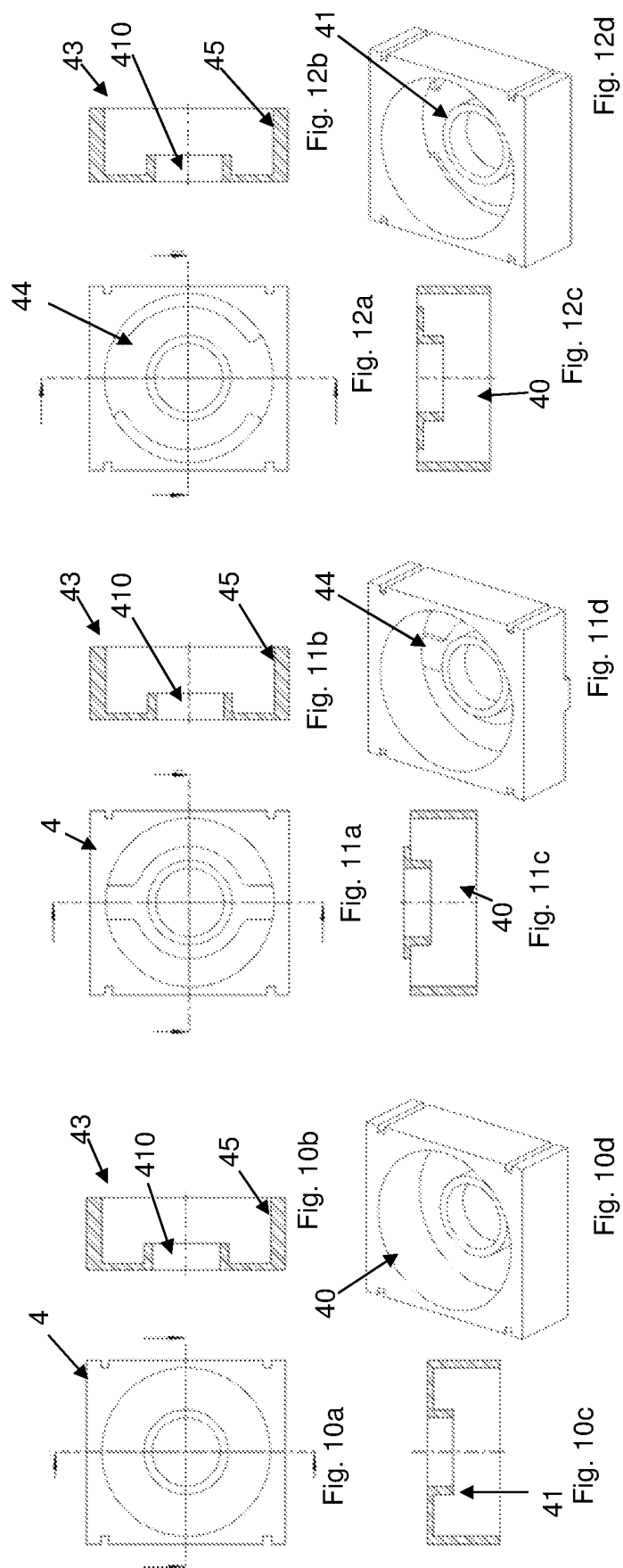
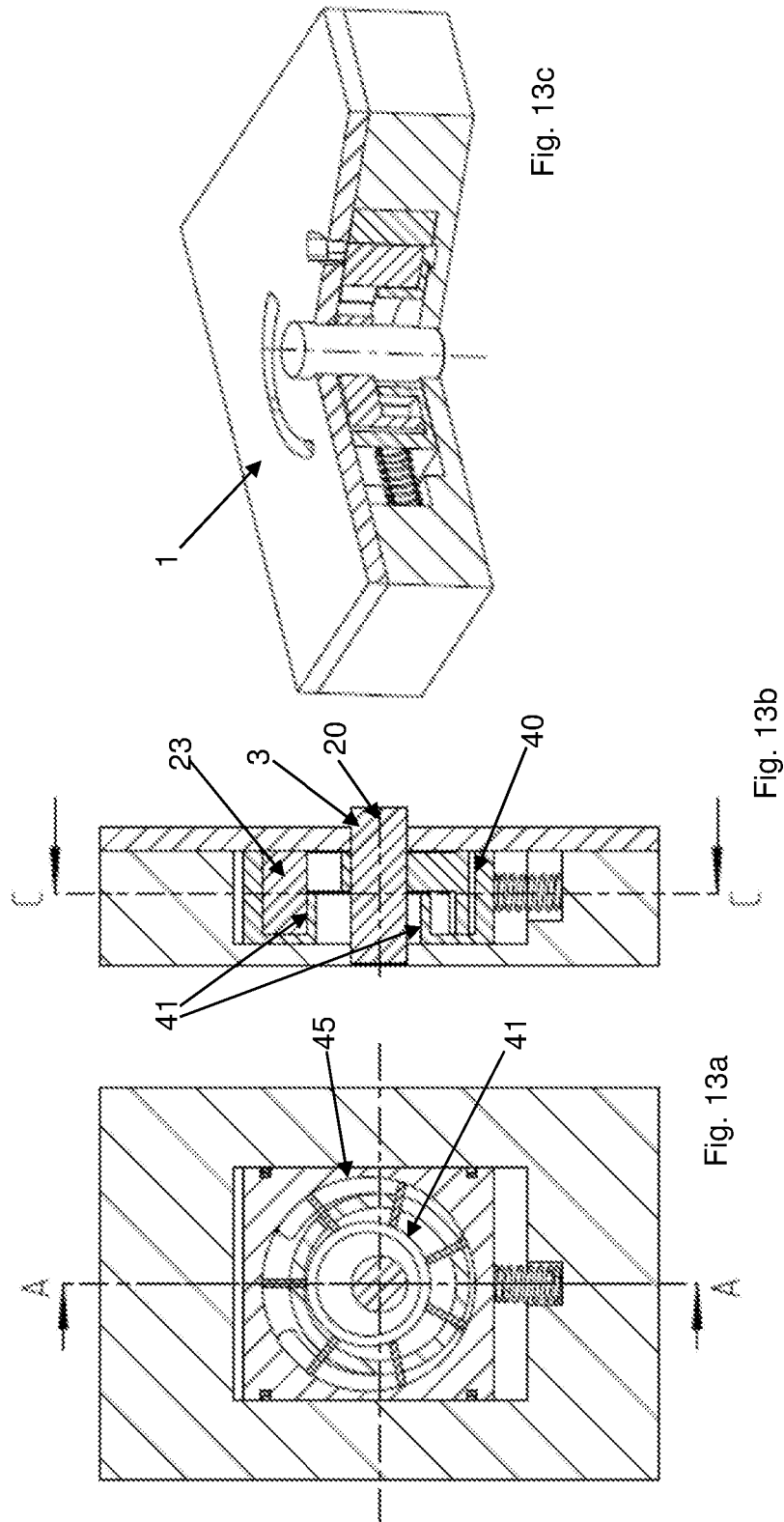
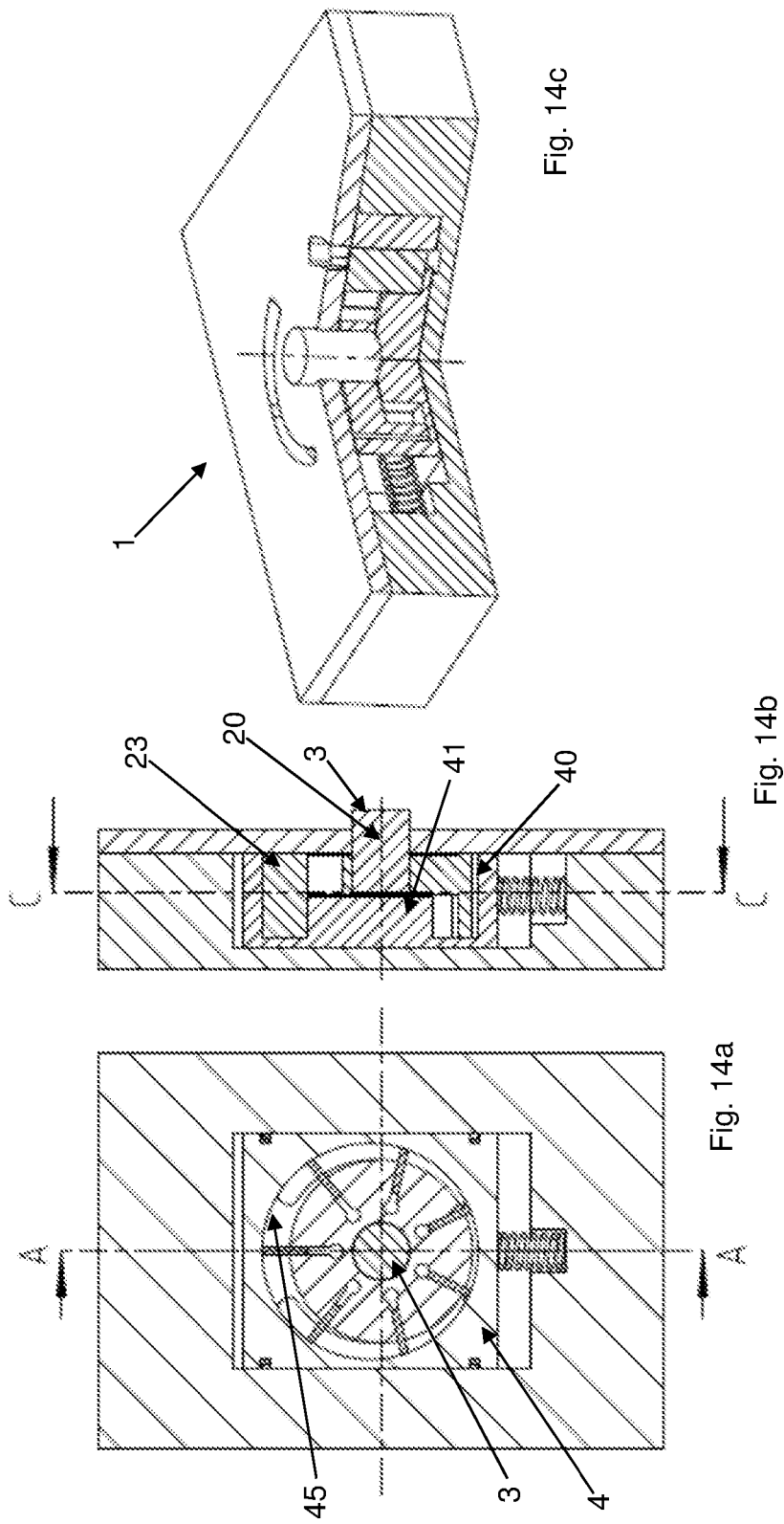


Fig. 9c







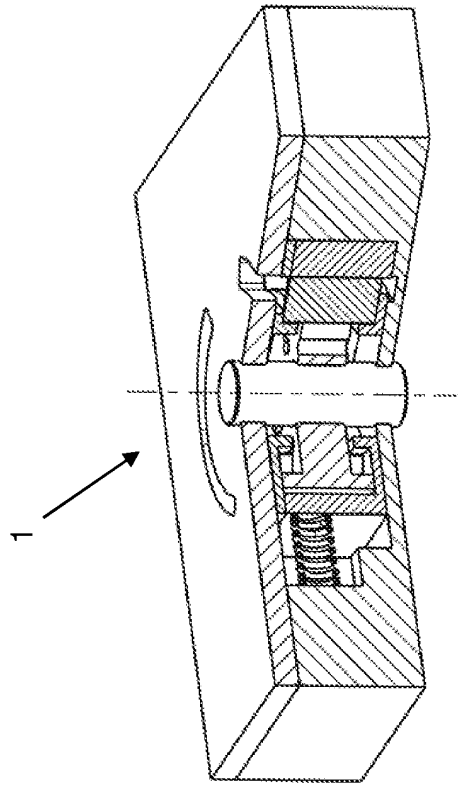


Fig. 15c

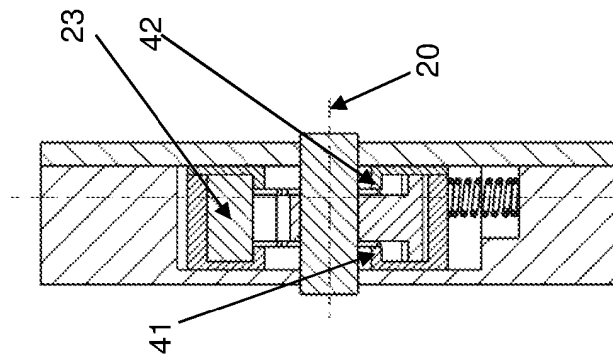


Fig. 15b

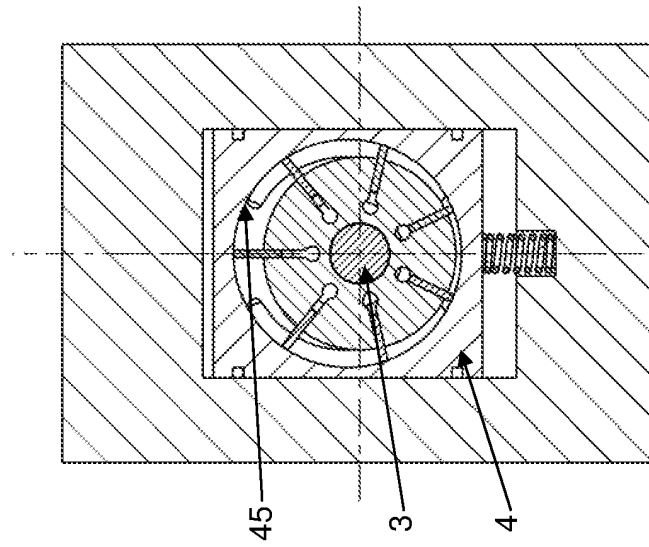


Fig. 15a

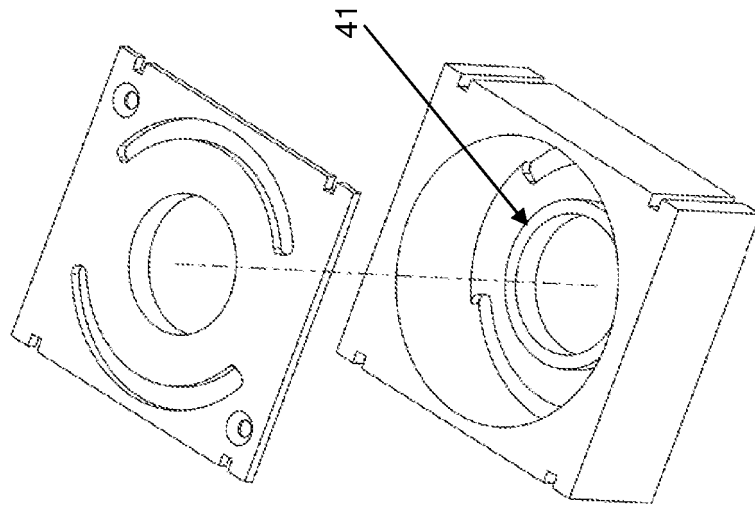


Fig. 16b

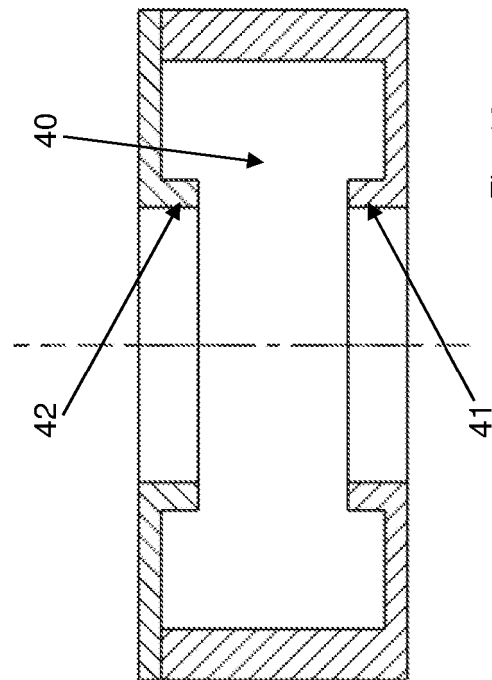


Fig. 16a

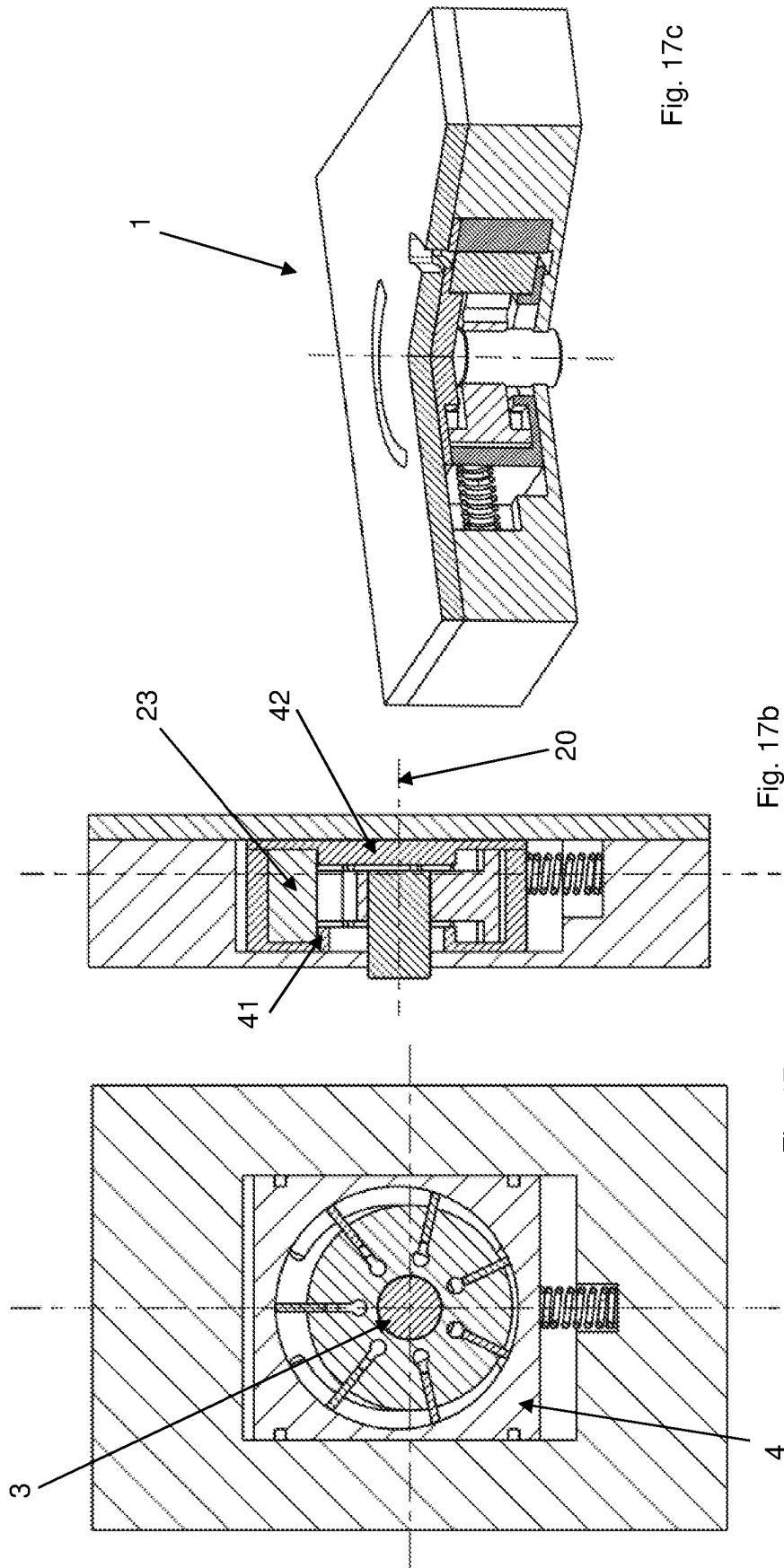


Fig. 17c

Fig. 17b

Fig. 17a

REFERENCES CITED IN THE DESCRIPTION

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