



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.12.2022 Bulletin 2022/49

(51) International Patent Classification (IPC):
F04D 1/06^(2006.01) F04D 29/041^(2006.01)

(21) Application number: **21177051.6**

(52) Cooperative Patent Classification (CPC):
F04D 29/0416; F04D 1/06

(22) Date of filing: **01.06.2021**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) **A BALANCING DRUM ASSEMBLY IN A CENTRIFUGAL PUMP AND METHOD OF OPERATING A BALANCING DRUM ASSEMBLY**

(57) Invention relates to a balancing drum assembly (10) in a centrifugal pump (100), wherein a shaft (14) adapted rotatably supported to a housing (12,12'), a balancing drum (16) having a first axial end (16.1) which is in fluid communication with a pressure channel (104) of the centrifugal pump (100), and the balancing drum (16) having a second axial end (16.2) which opposite to the first axial end (16.1), the housing (12,12') forming a space (18) for balancing fluid which space (18) is at least partly bordered by the second axial end (16.2) of the balancing drum (16), an outlet (20) arranged to the housing (12,12') for the balancing fluid, a flow control system (23) arranged between the outlet (20) and the space (18), comprising a first fluid flow control element (24) attached with the housing (12,12') in the space (18) at a side of the second axial end (16.2) of the balancing drum (16), the first fluid flow control element (24) comprising a first flow control surface (24'), which is co-axial with the shaft (14) and the balancing drum (16), and a second fluid flow control element (26) comprising a second flow control surface (26') arranged co-axial with the shaft (14) and the balancing drum (16), attached to a rotatable part of the balancing drum assembly (10), wherein the first flow control surface (24') and the second flow control surface (26') form an adaptive fluid constriction for the balancing fluid discharged to the outlet (20).

prising a first fluid flow control element (24) attached with the housing (12,12') in the space (18) at a side of the second axial end (16.2) of the balancing drum (16), the first fluid flow control element (24) comprising a first flow control surface (24'), which is co-axial with the shaft (14) and the balancing drum (16), and a second fluid flow control element (26) comprising a second flow control surface (26') arranged co-axial with the shaft (14) and the balancing drum (16), attached to a rotatable part of the balancing drum assembly (10), wherein the first flow control surface (24') and the second flow control surface (26') form an adaptive fluid constriction for the balancing fluid discharged to the outlet (20).

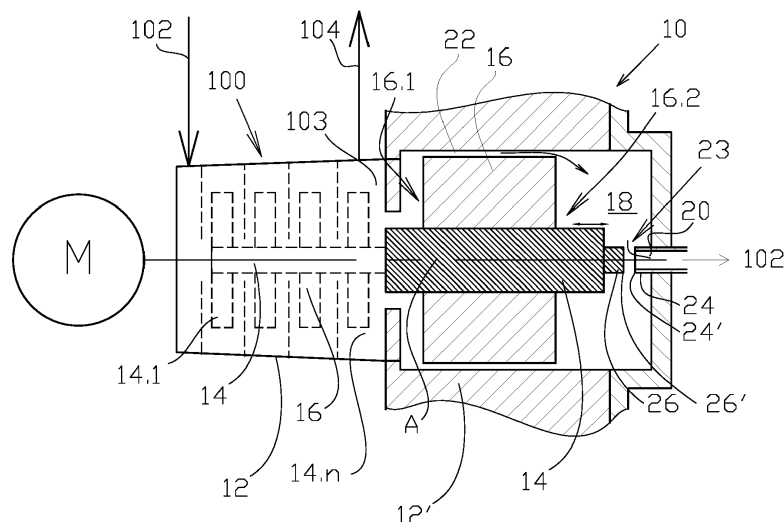


Fig. 1

Description

Technical field

[0001] The present invention relates to a balancing drum assembly in a centrifugal pump and a method of operating a balancing drum assembly.

Background art

[0002] Centrifugal multi-phase centrifugal pumps are provided with impeller wheels arranged into a housing by means of a rotatably supported shaft. During the operation of such centrifugal flow machines axial forces are subjected to the shaft. Such axial forces can be minimized by suitably designing the pump. Remaining forces are transmitted to the housing via a thrust bearing. Balancing axial forces is particularly relevant to multi-stage centrifugal flow machine where each stage results in an axial force component i.e. thrust to the system. The net axial thrust of an impeller is the difference between forces acting on back and front shrouds. There are number of hydrodynamic effects that can alter these forces. For instance, ring leakage or impeller axial positioning relative to the volute or diffuser can alter the pressure distribution between the impeller and sidewall gaps. Relatively small changes in pressure are greatly magnified by the large projected shroud surface areas. The result can be very large shifts in axial thrust in either direction.

[0003] It is known as such to use a so called balancing drum of minimizing the axial forces subjected to the bearings. Balancing drum is a part connected to a drive shaft of the machine, which drum has a cylindrical outer surface parallel with a center axis of the shaft of the centrifugal flow machine. The housing of the centrifugal flow machine is provided with a cylindrical space for the balancing drum. There is a clearance gap arranged between the balancing drum and the space in the housing. The purpose of the gap is to provide a flow restriction providing a pressure difference over the balancing drum. However, the clearance gap makes it possible for the process fluid to flow through the gap to some extent and therefore the efficiency of the centrifugal flow machine is decreased. Thus, it is often so that using the balancing drum cannot totally eliminate the need of a thrust bearing.

[0004] The balancing drum provides an axial force which is based on hydraulic properties of the pump, dimensional proportions and prevailing operating point of the pump. Production tolerances, number impeller wheels and actual shape of pumps components cause deviation from designed compensating force of the balance drum. Thus, actual residual axial force may be considerably greater than the dimensioned one, which effects on dimensioning, lifetime and/or service interval of bearings.

[0005] DE2043450A1 discloses an automatic axial thrust compensation for centrifugal pump in which adjustable hole is arranged to its housing downstream a

balancing drum. The adjustable hole faces an end face of the balancing drum.

[0006] EP2163767B1 discloses a balancing drum in connection with a multiple-stage centrifugal pump where the balancing drum is provided with a movable ring element which provides minimum leakage flow through the balancing drum.

[0007] Even if the solution offered by the prior art may be operational as such it is an object of the invention is to provide an assembly for a multi-stage pump in which axial forces are compensated in an improved manner.

Disclosure of the Invention

[0008] Objects of the invention can be met substantially as is disclosed in the independent claims and in the other claims describing more details of different embodiments of the invention.

[0009] A balancing drum assembly in a centrifugal pump, comprises

- a shaft adapted rotatably supported to a housing,
- a balancing drum having a first axial end which is in fluid communication with a pressure channel of the centrifugal pump, and a second axial end which opposite to the first axial end,
- the housing forming a space for balancing fluid which space is at least partly bordered by the second axial end of the balancing drum,
- an outlet arranged to the housing for the balancing fluid,
- a flow control system arranged between the outlet and the space, comprising
 - a first fluid flow control element attached with the housing in the space at a side of the second axial end of the balancing drum, the first fluid flow control element comprising a first flow control surface, which is co-axial with the shaft and the balancing drum,
 - a second fluid flow control element comprising a second flow control surface arranged co-axial with the shaft and the balancing drum, attached to a rotatable part of the balancing drum assembly, wherein the first flow control surface and the second flow control surface form an adaptive fluid flow constriction for the balancing fluid discharged to the outlet.

[0010] This way it is possible to set the flow control arrangement having suitable initial fluid flow constriction for a nominal position of the shaft. The initial fluid flow constriction is set such that it, in practical circumstances,

does not effect on the pressure at the side of the second axial end of the balancing drum.

[0011] According to an embodiment of the invention the second fluid flow control element is attached immovably to a rotatable part of the balancing drum assembly.

[0012] According to an embodiment of the invention the adaptive fluid constriction is formed by an open gap between the first flow control surface and the second flow control surface. The gap is maintained in adjustable manner during the operation of the pump and the balancing drum.

[0013] According to an embodiment of the invention the first flow control surface and the second flow control surface are arranged axially at a distance from each other and radially overlapping each other.

[0014] According to an embodiment of the invention at least one of the first flow control surface and the second flow control surface is axially adjustable.

[0015] This way it is possible to adjust the flow control arrangement after its assembly to have suitable initial fluid flow constriction for a nominal position of the shaft. The initial fluid flow constriction is set such that it, in practical circumstances, does not effect on the pressure at the side of the second axial end of the balancing drum. This makes it possible to compensate possible differences caused by manufacturing tolerances.

[0016] According to an embodiment of the invention the housing is arranged to cover the second axial end of the balancing drum and an end of the shaft, and the second fluid flow control element is attached immovably to the shaft, and the second control surface is arranged at central axis of the shaft, and the first fluid flow control element is arranged co-axial with the shaft, and the first flow control surface is arranged opposite to the end of the shaft, wherein the outlet opens into the space at a center axis of the shaft.

[0017] According to an embodiment of the invention the outlet comprising an axially adjustable first flow control surface, and wherein the first flow control surface and the second flow control surface form an adaptive discharge constriction for balancing fluid.

[0018] According to an embodiment of the invention outlet comprises a tubular part coaxial with the shaft, the tubular part having an axial through hole and its end face forming the first flow control surface, tubular part extending axially from the housing into the space to the proximity of the second flow control surface, and the tubular part is attached to the housing in axially movable manner.

[0019] According to an embodiment of the invention outlet comprises a tubular part, which comprises thread at its outer surface and the housing comprises a mating thread in an opening for the tubular part in the housing such that the axial position of the tubular part is adjustable by the threads.

[0020] According to an embodiment of the invention the second fluid flow control element is attached immovably to the balancing drum and having the second flow control surface is circular, and the first fluid flow control

element is arranged the housing having its first flow control surface circular, having its diameter greater than the diameter of the shaft and smaller than or equal to the diameter of the balancing drum.

[0021] According to an embodiment of the invention the second fluid flow control element is a sleeve arranged co-axial with the shaft to the balancing drum at its first axial end and the second flow control surface is arranged to a second axial end of the sleeve.

[0022] According to an embodiment of the invention the first fluid flow control element is a sleeve arranged co-axial with the shaft to the housing at its first axial end and the first flow control surface is arranged to a second axial end of the sleeve.

[0023] According to an embodiment of the invention the first fluid flow control element is an annular plate arranged to the housing, extending radially towards the shaft from its radially outer end and the first flow control surface is arranged to its radially inner end.

[0024] According to an embodiment of the invention the first flow control surface and the second flow control surface are circular.

[0025] According to an embodiment of the invention the first flow control surface and the second flow control surface are circular and they have equal diameters.

[0026] According to an embodiment of the invention the shaft is arranged axially floating in respect to the housing.

[0027] According to an embodiment of the invention the axial play of the shaft is 0,5 - 2 mm.

[0028] According to an embodiment of the invention the axial play of the shaft is provided with radial bearings only.

[0029] Method of operating a balancing drum assembly for a centrifugal pump comprising steps of

a) at non-operative stage

a1) setting the position of the shaft such that shaft is axially positioned at predetermined position,

a2) setting, the axial position of the first flow control surface in respect to the second flow control surface such that a gap re-mains therebetween,

b) at operative stage

b1) causing the axial position of the shaft to be changing according to a balance between axial forces created by one or more impellers of the pump and created by the balancing drum,

b2) adjusting the balance of the axial forces by axial distance between the first and the second flow control surfaces, such that in case the force created by one or more impellers is greater than the force created by the bal-

ancing drum the axial distance between the first and the second flow control surfaces increase, and balancing drum produces greater axial force, and

in case the force created by the balancing drum is greater than the force created by one or more impellers the axial distance between the first and the second flow control surfaces decrease, and balancing drum produces smaller axial force.

[0030] Invention provides a flow control system which controls balance fluid flow based on axial position of the shaft in respect to the housing. By means of the invention it is possible to control the pressure difference over the balance drum, and thus control of the balancing force is proportional to the axial position of the shaft. This provides an effect that during normal operation the axial force to the bearing is practically totally compensated.

[0031] According to an embodiment of the invention the constriction of the flow control system is axially adjustable even after the assembling of the balancing drum assembly by means of which it is possible to compensate dimensional differences due to manufacturing tolerances and/or wearing of the device.

[0032] The exemplary embodiments of the invention presented in this patent application are not to be interpreted to pose limitations to the applicability of the appended claims. The verb "to comprise" is used in this patent application as an open limitation that does not exclude the existence of also unrecited features. The features recited in depending claims are mutually freely combinable unless otherwise explicitly stated. The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims.

Brief Description of Drawings

[0033] In the following, the invention will be described with reference to the accompanying exemplary, schematic drawings, in which

Figure 1 illustrates a balancing drum assembly according to an embodiment of the invention,

Figure 2 illustrates a balancing drum assembly according to another embodiment of the invention,

Figure 3 illustrates a balancing drum assembly according to still another embodiment of the invention,

Figure 4 illustrates a balancing drum assembly according to still another embodiment of the invention,

Figure 5 illustrates a balancing drum assembly according to still another embodiment of the invention, and

Figure 6 illustrates a balancing drum assembly according to still another embodiment of the invention.

Detailed Description of Drawings

[0034] Figure 1 depicts schematically a multiphase centrifugal pump 100. The multi-stage pump 100 itself is not explained in more detailed manner. The pump has a fluid inlet 102 and a fluid outlet 104 for the fluid to be pumped. The pump has a shaft 14 and a housing 12. The shaft is rotatable supported to the housing 12 by means of suitable bearings (not shown) and it has a center axis A around which the shaft is rotatable. The bearings comprise at least radial bearings. The pump may also be provided with one or more axial thrust bearings, but the need for axial thrust bearings is minimized, or in some practical cases even eliminated, by means of the present invention. The shaft is arranged axially floating in respect to the housing so that the balancing drum assembly according to the invention may operate as intended. Suitable axial play of the shaft in most practical applications is 0,5 - 2 mm.

[0035] The pump in the figure has more than one impellers 14.1 ... 14.n which are attached to the shaft 14. The shaft may be driven by an electric motor M coupled with the shaft directly or via a coupling. The pump 100 is provided with a balancing drum assembly 10 according to an embodiment of the invention for compensating axial force created by the impellers to the shaft, in a manner known as such. The balancing drum assembly 10 comprises a balancing drum 16 which is arranged to the shaft 14. The shaft 14 is common with the centrifugal pump 100 and the balancing drum 16. It can be said that the shaft and the balancing drum 16 belong to the rotatable parts of the balancing assembly 10 by their nature when operating the pump. The balancing drum 16 is arranged to a housing 12' of the balancing drum assembly 10. Advantageously the centrifugal pump 100 and the balancing drum assembly 10 have a common housing 12, 12' which may be suitably constructed from separate parts.

[0036] The balancing drum 16 has a first axial end 16.1 which is in fluid communication with a pressure channel 103 at the outlet of the centrifugal pump 100, so the pressure of the fluid in the pump is transmitted to first axial end 16.1 of the balancing drum 16. The balancing drum 16 has a second axial end 16.2. which opposite to the first axial end 16.1 which is effected by a considerably lower pressure than the pressure of the pressure of the fluid transmitted to first axial end 16.1. The fluid flow communication between the first and the second axial ends is minimized by a gap 22 formed between the balancing drum and the housing, or other suitable means.

[0037] The housing 12' of the balancing drum and the second axial ends 16.2 forms a space 18 for balancing fluid, which space is at least partly bordered by the second axial end 16.2 of the balancing drum. This way the pressure difference and possible difference of projection areas of the first axial end 16.1 and the second axial end

16.2 defines the thrust compensating force created by the balancing drum 16. Some amount of balancing fluid leaks through the gap 22 between the balancing drum 16 and the housing 12' and there is an outlet 20 arranged to the housing 12' for the balancing fluid. The outlet 20 is advantageously in flow communication with the fluid inlet 102 of the pump 100. The thrust compensating force which is created by the balancing drum 16 is dependent on the pressure difference over the gap 22, or more particularly on the pressures which effects on the first axial end 16.1 of the balancing drum 16 and on the second axial end 16.2 of the balancing drum 16. The pressure, together with the area creates the trust compensating force to the axis 14. In order to control the thrust compensating force practically automatically, the balancing drum assembly is provided with a flow control system 23 which adjusts the pressure difference over the gap 22, i.e. the pressure prevailing in the space 18. The pressure effecting on the first axial end 16.1 of the balancing drum is practically the outlet pressure of pump, and the pressure in the space 18 is controlled by the flow control system 23. The adjustment is based on the relative position of the shaft 14 and the balancing drum 16 to the housing 12'. The effect of the balancing drum may be oversized because the flow control system 23 adjusts the thrust compensating force automatically while the pump is operated.

[0038] The flow of balancing fluid out from the space 18 via the outlet 20 is controlled by the first and the second fluid flow control elements 24, 26. Controlling of the flow is accomplished such that the first fluid flow control element 24 comprises a first flow control surface 24' and the second fluid flow control element 26 comprising a second flow control surface 26', which are arranged to face each other. The control surfaces being coaxial with the shaft and the balancing drum. The flow control surfaces 24', 26' are arranged radially at a distance from the center axis A and they are radially overlapping each other while being axially at a distance from each other. The axial distance between the flow control surfaces 24', 26' changes constantly according to axial force balance of the shaft 14. This way the flow control surfaces, and the gap between them, form an adaptive fluid constriction for the balancing fluid discharged to the outlet 20. The adaptive fluid constriction is responsive to the axial position of the shaft 14 in respect to the housing 12' and therefore the adaptive fluid constriction is responsive to the axial position of the second flow control surface 26' to the first flow control surface 24'. During the assembly work, the first and the second fluid flow control elements 24, 26 are initially positioned to axially suitable positions when the shaft is correctly positioned axially, such that the gap between the flow control surfaces has, in practical circumstances, only insignificant effect. The cross sectional, circumferential flow area of the gap, at its initial size, is substantially equal to the cross sectional area of the annual gap between the balancing drum and the housing. The gap between the flow control surfaces remains open

even if axial movement of the shaft (and the second fluid flow control element 26) takes place during the operation.

[0039] In the embodiment shown in the figure 1 the housing 12' is arranged to cover the second axial end 16.2 of the balancing drum 16 and an end of the shaft 14. Here the second fluid flow control element 26 is attached immovably to the end of the shaft 14, and the second control surface is arranged at central axis of the shaft. The second fluid flow control element 26 is radially at the center of, and at the end of the shaft 14. It may be an integral part i.e. machined thereto or a removably attached, separate part at the end of the shaft 14.

[0040] The first fluid flow control element 24 is arranged to the housing co-axial with the shaft 14, and opposite to the second fluid flow control element 26 at the end of the shaft 14. The outlet 20 is arranged to, and to extend through, the first fluid flow control element 24 and to open into the space at a center axis of the shaft via a gap between the first control surface 24' and the second control surface 26'. The first control surface 24' practically is the rim part of the outlet 20. The outlet 20 comprises in the figure 1 a tubular part which is coaxial with the shaft 14. The tubular part 20 has an axial through hole and its inner end face forms the first flow control surface 24'. The tubular part extends axially from the wall of the housing 12' into the space 18 to the proximity of the second flow control surface 26'.

[0041] The balancing drum assembly according the figure 1, is advantageously operated by a method which comprises steps of

a) at assembly stage, which is also a non-operating stage

a1) setting the axial position of the shaft such that the impellers are at designed and/or predetermined position. The position may be at the middle of the total obtainable axial movement of the shaft.

a2) setting the initial axial position of the first flow control surface in respect to the second flow control surface such that a gap remains within the range of predetermined play, which is accomplished by attaching the first flow control element to suitable axial position to the housing and the second flow control element to the rotatable part of the assembly to suitable axial position,

b) at operative stage

b1) causing the axial position of the shaft to be changing according to a balance between axial forces created by one or more impellers of the pump and created by the balancing drum,

b2) adjusting the balance of the axial forces by axial distance between the first and the second

flow control surfaces, such that

- in case the force created by one or more impellers is greater than the force created by the balancing drum the axial distance between the first and the second flow control surfaces increase, and balancing drum produces greater axial force, and
- in case the force created by the balancing drum is greater than the force created by one or more impellers the axial distance between the first and the second flow control surfaces decrease, and balancing drum produces smaller axial force.

[0042] The axial position of the first flow control surface in respect to the second flow control surface is set such that a gap causes insignificant share of total pressure losses in the flow path: pump 100 - balancing drum gap 22 - the flow control system 23 - outlet 20 - pump inlet 102.

[0043] Figure 2 shows with a balancing drum assembly 10 according to an embodiment of the invention for compensating axial force created by the impellers to the shaft of a multistage centrifugal pump 100. The balancing drum assembly 10 is to a great extent similar to that shown in the figure 1 having, however, its flow control system 23 different from that in the figure 1.

[0044] Similarly to the embodiment of the figure 1, also in the balancing drum assembly 10 according the figure 2 the flow control system 23 adjusts the pressure difference over the gap 21 based on the relative position of the shaft 14 and the balancing drum 16 to the housing 12'. In the figure 2 the flow control system 23 comprises a sleeve 24 as the first fluid flow control element. The sleeve is arranged co-axially with the shaft 14, and it is attached to the housing 12' from its first axial end. Respectively a second axial end of the sleeve comprises the first flow control surface 24'. The sleeve has a diameter which is greater than the diameter of the shaft 14 and smaller than or equal to the diameter of the balancing drum 16.

[0045] The second fluid flow control element 26 is also a sleeve 26 which is attached immovably to the balancing drum 16 at its second axial end 16.2. The second fluid control element has a diameter which is greater than the diameter of the shaft 14 and smaller than or equal to the diameter of the balancing drum 16. The second flow control surface 26' is arranged at an axial end of the sleeve 26 of the second fluid flow control element 26. Both the first and the second fluid flow control surfaces are circular and they have an equal diameter which is greater than the diameter of the shaft 14 and smaller than or equal to the diameter of the balancing drum 16.

[0046] Figure 3 shows with a balancing drum assembly 10 according to an embodiment of the invention for compensating axial force created by the impellers to the shaft of a multistage centrifugal pump 100. The balancing drum

assembly 10 is to a great extent similar to that shown in the figures 1 - 2 having, however, its flow control system 23 different from that in the figures 1 to 2. Also in the balancing drum assembly 10 according the figure 3 the flow control system 23 adjusts the pressure difference over the gap 22 based on the relative position of the shaft 14 and the balancing drum 16 to the housing 12'. In the figure 3 the first fluid flow control element 24 is an annular plate 24 arranged to the housing 12'. The annular plate 24 is extending radially towards the shaft 14 from its radially outer end, which is against and attached to the inner wall of the housing 12'. The annular plate is arranged axially between the balancing drum 16 and the axial end housing. The first flow control surface 24' is arranged to the radially inner end of the annular plate.

[0047] The second fluid flow control element 26 comprises also a radially extending plate 26 which is attached immovably to the shaft 14 at its radially inner end and the second flow control surface 26' is arranged at an radially outer end of the plate. There is a short sleeve part at the radial outer end of plate extending axially away from the balancing drum 16. the end of the sleeve 26 of the second fluid flow control element 26.

[0048] Both the first and the second fluid flow control surfaces are circular and they have a diameter which is greater than the diameter of the shaft 14 and smaller than or equal to the diameter of the balancing drum 16. Practically in the figure 3 functions similarly to that shown in the figure 2 but is only attached differently.

[0049] Figure 4 discloses an embodiment of the invention which is otherwise similar to the embodiment shown in the figure 2 but where the flow control system 23 is not at the end of the shaft 14. Here the shaft 14 extends through the housing 12' of the balancing drum. This way the balancing drum may be arranged between stages of the pump.

[0050] Figure 5 discloses an embodiment of the invention where the flow control system 23 comprises two stages of flow control elements 26, 24, and respectively flow control surfaces 24', 26'. In addition to the flow control system according to the figure 1 the figure 5 has a primary flow control system 23 in connection with the balancing drum. The balancing drum 16 acts as the second fluid flow control element 26 and the first fluid flow control element 24 is an annular plate 24 arranged to the housing 12'. The annular plate 24 is extending radially towards the shaft 14 from its radially outer end, which is against and attached to the inner wall of the housing 12'. The annular plate is arranged axially adjacent to the balancing drum 16 so as to form the control gap between the plate and the balancing drum.

[0051] Figure 6 shows and embodiment of the invention which is further modified from the embodiment shown in the figure 1. Therefore, the description of the figure 1 is applicable to the embodiment shown in the figure 6. However, in the figure 6 the flow control system 23 is different from that shown in the figure 1 in the following way. The flow control system 23 comprises a first

fluid flow control element 24 which attached to the housing 12' in axially adjustable manner, meaning that the initial axial position of the first fluid flow control element 24, and thus also the first flow control surface 24' in the first fluid flow control element 24 is axially adjustable even after the assembling of the balancing drum assembly. The first fluid flow control element 24 is a tubular part, which comprises thread at its outer surface. Respectively the housing 14' comprises a mating thread in an opening for the tubular part in the housing such that the axial position of the tubular part is adjustable by the threads. The position of the tubular part is advantageously locked in respect to the housing such that it may not move during the operation of the assembly. As a particular feature of the figure 6, the first fluid flow control element 24 is axially adjustable during operation of the balancing drum assembly and the pump.

[0052] Optionally, as is shown in the figure 6, the assembly may comprise a separate fitting part 30 via which the first fluid flow control element 24 is coupled to the housing 12'. Here the fitting part 30 is attached to the housing 12' by suitable means. It is also provided with an opening for the tubular part provided with an inner thread in the opening. Also in this embodiment, during normal operation of the balance drum, the first fluid flow control element 24 holds its position in relation to the housing 12', even if the position may be easily pre-adjusted.

[0053] The flow control system 23 comprises also a second fluid flow control element 26 which coupled to the shaft 14 or the balancing drum 16 in adjustable manner. Also in this embodiment, during normal operation of the balance drum, the second fluid flow control element 26 holds its position in relation to the shaft 14, even if the position may be easily adjusted during standstill of the pump. The second fluid flow control comprises a screw section 32 which can be screwed to a hole 34 arranged at an end of the shaft. The axial position of the second fluid flow control element 26 can be pre-adjusted by positioning a suitable shim 36 to the screw section. Figure 6 is shown to illustrate that at least one of the first fluid flow control element 24 and the second fluid flow control element 26 is axially adjustable.

[0054] The balancing drum assembly for a centrifugal pump according to figure 6, is advantageously operated by a method which comprises steps of

a) at non-operative stage

a1) setting the axial position of the shaft such that the impellers are at designed position, where the impellers are at correct position for operating the pump.

a2) setting the initial axial position of the first flow control surface in respect to the second flow control surface such that a gap remains within the range of predetermined play

b) at operative stage

b1) causing the axial position of the shaft to be changing according to a balance between axial forces created by one or more impellers of the pump and created by the balancing drum,

b2) adjusting the balance of the axial forces by axial distance between the first and the second flow control surfaces, such that

- in case the force created by one or more impellers is greater than the force created by the balancing drum the axial distance between the first and the second flow control surfaces increase, and balancing drum produces greater axial force, and
- in case the force created by the balancing drum is greater than the force created by one or more impellers the axial distance between the first and the second flow control surfaces decrease, and balancing drum produces smaller axial force.

[0055] The shaft is arranged axially floating having a predetermined play such that the gap remains within the range of predetermined play, in which cross sectional flow area is 80-120% of cross sectional flow area of the gap between the balancing drum and the housing, such that the gap between the first flow control surface and the second flow control surface does not cause substantial pressure losses.

[0056] While the invention has been described herein by way of examples in connection with what are, at present, considered to be the most preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations or modifications of its features, and several other applications included within the scope of the invention, as defined in the appended claims. The details mentioned in connection with any embodiment above may be used in connection with another embodiment when such combination is technically feasible.

Claims

1. A balancing drum assembly (10) in a centrifugal pump (100), wherein

- a shaft (14) adapted rotatably supported to a housing (12,12'),
- a balancing drum (16) having a first axial end (16.1) which is in fluid communication with a pressure channel (104) of the centrifugal pump (100), and

- the balancing drum (16) having a second axial end (16.2) which opposite to the first axial end (16.1),
 - the housing (12,12') forming a space (18) for balancing fluid which space (18) is at least partly bordered by the second axial end (16.2) of the balancing drum (16),
 - an outlet (20) arranged to the housing (12,12') for the balancing fluid,
 - a flow control system (23) arranged between the outlet (20) and the space (18), comprising
 - a first fluid flow control element (24) attached with the housing (12,12') in the space (18) at a side of the second axial end (16.2) of the balancing drum (16), the first fluid flow control element (24) comprising a first flow control surface (24'), which is co-axial with the shaft (14) and the balancing drum (16),
 - a second fluid flow control element (26) comprising a second flow control surface (26') arranged co-axial with the shaft (14) and the balancing drum (16), attached to a rotatable part of the balancing drum assembly (10), wherein the first flow control surface (24') and the second flow control surface (26') form an adaptive fluid constriction for the balancing fluid discharged to the outlet (20).
2. A balancing drum assembly (10) according to claim 1, **characterized in that** the adaptive fluid constriction is formed by an open gap between the first flow control surface (24') and the second flow control surface (26').
 3. A balancing drum assembly (10) according to claim 1, **characterized in that** the first flow control surface (24') and the second flow control surface (26') are arranged axially at a distance from each other and radially overlapping each other.
 4. A balancing drum assembly (10) according to claim 1 or 2, **characterized in that** at least one of the first flow control surface (24') and the second flow control surface (26') is axially adjustable.
 5. A balancing drum assembly (10) according to any one of the preceding claims, **characterized in that** the housing (12,12') is arranged to cover the second axial end (16.2) of the balancing drum (16) and an end of the shaft (14), and the second fluid flow control element (26) is attached immovably to the shaft (14), and the second control surface is arranged at central axis of the shaft (14), and the first fluid flow control element (24) is arranged co-axial with the shaft (14), and the first flow control surface (24') is arranged opposite to the end of the shaft (14), wherein the outlet (20) opens into the space (18) at a center axis of the shaft (14).
 6. A balancing drum assembly (10) according to any one of the preceding claims, **characterized in that** the outlet (20) comprising an axially adjustable first flow control surface (24'), and wherein the first flow control surface (24') and the second flow control surface (26') form an adaptive discharge constriction for balancing fluid.
 7. A balancing drum assembly (10) according to any one of the preceding claims, **characterized in that** outlet (20) comprises a tubular part coaxial with the shaft (14), the tubular part having an axial through hole and its end face forming the first flow control surface (24'), tubular part extending axially from the housing (12,12') into the space (18) to the proximity of the second flow control surface (26'), and the tubular part is attached to the housing (12,12') in axially movable manner.
 8. A balancing drum assembly (10) according to any one of the preceding claims, **characterized in that** outlet (20) comprises a tubular part, which comprises thread at its outer surface and the housing (12,12') comprises a mating thread in an opening for the tubular part in the housing (12,12') such that the axial position of the tubular part is adjustable by the threads.
 9. A balancing drum assembly (10) according to claim 1, **characterized in that** the second fluid flow control element (26) is attached immovably to the balancing drum (16) and having the second flow control surface (26') is circular, and the first fluid flow control element (24) is arranged the housing (12,12') having its first flow control surface (24') circular, having its diameter greater than the diameter of the shaft (14) and smaller than or equal to the diameter of the balancing drum (16).
 10. A balancing drum assembly (10) according to claim 9, **characterized in that** the second fluid flow control element (26) is a sleeve arranged co-axial with the shaft (14) to the balancing drum (16) at its first axial end (16.1) and the second flow control surface (26') is arranged to a second axial end (16.2) of the sleeve.
 11. A balancing drum assembly (10) according to claim 9 or 10, **characterized in that** the first fluid flow control element (24) is a sleeve arranged co-axial with the shaft (14) to the housing (12,12') at its first axial end (16.1) and the first flow control surface (24') is arranged to a second axial end (16.2) of the sleeve.
 12. A balancing drum assembly (10) according to claim

9 or 10, **characterized in that** the first fluid flow control element (24) is an annular plate arranged to the housing (12,12'), extending radially towards the shaft (14) from its radially outer end and the first flow control surface (24') is arranged to its radially inner end. 5

13. A balancing drum assembly (10) according to any-one of the preceding claims, **characterized in that** the first flow control surface (24') and the second flow control surface (26') are circular. 10

14. A balancing drum assembly (10) according to any-one of the preceding claims, **characterized in that** the first flow control surface (24') and the second flow control surface (26') are circular and they have equal diameters. 15

15. Method of operating a balancing drum assembly (10) for a centrifugal pump (100), according to anyone of the preceding claims, comprising steps of 20

a) at non-operative stage

a1) setting the position of the shaft (14) such that shaft (14) is axially positioned at predetermined position, 25

a2) setting, the axial initial position of the first flow control surface (24') in respect to the second flow control surface (26') such that a gap remains therebetween, 30

b) at operative stage

b1) causing the axial position of the shaft (14) to be changing according to a balance between axial forces created by one or more impellers of the pump (100) and created by the balancing drum (16), 35

b2) adjusting the balance of the axial forces by axial distance between the first and the second flow control surface (26')s, such that in case the force created by one or more impellers is greater than the force created by the balancing drum (16) the axial distance between the first and the second flow control surface (26')s increase, and balancing drum (16) produces greater axial force, and 40 45

in case the force created by the balancing drum (16) is greater than the force created by one or more impellers the axial distance between the first and the second flow control surface (26')s decrease, and balancing drum (16) produces smaller axial force. 50 55

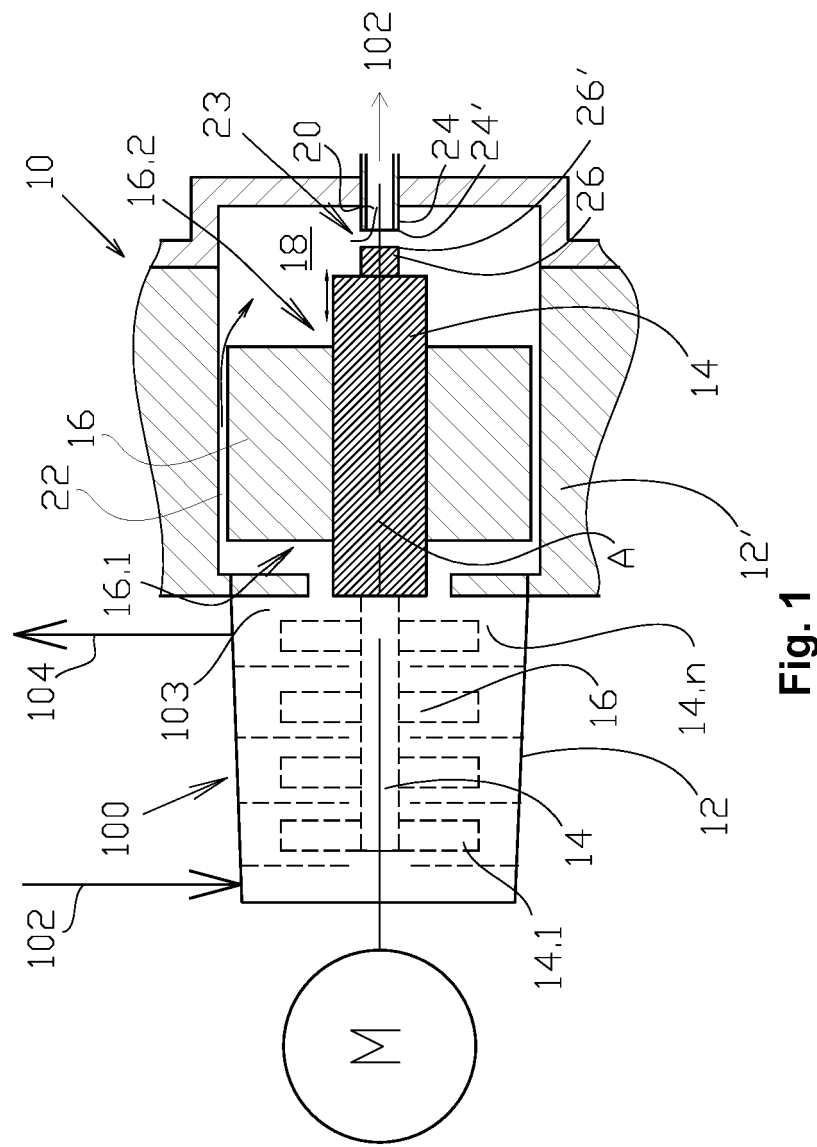


Fig. 1

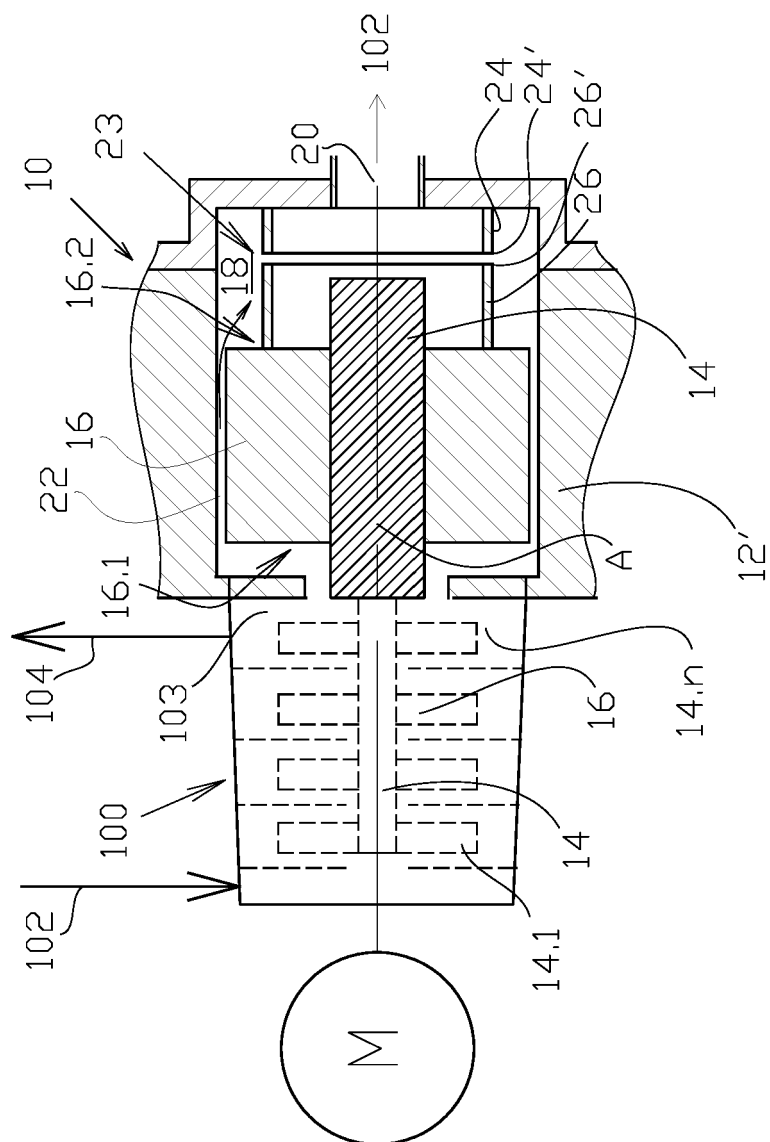


Fig. 2

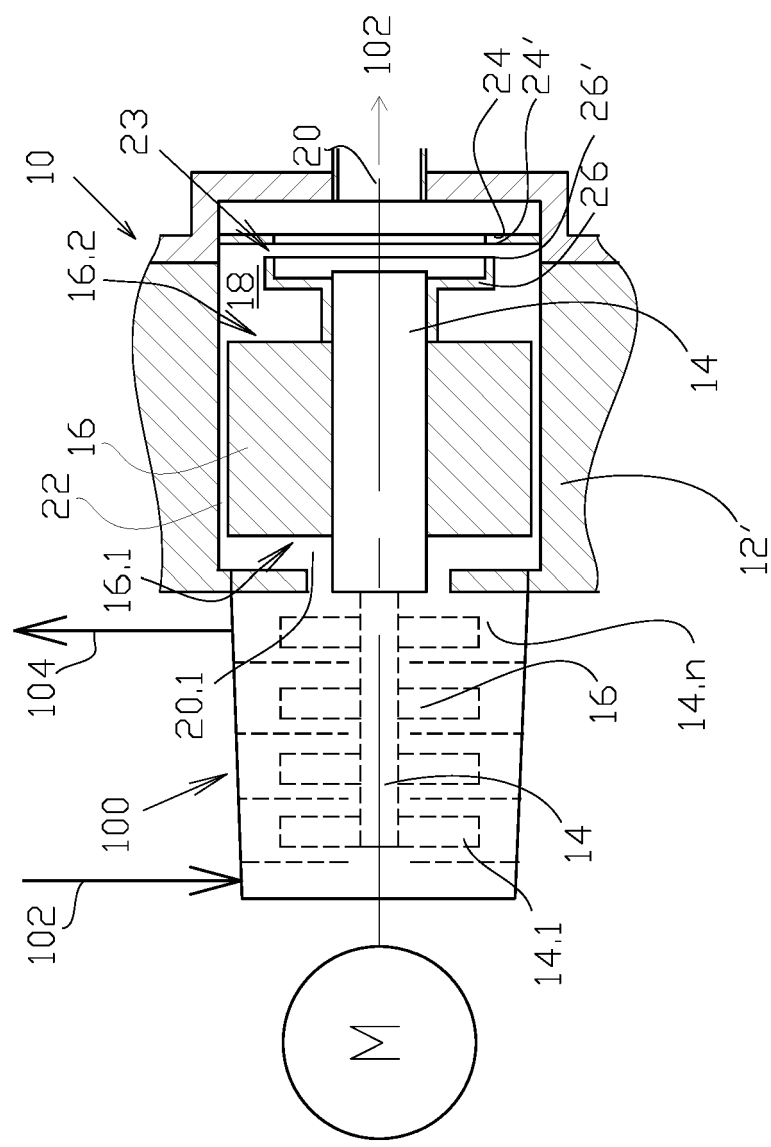


Fig. 3

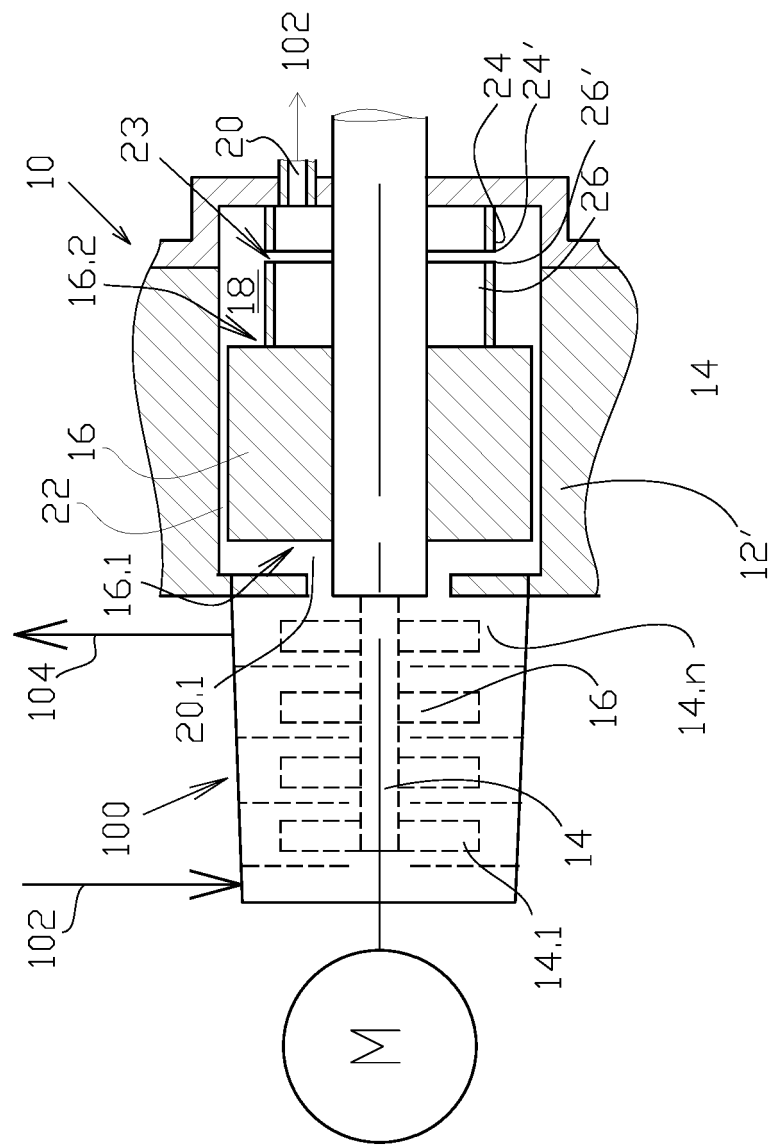


Fig. 4

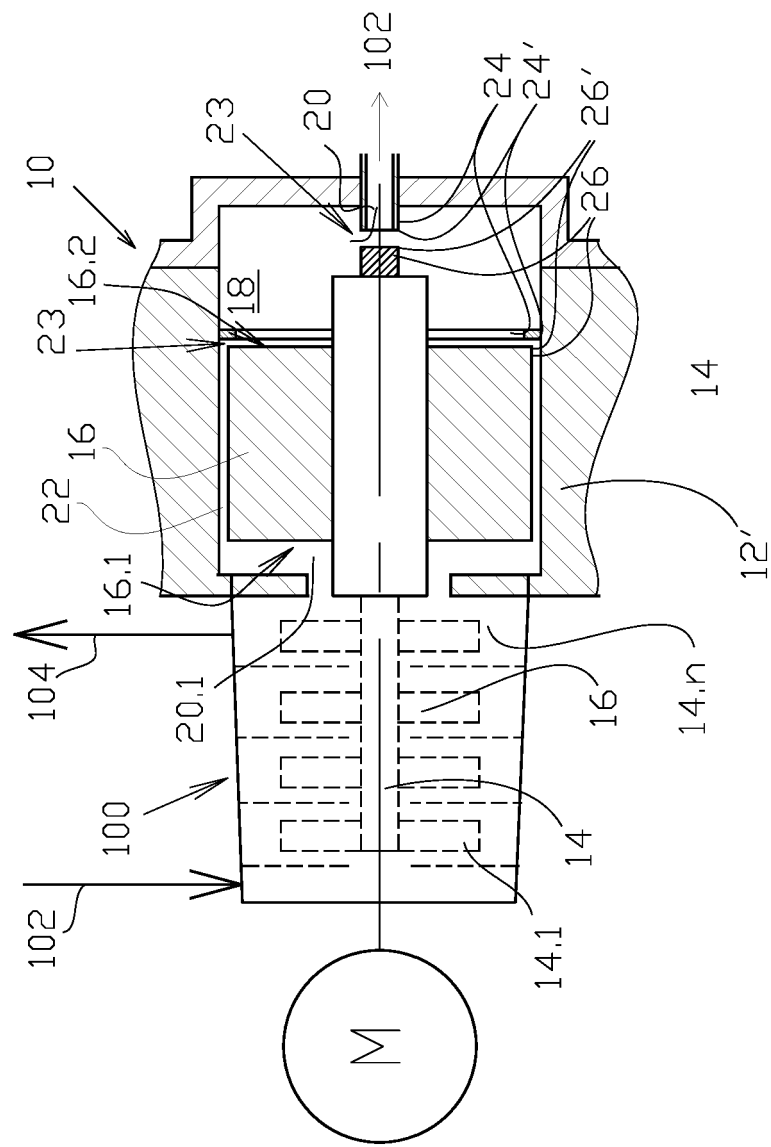


Fig. 5

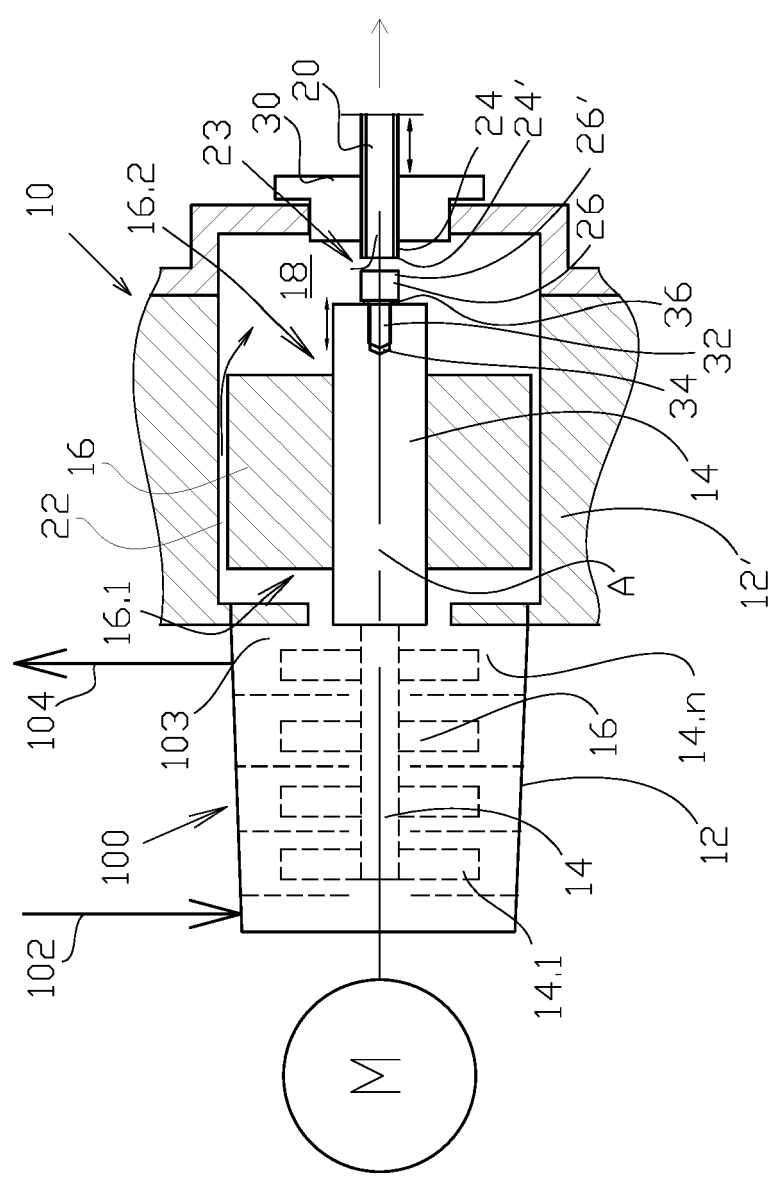


Fig.6



EUROPEAN SEARCH REPORT

Application Number
EP 21 17 7051

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 3 November 2021	Examiner Morales Gonzalez, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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