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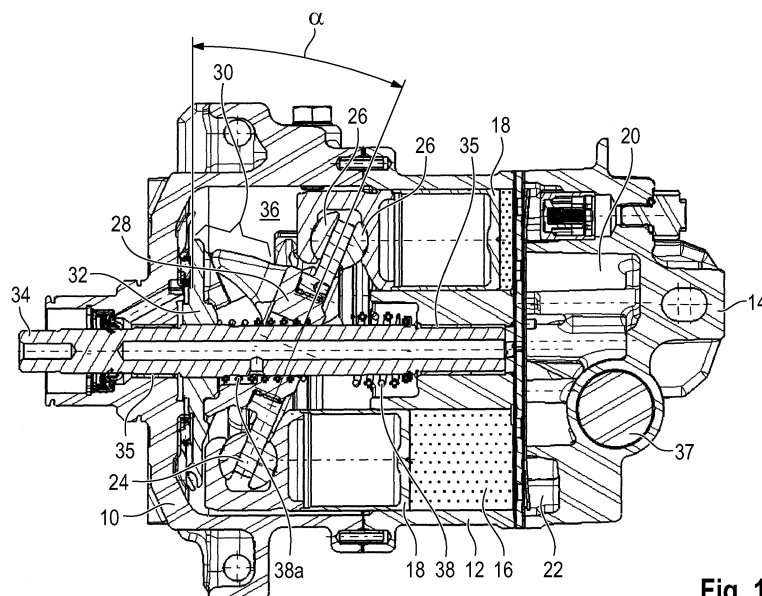
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(54) **VARIABLE DISPLACEMENT COMPRESSOR, IN PARTICULAR FOR A REFRIGERANT CIRCUIT OF A VEHICLE AIR CONDITION SYSTEM**

(57) A variable displacement compressor having a housing (10) enclosing a crank chamber (36), a suction chamber (20), and a discharge chamber (22); a plurality of cylinders (16) provided in said housing (10); a drive shaft (34) rotatably supported in said housing (10) and having a driving flange (32) connected thereto; a swash plate (24) arranged on said drive shaft (34) so as to have an adjustable inclination angle relative to a plane perpendicular to said drive shaft (34); a plurality of pistons (18), each of which is slidably disposed within one each of said cylinders (16); said pistons (18) being coupled to

said swash plate (24) so as to reciprocate within said cylinders (16) with a stroke depending from the inclination of said swash plate (24); and an engagement structure (30) for connecting said swash plate (24) to said driving flange, is characterized in that said engagement structure comprises axial contact surfaces (56, 58) for transmitting axial forces between said driving flange (32) and said swash plate (24), said contact surfaces having a first contact surface (56) which is facing said swash plate (24) and is distinct from a second contact surface (58) which is facing away from said swash plate (24).

**Fig. 1****EP 3 477 105 A1**

Description

[0001] The invention relates to a variable displacement compressor having a housing enclosing a crank chamber, a suction chamber, and a discharge chamber; a plurality of cylinders provided in the housing; a drive shaft rotatably supported in the housing and having a driving flange connected thereto; a swash plate arranged on the drive shaft so as to have an adjustable inclination angle relative to a plane perpendicular to the drive shaft; a plurality of pistons, each of which is slidably disposed within one each of the cylinders; the pistons being coupled to the swash plate so as to reciprocate within the cylinders with a stroke depending from the inclination of the swash plate; and an engagement structure for connecting the swash plate to the driving flange.

[0002] Variable displacement compressors of this type are a well-known component in an air conditioning system, in particular for vehicles. The reciprocating motion of the pistons serves for sucking refrigerant gas into the cylinders, compressing the refrigerant and discharging it towards the discharge chamber.

[0003] The displacement of the cylinders is adjusted by controlling the pressure within the crank chamber of the housing, thereby changing the inclination of the swash plate. The function of the engagement structure is to allow the swash plate to assume the respective inclination angle depending from the pressure within the crank chamber, while at the same time transmitting the rotary motion from the driving flange to a hub carrying the swash plate.

[0004] Many different types of engagement structures are known from the prior art. Some use levers while others use pins which engage in two slots. All of the known engagement structures have certain technical deficits.

[0005] The object of the invention is to provide an engagement structure which on the one hand is very compact and consists of a few components only while at the other hand ensures a reliable connection between the driving flange and the swash plate which can easily be mounted.

[0006] In order to achieve this object, the invention provides a variable displacement compressor as outlined above, characterized in that said engagement structure comprises axial contact surfaces for transmitting axial forces between said driving flange and said swash plate, said contact surfaces having a first contact surface which is facing said swash plate and is distinct from a second contact surface which is facing away from said swash plate. Using two distinct rounded contact surfaces (instead of a single cylindrical contact surface as this is the case when a pin is being used) allows adapting the different contact surfaces to different requirements. In particular, it is possible to allow transmitting high forces with one of the contact surfaces while configuring the other one in view of the mounting process.

[0007] Preferably, the axial contact surface facing the swash plate has a radius which is different from the radius

of the axial contact surface facing away from the swash plate, with the radius of the axial contact surface facing the swash plate preferably being smaller than the radius of the axial contact surface facing away from the swash plate. The larger radius allows transmitting higher axial loads while the smaller radius reduces the negative tilt angle which is necessary for connecting the swash plate to the driving flange.

[0008] According to the preferred embodiment, the axial contact surface facing the swash plate is concentric with the axial contact surface facing away from that swash plate. This configuration ensures that the axial play of the projections within the grooves is the same irrespective of the inclination angle of the swash plate.

[0009] For the actual radius of the axial contact surfaces, values in the order of 2 mm for the axial contact surfaces facing that swash plate and of 6 mm for the axial contact surface facing away from that swash plate have shown good results. In particular, the smaller radius for the axial contact surface facing the swash plate has shown to reduce the negative tilt angle by approximately 40% as compared to a structure with identical radii on both sides.

[0010] According to a preferred embodiment, the engagement structure comprises two projections engaging into two grooves, the axial contact surfaces being formed on the projections. The projections can be easily formed on the engagement structure.

[0011] Preferably, the said projections are formed integrally with and at a distal end of at least one male arm associated with said swash plate or said driving flange and engaging into the grooves associated with said driving flange or said swash plate. Thus, no additional parts such as pins known from the prior art have to be mounted. Further, small tolerances and a low weight can be achieved. Finally, as the projections are formed integrally with the male arm(s), they can be arranged at the very end of the arm(s) at a position where for example a pin known from prior art engagement structures cannot be arranged. Thus, the engagement structure is very compact in an axial direction.

[0012] Preferably, each of the projections is provided on one male arm, the male arms being spaced from each other. Using two arms spaced from each other allows obtaining a high rigidity of the engagement structure in case forces act on the swash plate which generate a torque around an axis perpendicular to the drive shaft and located in a central plane of the engagement structure, while at the same time reducing the weight of the engagement structure.

[0013] Preferably, two grooves are provided, each of the grooves being provided in one female arm, the female arm being spaced from each other. Here again, a high rigidity of the engagement structure can be achieved while at the same time the weight of the engagement structure can be kept low.

[0014] According to a preferred embodiment, the female arms are arranged at the driving flange. Preferably,

they can be formed integrally with the driving flange so that no mounting steps are necessary.

[0015] According to a preferred embodiment, the grooves are delimited by parallel side walls. This structure allows manufacturing the grooves with little effort as a milling cutter can be used for machining the grooves with a simple translational movement.

[0016] It has been found to be advantageous that the grooves extend at an angle with respect to the drive shaft which is between 60° and 70°.

[0017] According to a preferred embodiment, the grooves are facing each other while the projections are facing away from each other. In other words, the male arms are arranged between the female arms which thus reliably prevent the projections from disengaging from the grooves.

[0018] According to an embodiment of the invention, the projections have flat contact surfaces for lateral engagement with a bottom wall of the grooves, the flat contact surfaces facing away from each other. The lateral contact surfaces are very effective for transmitting loads in a circumferential direction between the driving flange and the swash plate.

[0019] The invention will now be explained with reference to the enclosed drawings in which an embodiment of the invention is shown. In the drawings,

- Figure 1 shows a schematic cross-section through a variable displacement compressor according to the invention, with the swash plate having a maximum inclination angle,
- Figure 2 shows the compressor of Figure 1 with the swash plate having a minimum inclination angle,
- Figure 3 shows in a perspective view the drive shaft with the driving flange and the swash plate connected thereto by means of the engagement structure,
- Figure 4 shows the components of Figure 3 in a top view,
- Figures 5a to 5d show the driving flange in a perspective view, a top view, a side view and a lateral view,
- Figures 6a to 6d show a mounting structure for the swash plate in a perspective view, a top view, a side view and a lateral view,
- Figure 7 shows a cross-section through the components of Figure 3 with the swash plate having a minimum inclination angle,
- Figure 8 shows a cross-section through the driving flange, the swash plate and the engagement structure, with the swash plate having a maximum inclination angle,

- Figure 9 shows a detail of one of the projections of the engagement structure,

- Figure 10 shows at an enlarged scale one of the projections received in the corresponding groove,

- Figures 11 a to 11c show one of the projections received in the corresponding groove at a position with a maximum inclination angle of the swash plate, a medium inclination angle and a minimum inclination angle, and

- Figures 12a to 12d show different steps of mounting the swash plate on the drive shaft.

[0020] In Figure 1, a variable displacement compressor is shown in a cross-section. As its general construction is known, it will be described only very briefly in the following.

[0021] The compressor has a housing which consists of three parts, namely a front housing 10, a cylinder block 12 and a rear head 14.

[0022] Within cylinder block 12, a plurality of cylinders 16 is provided. Within each cylinder, a piston 18 is slidably accommodated.

[0023] When pistons 18 reciprocate within cylinders 16, they suck refrigerant gas from a suction chamber 20 into the cylinder 16 and discharge the compressed refrigerant gas into a discharge chamber 22. Suction chamber 20 and discharge chamber 22 are formed within rear head 14.

[0024] The compressed refrigerant gas then circulates from the discharge chamber through a condenser, an expansion device and a vaporizer so as to again arrive as the suction chamber 20.

[0025] The variable displacement compressor, the condenser, the expansion device and the vaporizer are the main components of an air conditioning system which allows removing heat from air to be admitted into the cabin of a vehicle.

[0026] The reciprocating motion of pistons 18 is generated by means of a swash plate 24 to which each piston 18 is connected by means of a pair of sliding shoes 26. The swash plate 24 is fixed to a hub 28 which is connected via an engagement structure 30 with a driving flange 32. The driving flange in turn is mounted non-rotationally on a drive shaft 34. Drive shaft 34 is rotatably mounted within housing by means of bearings 35.

[0027] Drive shaft 34 is driven from a motor of the vehicle in which the air condition system is arranged. As an example, the motor can be a combustion engine to which drive shaft 34 is connected via pulleys and a drive belt. Alternatively, a separate driving motor for the compressor can be provided.

[0028] Engagement structure 30 on the one hand transmits a rotary motion of driving flange 32 to hub 28. On the other hand, engagement structure 30 allows hub 28 and thereby swash plate 24 to assume different angles

of inclination with respect to a plane which is perpendicular to drive shaft 34. This can be seen by comparing Figures 1 and 2.

[0029] In Figure 1, swash plate 24 is shown with a maximum inclination angle α . In Figure 2, swash plate 24 has a minimum inclination angle which here is slightly greater than 0.

[0030] When the inclination angle is at the minimum inclination angle, the stroke of pistons 18 within cylinders is very small. Thus, the discharge volume of the compressor is very small as well. For any inclination angle different from 0, each piston, during one revolution of drive shaft 34, performs one stroke. Looking at Figure 1, each piston travels from a position in which the remaining volume within cylinder 16 is minimum (please see piston 18 shown in the upper half of Figure 1) to a position in which the volume within cylinder 16 is maximum (please see piston 18 shown in the lower half of Figure 1) and back to the first position.

[0031] The inclination angle of swash plate 24 is adjusted by controlling the pressure in the space in which swash plate 24 is arranged (referred to as "crank chamber" and denominated with reference numeral 36). The pressure within crank chamber 36 is controlled via a solenoid valve 37 controlling the flow connection between discharge chamber 22 and crank chamber 36. Details of this way of controlling the inclination angle of swash plate 24 are well-known from the prior art.

[0032] A stroking spring 38 and a destroking spring 38a help in controlling movement of hub 28 in response to changes of the pressures within crank chamber 36.

[0033] Hub 28 is provided with a through hole 37 through which drive shaft 34 extends. Through hole 37 has an inner wall which is formed by two cylindrical holes crossing each other, namely one cylindrical hole which extends through the hub in an orientation which corresponds to a slightly negative inclination angle, and one cylindrical hole which extends through the hub in an orientation which corresponds to the maximum inclination angle.

[0034] Accordingly, as can be seen in Figures 1, 2 and 8, the contour of through hole 37 approximates the outer surfaces of drive shaft 34 at a lower left side and an upper right side for the maximum inclination of the hub (visible in Figure 1 and 8, with reference to "right", "left", "upper" and "lower" being made to the orientation shown in the drawings), and at an upper left side and a lower right side (please see Figure 2).

[0035] With reference to Figures 3 to 6, engagement structure 30 will now be described in detail.

[0036] Very generally speaking, engagement structure 30 consists of two female arms 40 of which each is provided with a groove 42, and two male arms 44 of which each is provided with a projection 46 which is an integral part of the respective male arm, with each projection 46 engaging into an associated one of grooves 42.

[0037] The projections being integrally formed with the male arms, no mounting step is necessary.

[0038] As can be seen in particular in Figure 5a to 5d, female arms 40 are formed integrally with and extend generally in an axial direction from driving flange 32. Female arms 40 have a distance from each other which is in the order of twice the diameter of drive shaft 34.

[0039] Each groove 42 is provided in the respective female arm 40 on its side facing the other female arm 40. Thus, two grooves 42 are provided which are arranged symmetrically opposite each other with respect to a center plane C.

[0040] Each groove 42 is delimited by a bottom wall 48 and two side walls 50, 52.

[0041] Side walls 50, 52 are arranged parallel to each other. Further, they are arranged perpendicular with respect to bottom wall 48. Furthermore, the side walls 50 of both grooves 42 extend in the same plane as well as side walls 52 of opposite grooves 42 extend in one and the same plane. Thus, grooves 42 define a (virtual) cubic space.

[0042] Because of the cubic nature of the space defined by grooves 42, they can be milled with a single milling cutter which is advanced along a straight path between the two female arms 40.

[0043] Driving flange 32 is provided with a counter weight 54 so that driving flange 32 is balanced with respect to centrifugal loads.

[0044] As can be seen in particular in Figures 6a to 6d, male arms 44 are formed integrally with hub 28 on which swash plate 24 is mounted. The space between the two male arms 40 corresponds approximately to the diameter of drive shaft 34.

[0045] Each projection 46 is provided with two axial contact surfaces 56, 58 and with one lateral contact surface 60.

[0046] Axial contact surface 56 is arranged on the side of protrusion 46 which, in a completely mounted condition of the compressor, faces swash plate 24. Conversely, axial contact surface 58 is arranged such that it faces away from swash plate 24.

[0047] Accordingly, axial contact surfaces 56 cooperate with side walls 52 of grooves 42 and axial contact surfaces 58 cooperate with side walls 50 of grooves 42.

[0048] Lateral contact surfaces 60 are arranged on protrusions 46 such that they face away from each other. They cooperate, in a mounted condition, with bottom walls 48 of grooves 42.

[0049] For balancing hub 28, a counter weight 61 is provided.

[0050] With reference to Figures 7 to 10, details regarding the axial contact surfaces 56, 58 will now be explained in more detail.

[0051] Axial contact surfaces 58, 56 have the shape of a portion of a cylinder. In other words, each point of an axial contact surface has the same distance ("radius") from an axis (schematically shown in Figures 6b and 6c and denominated with reference numeral K) at which all the centers of curvature of the axial contact surfaces are located. In a cross section perpendicularly to axis K, K

is the center of curvature of the contour of the contact surface.

[0052] It is important to note that both contact surfaces 56, 58 have one and the same axis of curvature K. However, as can be seen in Figure 7, the axis of curvature K is not located centrally between the axial contact surfaces 56, 58 but is arranged closer to axial contact surface 56. In other words, the radius RY of axial contact surface 56 is smaller than the radius RX of axial contact surface 58.

[0053] Considering the overall dimensions as limited, using a smaller radius for axial contact surface 56 allows using a larger radius for axial contact surface 58 which is beneficial in that axial contact surface 58 typically is exposed to larger forces than axial contact surface 56. Thus, a larger radius results in a lower specific surface pressure.

[0054] In the example shown in Figure 10, the radius for axial contact surface 56 is chosen to be 2 mm while the radius for axial contact surface 58 is chosen to be 6 mm. Accordingly, the width of groove 42 (the distance between side walls 50, 52) is 8 mm.

[0055] Because of axial contact surfaces 56, 58 having the same axis of curvature K, the effective diameter of the protrusions 46 within grooves 42 remains constant when the orientation of protrusions 46 is changed within groove 42. This can be seen in Figures 11 a to 11 c.

[0056] When the orientation of the swash plate is being changed (and thus the inclination angle is changed from a maximum inclination angle to a minimum inclination angle), protrusion 46 is displaced within groove 42 from an upper end (please see Figure 11 a) towards the lower end (please see Figure 11c). At the same time, protrusion 46 is rotated within groove in a counterclockwise direction (with reference to Figures 11a to 11c). Nevertheless, the effective diameter of protrusion 46 remains to be 8 mm.

[0057] Grooves 42 are arranged such that their longitudinal axis (schematically shown in Figure 7 and denominated with reference numeral B) extends with an angle β with respect to the drive shaft 34, with the angle β being between 60° and 70°.

[0058] With reference to Figures 12a to 12d, the process of mounting the swash plate (and engaging the engagement structures into each other) will be explained.

[0059] Swash plate 24 together with hub 28 and male arms 44 is advanced in axial direction towards driving flange 32. For inserting protrusions 46 into grooves 42, swash plate 24 together with hub 28 has to be tilted in a negative orientation (please see Figure 12b). This tilting in a counterclockwise direction is critical as it requires a larger clearance between drive shaft 34 and through hole 37 of hub 28 which is not necessary during normal operation of the compressor. Thus, it is desirable to maintain the necessary tilting in the negative direction at a minimum. Using a small radius for axial contact surfaces 56 is advantageous in this regard as a smaller radius results in less necessary tilting in the negative direction (and thus requires a smaller clearance within the hub of swash plate 24).

[0060] After the protrusions 46 have been engaged into grooves 42, the swash plate is returned into a neutral orientation (please see Figure 12c), and stroking spring 38 can be mounted and fixed with a circlip 39. Then, mounting of the swash plate on drive shaft 34 is completed.

[0061] The smaller radius for the axial contact surface facing the swash plate has shown to reduce the negative tilt angle by nearly 40% (the exact value is 38%) as compared to a structure with identical radii on both sides.

[0062] The reduced negative angle additionally has shown to reduce the minimum clearance between the hub and the shaft in a vertical direction by nearly 50% (the exact value is 47%) as compared to a structure with identical radii on both sides.

Claims

1. A variable displacement compressor having a housing (10) enclosing a crank chamber (36), a suction chamber (20), and a discharge chamber (22); a plurality of cylinders (16) provided in said housing (10); a drive shaft (34) rotatably supported in said housing (10) and having a driving flange (32) connected thereto; a swash plate (24) arranged on said drive shaft (34) so as to have an adjustable inclination angle relative to a plane perpendicular to said drive shaft (34); a plurality of pistons (18), each of which is slidably disposed within one each of said cylinders (16); said pistons (18) being coupled to said swash plate (24) so as to reciprocate within said cylinders (16) with a stroke depending from the inclination of said swash plate (24); and an engagement structure (30) for connecting said swash plate (24) to said driving flange, **characterized in that** said engagement structure comprises axial contact surfaces (56, 58) for transmitting axial forces between said driving flange (32) and said swash plate (24), said contact surfaces having a first contact surface (56) which is facing said swash plate (24) and is distinct from a second contact surface (58) which is facing away from said swash plate (24).
2. The variable displacement compressor of claim 1, **characterized in that** said axial contact surface (56) facing said swash plate (24) has a radius which is different from the radius of said axial contact surface (58) facing away from said swash plate (24), with the radius of said axial contact surface (56) facing said swash plate (24) preferably being smaller than the radius of said axial contact surface (58) facing away from said swash plate (24).
3. The variable displacement compressor of claim 2, **characterized in that** said axial contact surface (56) facing said swash plate (24) being concentric with said axial contact surface (58) facing away from said

swash plate (24).

4. The variable displacement compressor of claim 2 or claim 3, **characterized in that** the radius of said axial contact surface (56) facing said swash plate (24) is in the order of 2 mm. 5
5. The variable displacement compressor of any of claims 2 to 4, **characterized in that** the radius of said axial contact surface (58) facing away from said swash plate (24) is in the order of 6 mm. 10
6. The variable displacement compressor of any of the preceding claims, **characterized in that** said engagement structure comprises two projections (46) engaging into two grooves (42), said axial contact surfaces (56, 58) being formed on said projections (46). 15
7. The variable displacement compressor of claim 6, **characterized in that** said projections (46) are formed integrally with and at a distal end of at least one male arm (44) associated with said swash plate (24) or said driving flange (32) and engaging into the grooves (42) associated with said driving flange (32) or said swash plate (24). 20 25
8. The variable displacement compressor of claim 7, **characterized in that** each of said projections (46) is provided on one male arm (44), said male arms (44) being spaced from each other. 30
9. The variable displacement compressor of any of claim 6 to 8, **characterized in that** each groove (42) is provided in one female arm (40), said female arms (40) being spaced from each other. 35
10. The variable displacement compressor of claim 9, **characterized in that** said female arms (40) are arranged at said driving flange (32). 40
11. The variable displacement compressor of claim 10, **characterized in that** said female arms (40) are formed integrally with said driving flange (32). 45
12. The variable displacement compressor of any of claims 6 to 11, **characterized in that** said grooves (42) are delimited by parallel side walls (50, 52).
13. The variable displacement compressor of claim 12, **characterized in that** said grooves (42) extend at an angle with respect to said drive shaft (34) which is between 60° and 70°. 50
14. The variable displacement compressor of any of claims 6 to 13, **characterized in that** said grooves (42) are facing each other while said projections (46) are facing away from each other. 55
15. The variable displacement compressor of any of claims 6 to 14, **characterized in that** said projections (46) have flat contact surfaces (60) for lateral engagement with a bottom wall (60) of the respective groove (42), said lateral contact surfaces (60) facing away from each other.

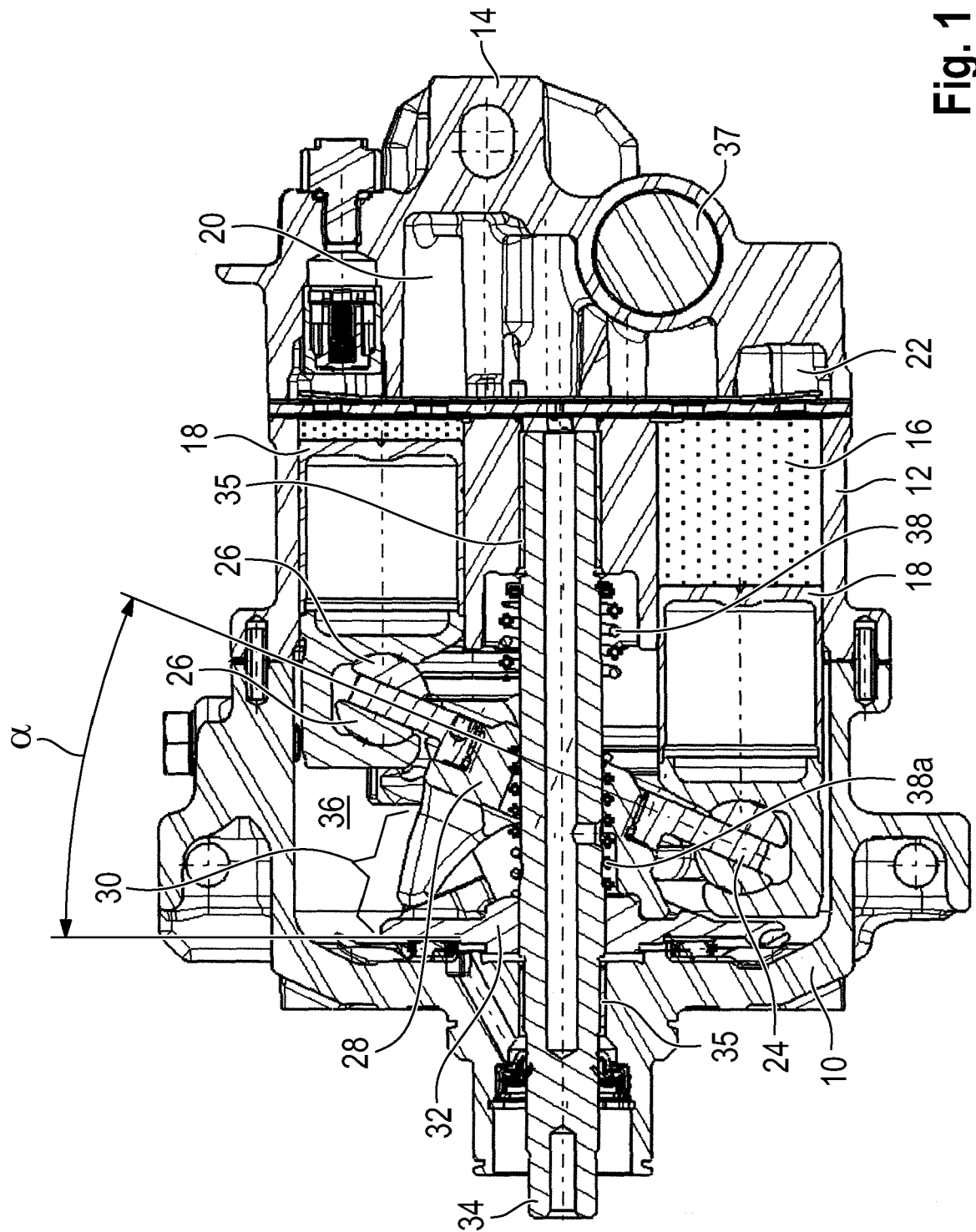


Fig. 1

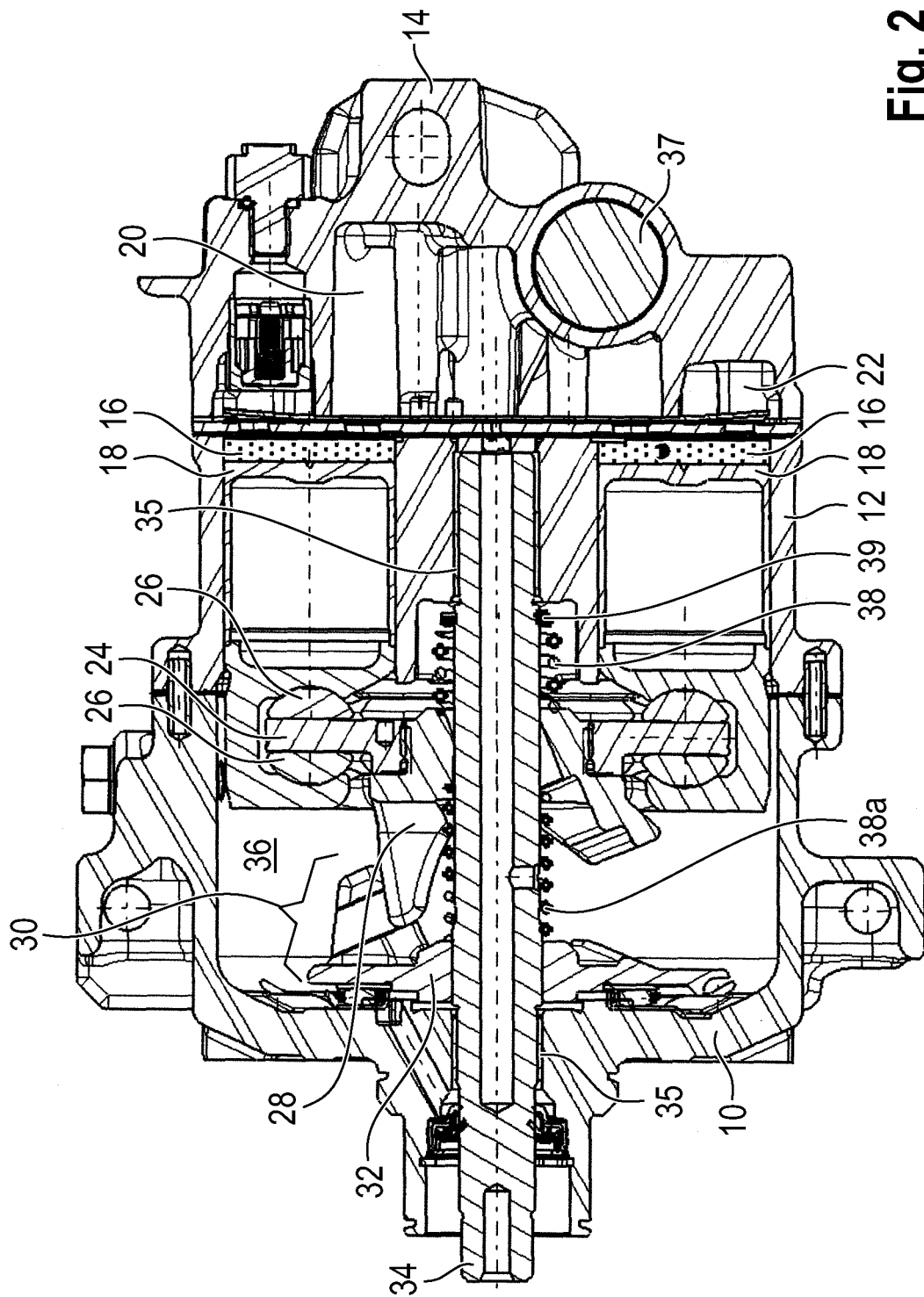


Fig. 2

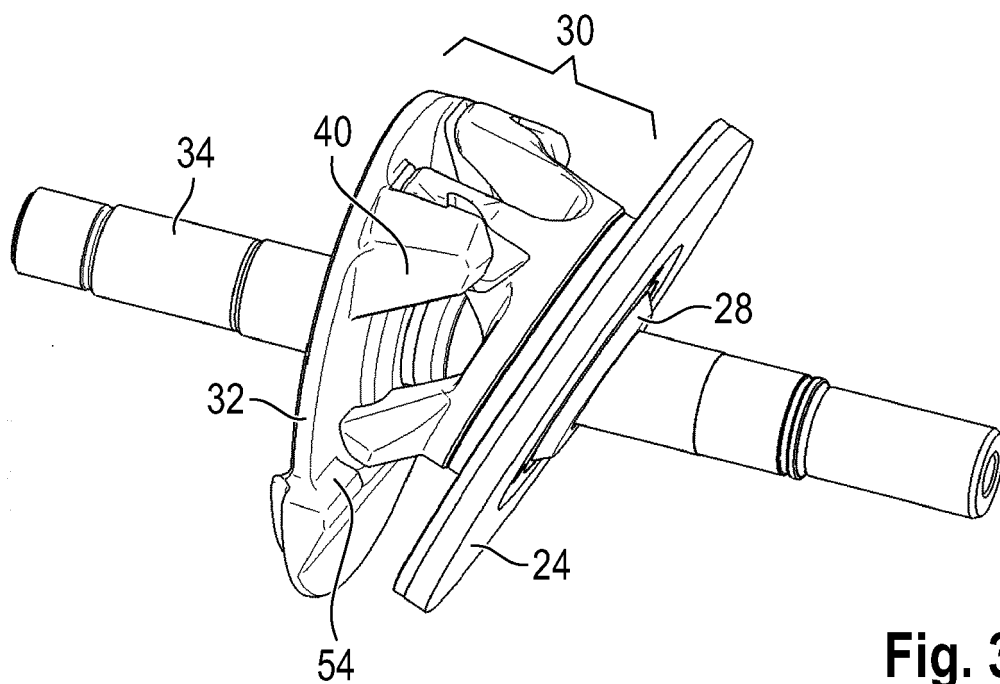


Fig. 3

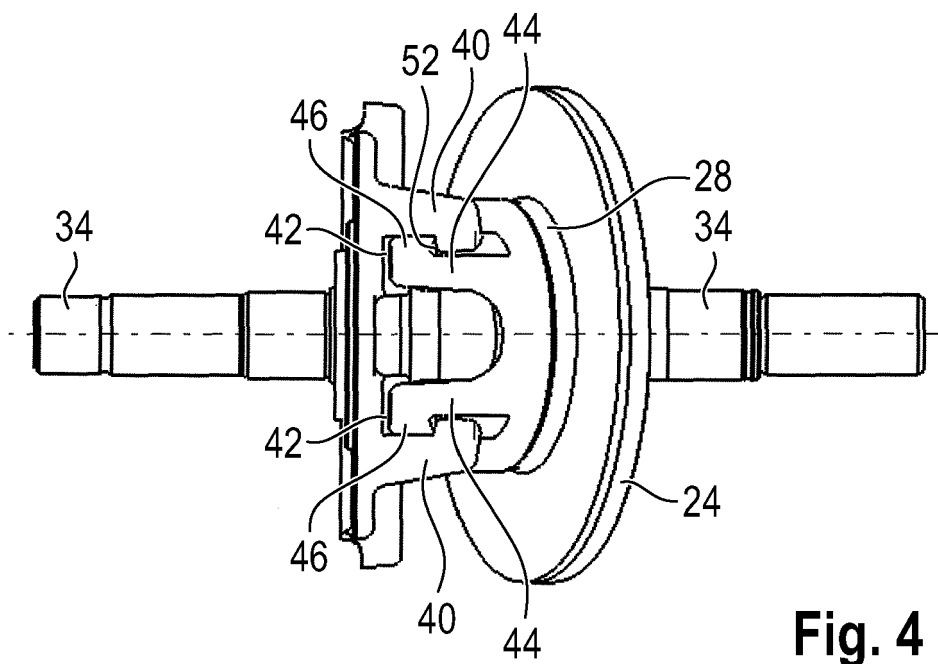


Fig. 4

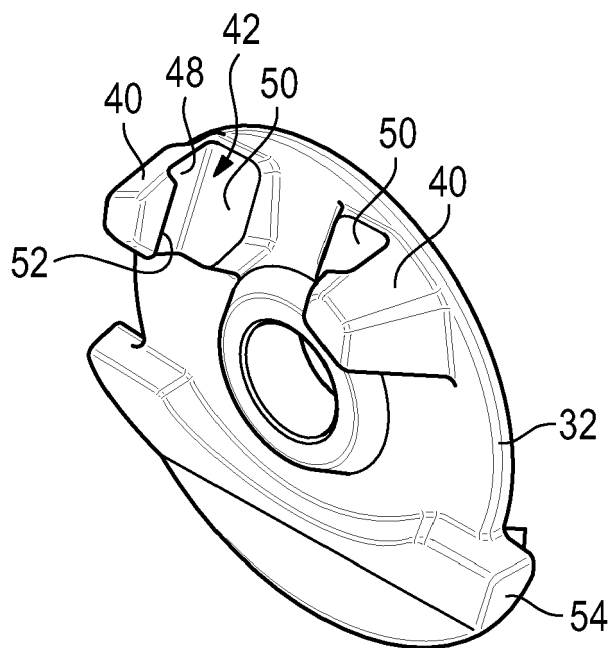


Fig. 5a

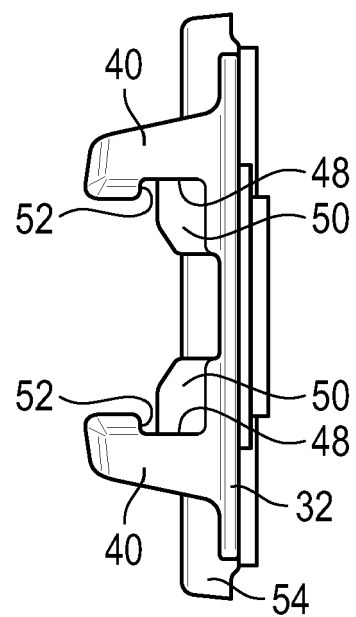


Fig. 5b

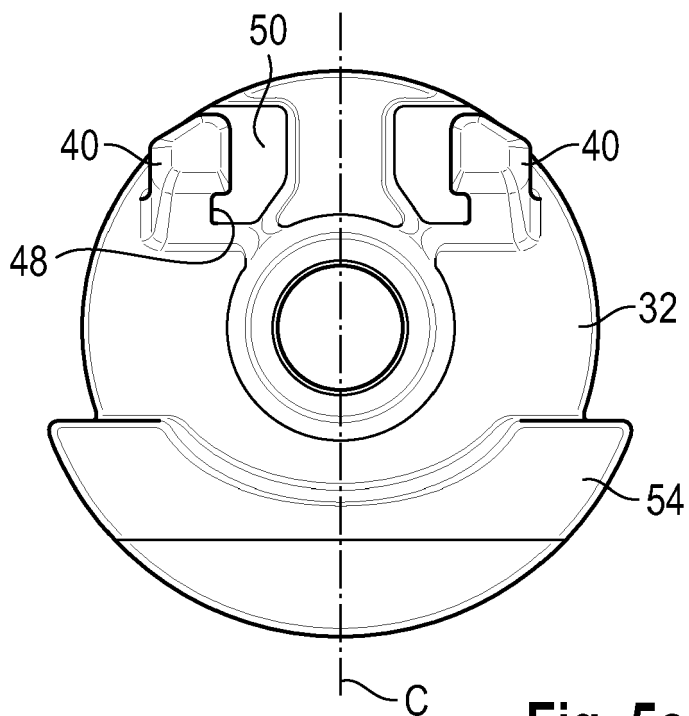


Fig. 5c

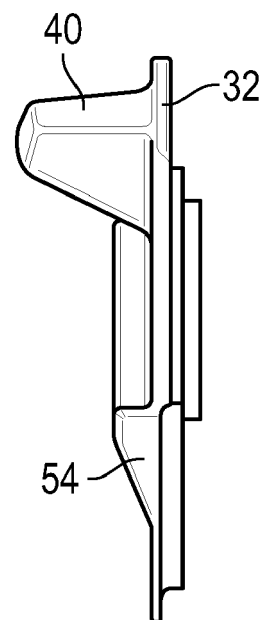


Fig. 5d

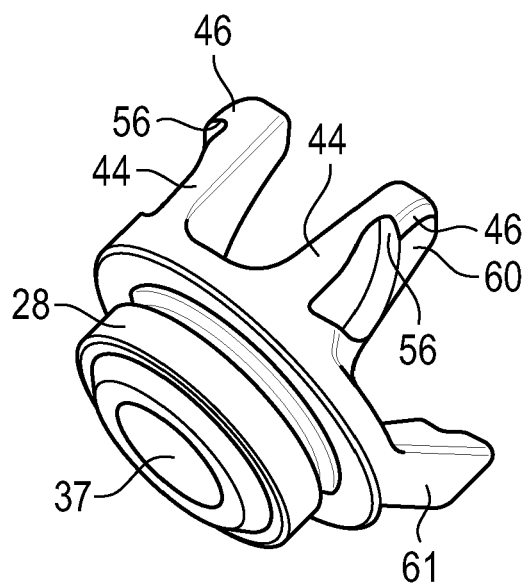


Fig. 6a

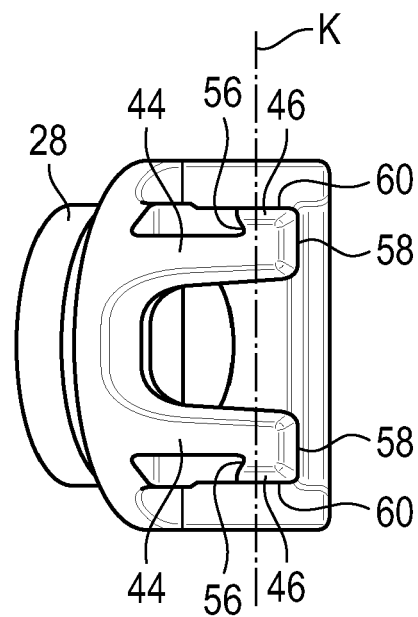


Fig. 6b

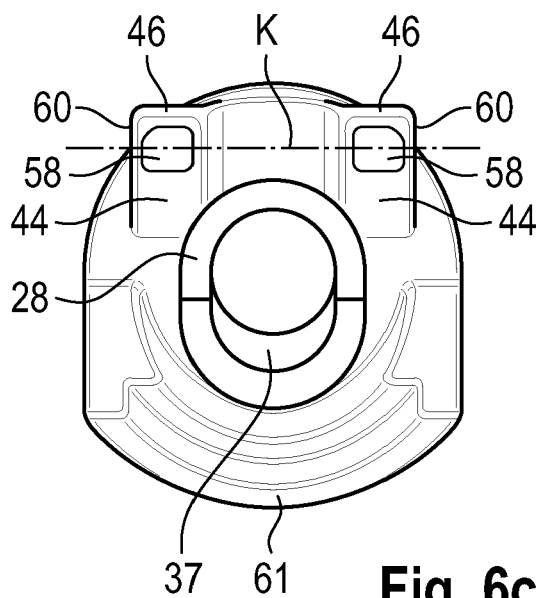


Fig. 6c

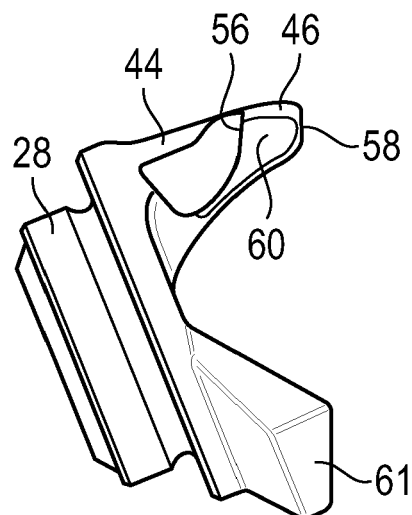
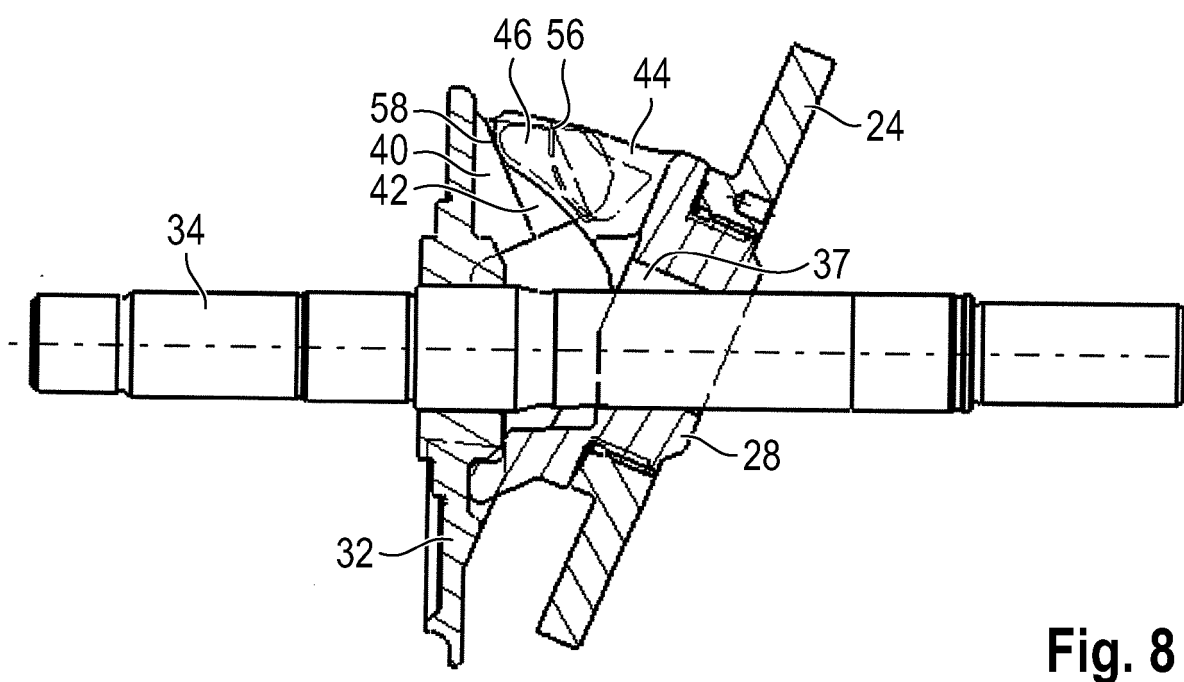
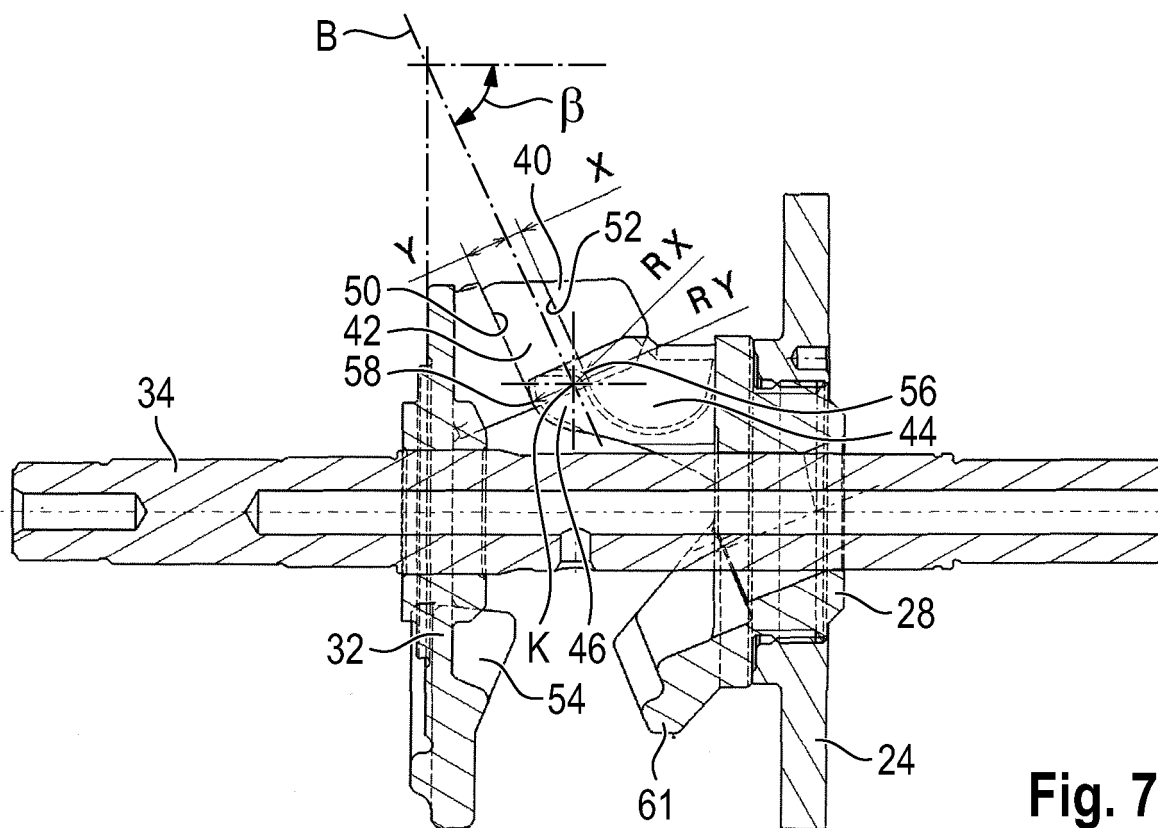


Fig. 6d



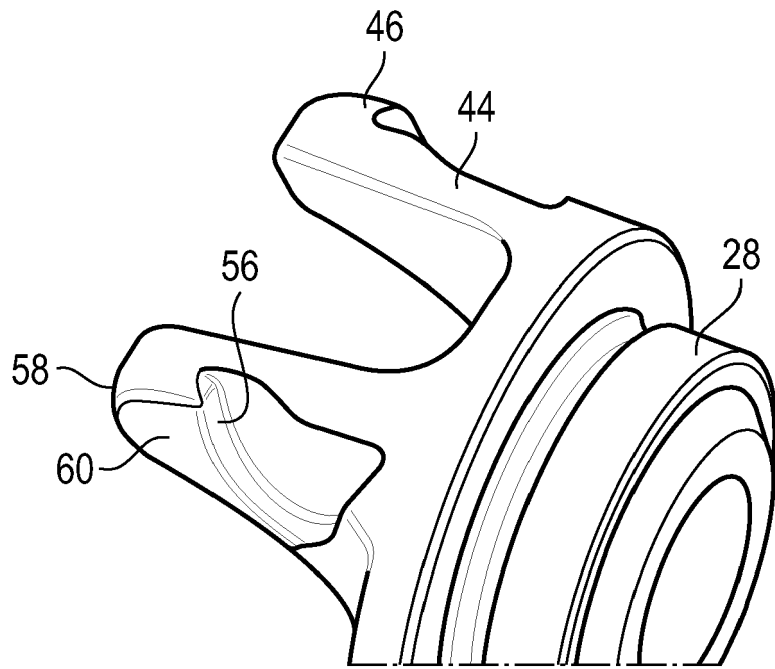


Fig. 9

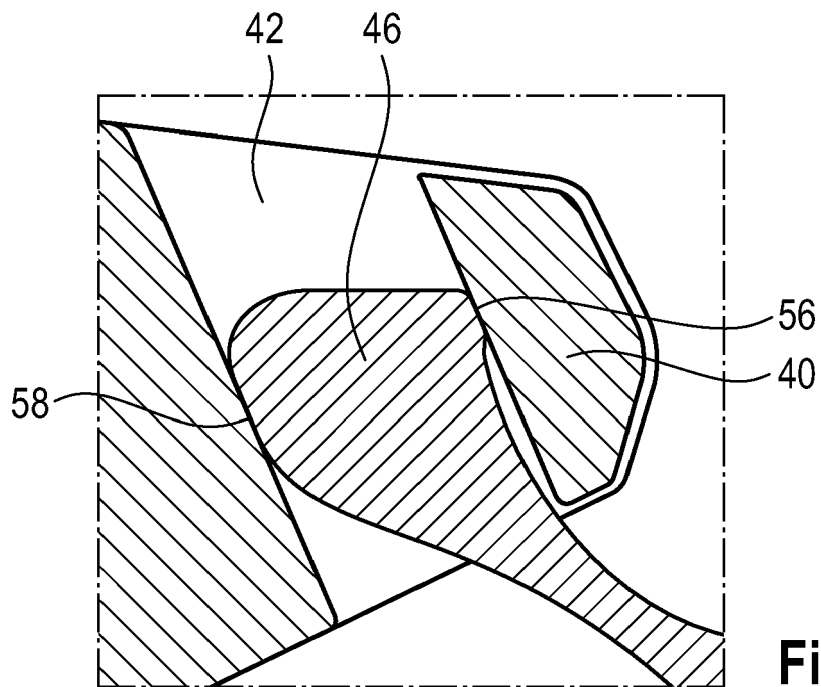


Fig. 10

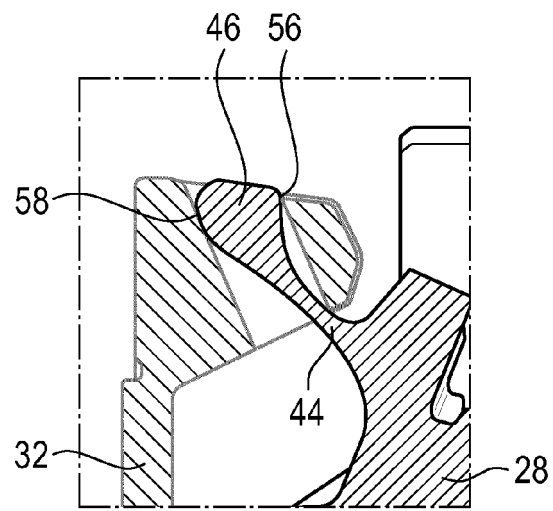


Fig. 11a

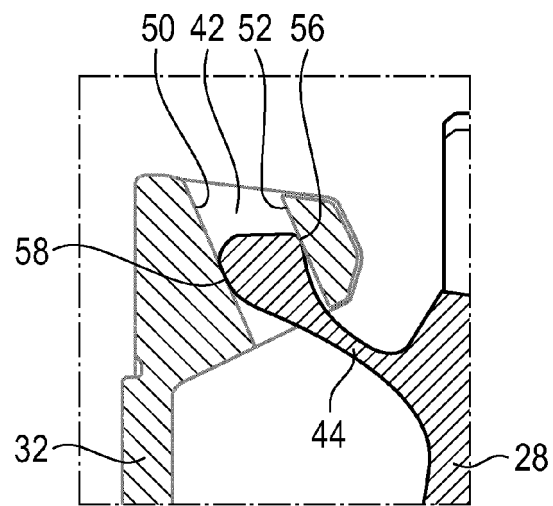


Fig. 11b

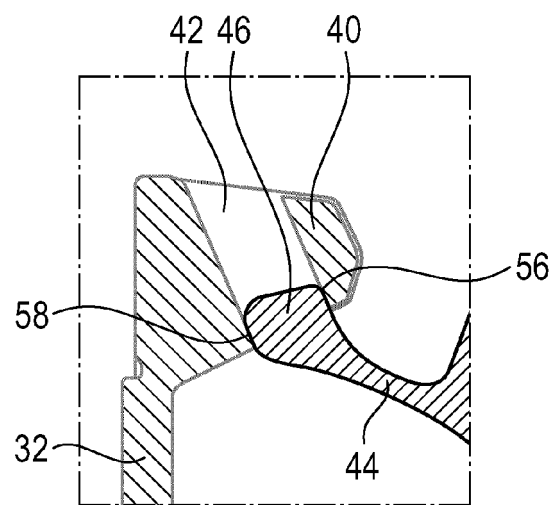
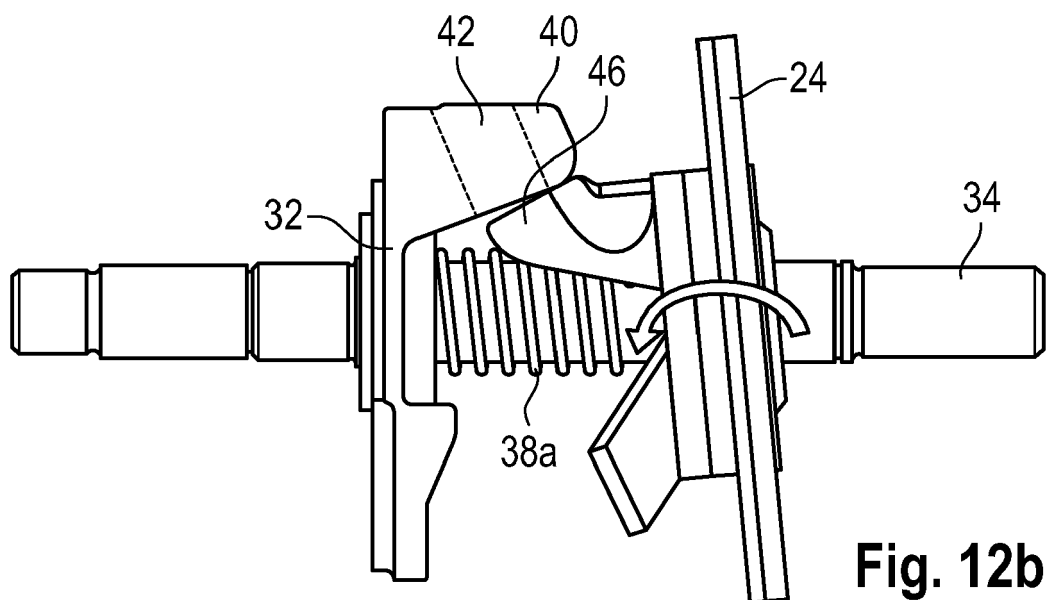
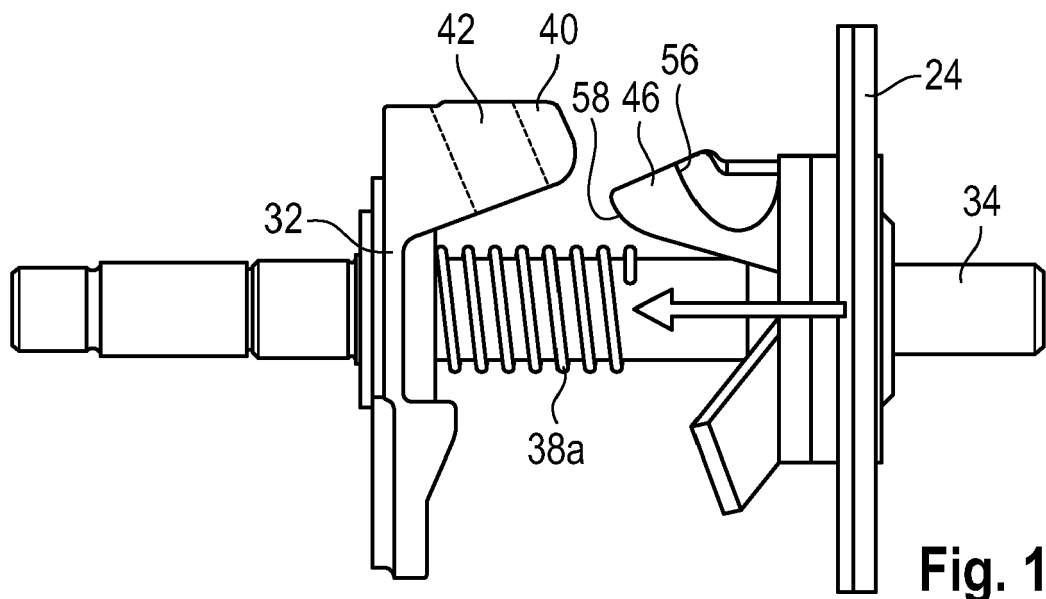
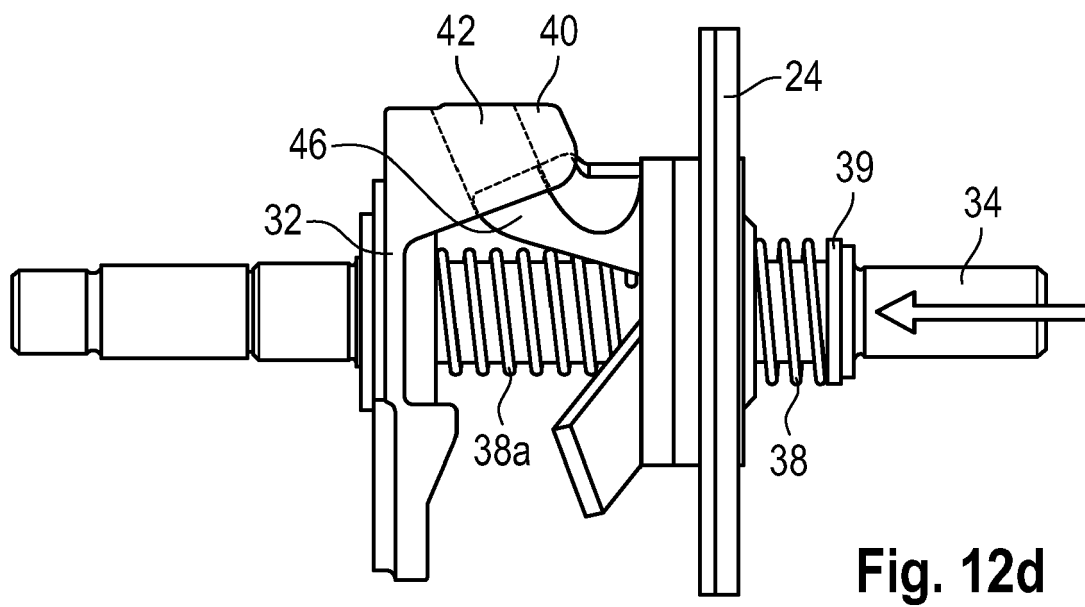
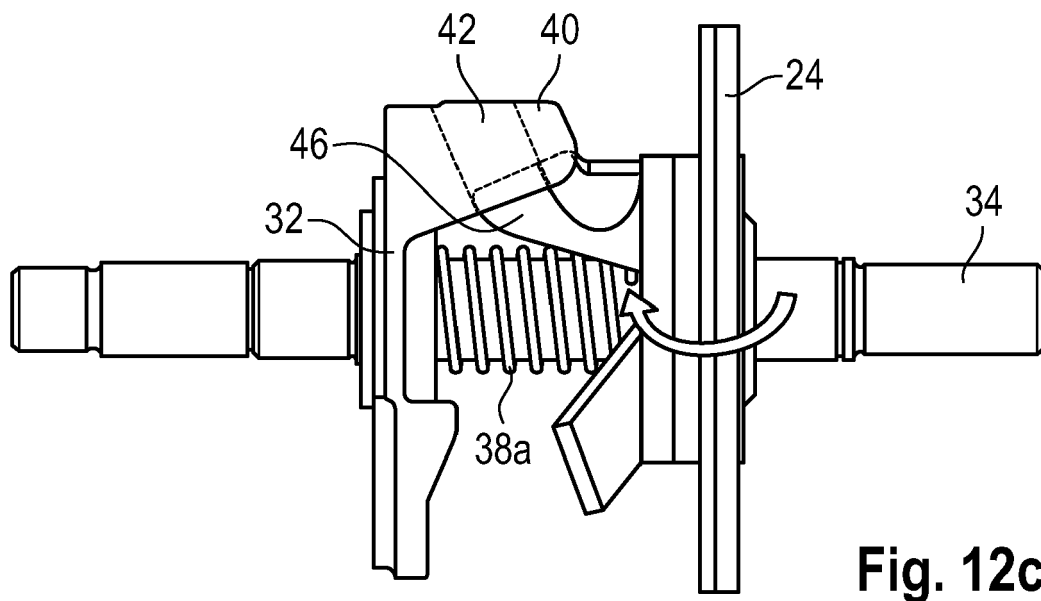


Fig. 11b







EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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Place of search Munich		Date of completion of the search 17 April 2018	Examiner Jurado Orenes, A
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