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(71) Applicant: **Airtex Products, S.A.**
50197 Zaragoza (ES)

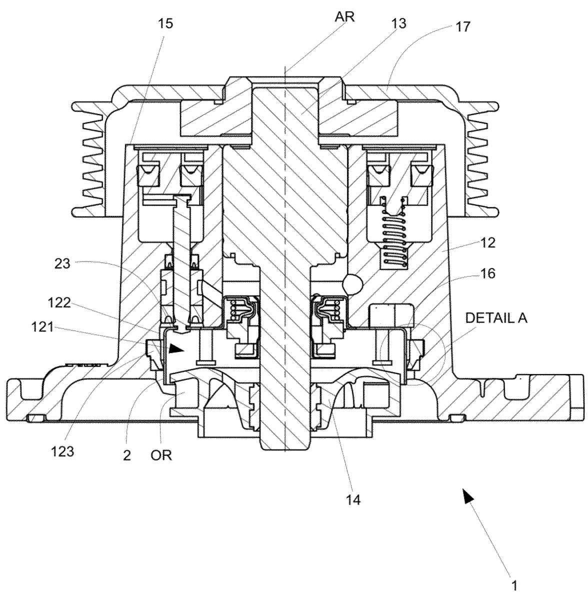
(72) Inventors:
- **Peribáñez Subirón, Carlos**
  50012 ZARAGOZA (ES)
- **López Bosque, Irene**
  50006 ZARAGOZA (ES)
- **Miguel Gracia, Fernando**
  50013 ZARAGOZA (ES)
- **Roche Royo, Joaquín**
  50014 ZARAGOZA (ES)
- **Pomar Miguel, José Luis**
  50016 ZARAGOZA (ES)
- **Lozano Beltrán, Carlos**
  50008 ZARAGOZA (ES)
- **Sebastián Solano, David**
  50012 ZARAGOZA (ES)

(74) Representative: **ZBM Patents - Zea, Barlocci & Markvardsen**
Rambla Catalunya, 123
08008 Barcelona (ES)

(54) **ADJUSTABLE COOLANT PUMP**

(57) An adjustable coolant pump comprising: a housing 12; a shaft 13 to rotate around an axis of rotation of the housing; an impeller 14 assembled in the shaft; a shutter 2 displaceable along the axis of rotation to cover, at least partially, an outflow region of the impeller such that an amount of the coolant delivered by the pump is adjustable; an adjustment sealing arrangement provided between the shutter and an annular wall 122, wherein the housing comprises: a top face 15 and a bottom face 16 disposed substantially perpendicular to the axis of rotation, the bottom face being provided between the top face and the shutter. Also provided is a method of operation of an adjustable coolant pump.

Fig. 1



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Description

[0001] The present disclosure relates to coolant pumps, particularly adjustable coolant pumps. The present disclosure further relates to methods of operation of adjustable coolant pumps.

BACKGROUND

[0002] Some of the recent developed pumps for reducing global fuel consumption in combustion engine vehicles are based on adjusting or regulating elements that total or partially cover the outlet area of the main impeller. A variety of solutions have been proposed to activate this adjusting element, for instance those mentioned in the background of the application DE102005062200.

[0003] The aforementioned application presents a controllable coolant pump where the adjustment element is mechanically activated by means of a vacuum. This negative pressure is applied to an annular membrane which is deformed due to the pressure gradient respect to the atmospheric pressure at the other side of the annular membrane.

[0004] As result of this deformation, the membrane pushes a support element connected, through several rods, to the adjustment element, covering the output of the impeller of the pump, which never stops spinning. Therefore the hydraulic resistance of the circuit is increased due to the adjustment element, and this is reflected in a reduction of the flow rate.

[0005] In that type of configuration of adjustable pump, there are some drawbacks. When regulation system is activated, namely when the impeller is covered by the adjustment element, the coolant fluid is still driven by the impeller and retained by the adjustment element. It is known that the driven fluid which is retained by the adjustment element tends to generate a backflow between the adjustment element and the housing of the pump. This way, the adjustment capability of the adjustment element is reduced.

[0006] Known solutions as the above mentioned application, include gaskets and static sealing elements which seal the gap between the housing and the adjustment element when the adjustment element reaches the end of stroke. The end of stroke of the adjustment element can be reached in an activated condition of the regulation system when covering the impeller. These solutions have at least three drawbacks:

Firstly, the known solutions are highly dependent on the manufacturing and assembly tolerances along the whole chain of parts that contribute in a final activated position of the adjustment element. The latter makes it complex and low repeatable to assure the sealing between the housing and the adjustment element.

Secondly, the static sealing systems are solutions which are hardly adjustable to different requirements of the stroke of the shutter. Therefore, the resulting designs of pumps are barely adaptable and flexible.

Thirdly, static sealing systems, which are solutions where sealing is only achieved at the end of the stroke, allow the fluid migration between zones at different pressures during the shutter displacement in axial direction, resulting in a slower and more inefficient activation of the system and in a reduction of the adjustment capability during the activation.

[0007] In some other known solutions, the static sealing elements have to be adjusted on the basis of the position of the end of stroke embodied by a machined portion of the engine block. The position of the end of stroke is thus defined by the machined portion and is influenced by a long chain of tolerances, i.e. tolerances through a long chain of parts. Adaptations of the construction to other applications are thus complicated.

[0008] Furthermore, in the known solutions with static sealings in axial direction a force exerted by the regulation system is distributed between two sealing points, shutter - engine block or shutter - housing of the pump. Because of that, the ratio of sealing force distribution between both points depends on the chain of tolerances of the whole set of the pump and the machined portion of the engine. Therefore, that ratio of sealing force distribution is an uncertain variable.

[0009] Moreover, known regulation systems which may fully prevent the coolant to flow through the engine block may cause two potential drawbacks:

- When the regulation system is activated, no coolant or a negligible amount is supplied to the engine although the shaft of the pump may be kept rotating. Rotation of the shaft may cause a temperature rising of a (mechanical) shaft seal. In that scenario, coolant fluid inside shaft seal region and/or the cavity of the pump cannot be renewed so if the engine is revved above a determined number of revolutions per minute an overheating of the shaft seal may occur. That overheating may shorten service life of the pump or even a major failure thereof.
- As above mentioned, when the regulation system is activated, no coolant or a negligible amount is supplied to the engine. Therefore, fluid inside the block engine may be prevented from flowing, which may cause an overheating of certain specific parts of the engine above a determined number of revolutions per minute.

[0010] There are some other examples of adjustable pumps in the prior art where the adjustment element and the block engine are not brought into contact. These types of pump have some other drawbacks as well. Again, the problem is that final position of the adjustment element, when vacuum is applied, depends on the accumulated clearances of all the chain of assembled components from the annular membrane to the adjustment element.

[0011] Due to the lack of a well-defined final position, there is a potential risk of interference between the impeller and the adjustment element which could lead to severe damages and/or undesired noise and wear.

[0012] In addition, the flexible material of the membranes may be prone to suffer from wear which may cause inaccuracy of the function of regulation of the shutter and even a failure of the membrane.

[0013] Furthermore, some examples of pumps comprise a plate positioned between the impeller and the shutter or adjustment element to avoid the risk of interference. However, this plate generates a bulky and complex configuration of the adjustable coolant pump.

[0014] Besides that potential risk of interference, known solutions for regulating coolant pumps also suffer from other drawbacks. Final response of the pump regulation is directly related to the finally covered output area of the impeller, therefore, differences in this final position due to manufacturing and assembly tolerances could become in a product with a low repeatability in the regulation function.

[0015] It is an object of the present disclosure to provide examples of adjustable coolant pumps and methods for operating such pumps that avoid or at least reduce the aforementioned drawbacks.

SUMMARY

[0016] In a first aspect, an adjustable coolant pump is provided. The adjustable coolant pump comprises: a housing, a shaft to rotate around an axis of rotation of the housing, an impeller assembled in the shaft; a shutter displaceable along the axis of rotation to cover, at least partially, an outflow region of the impeller such that an amount of the coolant delivered by the pump is adjustable. The housing comprises: a top face and a bottom face disposed substantially perpendicular to the axis of rotation, the bottom face being provided between the top face and the shutter. The housing further comprises an annular wall extending from the bottom face in axial direction in such a way that a cavity to receive the shutter is defined at least by the annular wall and the bottom face. The adjustable coolant pump further comprises an adjustment sealing arrangement provided between the shutter and the annular wall, the sealing arrangement comprising a ring seal attached either to the shutter or the annular wall in such a way that a dynamic sealing between the shutter and the housing is defined.

[0017] According to this aspect, a gap between the annular wall of the housing and the shutter may be eliminated. Thus, a backflow of the coolant between the shutter and the housing is avoided or at least reduced, even when the shutter is displaced along the axis of rotation. Therefore, the adjustment capability of the shutter is not reduced.

[0018] As there may be a relative motion between the annular wall and the shutter the adjustment sealing arrangement may provide a dynamic sealing between the shutter and the housing along the stroke of the shutter. The sealing may be achieved in the annular wall which may be substantially parallel to the direction of a relative motion between the annular wall and the shutter.

[0019] A sealing function of the adjustment sealing arrangement may be independent of the aforementioned clearances and tolerances of the manufacturing and assembly of the components. Therefore, the sealing function of the adjustment sealing arrangement may be achieved and maintained regardless of the clearances and tolerances between the shutter and the housing.

[0020] The sealing function of the adjustment sealing arrangement may be present regardless of the relative position between the shutter and the housing. The sealing function may be also achieved in the end points of the stroke of the shutter.

[0021] In some examples of the adjustable coolant pump, the housing may further comprise at least one end-stop element attached to a portion of the housing to define an end of stroke for the shutter when covering, at least partially, the outflow region, wherein the end-stop element is attached to the bottom face. According to this example, a repeatable regulation response during all the actuations may be obtained, the end-stop element may provide a perfectly defined and fixed end-stop position for the adjustment element or shutter, when covering, at least partially the impeller.

[0022] Furthermore, adjustable coolant pump comprising the end-stop element may to avoid any possible contact of the shutter and the impeller, for instance, when the impeller may spin and at least a portion of the outflow region may be covered.

[0023] The adjustable coolant pump according to this example may absorb at the same time the clearances and tolerances of the manufacturing and assembly of the components in so way that regulation function may not be affected.

[0024] Last but not least, the adjustable coolant pump according to this example does not comprise any plate between the impeller and the shutter, so a simple, compact and reliable configuration may be achieved.

[0025] In some examples, the adjustable coolant pump may further comprise an annular piston displaceable in axial direction, an annular groove inside of which the annular piston is displaceable, wherein the annular groove is divided in at least a first and a second pressure chambers by the annular piston, wherein the annular piston is mechanically connected to the shutter such that a displacement of the annular piston in axial direction is transmitted to the shutter.

[0026] According to that further example, the adjustable coolant pump does not comprise any membrane but an annular piston displaceable inside the annular groove. Therefore, an accurate and predictable displacement of the piston may be achieved.

[0027] Furthermore, according to that further example a reliable function of regulation of the shutter may be obtained. The risk of failure and wear related to the membranes may be avoided.

[0028] According to another aspect, a method of operation of an adjustable coolant pump is provided. The adjustable coolant pump is according to any of the herein disclosed examples. The method comprises: rotating the shaft for rotating the impeller to set in motion an amount of coolant, displacing the shutter along the axis of rotation for covering, at least partially, the outflow region of the impeller so as to adjust the amount of the coolant delivered by the pump, providing a sealing between the shutter and the annular wall when the shutter is displaced.

[0029] The method of this aspect may provide the same advantages as the adjustable coolant pump of the first aspect.

[0030] In one example of the method, it may further comprise stopping the displacement of the shutter at a predefined end of stroke by means of the end-stop element, when the shutter covers, at least partially, the outflow region.

[0031] According to this example, a method with an accurate adjustment function of the shutter may be achieved. The shutter may be displaced until a predefined end of stroke by means of the end-stop element.

[0032] Throughout the present disclosure, the terms "shutter" and "adjustment element" are used interchangeably.

[0033] Throughout the present disclosure, a coolant is to be understood as a fluid such as a liquid used to remove heat.

[0034] Throughout the present disclosure, by "dynamic sealing" is meant a sealing provided at least between two surfaces and there is a relative motion between them.

[0035] Throughout the present disclosure, by "static sealing" is meant a sealing provided at least between two surfaces and there is no relative motion between them.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] Non-limiting examples of the present disclosure will be described in the following, with reference to the appended drawings, in which:

Figure 1 schematically shows a longitudinal cross section view of an adjustable coolant pump according to an example when a regulation function is deactivated;

Figure 2 schematically shows a longitudinal cross section view of the adjustable coolant pump of the figure 1 when a regulation function is activated;

Figure 3 schematically shows an enlarged detail A of an adjustment sealing arrangement of the adjustable coolant pump of the figure 1;

Figure 4 schematically shows an enlarged detail B of an adjustment sealing arrangement of the adjustable coolant pump of the figure 2;

Figure 5 schematically shows a partial longitudinal cross section view of the adjustable coolant pump of the figure 1 with a flow of coolant;

Figure 6 is a flow chart of an exemplary method of operation of an adjustable coolant pump.

Figure 7 schematically shows a longitudinal cross section view of an adjustable coolant pump according to a further example when a regulation function is deactivated;

Figure 8 schematically shows a longitudinal cross section view of the adjustable coolant pump of the figure 7 when a regulation function is activated;

Figures 9A-9B schematically show enlarged details C and D of connections between a rod and respectively an annular piston and a shutter of the adjustable coolant pump of the figure 7 when a regulation function is deactivated;

Figures 10A-10B schematically show enlarged details E and F of connections between a rod and respectively an annular piston and a shutter of the adjustable coolant pump of the figure 7 when a regulation function is activated;

DETAILED DESCRIPTION OF EXAMPLES

[0037] In the following some examples of an adjustable coolant pump 1 will be described. Although those examples may be related to an internal combustion engine, the adjustable coolant pump 1 could be related to any kind of engine or the like. The adjustable coolant pump 1 may be used for conveying and circulating a coolant or coolants.

[0038] Figure 1 schematically shows a longitudinal cross section view of an adjustable coolant pump 1 according to an example when a regulation function is deactivated and figure 2 schematically shows a longitudinal cross section view of the adjustable coolant pump of the figure 1 when a regulation function is activated.

[0039] When the regulation function is deactivated, the pump 1 may be able to provide its flow rate of coolant. Conversely, when the regulation function is activated the pump 1 may be able to provide a percentage of its flow rate or even nothing.

[0040] The adjustable coolant pump 1 according to some examples may be pneumatically actuated.

[0041] Figure 7 schematically shows a longitudinal cross section view of an adjustable coolant pump 1 according to a further example when a regulation function is deactivated and figure 8 schematically shows the adjustable coolant pump 1 of the figure 7 when a regulation function is activated.

[0042] An exemplary adjustable coolant pump 1 may comprise:

a housing 12. This housing may be directly or indirectly attached to an engine or the like and may be made from metallic material;

a shaft 13 to rotate around an axis of rotation AR of the housing 12. The shaft 13 may be driven by the pulley 17 which in turn may be driven by a crankshaft (not illustrated) of an engine through a belt (not illustrated). However, alternative power sources to drive the shaft 13 may be envisaged. This shaft 13 may be positioned, at least partially, in the housing 12. The axis of rotation AR may match the longitudinal axis of the housing 12 in some examples;

an impeller 14 assembled in the shaft 13. This may be understood as the impeller 14 may be attached or fixed to the shaft 13 or even the impeller 14 may be integrally formed with the shaft 13. The impeller 14 may be placed in the shaft 13 at the end opposite to the pulley 17 as can be seen in figures 1-2. The construction of the impeller 14 may be similar to that one of impellers available in the market, so no further explanation will be provided. A shaft seal 11 may be disposed for instance around the shaft 13 for preventing the coolant from going from the impeller area to the pulley area. This shaft seal 11 may be fitted in a fix manner in the housing 12;

a shutter 2 displaceable along the axis of rotation AR to cover, at least partially, an outflow region OR of the impeller 14 such that an amount of the coolant (not illustrated) delivered by the pump 1 may be adjustable. The shutter 2 may comprise a cup-like construction or any other shape which allows covering, at least partially, the outflow region OR of the impeller 14. An outflow region OR may comprise a portion of the impeller area where the outgoing coolant may leave the impeller 14. This impeller area may be associated, for instance, with a coolant circuit of an engine;

wherein the housing 12 comprises a top face 15 and a bottom face 16 disposed substantially perpendicular to the axis of rotation AR, the bottom face 16 may be provided between the top face 15 and the shutter 2. The housing also comprises an annular wall 122 extending from the bottom face 16 in axial direction in such a way that a cavity 121 to receive the shutter 2 may be defined at least by the annular wall 122 and the bottom face 16;

wherein the adjustable coolant pump 1 further comprises an adjustment sealing arrangement provided between the shutter 2 and the annular wall 122, the sealing arrangement comprising a ring seal 123 attached either to the shutter 2 or the annular wall 122 in such a way that a dynamic sealing between the shutter 2 and the housing 12 may be defined. The dynamic sealing may be achieved along the stroke of the shutter 2.

[0043] The ring seal 123 could be made from e.g. rubber or the like or from any suitable material available in the market such as metallic material.

[0044] In an example of the adjustable coolant pump in figure 2 the shaft seal 11 may be in fluid communication with the cavity 121, e.g. the shat seal 11 may be arranged so as to receive coolant from the cavity 121. In the example of figure 2, the shaft seal 11 is received, at least partially, in a seal region 130 of the housing 12, and the seal region is in fluid communication with the cavity 121. It can be seen that the outflow region OR is in fluid communication with the cavity 121 (and the seal region 130 if present) through a shutter hole 23 provided in the shutter 2. The sealing arrangement may be configured / adapted to prevent a flow of coolant, i.e. null or negligible, therethrough and from the cavity 121 when the pressure in the cavity is below a predetermined threshold.

[0045] In figures 2 and 5, it can be seen an example of the adjustable coolant pump where the shaft seal 11 is in fluid communication with the cavity 121, e.g. the shat seal 11 may be arranged so as to receive coolant from the cavity 121. In those examples, the shaft seal 11 is received, at least partially, in a seal region 130 of the housing 12, and the seal region 130 is in fluid communication with the cavity 121.The outflow region OR may be in fluid communication with the cavity 121 (and the seal region 130 if present) through the shutter hole 23 provided in the shutter 2. The sealing arrangement may be configured / adapted to allow a flow F of coolant therethrough and from the cavity 121 when the pressure in the cavity is above the predetermined threshold, as illustrated in figure 5. Details about that flow F will be provided later.

Alternatively, in examples not illustrated, the

[0046] By providing a radial dynamic sealing arrangement, the following potential drawbacks may be avoided at least partially:

- When the regulation system is activated no coolant, i.e. null or negligible, is supplied to the engine although the shaft of the pump may be kept rotating. In that scenario, coolant fluid inside seal region 130 and/or the cavity 121 of the pump cannot be renewed so if the engine is revved above a determined number of revolutions per minute an overheating of the shaft seal 11 may occur. That overheating may shorten service life of the pump or even a major failure thereof. The proposed solution may produce a predetermined flow rate of coolant that allows a renewal of the fluid inside the seal region 130 and/or the cavity 121 also when the engine is revved above a determined number of revolutions per minute. This solution may allow keeping unchanged the expected service life of the pump and a major failure thereof.

- When the regulation system is activated no coolant is supplied to the engine. Therefore, fluid inside the block engine may be prevented from flowing, which may cause an overheating of certain specific parts of the engine above a determined number of revolutions per minute. The proposed solution may supply a predetermined flow rate of coolant to the block engine so as to avoid any overheating of those specific parts of the engine and to homogenize the temperature of the coolant inside the block engine

[0047] As can be seen in figures 3 and 4 the ring seal 123 may comprise a flange 124 protruding from the rest of the ring seal 123 to contact the shutter 2 or the annular wall 122, the ring seal 123 may be deformable.

[0048] In some examples, the ring seal 123 may be disposed about the axis of rotation AR.

[0049] In some examples, the annular wall 12 may be integrally formed with the rest of the housing 12 or may be a separate part which can be attached to the rest of the housing 12.

[0050] In the example illustrated in figures 1 and 2, the ring seal 123 is attached to the annular wall 122. Alternatively, the ring seal 123 may be attached to the shutter 2, particularly in a sidewall of the cup-like shutter 2.

[0051] As there may be a relative motion between the shutter 12 and the annular wall 122 of the housing 2, and the ring seal 123 may be attached either to the shutter 2 or the annular wall 122, there may be a relative motion between the ring seal 123 and the annular wall 122 or the shutter 2.

[0052] This relative motion between the ring seal 123 and the shutter 12 or the annular wall 122 keep unchanged the sealing capability along all the stroke of the shutter 12. This way, the sealing may be made independent from the end of stroke formed by the machined portion of the engine, and so, from the design of parts outside the pump itself. Thus, design of the pump 1 may be made more flexible and adaptable to different applications.

[0053] Furthermore, the pump 1 according to some examples may ensure that all the available force of regulation system may be used for sealing between shutter 2 and block engine (not illustrated), making it independent the sealing between shutter and housing from the chain of tolerances of axial motion and from the overall force realized by the regulation system.

[0054] Figure 3 schematically shows an enlarged detail A of an adjustment sealing arrangement of the adjustable coolant pump 1 of the figure 1 and figure 4 schematically shows an enlarged detail B of an adjustment sealing arrangement of the adjustable coolant pump 1 of the figure 2.

[0055] In figures 3 and 4, it can be seen an annular recces 125 in the annular wall 122 where the ring seal 123 may be received. More particularly, the annular recess 125 is formed in an inner face of the annular wall 122, the inner face forming the cavity 121 where the shutter 2 may be housed. The inner face is facing the shutter 2.

[0056] The ring seal 123 may comprise a flange 124 or lip to contact the shutter 2. Alternatively the ring seal 123 may be an O-ring, "X" or squared cross-section shaped or the like. The ring seal 123 may be manufactured from a resilient material. The flange 124 may protrude from the rest of ring seal 123 to obtain a better contact with the shutter 2. In figures 3 and 4 it is shown that the flange 124 also protrudes from the inner wall of the annular wall 122. In those figures it is also shown that the ring seal 123 may be configured so as to allow an empty space 126 or void defined in the annular recess 125 and covered at least partially by the flange 124. The flange 124 may be received by the empty space 126 when it is bent due to the relative motion between the shutter 2 and the housing 12.

[0057] Details A and B, in figures 3 and 4, are related to examples of the adjustable coolant pump 1 wherein the flange 124 is disposed facing the outflow region OR. Alternatively, the flange 124 may be disposed in any other direction, provided that a contact with the annular wall 122 and the shutter 2 can be achieved.

[0058] The adjustable coolant pump 1 may further comprise at least one end-stop element 3 attached to a portion of the housing 12 to define an end of stroke for the shutter 2 when covering, at least partially, the outflow region OR. The end-stop element 3 may also act as a guide for the shutter 2 when displacing along the axis of rotation AR. By way of example, the pump 1 illustrated in figures 7 and 8 may comprise three end-stop elements 3 disposed around and parallel to the axis of rotation AR at 120° the one to the other. The end-stop element may be attached to the bottom face 16.

[0059] The axis of rotation AR may match or at least be parallel to the longitudinal axis of the shaft 13, according to one example.

[0060] According to some examples, the housing 12 may also comprise side walls to join the top face 15 and the bottom face 16 such that the housing 12 may comprise a cylinder-shaped body.

[0061] In further examples, the end-stop element 3 may comprise a shank 31 fixed at one end to the portion of the housing 12 and may further comprise a widening 32 at the other end to stop the shutter 2 when covering, at least partially, the outflow region OR.

[0062] In some examples, the shank 31 may have a predefined length such that this predefined length of the shank 31 may correspond to a predefined end of stroke for the shutter 2 when covering, at least partially, the outflow region OR. The predefined length of the shank 31 may be chosen depending on the expected reduction percentage of flow rate and therefore on the amount of coverage. By adopting different lengths of the shank 31 the end of stroke of the shutter 2 may be located at different positions related to the impeller 14 (and the housing 12). The reduction percentage of the flow rate may be easily adjusted by adopting a different length of the shank 31. For instance, a shank 31 with a short length (shorter stroke of shutter 2) may achieve less reduction percentage than a shank 31 with longer length (longer stroke of shutter 2).

[0063] According to some examples of the adjustable coolant pump 1, the end-stop element 3 may comprise a bolt; alternatively the end-stop element 3 may be a rivet or any analogous element. This bolt or rivet may be fixed to a corresponding orifice in the bottom face 16.

[0064] As can be seen in figures 7 and 8, the adjustable coolant pump 1 may further comprise:

an annular piston 4 which may be displaceable in axial direction. The annular piston 4 may be made from any suitable material. The axial direction may be coaxial or not to a pump center axis. The pump center axis may be the same as the axis of rotation AR;

an annular groove 5 inside of which the annular piston 4 may be displaceable. The annular groove 5 may be shaped so as to allow a swinging or back and forth movement of the annular piston 4 in axial direction;

wherein the annular groove 5 may be divided in at least a first 51 and a second 52 pressure chambers by the annular piston 4. The presence of the annular piston 4 may define those pressure chambers 51, 52. Although the overall size (volume) of the annular groove 5 may remain unchanged during operation of the pump 1, the size of each of those pressure chambers may change depending on whether the regulation function may be activated or not. In some examples, the second pressure chamber 52 may be positioned closer to the impeller 14 and the first pressure chamber 51 may be positioned farther (taking into account the length of the axis of rotation AR);

wherein the annular piston 4 may be mechanically connected to the shutter 2 such that a displacement of the annular piston 4 in axial direction may be transmitted to the shutter 2. The length of displacement of the annular piston 4 may vary depending on the case. The amount of displacement defines the percentage of regulation of the outflow region OR of the impeller 14.

[0065] Both the annular piston 4 and the annular groove 5 may be disposed around the shaft 13 or the axis of rotation AR thereof, as depicted in figures 1-2.

[0066] According to some examples, the adjustable coolant pump 1 may further comprise at least one rod 6 to mechanically connect the annular piston 4 to the shutter 2.

[0067] The rod 6 may comprise two notches 61, 62 respectively at its ends to allow a fixation respectively to the annular piston 4 and the shutter 2. These notches 61, 62 may match a corresponding hole 22 in the shutter 2 or slot 42 in the annular piston 4. Alternatively, the relative fixation of the rod 6 to the annular piston 4 and the shutter 2 may be achieved by welding, bonding or the like.

[0068] Although the rod 6 has been depicted as a single element, alternatively it may be envisaged as a plurality of parts that allow a mechanical connection between the shutter 2 and the piston 4.

[0069] According to some examples, the rod 6 may slidably move along a rod bearing 63 to facilitate the transmission of movement from annular piston 4 and the shutter 2. This rod bearing 63 may be positioned between the rod 6 and the housing 12. Some rod seals may be disposed for preventing the coolant from going from the impeller area to the annular groove 5.

[0070] Figures 9A-9B schematically show enlarged details of connections between the rod 6 and respectively the annular piston 4 and the shutter 2 when a regulation function is deactivated. Meanwhile, figures 10A-10B schematically show enlarged details of those connections between the rod 6 and respectively the annular piston 4 and the shutter 2 when the regulation function is activated.

[0071] The use of notches 61, 22 may bring the presence of some clearances C1, C2 in the area of connection of those notches 61, 62 to hole 22 and slot 42. These clearances may facilitate the assembling of the pump 1. Such clearances C1, C2 may vary depending on the status of the pump 1 as will be explained later.

[0072] In some other examples of the adjustable coolant pump 1, the first pressure chamber 51 may comprise an opening 55 to allow atmospheric air entering the first pressure chamber 51 and the second pressure chamber 52 may be associated with a vacuum source (not illustrated). The second pressure chamber 52 may comprise a vacuum connection 54 to allow the fluid connection to the vacuum source.

[0073] In further examples, the piston 4 may comprise a piston seal 41 for sealing the first 51 and the second 52 pressure chambers each other. The piston seal 41 may be a lip seal or the like which may contact the walls of the annular groove 4.

[0074] According to one example, the adjustable coolant pump 1 may further comprise a resilient element 7 to push the annular piston 41 in axial direction and away from the impeller 14, wherein the resilient element 7 may be located in a corresponding accommodation 53 opened out to the annular groove 5. As depicted in figures 1 and 2, there may be a plurality of resilient elements 7 such as three, around and parallel to the axis of rotation AR at 120° the one to the other.

[0075] The resilient element 7 may comprise a spring, for instance.

[0076] According to an example, the shutter 2 may comprise at least one bore 21 to slidably receive the corresponding end-stop element 3. The number of bores 21 may be the same as the number of end-stop elements 3.

[0077] Thanks to the configuration of the shank 31 with a predefined length it may be possible to easily adjust the reduction percentage above mentioned without adjusting the output delivered by the power source which drives the shaft 13, and/or without adjusting the vacuum source associated to the second pressure chamber 52.

[0078] Figure 6 is a flow chart of an exemplary method of operation of an adjustable coolant pump. Although figure 6 shows a specific sequence, it should be understood that other sequences may be followed not deviating from the scope of the present disclosure.

[0079] The method of operation 100 may be related to the herein disclosed examples of adjustable coolant pump 1, for instance those examples which may comprise:

a housing 12;
a shaft 13 which may rotate around an axis of rotation AR of the housing 12;
an impeller which may be assembled in the shaft 13;
a shutter 2 which may be displaceable along the axis of rotation AR to cover, at least partially, an outflow region OR of the impeller 14 such that an amount of the coolant delivered by the pump 1 may be adjustable; wherein the housing 12 comprises a top face 15 and a bottom face 16 disposed substantially perpendicular to the axis of rotation AR, the bottom face 16 may be provided between the top face 15 and the shutter 2;
an annular wall 122 extending from the bottom face 16 in axial direction in such a way that a cavity 121 to receive the shutter 2 may be defined at least by the annular wall 122 and the bottom face 16;
wherein the adjustable coolant pump 1 further comprises:
an adjustment sealing arrangement provided between the shutter 2 and the annular wall 122, the sealing arrangement comprising a ring seal 123 attached either to the shutter 2 or the annular wall 122 in such a way that a dynamic sealing between the shutter and the housing is defined.

[0080] According to those examples the method 100 may comprise:

rotating the shaft 101 for rotating the impeller 14 to set in motion an amount of coolant. The rotation of the shaft 13 may be driven as explained before;
displacing the shutter 102 along the axis of rotation AR for covering, at least partially, the outflow region OR of the impeller 14 so as to adjust the amount of the coolant delivered by the pump 1. The displacement of the shutter 2 can be seen in figures 1 and 2. In figure 1, the shutter 2 does not cover the outflow region OR of the impeller 14 yet. In figure 2, the shutter has been displaced along the axis of rotation AR and towards the impeller 14 in order to cover at least partially the outflow region OR. The shank 31 may act as a guide for an accurate displacement of the shutter 2;
providing a sealing 103 between the shutter 2 and the annular wall 122 when the shutter 2 is displaced. This way a sealing may be provided when there is a relative motion between the shutter 2 and the annular wall 122.

[0081] When the shutter 2 is displaced along the axis of rotation AR a sealing may be achieved between the shutter 2 and the housing 12, more particularly, between the shutter 2 and the annular wall 122. This way, a sealing function of the adjustment sealing arrangement may be maintained not only at the end points of the stroke of the shutter 2 but also along said stroke.

[0082] In the examples of figures 1 to 5, the flange 124, and particularly the cross section of the flange 124, may be bent or deformed when the shutter 2 is displaced along the axis of rotation AR so as to ensure the sealing along the whole shutter stroke.

[0083] Furthermore, the method 100 may comprise:

allowing an amount of coolant from the outflow region OR to pass through the shutter hole 23. As above mentioned, the shutter 2 may be activated and the shaft 13 may be kept rotating. The impeller 14 may drive coolant in spite of the activation of the shutter 2 so the coolant may be driven through the shutter hole 23 and may reach the cavity 121 which may be in fluid communication with the seal region 130. The flow rate of coolant through the shutter hole 23 may depend on the rotation of the impeller, i.e. the faster it rotates the higher amount of coolant;
allowing a pressure to build-up inside the cavity 121. The coolant passing through the shutter hole 23 may be trapped into the cavity 121, at least partially, (and the seal region 130 if present), because of the sealing arrangement between the shutter 2 and the annular wall 122.

[0084] When the built-up pressure inside the cavity 121 is below a predefined pressure threshold, the sealing arrangement may prevent a flow of coolant to pass therethrough i.e. the sealing arrangement may block the coolant inside the cavity 121. By preventing the flow of coolant is meant that a negligible amount or no coolant could pass. The pressure threshold may depend on features of the ring seal 123 such as material, shape or even the presence of accessories e.g. a flange 124, and so the pressure threshold may be predefined.

[0085] When the built-up pressure rises and reaches a value above the predefined pressure threshold, a flow of coolant may be allowed to pass between the shutter 2 and the annular wall 122 towards a portion of the volute 140 which is not under the influence of the shutter 2 when the shutter 2 is activated. This portion of the volute may be in fluid communication with the rest of the cooling system of the engine block (not illustrated) even if the shutter 2 is activated. Thus, the flow F allowed by the sealing arrangement may run through the cooling system and cool some parts of the engine which may become overheated. This may occur e.g. when the engine is revved above a predefined number of rpm's. Figure 5 shows a path of a flow F of coolant from the impeller, passing through the shutter hole 23, the cavity 121 and seal region 130, between the shutter 2 and the annular wall and towards the portion of volute 140.

[0086] A clearance C3 between the flange 124 and the shutter 2 has been magnified for the sake of clarity.

[0087] The flow F between the shutter 2 and the annular wall 122 may allow to renew coolant at the cavity 121 (and the seal region 130 if present), and thus to cool the shaft seal 11.

[0088] The sealing arrangement may allow the flow F between the shutter 2 and the annular wall 122 towards the portion of volute 140 by a further deformation of the ring seal 123. The flange 124 may be further bent (in a direction of arrow BD of figure 5 towards the annular wall 122) by the coolant which has been pressurized in the cavity 121 (and seal region 130 if present) when the engine is revved above a predetermined number of rpm. Fluid closed inside the cavity 121 (and seal region 130 if present) may be driven and bend the flange 124 allowing a flow of coolant from cavity 121 to the portion of the volute 140 through a path defined by the shutter 2 and the annular wall 122. In alternative examples, the whole ring seal 123 may be further bent to allow the pass the coolant. The portion of the volute 140 may be at lower pressure relative to the cavity 121 because the shutter 2 may act as a barrier to the coolant driven by the impeller.

[0089] Therefore, in some examples the sealing arrangement may have a dual behaviour: preventing the flow and/or allowing a relative little amount of coolant to pass therethrough towards the portion of the volute 140 which is not under the influence of the shutter 2, depending on the pressure built-up in the cavity.

[0090] Alternatively, the sealing arrangement may prevent the flow through the whole range of rpm's of the engine. By way of example, the ring seal 123 could be made from such a material that it does not undergo any deformations in spite of the built-up pressure, e.g. metal or the like.

[0091] In the examples where the pump 1 further comprises at least one end-stop element 3 as above described, the method 100 may further comprise stopping the displacement of the shutter at a predefined end of stroke by means of the end-stop element 3, when the shutter 2 covers, at least partially, the outflow region OR. In figures 8 and 10B, the shutter 2 has reached the end of stroke which may be determined by the widening 32 of the end-stop element 3. The sum of end-areas of each end-stop element 3 may define an activation stroke limit and may provide a planar contact surface for the shutter 2, particularly for the face of the shutter opposite to the annular piston 4.

[0092] In some further examples, the method 100 related, for instance, to those herein disclosed examples in which the adjustable coolant pump 1 may further comprise:

an annular piston 4 which may be displaceable in axial direction;

an annular groove 5 inside of which the annular piston 4 may be displaceable;

wherein the annular groove 5 may be divided in at least a first 51 and a second 52 pressure chambers by the annular piston 5;

wherein the annular piston 4 may be mechanically connected to the shutter 2 such that a displacement of the annular piston 4 in axial direction may be transmitted to the shutter 2.

[0093] According to those examples the method 100 may further comprise:

reducing the pressure of the second pressure chamber 52 to at least one predefined level lower than the pressure of the first pressure chamber 1 for displacing the annular piston 4 in axial direction to the impeller 14 and covering, at least partially, the outflow region OR of the impeller 14 by the shutter 2. Reducing the pressure of the second pressure chamber 52 may comprise actuating a vacuum source (not illustrated) associated to the second pressure chamber 52 and allowing atmospheric air entering the first pressure chamber 51 through an opening 55 thereof. By actuating the vacuum source, for instance, a gas may be removed from the second pressure chamber 52. Meanwhile, the opening 55 may allow atmospheric air entering the first pressure chamber 51. Owing to the difference of pressures between the first and second pressure chambers, the annular piston 4 may move in axial direction towards the impeller 14, so the size (volume) of the second pressure chamber 52 may become smaller than the first pressure chamber 51. As the shutter 2 may be mechanically associated to the annular piston 4, the shutter 2 may describe a similar displacement.

[0094] By way of example, for activating the adjustment of the coolant, the pressure inside the second pressure chamber 52 may be kept below the atmospheric pressure of the environment of the pump 1.

[0095] Once the regulation function may be deemed as not necessary it may be deactivated. The vacuum source may be no longer activated. Then the resilient elements 7 may displace the annular piston 4 away from the impeller 14 in axial direction. The force generated by the springs 15 may be lower than the force created by the vacuum pressure of the vacuum source when the regulation function is activated so as to displace the shutter 2 towards the impeller 14 and at the same time this force may be sufficient as to return both annular piston 4 and shutter or adjusting element 2 when regulation function is deactivated. The first pressure chamber 51 may become smaller than the second pressure chamber 52.

[0096] When the regulation function is deactivated, the face of the shutter opposite to the impeller 14 may contact the bottom face 16 which may act as deactivation stroke limit.

[0097] All in all, a difference of pressure between the first 51 and the second 52 chambers may cause the displacement of the annular piston 4 in axial direction. Thus, the first pressure chamber may be fed with air directly taken from the environment of the pump (for instance atmospheric air) or a gas at a pressure higher than the gas inside the second pressure chamber 52 may be forced to enter the first chamber 51.

[0098] In some examples, the control unit may determine that a regulation of the flow-rate of the pump 1 may be activated. The control unit may send a command to the vacuum source to remove a predefined quantity of fluid form the second pressure chamber 52. This way, the outflow region OR may be at least partially occluded. Owing to the displacement of the piston 4, an atmospheric pressure fluid (such as ambient air) may enter the first pressure chamber 51 or an atmospheric pressure fluid may be forced to enter. The force of the generated vacuum may be greater than the opposite force of the resilient elements 7 to displace the piston towards the impeller 14.

[0099] When the control unit may determine that the regulation function may be no longer needed, it may send a command to the vacuum source to stop generating vacuum. Upon stopping the vacuum generation, the atmospheric pressure fluid (such as ambient air) may enter the second pressure chamber 52, for instance through the vacuum connection 54 which may be in fluid communication with an atmospheric air intake (not illustrated). The aperture/closure of the atmospheric air intake may be ruled by the control unit. This way, the difference of pressure between the first 51 and the second 52 chambers may no longer exist and both chambers 51, 52 may contain fluid at substantially the same pressure. Then resilient elements 7 may push the piston away from the impeller 14 in axial direction.

[0100] As above mentioned, the clearances C1, C2 may vary depending on the status of the pump 1. For instance, in figures 3A-3B the function may be deactivated but in figures 10A-10B activated. The size of the clearance C1, C2 may be the same in both cases but their distribution may vary like the size of the first and second pressure chambers 51, 52 by activation or deactivation of regulation.

[0101] In some examples, when the regulation is activated (see figures 10A-10B), clearance C1, C2 may be larger in the connection area disposed closer to the impeller 14. Conversely, when the regulation is activated (see figures 9A-9B), clearance C1, C2 may be larger in the connection area disposed farther from the impeller 14.

[0102] Thanks to the presence of the end-stop elements 3, an end of the stroke of the annular piston 4 and thus the shutter 2 may be accurately defined despite the clearances C1, C2 (for instance, when the regulation is activated). Furthermore, thanks to the bottom face 16, the other end of stroke of the annular piston 4 and thus the shutter 2 may be accurately defined despite the clearances C1, C2 (for instance, when the regulation is deactivated).In some cases, the adjustable coolant pump 1 according to herein disclosed examples may be configured to carry out the method 100.

[0103] Although only a number of examples have been disclosed herein, other alternatives, modifications, uses and/or equivalents thereof are possible. Furthermore, all possible combinations of the described examples are also covered. Thus, the scope of the present disclosure should not be limited by particular examples, but should be determined only by a fair reading of the claims that follow. If reference signs related to drawings are placed in parentheses in a claim, they are solely for attempting to increase the intelligibility of the claim, and shall not be construed as limiting the scope of the claim.

Claims

1. An adjustable coolant pump comprising:

a housing;
a shaft to rotate around an axis of rotation of the housing;
an impeller assembled in the shaft;
a shutter displaceable along the axis of rotation to cover, at least partially, an outflow region of the impeller such that an amount of the coolant delivered by the pump is adjustable;
wherein the housing comprises:

a top face and a bottom face disposed substantially perpendicular to the axis of rotation, the bottom face being provided between the top face and the shutter;
an annular wall extending from the bottom face in axial direction in such a way that a cavity to receive the shutter is defined at least by the annular wall and the bottom face;
wherein the adjustable coolant pump further comprises:
an adjustment sealing arrangement provided between the shutter and the annular wall, the sealing arrangement comprising a ring seal attached either to the shutter or the annular wall in such a way that a dynamic sealing between the shutter and the housing is defined.

2. The adjustable coolant pump according to claim 1, further comprising:

a shaft seal disposed around the shaft, the shaft seal being in fluid communication with the cavity;
wherein the outflow region is in fluid communication with the cavity through a shutter hole provided in the shutter;
wherein the sealing arrangement prevents a

flow of coolant therethrough and from the cavity when the pressure in the cavity is below a predetermined threshold.

3. The adjustable coolant pump according to any of claims 1 - 2, further comprising:

a shaft seal disposed around the shaft, the shaft seal being in fluid communication with the cavity;
wherein the outflow region is in fluid communication with the cavity through a shutter hole provided in the shutter;
wherein the sealing arrangement allows a flow of coolant therethrough and from the cavity when the pressure in the cavity is above the predetermined threshold.

4. The adjustable coolant pump according to any of claims 2 - 3, wherein the shaft seal is received, at least partially, in a seal region of the housing, and the seal region is in fluid communication with the cavity and the outflow region.

5. The adjustable coolant pump according to any of claims 1 - 4, wherein the ring seal comprises a flange protruding from the rest of the ring seal to contact the shutter or the annular wall, the ring seal being deformable.

6. The adjustable coolant pump according to claim 5, wherein the flange is disposed facing the outflow region.

7. The adjustable coolant pump according to any of claims 1 - 6, further comprising:

at least one end-stop element attached to a portion of the housing to define an end of stroke for the shutter when covering, at least partially, the outflow region;
wherein the end-stop element is attached to the bottom face.

8. The adjustable coolant pump according to claim 7, wherein the end-stop element comprises a shank fixed at one end to the portion of the housing and further comprising a widening at the other end to stop the shutter when covering, at least partially, the outflow region.

9. The adjustable coolant pump according to claim 8, wherein the shank has a predefined length such that the predefined length of the shank corresponds to a predefined end of stroke for the shutter when covering, at least partially, the outflow region.

10. The adjustable coolant pump according to any of claims 8 - 9, wherein the end-stop element comprises a bolt or a rivet.

11. The adjustable coolant pump according to any of claims 1 - 10, further comprising:

an annular piston displaceable in axial direction;
an annular groove inside of which the annular piston is displaceable;
wherein the annular groove is divided in at least a first and a second pressure chambers by the annular piston;
wherein the annular piston is mechanically connected to the shutter such that a displacement of the annular piston in axial direction is transmitted to the shutter.

12. The adjustable coolant pump according to claim 11, further comprising at least one rod to mechanically connect the annular piston to the shutter.

13. A method of operation of an adjustable coolant pump, the adjustable coolant according to claim 1, wherein the method comprises:

rotating the shaft for rotating the impeller to set in motion an amount of coolant;
displacing the shutter along the axis of rotation for covering, at least partially, the outflow region of the impeller so as to adjust the amount of the coolant delivered by the pump;
providing a sealing between the shutter and the annular wall when the shutter is displaced.

14. The method according to claim 13, the adjustable coolant pump according to any of claims 2 or 3, wherein the method further comprises:

allowing an amount of coolant from the outflow region to pass through the shutter hole;
allowing a pressure to build-up inside the cavity.

15. The method according to any of claims 13 - 14, the adjustable coolant pump according to claim 6, wherein the method further comprises:
stopping the displacement of the shutter at a predefined end of stroke by means of the end-stop element, when the shutter covers, at least partially, the outflow region.

Fig. 1

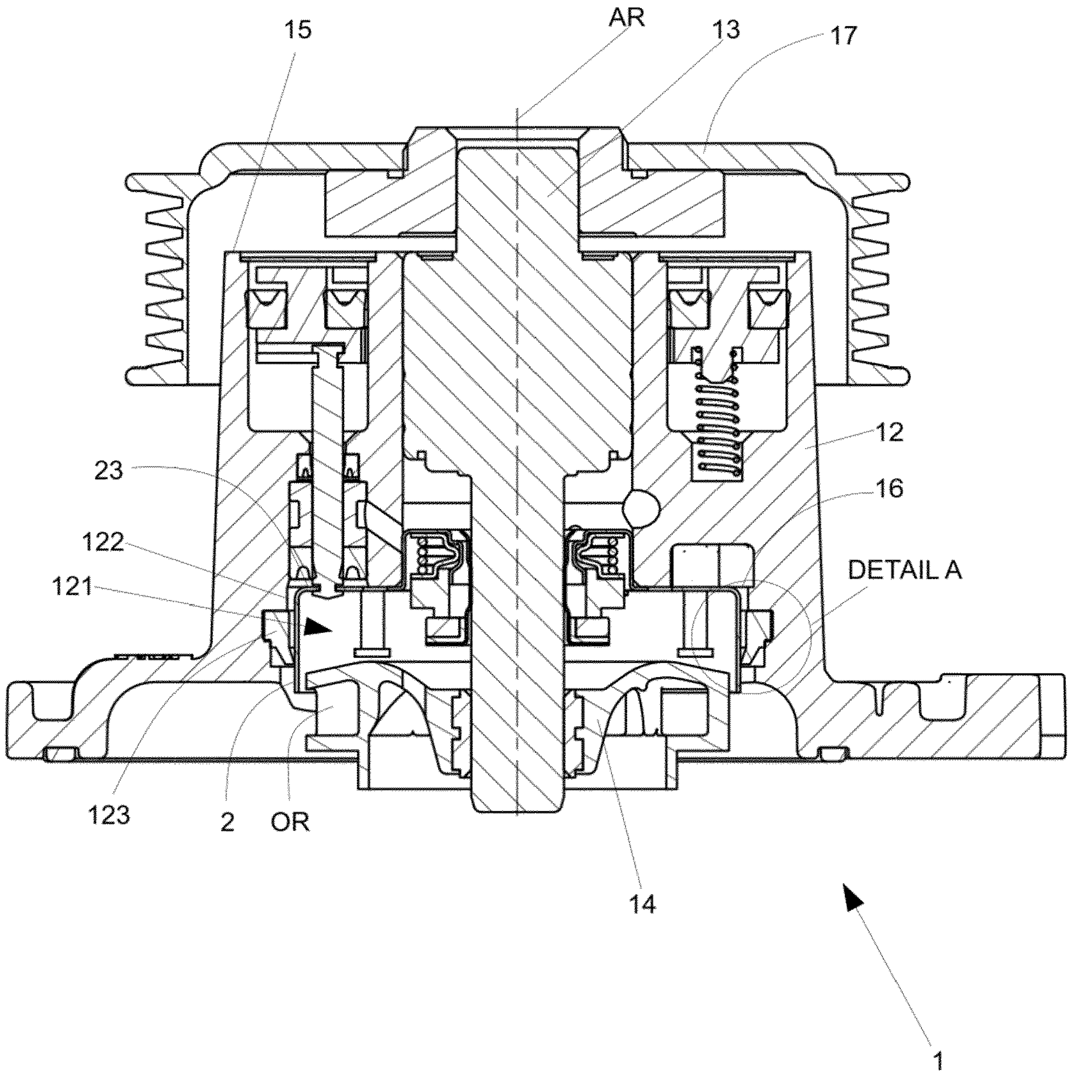


Fig. 2

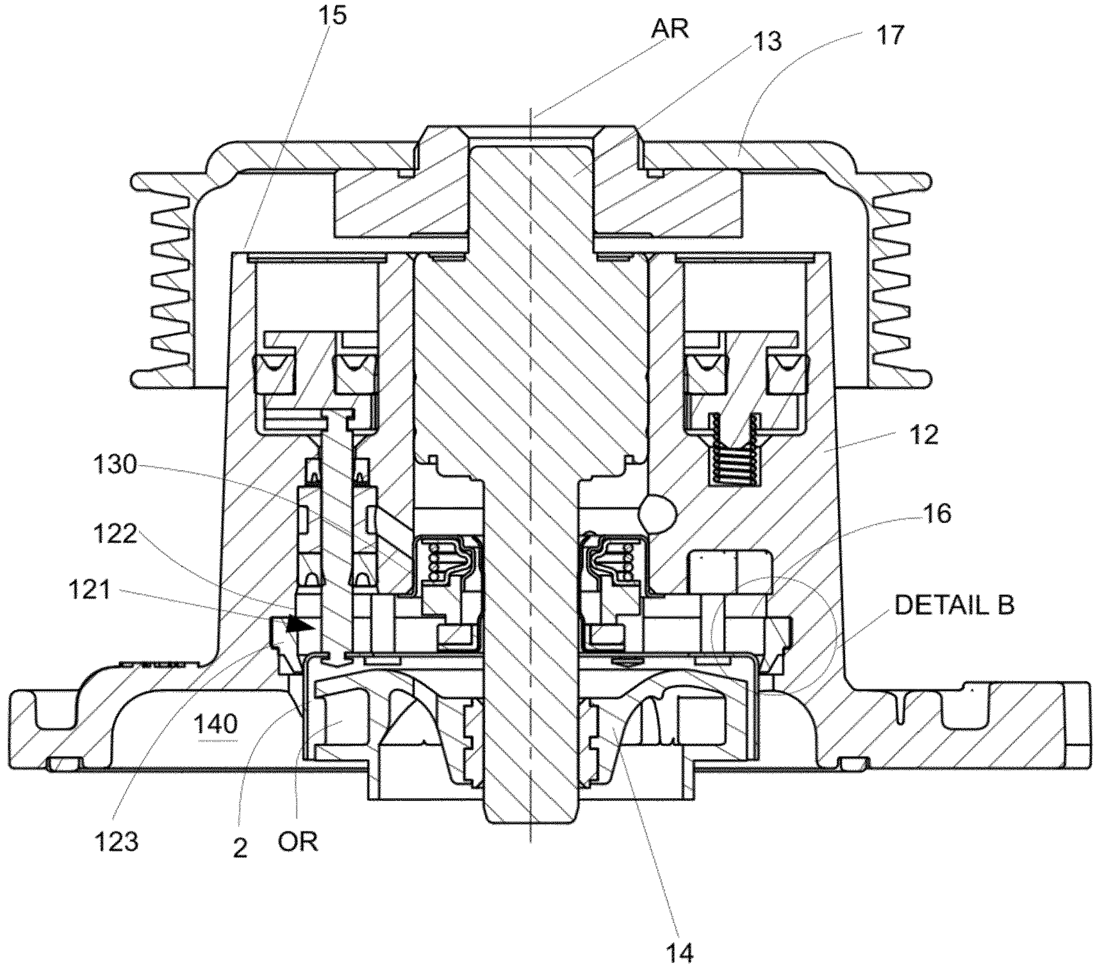


Fig. 3

DETAIL A

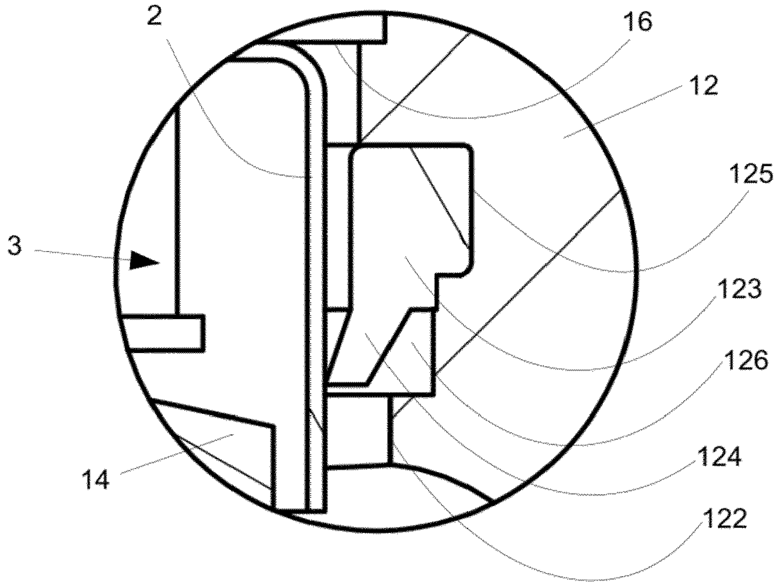


Fig. 4

DETAIL B

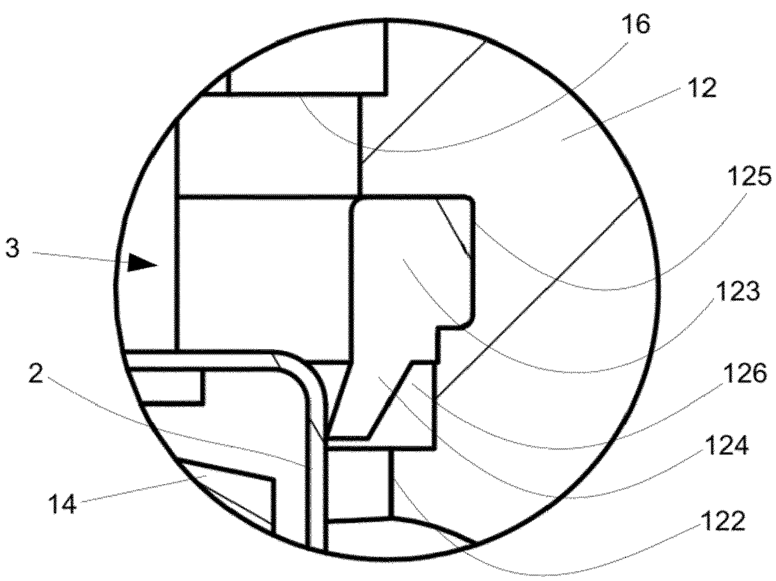


Fig. 5

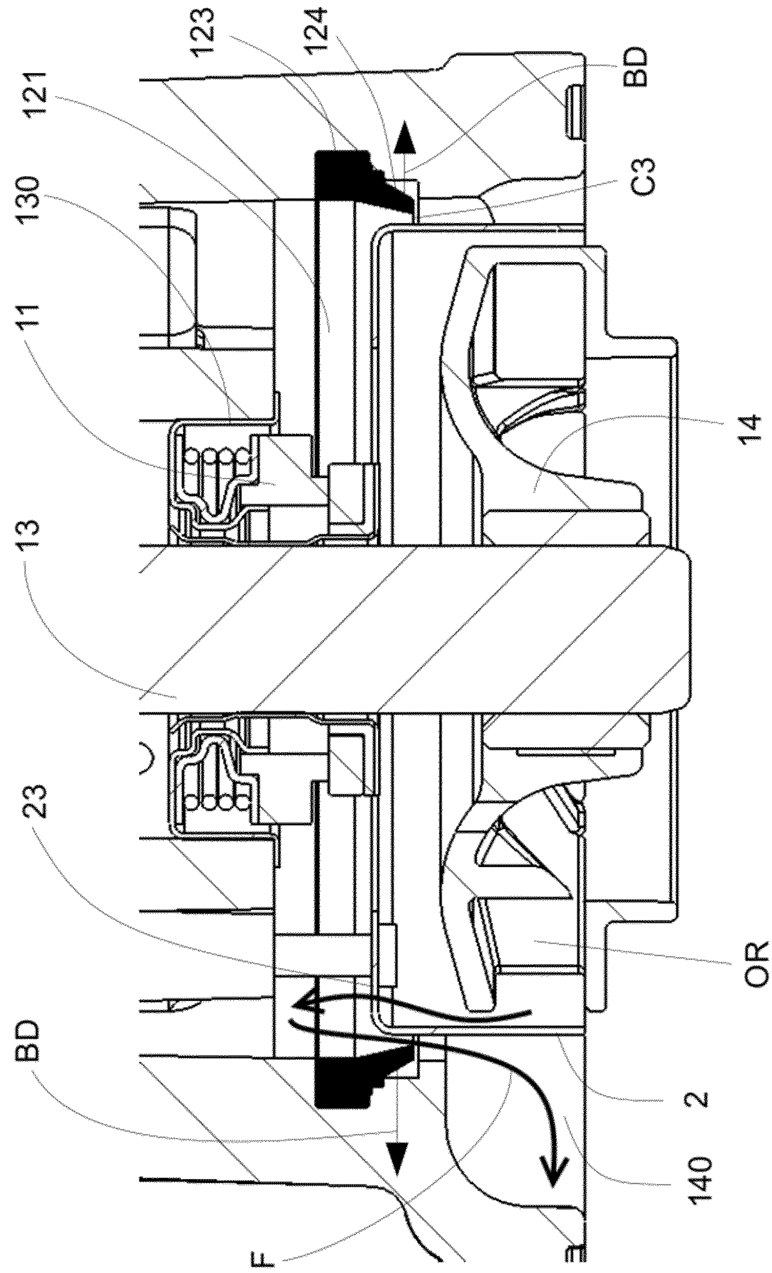


Fig. 6

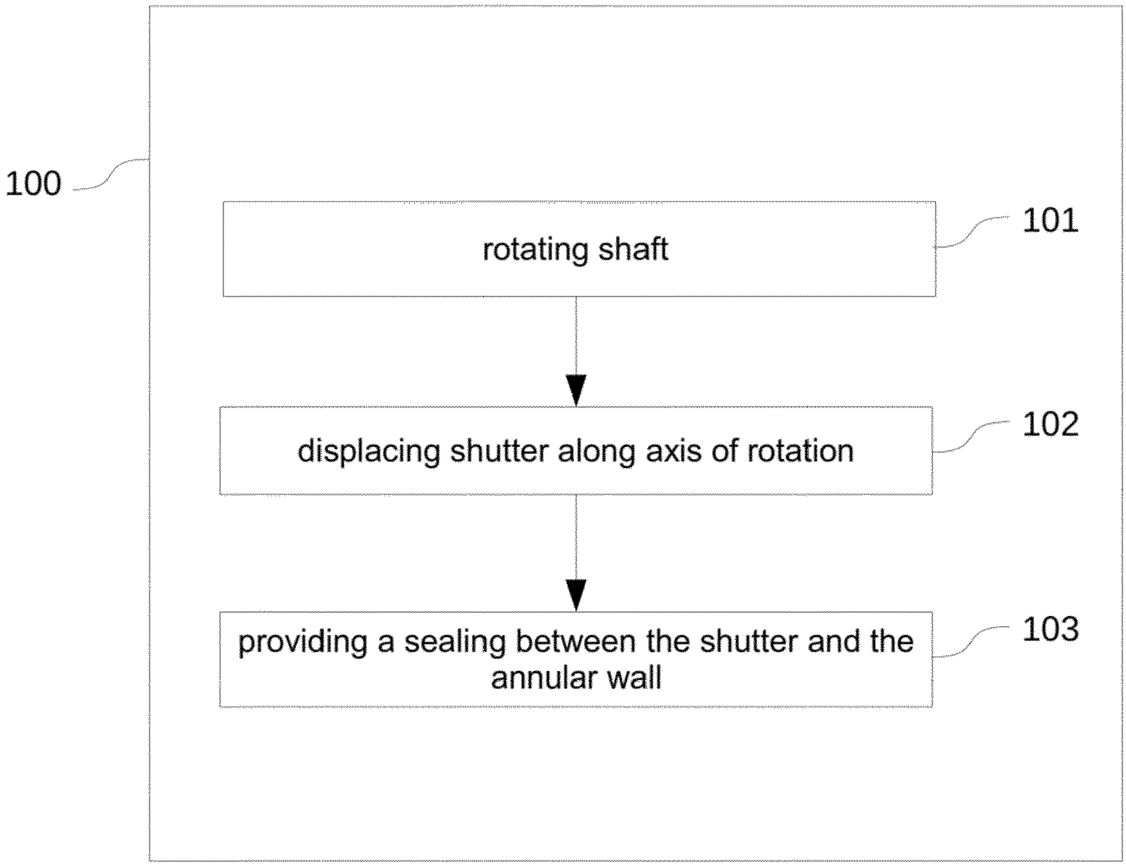
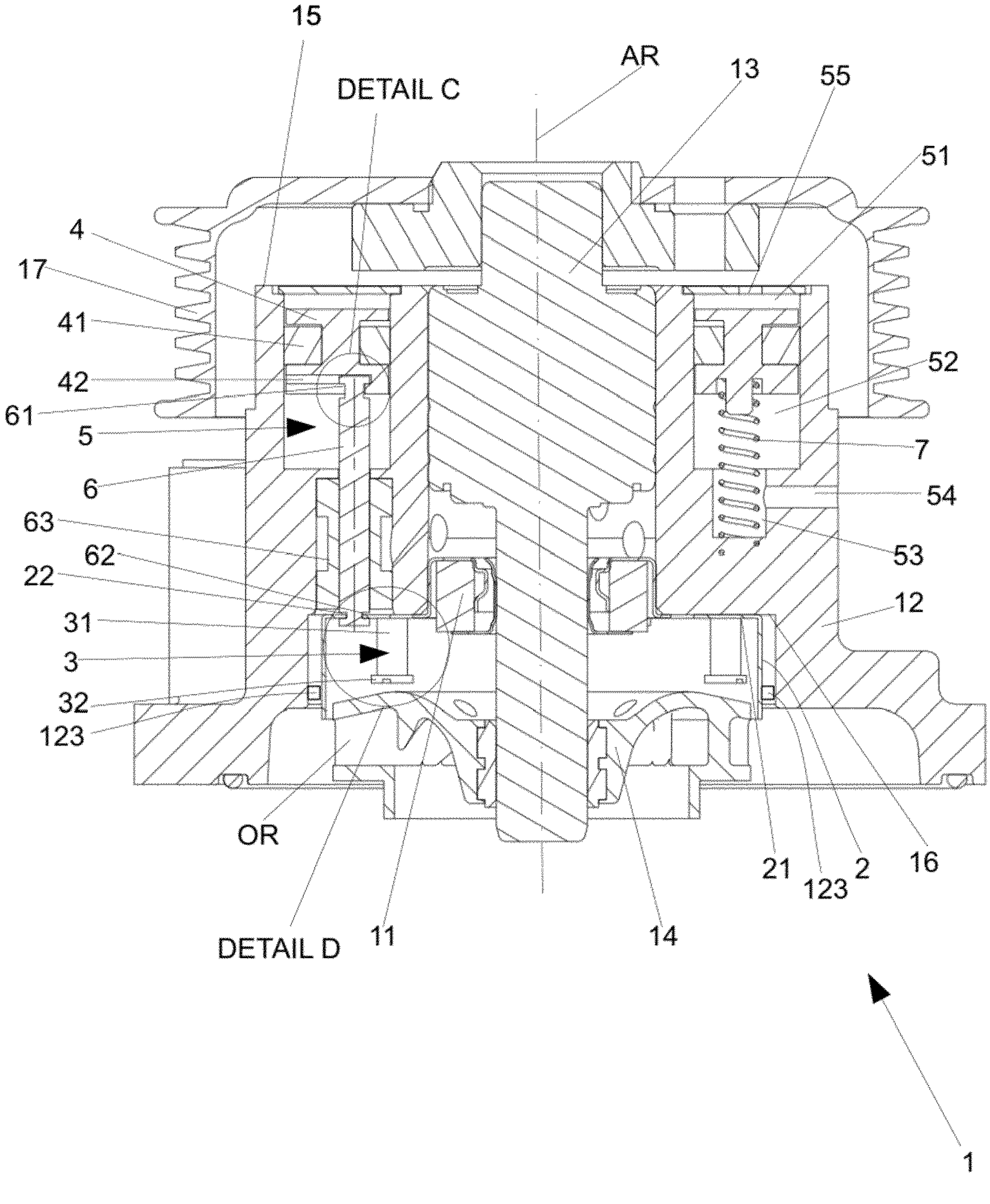

100
rotating shaft
101
displacing shutter along axis of rotation
102
providing a sealing between the shutter and the annular wall
103

Fig. 7


15
DETAIL C
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52
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12
OR
DETAIL D
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14
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123
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16
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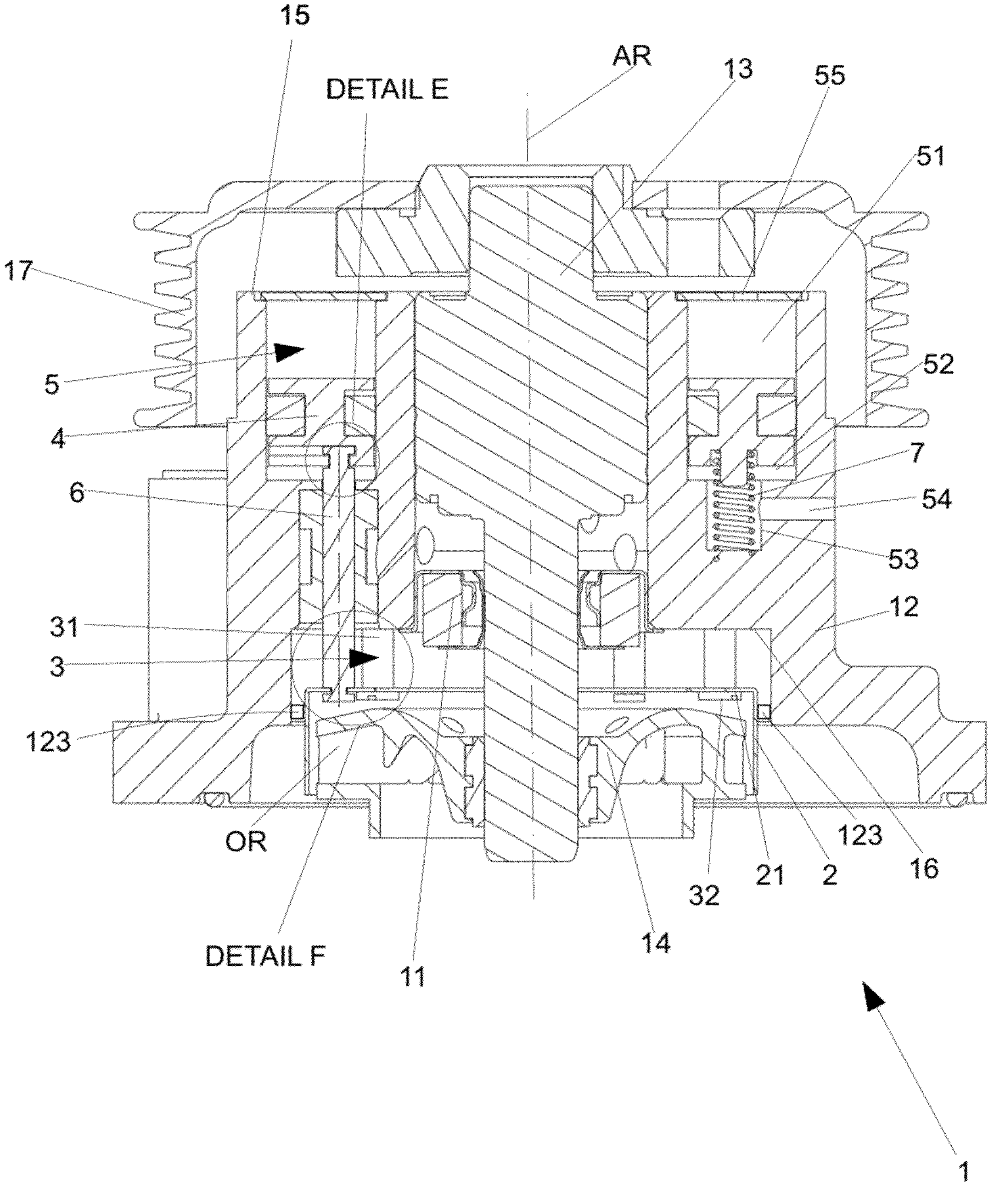
Fig. 8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DETAIL E
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OR
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DETAIL F
11
1

Fig. 9A

DETAIL C

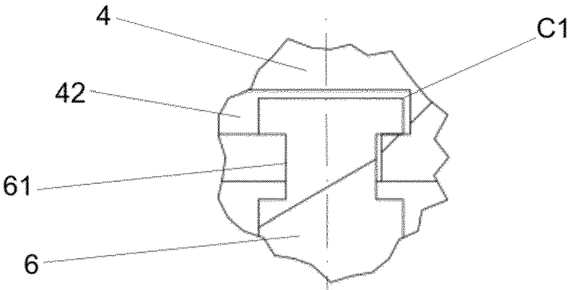


Fig. 9B

DETAIL D

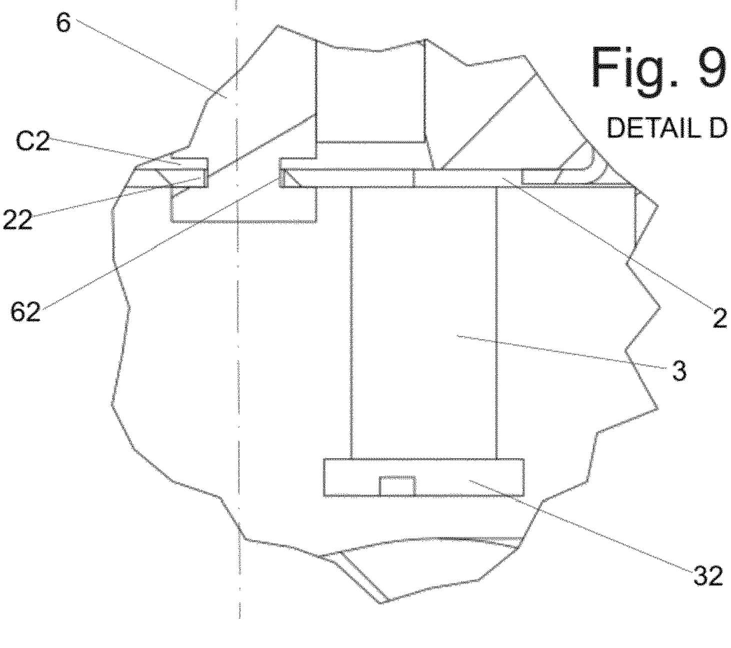


Fig. 10A

DETAIL E

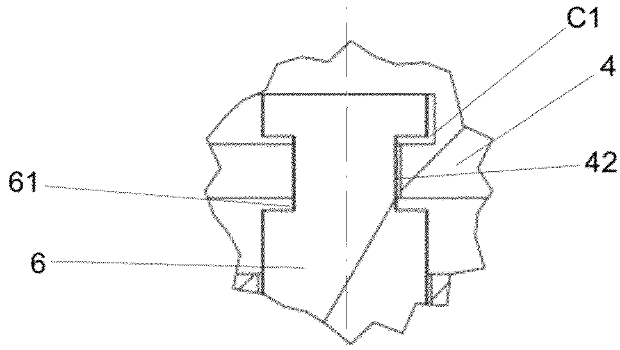
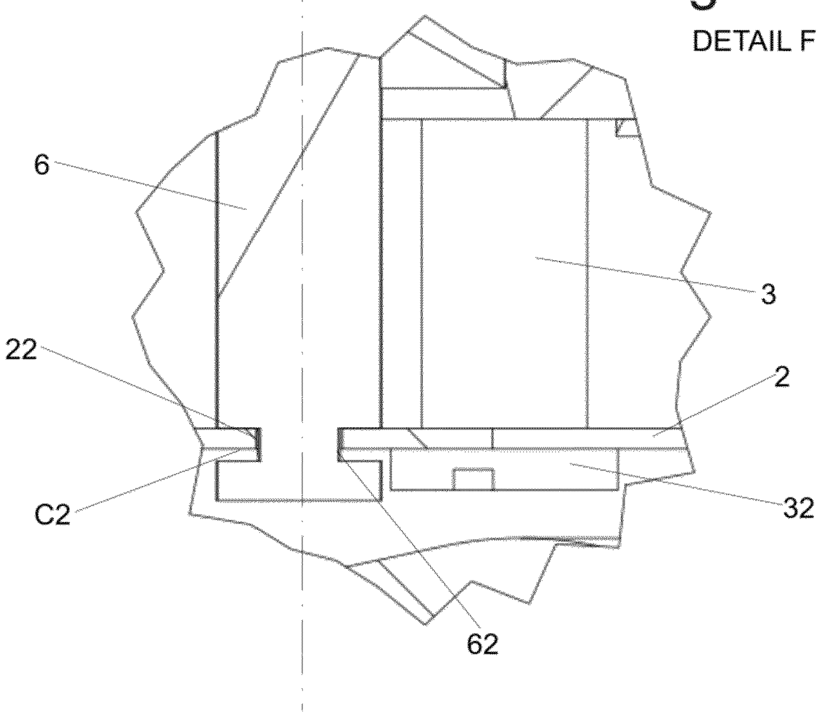


Fig. 10B

DETAIL F



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EUROPEAN SEARCH REPORT

Application Number
EP 18 38 2968

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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F04D
F01P
F01D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 July 2019	de Martino, Marcello

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