(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 3 150 851 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.04.2017 Bulletin 2017/14

(21) Application number: **15187889.9**

(22) Date of filing: **01.10.2015**

(51) Int Cl.:
F04B 1/12 *(2006.01)*
F04B 1/20 *(2006.01)*
F04B 11/00 *(2006.01)*
F01B 3/00 *(2006.01)*
F03C 1/34 *(2006.01)*

(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:
MA

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(54) IMPROVED DISPLACEMENT PUMP

(57) The present invention refers to exemplary embodiments of a pressure control device, a displacement control arrangement and a pumping arrangement, wherein the displacement control arrangement is part of the pumping arrangement and comprises a control ring, a rear face of a pump unit and the pressure control device. The rear face of the pump unit may belong to any type of pump unit comprising pressure chambers. The pressure control device is provided with a plurality of rotation symmetrically arranged through holes. Respective through hole is defined by a circumferential inner surface, wherein the circumferential inner surface of the through hole is provided with at least one protrusion extending into the through hole such that a midsection of the through hole has a smaller extension in an intended rotational direction than an outer section and an inner section of the through hole. The pressure control device is fixedly arranged to an axial surface of the rear face of a pump unit and the second axial surface of the pressure control device is facing an axial surface of the control ring. The rear face of a pump unit and the pressure control device are rotational symmetrically arranged about a first rotational axis and the control ring, which is provided with at least a first and a second opening formed as semi-circular arcs, and which are separated by a first and a second land, is rotational symmetrically arranged about a second rotational axis, wherein the second rotational axis is radially offset by a distance E in relation to the first rotational axis, and is arranged in parallel to the first rotational axis. Due to the radial offset between the first and second rotational axis, and due to the configuration of the through holes, by changing the displacement of the displacement pump the angular distance, thus the period pf time, the through holes are completely blocked by the first and second lands may be varied.

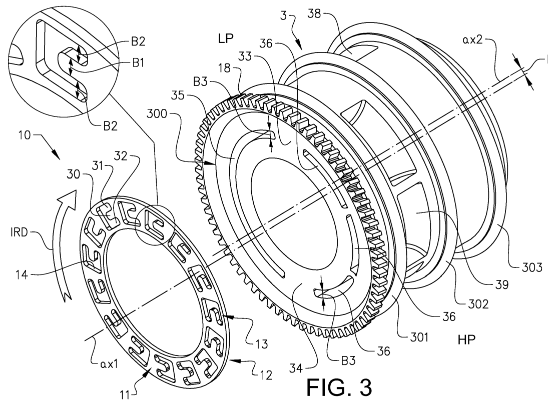

FIG. 3

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to the field of pumping/motor arrangements and especially to displacement pumps/motors. More particularly, the disclosure relates to the field of means for controlling the flow of pressure medium within displacement pumps/motors.

BACKGROUND ART

[0002] The displacement of a displacement pump, such as a rotating piston displacement pump, a bent axis pump or gerotor pump, is commonly controlled by means of a control ring. The control ring is provided with openings in order to control the flow of pressure medium from the displacement pump. Typically, there are at least two openings, which are divided by intermediate sections, referred to as land. The land, and the blocking of pressure chambers provided by the land, is necessary in order to avoid the low pressure side of the control ring to be connected to the high pressure side of the control ring.

[0003] When pressure chambers of a pumping unit of the displacement pump passes over the land between the high pressure side, with the high pressure opening, and the low pressure side, with low pressure opening, of a control ring, the pressure of pressure medium is decreasing/increasing rapidly due to that the land is blocking the flow of pressure medium from/to the pressure chambers of the pumping unit to/from the high/low pressure opening of the control ring. Pumping unit is herein defined as the unit of the displacement pump that provides the pumping functionality of the displacement pump such as the cylinder/piston arrangement of a piston displacement pump or the inner and outer gerotor of a gerotor pump. When a pressure chamber has passed over the land and reaches the high/low pressure opening in the control ring the sudden pressure equalization causes vibrations due to the large pressure differences. This in turn may cause disturbing noises.

[0004] This problem may be addressed by pre-compression and/or pre-decompression. Pre-compression/pre-decompression, and how it varies, depends on the position of the control ring. In a displacement pump with a control ring arranged for 100% displacement, the pressure rises slowly over the land. In a displacement pump with a control ring arranged for 0% displacement, the pressure rises very rapidly over the land, causing high pressure differences between the opening of the pressure chamber and the opening in the control ring to which it opens to.

[0005] The standard solution of today is a compromise, in which the land is adapted such that it gives an ideal pre-compression in an intermediate position of the control ring. An obvious drawback to this solution is that in any other control position of the displacement pump, the pre-compression becomes to large/small, whereby the displacement pump still experience problems with pressure pulses, and therefrom derived vibrations and disturbing noises.

[0006] Thus, there is a need of further improvements.

SUMMARY OF THE INVENTION

[0007] An exemplary object of the exemplary embodiments disclosed herein is to provide a pressure control device, a displacement control arrangement and a pumping arrangement, which balances the pressure forces generated within the pumping arrangement and minimizes the pressure pulses. An exemplary embodiment of a pressure control device is disclosed in claim 1, an exemplary embodiment of a displacement control arrangement is disclosed in claim 8 and an exemplary embodiment of a pumping arrangement is disclosed in claim 15. Further exemplary advantageous embodiments of pressure control devices, displacement control arrangements and pumping arrangements are disclosed in the dependent claims.

[0008] The pressure control devices, displacement control arrangements and pumping arrangements of the exemplary embodiments are based on that pre-compression/pre-decompression can be obtained by applying embodiments of a pressure control device that adjusts the perceived length of transition between the high pressure side and the low pressure side of a control ring during which no fluid can flow from/to pressure chambers of a pump unit to/from a control ring, i.e. the length of the land, wherein the land is defined as intermediate sections separating the high pressure opening of the high pressure side and the low pressure opening of the low pressure side of the control ring, can be varied. The pressure chambers are defined as the conduits of respective pump unit through which a fluid pressure medium is sucked in and pushed out of during pumping operation, such as e.g. the cylinders of a piston displacement pump with reciprocating pistons. When hereafter referring to pressure chambers what is intended is the conduit, in one end opening up to the control ring via a pressure chamber outlet and in one opposite end delimited by e.g. a reciprocating piston of the piston displacement pump. This will be explained more in detail in the following detailed description.

[0009] For a displacement pump generally applies that when the pressure rises rapidly, such as when the control ring is arranged for 0% displacement, it is desirable that the land is perceived to be small, wherein the pressure chamber is blocked for a limited time, and when the pressure rises slowly, such as when the control ring is arranged for 100% displacement, it is acceptable that the land is perceived to be larger, wherein the pressure chamber may be blocked for a longer period of time.

[0010] According to the exemplary embodiments disclosed herein the design of the pressure control device is such that by adjusting the position of the control ring in relation to the position of the pressure control device the size of the land (i.e. the perceived length of the land over which the pressure chambers passes) can be varied dependent of the position of the control ring. The exemplary embodiments disclosed herein can advantageously be applied for controlling the flow of a pressure medium in any form of displacement pump comprising pressure chambers.

[0011] Herein initially embodiments of pressure control devices are disclosed, subsequently embodiments of displacement control arrangements comprising pressure control devices are disclosed and finally embodiments of pumping arrangements comprising displacement control arrangements are disclosed. Features of the exemplary embodiments of pressure control devices, which herein are described separately but may be, but is not limited to be, an integrated part of the rear face of a pump unit, are disclosed and exemplary advantages of the features are subsequently explained in relation to the displacement control arrangements and the pumping arrangements.

[0012] Further, herein the exemplary embodiments of pressure control devices, of displacement control arrangements and of pumping arrangements are disclosed starting from the assumption that the pressure control devices, displacement control arrangements and pumping arrangements are used in/as displacement pumps. It is considered to be generally known that a displacement pump also can be used as a motor if a flow of the pressure medium is reversed. Thus, when hereafter referring to flow directions, components indicting specific flow directions such as e.g. inlet and outlet, this is based on that the pressure control devices, the displacement control arrangements and the pumping arrangements are used as displacement pumps and not as motors. Thus, the pumping arrangement could also be referred to as a pumping/motor arrangement, or if being used as a motor, simply being referred to as a motor arrangement.

[0013] According to an exemplary embodiment of a pressure control device, wherein the pressure control device is configured for controlling or at least influencing the flow of a pressure medium in a displacement pump, the pressure control device comprises a first and a second, circumferentially circular, axial surface, wherein the first and second axial surfaces are arranged facing essentially opposite directions. The pressure control device is rotational symmetric about a first rotational axis, wherein the first rotational axis is extending in a direction perpendicular to the first and/or second axial surface of the pressure control device, and wherein the pressure control device is extending with a thickness cdt1 along the first rotational axis. Thus, the disc that constitutes the pressure control device has a thickness cdt1.

[0014] When hereafter referring to axial direction a direction parallel to, or coinciding with, the rotational axis is intended. When hereafter referring to radial direction a direction perpendicular to the axial direction is intended.

[0015] The pressures control device has a circular outer circumference. Further, the pressure control device is preferably provided with a centrally arranged hole forming a circular passage through the pressure control device in axial direction. The pressure control device is also provided with a plurality of rotation symmetrically arranged through holes, wherein respective through hole has an extension in radial direction and an extension in an intended rotational direction and wherein respective through hole extends from one axial surface to the other axial surface. With a plurality of rotation symmetrically arranged through holes is meant that a number of holes are evenly arranged close to an outer edge of the disc constituting the pressure control device. Respective through hole is defined by a circumferential inner surface. The circumferential inner surface of respective through hole is further provided with at least one protrusion extending into the through hole such that a midsection, in radial direction in respect to the disc shaped pressure control device, of the through hole having a smaller extension in an intended rotational direction than an outer section and an inner section, in radial direction in respect to the disc shaped pressure control device, of the through hole, is formed. Thus, this can also been seen as that a protrusion of the disc shaped pressure control device extends into respective through hole and forms a midsection of respective through hole that is narrower than an inner and an outer section in radial direction of respective through hole. The intended rotational direction, the radial direction and the through holes are disclosed more in detail in the following detailed description.

[0016] According to one exemplary embodiment of the present disclosure respective through hole is defined by a circumferential inner surface, wherein respective at least one protrusion, extending from a circumferential inner surface of respective through hole, extends from a portion of the circumferential inner surface facing away from an intended rotational direction of the pressure control device. This exemplary embodiment has the advantage, as will be disclosed in the following disclosure where the embodiments of pressure control devices are used in displacement control arrangements and pumping arrangements, that by arranging such that the protrusion is extending in a direction opposite the intended rotational direction the flow of pressure medium through the pressure control device is controlled by the design of the through hole and that additionally choking effects, which arises due to the interaction between the protrusions and the first and second openings, may be used to control the flow. According to another exemplary embodiment of the present disclosure at least respective at least one protrusion of respective circumferential inner surface of respective through hole extends from a portion of the circumferential inner surface facing an intended rotational direction of the pressure control device. According to yet another exemplary embodiment of the present disclosure at least one protrusion, extending from a circumferential inner surface of respective through hole, extends from the portion of the circumferential inner surface facing away from an intended rotational direction of the pressure control device and at least one protrusion of respective circumferential inner surface of respective through hole extends from the portion of the circumferential inner surface facing an intended rotational direction of the pressure control device, wherein the through hole takes the form of an I-beam in cross-section. This aspect of the present disclosure e.g. has the exemplary advantage that the functionality of the pressure control device is more flexible in terms of mounting and during reverse operation.

[0017] The three different exemplary embodiments of alternatives of through hole designs presented herein will be disclosed more in detail in the detailed description.

[0018] According to an aspect of an exemplary embodiment of the pressure control device respective protrusion comprises at least a first and a second axial surface, and the first axial surface of the protrusion forms a planar surface with the first axial surface of the pressure control device. According to another aspect of an exemplary embodiment of the pressure control device the second axial surface of the protrusion forms a planar surface with the second axial surface of the pressure control device. According to yet another aspect of an exemplary embodiment of the pressure control device both the first and second axial surface of the protrusion are essentially planar and the first axial surface of the protrusion forms a planar surface with the first axial surface of the pressure control device and the second axial surface of the protrusion forms a planar surface with the second axial surface of the pressure control device.

[0019] According to aspects of the exemplary embodiment of the at least one axial surface of the at least one protrusion forms an essentially rectangular protrusion with a width B1 in radial direction. According to other aspects of the pressure control device a first and a second slot is formed on a first and second radial side of the protrusion. According to yet other aspects of the exemplary embodiment the first and second slots are also essentially rectangular. Thereby respective through hole adopts a U-shape wherein the U is formed enclosing the protrusion. According to aspects the indentations of the first and second slot has a radial width B2. For exemplary embodiments with two protrusions extending into the through holes from opposite directions the through hole adopts the shape of an I-beam in cross section.

[0020] According to preferred aspects of the exemplary embodiment of the pressure control device B1 is essentially equal to B2, but as is apparent from the following description also other relations between B1 and B2 are possible in order to fulfil the requirements of the protrusion and the slots respectively. According to one exemplary embodiment of the pressure control device the first and/or second slot are formed as tapered grooves. According to yet other exemplary embodiments the tapered grooves are continuously tapered. In alternative exemplary embodiments the tapered grooves are provided with a stepped tapered form.

[0021] Referring now to exemplary embodiments of displacement control arrangements:

[0022] According to an exemplary embodiment of a displacement control arrangement the displacement control arrangement comprises a control ring, a rear face of a pump unit and a there between arranged pressure control device. The pressure control device may be of any of the herein described embodiments of pressure control devices. The first axial surface of the pressure control device is fixedly arranged to an axial surface of the rear face of the pump unit, wherein the second axial surface of the pressure control device is facing an axial surface of the control ring, such that the pressure control device is arranged between an axial surface of the rear face of a pump unit and an axial surface of the control ring. The second axial surface of the pressure control device is arranged to be movable in relation to the axial surface of the control ring.

[0023] The rear face of a pump unit, wherein the pump unit, as will be disclosed more in detail, may be any pump unit comprising cylinders or like, comprises a number of pressure chambers. Pressure chambers are herein defined as a conduit through which pressure medium is sucked and pushed during the operation of the pump unit, and may e.g. be a cylinder of piston displacement pump. At one end the pressure chambers open up to the axial surface of the rear face of a pump unit via a pressure chamber outlet. The pressure control device, wherein the first axial surface of the pressure control device is arranged to the axial surface of the rear face of a pump unit, is arranged such that a through hole of the pressure control device is arranged to respective pressure chamber outlet of a pressure chamber. Thereby pressure medium flowing into a pressure chamber and out from a pressure chamber during operation of the pump unit flows through the through holes of the pressure control device.

[0024] The control ring is provided with at least a first and a second opening on the axial surface of the control ring. The first and second openings are formed as semicircular arcs and are separated by a first and a second intermediate section herein referred to as land. When the control ring is used within a displacement pump, one of the openings is a high pressure opening on a high pressure side and one of the openings is a low pressure opening on a low pressure side. As previously stated, dependent on if the pumping arrangement is used as a pump or as a motor which opening that is the high pressure opening and which opening that is the low pressure opening may change. The first and second openings of the control ring also opens up to the second axial surface of the pressure control device.

[0025] The rear face of a pump unit and the pressure control device are rotational symmetrically arranged about the first rotational axis. The control ring is rotational symmetrically arranged about a second rotational axis. The second rotational axis is radially offset by a distance E in relation to the first rotational axis and is arranged in parallel to the first rotational axis. By arranging a rear face of a pump unit provided with a pressure control device, wherein the rear face of the pump unit and the thereto fixedly arranged pressure control device are centred around a first rotational axis, in relation to a control ring, wherein the control ring is centred around a second rotational axis with an offset between the first rotational axis and the second rotational axis, the configuration of the through holes of the pressure control device will vary the experienced length of the lands depending on in which rotational position the control ring is positioned, i.e. the displacement. This enables pre-compression/pre-decompression which in turn reduces vibrations and noise of the pumping device. This is explained in further detail in following detailed description of the drawings.

[0026] According to another exemplary embodiment of a displacement control arrangement the pressure control device is an integrated part of the rear face of a pump unit. Having the pressure control device as an integrated part of the rear face of a pump unit may be advantageous from manufacturing and durability perspective. However, note that herein the pressure control device is predominantly described as a separate component.

[0027] According to yet an exemplary embodiment of a displacement control arrangement at least an end portion of the first and second openings has a radial width B3, and wherein B3 is essentially equal to the width B1 of the protrusion/protrusions. That the radial width B1 of the protrusion/protrusions is essentially equal to the radial width B3 of the first and second openings of the control ring, or at least an end portion of respective first and second opening, provides the important effect that by setting the displacement of the displacement pump for 100% displacement, as the rear face of a pump unit and the pressure control device rotates in relation to the control ring, the protrusion/protrusions completely block the first and second openings for a period of time that is significantly longer than when the displacement of the displacement pump is set for 0% displacement.

[0028] According to another exemplary embodiment of a displacement control arrangement, when the control ring is positioned for 100% displacement the through holes of the pressure control devices are passing over the first land and are fully covered by the first land during a first predetermined angular distance, and
when the control ring is positioned for 0% displacement the through holes of the pressure control devices are passing over the first land and are fully covered by the first land during a second predetermined angular distance, wherein the first predetermined angular distance is longer than the second predetermined angular distance.

[0029] Thus, by changing the displacement the angular distance, thus the time, for which the through holes are completely blocked when moving over the first (or second) land can be controlled.

[0030] To clarify, looking closer at the pressure build up in a pressure chamber, which opens up to the high pressure opening of a high pressure side (and low pressure opening of a low pressure side) of a control ring via a through hole, for 100% displacement and 0% displacement:

[0031] When the control ring is positioned in a position for 100% displacement, the land is arranged between the high pressure and the low pressure side. In this position the pressure is raised minimal for each angular distance the through hole of the pressure chamber is moved over the land. Therefore it is desired that the through hole is blocked by the land sufficiently long to build up a pressure in the through hole passing over the land, which correlates with the pressure in the high pressure opening of the high pressure side. Hence, the length of the land is adjusted to reach such a pressure increase in the through hole. Because the pressure thereby is essentially equal in the high pressure opening as in the through hole there will be no pressure spikes causing vibrations or noise as pressure medium is delivered from the pressure chamber, via the through hole of the pressure control device, and into the high pressure opening.

[0032] When the control ring is positioned for 0% displacement, i.e. rotated 90 degrees from the 100% displacement position; the land is arranged in the middle of the high pressure opening of the high pressure side, where the pressure raises quickly with the angular distance the through hole of the pressure chamber is moved over the land. Therefore it is desired that through hole is blocked by the land for as short time as possible.

[0033] The design of the through holes, and the radial offset between the fist rotational axis and the second rotational axis, i.e. the eccentric arrangement of the control ring relative the pressure control device and pump unit, the angular distance the land completely covers the through holes can be varied with the position of the control ring.

[0034] According to yet another exemplary embodiment of a displacement control arrangement

> a displacement may be changed between 100% and 0%, wherein:
>
> when the control ring is positioned for 100% displacement the through holes of the pressure control devices are passing over the first land and are at least partially covered by the first land during a third predetermined angular distance, and
>
> when the control ring is positioned for 0% displacement the through holes of the pressure control devices are passing over the first land and are at least partially covered by the first land during a fourth predetermined angular distance, wherein said third predetermined angular distance is shorter than said fourth predetermined angular distance.

[0035] It is desirable that each pressure chamber of the rear face of a pump unit opens up to one through hole of the pressure control device integrated with, or arranged to, respective rear face of a pump unit, wherein according to one exemplary embodiment of a displacement control arrangement the number of pressure chambers, thus pressure chamber openings, on the axial surface of the rear face of the pump unit is equal to the number of through holes of the pressure control device.

[0036] According to yet one exemplary embodiment of a displacement control arrangement the radial offset E between the first rotational axis and the second rotational axis is essentially equal to the width B1 of the protrusion/protrusions of the through holes.

[0037] According to another exemplary embodiment of a displacement control arrangement the pressure chamber has a first radial cross-sectional area and respective through hole of the pressure control device, which is arranged adjacent the pressure chamber, has a second cross-sectional area. The radial cross-sectional area is defined as the total area of a cross-section in radial direction of a pressure chamber, through hole, cylinder or like. According to yet an exemplary embodiment of a displacement control arrangement the first radial cross-sectional area is essentially equal to a second radial cross-sectional area. In order for a displacement pump where a piston reciprocates within a pressure chamber, such as the exemplary embodiments of pumping arrangements disclosed herein, to run smoothly it is preferred that there is a pressure balance between the high pressure side and the low pressure side of the displacement pump, meaning that there should not be a higher force acting to push the control ring away from the rear face the pump unit on the high pressure side than on the low pressure side. If there is a pressure difference between the high pressure side and the low pressure side this may cause durability problems and problems due to leakage. This is avoided by configuring the first radial cross-sectional area to be essentially equal to a second radial cross-sectional area.

[0038] Referring now to exemplary embodiments of pumping arrangements:

According to an exemplary embodiment of a pumping arrangement the pumping arrangement comprises a pump unit and a displacement control arrangement according to any exemplary embodiment of displacement control arrangements disclosed herein, wherein the pump unit comprises a cylinder plate, wherein the cylinder plate in turn comprises the rear face of a pump unit, a swashplate, an axis and a housing, wherein the housing in turn comprises a front housing and a rear housing. The control ring is arranged between the rear housing and the rear face of a pump unit of the cylinder plate. The swashplate is arranged between cylinder plate and the front housing. The axis extends through the control ring, the cylinder plate and the swashplate wherein the control ring and the swashplate are configured to rotate freely in relation to the axis and the cylinder plate is rotationally arranged to the axis e.g. by means of splines or like.

[0039] As previously stated the pressure chambers may e.g. be cylinders of a piston displacement pump with reciprocating pistons. Thus, according to exemplary embodiments of a pumping arrangement the pump unit comprises a number of cylinders, wherein the number of pressure chambers on the first axial side of the rear face of the pump unit is equal to a number of cylinders of the pump unit. According to yet another exemplary embodiment of a pumping arrangement respective cylinder has a third radial cross-sectional area, thus the third radial cross-section is essentially equal to the first radial cross-sectional area of the pressure chamber, wherein also the third radial cross-section is also essentially equal to the second radial cross-sectional area of respective through hole.

[0040] According to one exemplary embodiment of a pumping arrangement said pump unit is a bent-axis displacement pump unit. According to another exemplary embodiment of a pumping arrangement the pump unit is a rotational piston displacement pump unit or a development of a rotational piston displacement pump unit. According to yet another exemplary embodiment of a pump unit of the pumping arrangement is a gerotor pump. If the pumping arrangement comprises a gerotor pump the cylinders referred to in the exemplary embodiments disclosed above may instead be on form of conduits of rear support plate.

[0041] To sum up the functionality of the exemplary embodiments of pressure control devices, displacement control arrangements and pumping arrangements:

The pumping device according to above, provided with an inventive pressure control device, enables that the experienced length of the land may be varied. Due to the configuration of the pressure control device, i.e. first and foremost the configuration of the through holes of the pressure control device, and the eccentric configuration of the pressure control device in relation to the control ring, the angular distance along which an axial outlet of the a pressure chamber of a pump unit passes over the first land and is fully covered by it can be varied dependent on the position of the control ring.

[0042] It is preferred that the pump unit and the control ring is arranged within the same housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043]

Fig. 1 discloses exemplary embodiments of pumping arrangements,

Fig. 2a-2c disclose exemplary embodiments of pressure control devices,

Fig. 3 discloses an exemplary embodiment of a pressure control device and of a control ring,

Fig. 4 discloses one embodiment of a rear face of a pump unit, and

Fig. 5a-5f disclose exemplary embodiments of the interaction between pressure control devices and control rings at different displacements.

DETAILED DESCRIPTION

[0044] As previously emphasized, in the following detailed description exemplary embodiments of pressure control devices, of displacement control arrangement and of pumping arrangements are disclosed starting from the assumption that the pumping arrangements is used as a displacement pump. However, it is considered to be generally known, which is disclosed in prior art, that a displacement pump also can be used as a motor.

[0045] In order to separate the high pressure side from the low pressure side of a control ring of a displacement pump a low pressure, first opening is separated from a high pressure, second opening by a first and a second land. During operation of the displacement pump pressure chambers of a cylinder plate rotates over the control ring and when such pressure chambers moves over the first land between the low pressure, first opening and to the high pressure, second opening a pressure is built up. Build-up of large pressure differences causes vibrations and noises as the pressure chambers opens up. The degree of pressure build-up is dependent on the displacement of the displacement pump wherein a larger pressure difference is built up for 0% displacement. The opposite applies for when the pressure chambers moves over the second land between the high pressure, second opening and to the low pressure, first opening. Then an under pressure is built up.

[0046] Fig. 1 discloses exemplary embodiments of pumping arrangements 1 wherein four exemplary pump units 2a-2d, are presented as alternative pump units 2a-2d that may be used in combination with a displacement control arrangement 5 comprising a pressure control device 10. An actuator pin 8 is provided, which acts upon a gearing 18 of the control ring 3 in order to rotate the control ring 3 into different control positions. By rotating the control ring 3, the displacement of the displacement pump 1 can be set between 0 and 100 %. This will be discussed more in detail later in the detailed description. A first rotational axis ax1 is extending through the pumping arrangement 1 wherein e.g. the pressure control device 10 is rotational symmetric about the first rotational axis ax1. The control ring 3 is rotational symmetric about a second rotational axis ax2, wherein the second rotational axis is radially offset in relation to the first rotational axis ax1 and is parallel to the first rotational axis ax1. The displacement control arrangement 5 comprises, except for pressure control device 10, the control ring 3 and a rear face of a pump unit 6a-6d. Further, the pump unit 2a-2d, the pressure control device 10 and the control ring 3 is enclosed by a housing 7a, 7b, comprising of a front housing 7a and a rear housing 7b.

[0047] In the exemplary embodiment shown in fig. 1, the control ring 3 is provided in between the rear face of a pump unit 6a-6d with the pressure control device 10 and the rear housing 7b, such that it controls the flow of pressure medium between an inlet 38 and an outlet 39 of the control ring 3 and pressure chambers 25a-25d of respective pumping unit 2a-2d. An additional plate with conduits for pressure medium could however also be arranged between the control ring and the pressure control device, or even between the pressure control device and the rear face of a pump unit, without affecting the functionality.

[0048] The rear face of a pump unit 6a-6d is defined as the rear part of respective pump unit 2a-2d, which is similarly configured independently of which pump mechanism that is used in respective pump unit 2a-2d. All rear faces of a pump unit 6a-6d disclosed herein comprises pressure chambers which opens up to the pressure control device 10 via pressure chamber outlets. Pressure chambers 25a-25d are defined as the conduits through which pressure medium is sucked and pushed by respective pump mechanism, such as e.g. the cylinders of a piston displacement pump. Fig. 1 is intended to demonstrate that the exemplary embodiments of pressure control devices 10, displacement control arrangements 5 and pumping arrangements 1 disclosed herein is compatible with any displacement pump with pressure chambers 25a-25d. Thus, independently of which pump mechanism that is used in the pump unit 2a-2d the herein disclosed embodiments of displacement control arrangements 5 and of pressure control devices 10 may be used. The functionality of the different pump mechanisms referred to herein is considered to be part of prior art except for what herein is referred to as a development of a piston displacement pump. The pump mechanism herein referred to as development of a piston displacement pump is the subject of another patent application. Everything that is of importance for the disclosed embodiments of displacement control arrangements 5 and of pressure control devices 10 is essentially the same independently of which pump unit 2a-2d that is used. This is herein represented by that four exemplary pump units 2a-2d, based on four different pumping mechanisms are presented, as alternative pump units 2a-2d.

[0049] The exemplary pump units 2a-2d that schematically are disclosed in fig. 1 are:

a bent-axis displacement pump 2a, a conventional piston displacement pump 2b, an improved displacement pump 2c, which is a development of a conventional piston displacement pump and is the subject of another patent application, and a gerotor pump

2d. However, it should be emphasized that also other pumps, based on other pumping mechanisms, may be used with herein disclosed exemplary embodiments of displacement control arrangements 5 comprising pressure control devices 10. Respective pump unit 2a-2d comprises a swashplate or like 21a-21d, a cylinder plate or like 22a-22d and an axis 23a-23d. The gerotor pump 2d is differently configured than the other pump units 2a-2c, wherein the gerotor pump 2d e.g. may be considered to comprise first support plate 21d instead of a swashplate, an inner/outer gerotor 22d instead of a cylinder plate and additionally comprises a second support plate 24, but the actual functionality and construction of respective pump unit 2a-2d is of less relevance for the herein presented exemplary embodiments of displacement control arrangements 5 and of pressure control devices 10. Irrespective of which pumping mechanism that is applied respective pump unit 2a-2d comprises the rear face of a pump unit 6a-6d. The rear face of a pump unit 6a-6d, and the interface the rear face of a pump unit 6a-6d provides to adjacent pressure control device 10 and control ring 3, is similar irrespective of applied pumping mechanism. Thus, the embodiments of displacement control arrangements 5, and the embodiments of pressure control devices 10, is not limited by which pump unit 2a-2d that is used. Further, for bent axis pump 2a swashplate 21a is angled by an angle A in relation to the first rotational axis ax1.

[0050] For simplicity reasons, when hereafter referring to the pump units 2a-2d the pump units comprising pressure chamber 25a-25c, in form of cylinders, and reciprocating pistons are referred to.

[0051] The offset between the first and second rotational axis together with the design of through holes of the pressure control device according to the present disclosure enables the experienced length of the first and second land to be varied wherein the problem of build-up of pressure differences, causing noise and vibrations, can be solved.

[0052] Fig. 2a discloses an exemplary embodiment of a pressure control device 10. The pressure control device 10 is rotational symmetric about a first rotational axis ax1 and has a thickness cdt1 in the direction of the first rotational axis ax1. The pressure control device 10 is in form of an essentially planar, round disc having a first axial surface 11 on a first side of the pressure control device 10 and a second axial surface 12 on a second side of the pressure control device 10, wherein the first and second axial surface are arranged to face essentially opposite axial directions. Further, the pressure control device 10 is provided with a centrally arranged hole 15 in the planar surface of the pressure control device 10, extending from the first axial surface 10 to the second axial surface 11 in the middle of the pressure control device 10 such that the pressure control device 10 may be arranged to encircle an axis extending through said hole 15.

[0053] An intended rotational direction of the pressure control device 10 is indicated by an arrow IRD. When herein referring to rotational direction such rotational direction is what is intended. A radial direction in relation to the circular pressure control device 10 is indicated by an arrow RD pointing from said first rotational axis ax1 in a radial direction.

[0054] The pressure control device 10 is additionally provided with a plurality of through holes 13. The through holes 13 are evenly distributed around, and close to the outer edge of, the pressure control device 10. Further, the through holes 13 of the exemplary embodiment of fig. 2a are essentially rectangular (but with - as will be discussed below - a protrusion giving them a U-shape) and have a thickness cdt1 in the direction of the first rotational axis ax1. Respective through hole 13 extends from the first axial surface 11 to the second axial surface 12, and respective through hole 13 is defined by an enclosing, circumferential inner surface 14. The circumferential inner surface 14 is defined by the thickness cdt1 of the pressure control device 10 and outer edges 16 of respective through hole 13. According to the exemplary embodiment of fig. 2a a portion of the circumferential inner surface 14 of respective through hole 13 in the intended rotational direction IRD of the pressure control device 10 is provided with a protrusion 30 extending into the through hole 13. When herein referring to protrusion of a through hole what is intended is a protrusion extending from a circumferential inner surface, formed by the pressure control device, of respective through hole. The protrusions 30 of the exemplary embodiment disclosed in fig. 2 are essentially rectangular and have a thickness cdt2. The thickness cdt1 is essentially equal to the thickness cdt2. On a first and second side in the radial direction RD from the first rotational axis ax1 a first and second slot 31, 32 are formed. Thereby the through holes 13 of the exemplary embodiment of the pressure control device 10 of fig. 2a may be described as U-shaped. The first and second slot 31, 32 of the exemplary embodiment disclosed in fig. 2a are also essentially rectangular. The through holes 13 has a second radial cross-sectional area RA2, wherein the second radial cross-sectional area RA2 is defined by the outer edge 16 of the circumferential inner surface 14 of the through hole 13.

[0055] In the exemplary embodiment of a pressure control device 10 of fig. 2a the essentially rectangular protrusion 30 has a width B1 in the radial direction RD, the first and second slots 31, 32 have a width of B2 in the radial direction RD respectively and the through holes 13 have a width B4 in the radial direction RD. Further, in the exemplary embodiment of a pressure control device 10 of fig. 2a B1 is essentially equal to B2 and B4 is essentially equal to the sum of B2, the width of the first slot 31, B1, the width of the protrusion 30, and B2, the width of the second slot 32. This is just one exemplary embodiment of a pressure control device 10. As is realized also other configurations of the pressure control device 10 and the through holes 13 are possible.

[0056] Further, as will be realized from the following detailed description, the exemplary embodiment of the pressure control device 10 disclosed in fig. 2a has the advantage that by rotating the pressure control device 10 around the first rotational axis ax1 in the intended rotational direction IRD in relation to a control ring 3, being centred around the second rotational axis, in combination with the configuration of the through holes 13 having a narrower midsection MS, depending on the displacement of the control ring 3 the angular distance, thus period of time, the through hole 13b is completely blocked by a land can varied. According to the exemplary embodiment disclosed in fig. 2a the through hole 13 has a midsection MS which is significantly narrower than an adjacent outer section OS and an adjacent inner section IS.

[0057] Fig. 2b discloses another exemplary embodiment of a pressure control device 10b. In relation to the exemplary embodiment disclosed in fig. 2a the through holes 13b of the exemplary embodiment disclosed in fig. 2b are turned 180 degrees, such that the protrusion 30b is extending in opposite direction then of the exemplary embodiment of fig. 2a, in relation to the intended rotational direction. According to the exemplary embodiment of fig. 2b a portion of the circumferential inner surface 14 of respective through hole 13b opposite the intended rotational direction IRD of the pressure control device 10 is provided with a protrusion 30b extending into the through hole 13b. As for the exemplary embodiment disclosed in fig. 2a the through holes 13b of the exemplary embodiment of fig. 2b have a midsection MS which is significantly narrower than adjacent outer section OS and inner section IS. An exemplary advantage with through holes 13b configured accordingly is that, depending on the displacement of control ring 3, this enables that the angular distance, thus period of time, the through hole 13b is completely blocked by a land to be varied.

[0058] Fig. 2c discloses yet another exemplary embodiment of a pressure control device 10c. The through holes 13c of fig. 2c are provided with two protrusions 30, 30b, wherein a first protrusion 30 extends from the circumferential inner surface 14 of respective through hole 13c in the intended rotational direction IRD of the pressure control device 10c and a second protrusion 30b extends from the circumferential inner surface 14 of respective through hole 13c opposite the intended rotational direction IRD of the pressure control device 10c, such that respective through hole 13c essentially is in form of a cross-section of an I-beam. Also for the exemplary embodiment of fig. 2c is the midsection MS significantly narrower than adjacent outer section OS and inner section IS. In accordance with what is disclosed for the through holes 13, 13b of fig. 2a and 2b, an exemplary advantage with through holes 13c configured according to the exemplary embodiment of fig. 2c is that this enables that the angular distance, thus period of time, the through hole 13c is completely blocked by a land to be varied.

[0059] Fig, 2a. 2b and 2c discloses preferred exemplary embodiments of pressure control devices 10. However, also other configurations, e.g. other configurations of the through holes, the protrusions or the slots, providing essentially the same functionality, are also realizable and thereby considered to be within the scope of the present disclosure.

[0060] Fig. 3 discloses an exemplary embodiment of a pressure control device 10 and of a control ring 3. The exemplary embodiment of the pressure control device 10 corresponds to the exemplary embodiment of the pressure control device 10 disclosed in relation to fig. 1 and 2a to 2c, wherein the pressure control device 10 is arranged along the first rotational axis ax1. The exemplary embodiment of the control ring 3 corresponds to the exemplary embodiment of the control ring 3 disclosed in relation to fig. 1. The control ring 3 is rotational symmetric about the second rotational axis ax2, wherein the second rotational axis ax2 is radially offset by a distance E in relation to the first rotational axis ax1. The control ring is further provided with a high pressure side HP and a low pressure side LP. The low pressure side LP is provided with at least a semi-circular arc shaped first opening 35 and the high pressure side HP is provided with at least a semi-circular arc shaped second opening 36. In the exemplary embodiment of the control ring 3 disclosed in fig. 3 the second opening 36 is divided into three openings due to durability reasons. At least an end portion of the first opening 35 and of the second openings 36 has a radial width B3. According to the preferred exemplary embodiments disclosed in fig. 1 to 3, and later in the detailed description also in fig. 5a-5f, the whole extension of as well the first opening 35 as of the second opening 36 has the radial width B3. The first and second openings 35, 36 are separated by a first land 33 and a second land 34. Further, the second opening 36 is in fluid communication with the outlet 39 and the first opening 35 is in fluid communication with the inlet 38. However, it should be highlighted that in case the pumping arrangement 1 as disclosed in fig. 1, comprising the control ring 3, is used as a motor the present inlet 38 may be used as an outlet and the present outlet 39 may be used as an inlet.

[0061] Referring now to the pressure control device 10. The exemplary embodiment of a pressure control device 10 disclosed in fig. 3 corresponds to the exemplary embodiment of a pressure control device of fig. 2a, wherein the pressure control device has a first axial surface 11 and a second axial surface 12, wherein the second axial surface 12 is facing the control ring 3, and wherein the pressure control device 10 is provided with a number of through holes 13. The through holes 13 are formed with protrusions 30 extending from an inner circumferential surface 14 of respective through hole 13 in an intended rotational direction IRD of the pressure control device 10. The through holes 13 are further formed to have a first and a second slot 31, 32 on a first and second radial side of the protrusions 13.

[0062] As disclosed in fig. 3 the protrusion 30 has a radial width B1 and the first and second slot 31, 32 have a radial width B2.

[0063] According to the exemplary embodiment of the pressure control device 10 and the control ring 3 disclosed in fig. 3 the width B1 is essentially equal to B3. B1 and B3 are also essentially equal to E. That the protrusion 30 is rectangular, and that B1 = B3 = E, has the exemplary advantage that by such configuration of the through hole 13 will be blocked for a longer angular distance, thus longer period of time, when the control ring is set for 100% displacement and for a shorter angular distance, thus shorter period of time, when the control ring is set for 0% displacement. According to yet an exemplary embodiment of the pressure control device 10 B1, B2 and E is additionally essentially equal to B2. That the protrusion 30 and first and second slots 31, 32 are rectangular, and that B1 = B2 = B3 = E, also provides has the exemplary advantage described above.

[0064] Further, in the exemplary embodiment disclosed in fig. 3 the first and the second opening 35, 36 of the control ring 3 is fluidly connected to the inlet 38 and the outlet 39, wherein the inlet 38 and the outlet 39 are provided at different axial distance from an axial surface 300 of the control ring 3. The different axial distance is important in order to create two separate areas between a radial outer surface of the control ring 3 and an inner radial surface of an enclosing rear housing 7b. A first, a second and a third seal ring 301, 302, 303 is provided in order to create these separate areas. One of the inlet and outlet 38, 39 is connected to a respective separated area between the seal rings 301, 302, 303.

[0065] The control ring 3 is further provided with a gearing 18 used to adjust the displacement of the control ring 3. Since offset E between the first rotational axis ax1 in relation to the second rotational axis ax2 the displacement of the control ring 3 in relation to the pressure control device 10, and due to the configuration of the through holes 13 with protrusions 30, the displacement of the control ring will affect how long respective first and second lands 33, 34 completely blocks the through holes 13 during operation when the pressure control device 10 rotates in relation to the control ring 3. This will be disclosed more in detail in relation to fig. 5a-5f.

[0066] Referring now to fig. 4, disclosing an exemplary embodiment of a rear face of a pump unit 6c, and with reference to the previously disclosed fig. 1, fig.2a-2c and fig. 3. Fig. 4 discloses that the first axial surface of an exemplary embodiment of a pressure control device 10b is fixedly arranged to an axial surface 400 of the rear face of a pump unit 6c. A second axial surface 12 of the pressure control device 10b, arranged on opposite axial side than the first axial surface of the control device 10b, is facing away from the rear face of a pump unit 6c. The rear face of the pump unit 6c and the pressure control device 10b are centred along the first rotational axis ax1. The pressure control device 10b may be fixedly arranged to the axial surface 400 of the rear face of a pump unit 6c or an integrated part of the rear face of a pump unit 6c.

[0067] The rear face of a pump unit 6c disclosed in fig. 4 belongs to an improved piston displacement pump and is defined as a rear portion, which is essentially equal independently on which pump unit that is applied, of a cylinder plate 22c. The improved piston displacement pump further comprises a swashplate 21c with pistons 42, wherein the pistons 42 are configured for reciprocating in cylinders. During operation of the piston displacement pump the pistons 42 reciprocates within the cylinders as the swashplate 21c and the cylinder plate 22c rotates due to the skew arrangement of the swashplate 21c in relation to the cylinder plate 22c. The cylinders of the improved piston displacement pump are herein generically referred to as pressure chambers 25c. Further, the pressure control device 10b is provided with one through hole 13b for each pressure chamber 25c (cylinder). An axis 23c is extending through the swashplate 21c and the cylinder plate 22c comprising the pressure control device 10b, wherein the cylinder plate 22c is fixedly arranged, e.g. by splines, to the axis 23c and the swashplate 21c is arranged to rotate freely in relation to the axis 23c.

[0068] In order for a displacement pump where a piston reciprocates within a pressure chamber, such as the exemplary embodiments of pumping arrangements disclosed herein, to run smoothly it is preferred that there is a pressure balance between the high pressure side and the low pressure side of the displacement pump, meaning that there should not be a higher force acting to push the control ring away from the rear face the pump unit on the high pressure side than on the low pressure side. If there is a pressure difference between the high pressure side and the low pressure side this may cause durability problems and problems due to leakage.

[0069] In the exemplary embodiments disclosed herein, e.g. in fig. 4, a first radial cross-sectional area RA1 of the pressure chamber 25c (cylinder), which is essentially equal to a radial cross-sectional area RA1 of the piston 42, is essentially equal to a second radial cross-sectional area RA2 of respective through hole 13. This enables perfect balance on the cylinder plate 22c, comprising the pressure control device 10, in relation to the control ring 3 at all times independently on the position of the piston 42 within the pressure chamber 25c (cylinder). Respective piston 42 will still be balanced when passing over the first or second land 33, 34, thus independently of if the pressure rises or drops and or on the magnitude of the pressure increase/drop. The first radial cross-sectional area RA1 of the pressure chamber 25c (cylinder)/piston 42 is defined by the an outer circumferential edge 43 of the piston 42/an inner wall 43 of the pressure chamber 25c (cylinder) whereas the second radial cross-sectional area RA2 of the through holes 13b are, as previously disclosed, defined by the outer edge 16 of the circumferential inner surface 14 of the through hole 13.

[0070] Respective pressure chamber 25c (cylinder) is arranged to be in fluid communication with respective through hole 13b via pressure chamber outlet 44. The pressure chamber outlet 44 is defined as a passage opening up respective pressure chamber 25c (cylinder) at an end opposite to the end where respective piston 42 enters respective pressure chamber 25c (cylinder).

[0071] Please note that in the exemplary embodiment disclosed in fig. 4 the pressure control device 10b disclosed in fig. 2b shown.

[0072] Fig. 5a discloses the control ring 3 and the pressure control device 10 as it interacts with the control ring 3. The pressure control device 10 is centred about the first rotational axis ax1 of the pumping arrangement 1, whereby the control ring 3 is eccentric arranged relative the rear pressure control device 10 and is centred about the second rotational axis ax2. The first and second rotational axes ax1, ax2 are separated by a distance E. In the pressure control device 10 the through holes 13 can be seen. During operation of the pumping arrangement the pressure control device 10, and the cylinder plate to which the pressure control device 10 is arranged etc., rotates with the first rotational axis ax1 in the intended rotational direction IRD, whereas the control ring is stationary.

[0073] In fig. 5a and 5b the pumping arrangement 1 is in the same position. In fig. 5b the pressure control device 10 is transparently depicted wherein the semi-circular, low pressure first opening 35 and the semi-circular, high pressure second opening 36 are visible. The first and second openings 35, 36 opens up to pressure chambers of the pressure control device 10. The second opening 36 also opens up to the outlet whereas first opening 35 also opens up to the inlet.

[0074] The control ring 3 can be turned to change the displacement by means of the actuator pin 8 interacting with the gearing 18, in order to change the displacement of the pumping arrangement 1, and thereby also change the position of the first and the second land 33, 34.

[0075] At some point when the through holes 13 passes over the first and the second land 33, 34 the through holes 13 are completely blocked by the first and the second land 33, 34 respectively. The blocking is necessary to avoid that the low pressure first opening 35 is connected to the high pressure second opening 36 of the control ring. However, during the passing over the first and the second land 33, 34 respectively a pressure rise/pressure drop in the through holes 13 occurs, because of the blocking.

[0076] In fig. 5b, the control ring 3 is positioned such that the first land and the second land 33, 34 are positioned in between the high pressure side HP and the low pressure side LP. In this position the pumping arrangement 1 is controlled to deliver 100% displacement. When in this position, at the transition between the high pressure chamber HP and the low pressure chamber LP, i.e. when a pressure chamber rotates from the low pressure side LP to the high pressure side HP, or vice versa, the pressure rises/decreases slowly. This means that a small pressure increase occurs for each angular distance a blocked through hole 13a moves over the first land 33 and a small pressure decrease occurs for each angular distance a blocked through hole 13a moves over the second land 34.

[0077] In fig. 5b the illustrated through hole 13 is in a position where it just became fully blocked by the first land 33. In this position no pressure medium can be provided out from the through hole 13. When referring to that no pressure medium can be provided out from the through hole 13 what is meant is that since the through hole 13 in one end is blocked by the first land 33 no pressure medium, which is provided to the through hole 13 by that the piston exerts pressure on pressure medium of the pressure chamber, which forces pressure medium into the through hole 13 of the pressure control device 10 via the pressure chamber outlet, may flow into the second opening 36 of the control ring 3.

[0078] In fig. 5c the control ring 3 is still in the same position as in figure 5b, however, in fig. 5c the pressure control device 10 has rotated a bit further wherein the illustrated through hole 13 is in a position such that it is just about to open up to the second opening 36, i.e. not be fully blocked by the first land 33 anymore. The pressure control device 10 has thereby moved a first angular distance AD1 between fig. 5b and fig. 5c. The first angular distance AD1 is the angular distance the through hole 13a moves over the first land 33 and is fully blocked thereby, when the control ring 3 is positioned in a position for 100% displacement.

[0079] Referring now to fig. 5d and 5e disclosing an exemplary embodiment where the control ring 3 has been turned 90 degrees in a counter clockwise direction, and is positioned in a position for 0% displacement. According to the exemplary embodiment of fig. 5d the through hole 13 is in a position where it just became fully blocked by the first land 33. However, as the pressure control device 10 continues to rotate, as is disclosed in fig. 5e, in the intended rotational direction IRD the through hole 13 will soon open up to the second opening 36. The pressure control device 10 has moved a second angular distance AD2 between fig. 5d and fig. 5e. The second angular distance AD2 the pressure control device 10 has moved over the first land 33 and is fully blocked thereby, when the control ring 3 is positioned in a position for 0% displacement, is shorter than first angular distance AD1. Thus, the through hole 13 will be completely blocked by the first land 33 for a significantly shorter period of time when the control ring is in a position for 0% displacement, as is disclosed in fig. 5d and 5e, than when the control ring is in a position for 100% displacement, as is disclosed in fig. 5b and 5c. This is an effect of the eccentric arrangement of the control ring 3, being centred around the second rotational axis ax2, in relation to the pressure control device 10, and all other parts of the pumping arrangement, being centred around the first rotational axis ax1, and of the configuration of the through hole 13.

[0080] The bigger pressure difference that is built up during the transition of a pressure chamber from the low pressure side LP to the high pressure side HP over the first land 33 the more vibrations and noise is created. In a displacement pump with a control ring 3 arranged for 100% displacement, the pressure rises slowly over the land. In fig. 5b to 5c the transition over the first land 33, during which period of time/first angular distance AD1 travelled the through hole 13 of the pressure chamber is completely blocked will result in a pressure build up, is disclosed. Since the pressure rises slowly over the first land 33 the relatively long period of time during which pressure is built up is not that severe.

[0081] However, in a displacement pump with a control ring arranged for 0% displacement, the pressure rises very rapidly over the land. If pressure was built up during the same period of time as disclosed in fig. 5b and 5c this would cause significant vibrations, hence disturbing noise. In fig. 5d to 5e the transition over the first land 33, during which period of time/distance travelled the through hole 13 of the pressure chamber is completely blocked will result in a pressure build up, is disclosed. The pressure rises very rapidly over the first land 33 when the control ring 3 is arranged for 0% displacement, but since period of time/second angular distance AD2 travelled is significantly shorter than the first angular distance AD1 of fig. 5b to 5c the pressure built up is not that severe neither for 0% displacement.

[0082] Further, according to the exemplary embodiment of fig. 5f, which corresponds to the exemplary embodiments of fig. 5d and 5e, but with a differently configured control ring 3 In the exemplary embodiment disclosed in fig. 5f the control ring 3 is arranged in a position for a 0% displacement and the through hole 13 is in a position where it just became fully blocked by the first land 33. However, as soon as the pressure control device 10 continues to rotate in the intended rotational direction IRD the through hole 13 will open up to the second opening 360. Thus, the through hole 13 will be completely blocked by the first land 33 only at one angle. In an ideal case the angular distance between a complete blocking of the through hole 13 and the reopening is zero, whereby no additional pressure will be able to be build up during the passing of the first land 33.

[0083] In fig. 5f the reduced angular distance the through hole 13 is completely blocked by the first land 33 is due to that the first and second openings 350, 360 are differently configured, but it is also possible to change the configuration of the through hole 13 in order to reach the same effect.

[0084] To sum up, what is important with the pressure control device 10, the pressure control arrangement 5 and the pumping arrangement 1 disclosed herein is the angular distance the through holes 13, 13b, 13c travels over the first land 33 and is fully blocked in relation to the displacement and the pressure built up during that a pressure chamber passes of a land at that displacement. The angular distance the through holes 13, 13b, 13c travels can be varied dependent on the position of the control ring 3 due to that the control ring 3 is eccentrically arranged relative the pressure control device 10, the pressure control arrangement 5 and the pumping arrangement 1, and due to the unique design of the through holes 1313b, 13c. As is apparent for a person skilled in the art, other designs of the through holes may give the same functionality as the exemplary design disclosed herein. Such designs, providing the same exemplary advantage, are considered to be within the scope of the present invention.

[0085] In fig. 5a to 5f only the first land 33 has been considered. However, the same principles apply for the transition between the high pressure side HP to the low pressure side LP over the second land 34.

Claims

1. Pressure control device (10, 10b, 10c) for controlling the flow of a pressure medium in a displacement pump (1), comprising:

    • a first and a second axial surface (11, 12), wherein the first and second axial surfaces (11, 12) are arranged facing essentially opposite directions, and
    wherein said pressure control device (10, 10b, 10c) is:
    • rotational symmetric about a first rotational axis (ax1), and
    • extending with a thickness (cdt1) along the first rotational axis (ax1),

    characterised in that
    the pressure control device (10, 10b, 10c) is provided with a plurality of rotation symmetrically arranged through holes (13, 13b, 13c), wherein respective through hole (13, 13b, 13c) has an extension in radial direction and an extension in an intended rotational direction (IRD) and wherein respective through hole (13, 13b, 13c) extends from one axial surface (11) to the other axial surface (12), wherein respective through hole (13) is defined by a circumferential inner surface (14), and wherein at least one protrusion (30, 30b) of the circumferential inner surface (14) extends into the through hole (13, 13b, 13c) such that the protrusion (30, 30b) forms a midsection of the through hole (MS) having a smaller extension in an intended rotational direction (IRD) than an outer section (OS) and an inner section (IS) of the through hole (13, 13b, 13c).

2. Pressure control device (10) for controlling the flow of a pressure medium in a displacement pump (1) according to claim 1, wherein respective at least one protrusion (30) of respective through hole (13) extends from a portion of the circumferential inner surface (14) facing away from an intended rotational direction (IRD) of the pressure control device (10).

3. Pressure control device (10b) for controlling the flow

of a pressure medium in a displacement pump (1) according to claim 1, wherein respective at least one protrusion (30b) of respective through hole (13b) extends from a portion of the circumferential inner surface (14) facing an intended rotational direction (IRD) of the pressure control device (10b).

4. Pressure control device (10c) for controlling the flow of a pressure medium in a displacement pump (1) according to any one of the preceding claims, wherein respective through hole (13c) is defined by a circumferential inner surface (14), and wherein at least one protrusion (30) of respective through hole (13c) extends from a portion of the circumferential inner surface (14) facing away from an intended rotational direction (IRD) of the pressure control device (10c) and at least one protrusion (30b) of respective through hole (13c) extends from a portion of the circumferential inner surface (14) facing an intended rotational direction (IRD) of the pressure control device (10c).

5. Pressure control device (10, 10b, 10c) for controlling the flow of a pressure medium in a displacement pump (1) according to any one of the preceding claims, wherein at least one axial surface (11, 12) of the at least one protrusion (30, 30b) forms an essentially rectangular protrusion (30, 30b) with a width B1 in radial direction.

6. Pressure control device (10, 10b, 10c) for controlling the flow of a pressure medium in a displacement pump (1) according to any one of the preceding claims, wherein a first and second slot (31 ,32) are formed on a first and second radial side of the protrusion (30, 30b) and wherein the first and second slots (31, 32) form essentially rectangular indentations with a width B2 in radial direction.

7. Pressure control device (10, 10b, 10c) for controlling the flow of a pressure medium in a displacement pump (1) according to any one of the preceding claims, wherein the radial width B1 of the essentially rectangular protrusion (30, 30b) is essentially equal to the radial width B2 of the essentially rectangular first and second slot (31, 32) on the first and second side in radial direction of the protrusion (30, 30b).

8. Displacement control arrangement (5) comprising a control ring (3), a rear face of a pump unit (2a-2d) and a pressure control device (10) according to any one of claim 1 to 7, **characterized in that**:

the first axial surface (11) of the pressure control device (10) is fixedly arranged to an axial surface (400) of the rear face of a pump unit (2a-2d), and the second axial surface (12) of the pressure control device (10) is facing an axial surface (300) of the control ring (3), such that the pressure control device (10) is arranged between the rear face of a pump unit (6a-6d) and the control ring (3), and wherein

the rear face of a pump unit (6a-6d) and the pressure control device (10) are rotational symmetrically arranged about the first rotational axis (ax1), and the control ring (3) is provided with at least a first and a second opening (35, 36) on the axial surface (300) of the control ring (3), which first and second openings (35, 36) are formed as semi-circular arcs and are separated by a first and a second land (33, 34), and wherein the control ring (3) further is rotational symmetrically arranged about a second rotational axis (ax2), wherein

the second rotational axis (ax2) is radially offset by a distance E in relation to the first rotational axis (ax1), and is arranged in parallel to the first rotational axis (ax1).

9. Displacement control arrangement (5) according to claim 8, wherein when the control ring (3) is positioned for 100% displacement the through holes (13) of the pressure control devices (10) are passing over the first land (33) and are fully covered by the first land (33) during a first predetermined angular distance (AD), and
when the control ring (3) is positioned for 0% displacement the through holes (13) of the pressure control devices (10) are passing over the first land (33) and are fully covered by the first land (33) during a second predetermined angular distance (AD2), wherein the first predetermined angular distance (AD1) is longer than the second predetermined angular distance (AD2).

10. Displacement control arrangement (5) according to any one of claims 8 or 9, wherein the pressure control device (10) is an integrated part of the rear face of a pump unit (6a-6d).

11. Displacement control arrangement (5) according to any one of claims 8 to 10, wherein the first and second openings (35, 36) has a radial width B3, and wherein B3 is essentially equal to the width B1 of the protrusions (30, 30b).

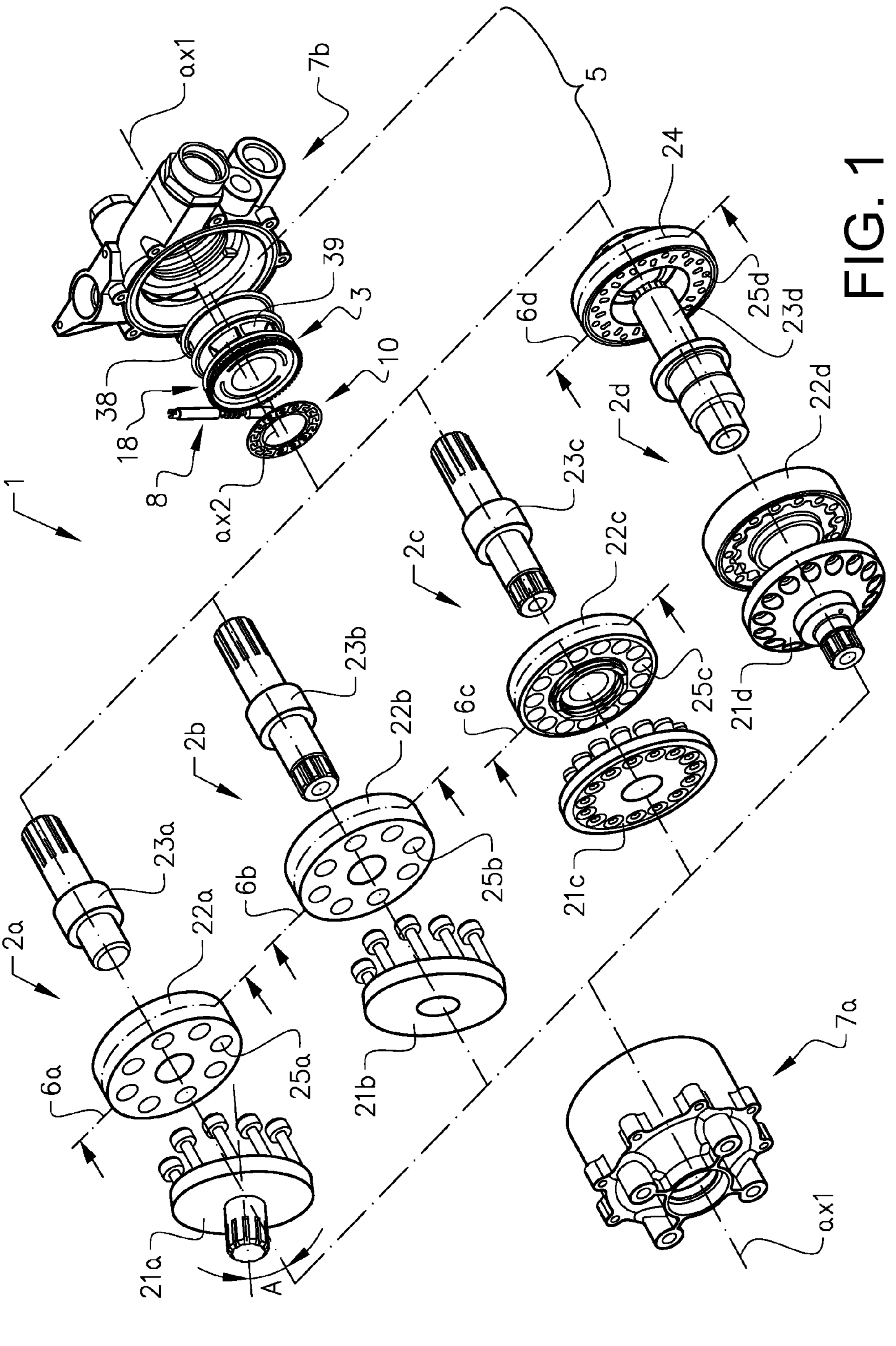
12. Displacement control arrangement (5) according to any one of claims 8 to 11, wherein the rear face of a pump unit (6a-6d) comprises a number of pressure chambers (25a-25d) mouthing to the axial surface (400) of the rear face of the pump unit (6a-6d), wherein the number of pressure chambers (25a-25d) are equal to the number of through holes (13) of the pressure control device (10).

13. Displacement control arrangement (5) according to

any one of claims 8 to 12, wherein the radial offset E between the first rotational axis (ax1) and the second rotational axis (ax2) is essentially equal to the width B1 of the protrusions (30, 30b).

14. Displacement control arrangement (5) according to any one of claims 8 to 13, wherein respective pressure chamber (25a-25d) has a first radial cross-sectional area (RA1) and respective through hole (13) has a second radial cross-sectional area (RA2), and wherein the first radial cross-sectional area (RA1) is essentially equal to a second radial cross-sectional area (RA2) of respective through hole (13).

15. Pumping arrangement (1) comprising a pump unit (2a-2d) and a displacement control arrangement (5) according to any one of claims 8 to 14, wherein the pump unit (2a-ad) comprises a cylinder plate (22a-22d), wherein the cylinder plate (22a-22d) in turn comprises the rear face of a pump unit (6a-6d), a swashplate (21a-21d), an axis 23a-23d and a housing (7a, 7b), wherein the housing in turn comprises a front housing (7a) and a rear housing (7b), and wherein the housing (7a, 7b)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2a
2b
2c
2d
3
5
6a
6b
6c
6d
7a
7b
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10
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21c
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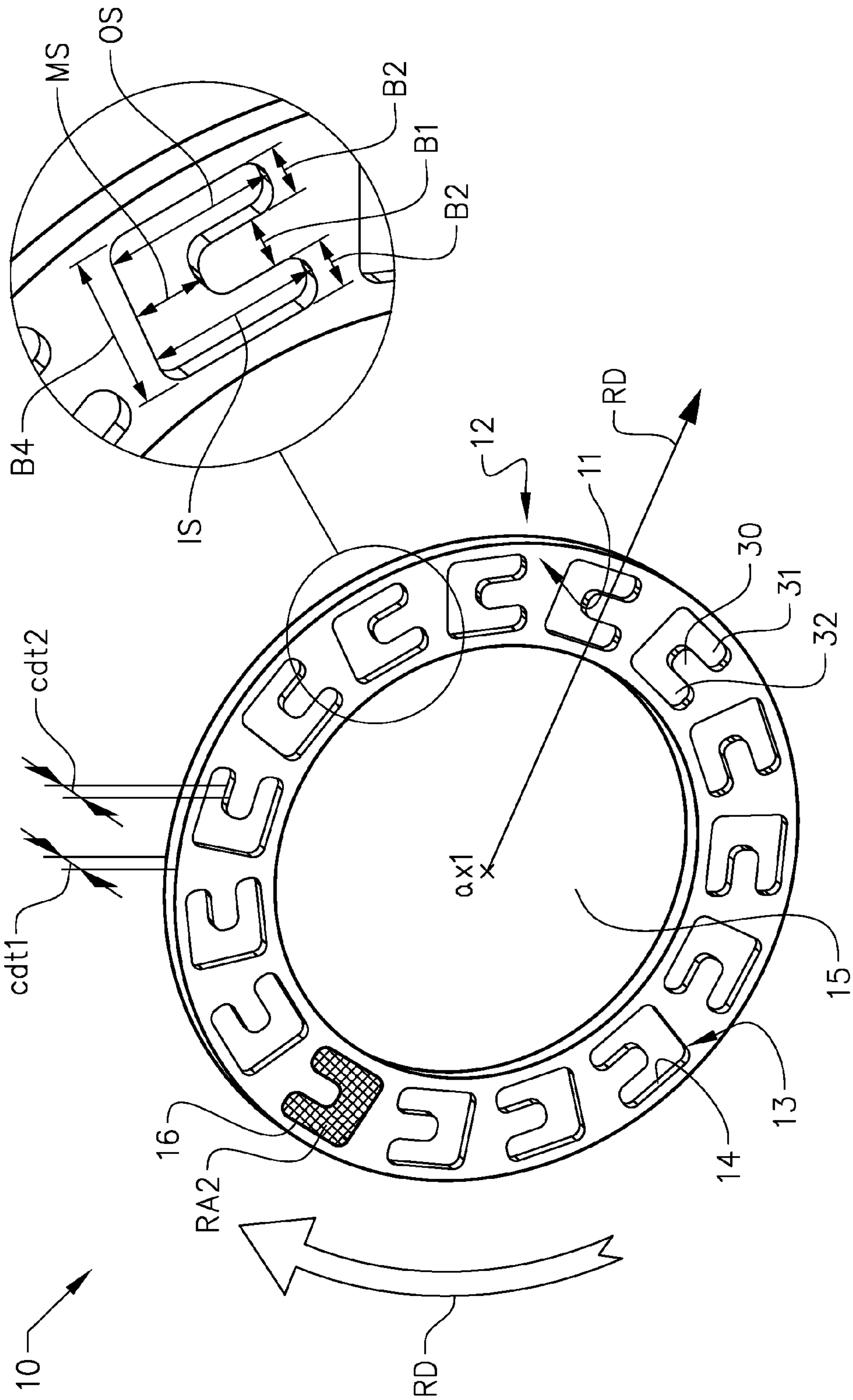
A
ax1
ax2

FIG. 1



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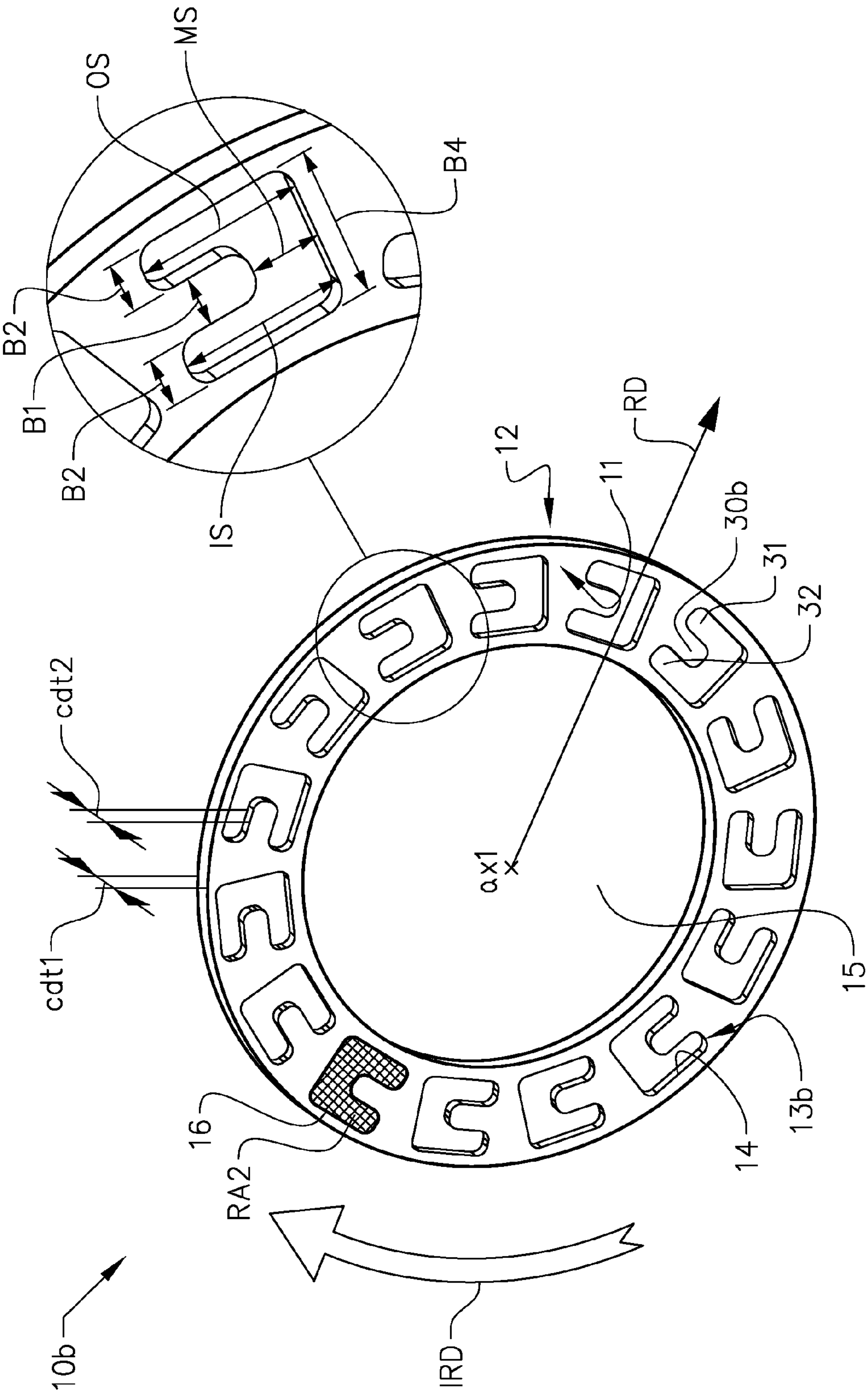
IRD
RA2
16
14
13
15
ax1
cdt1
cdt2
B4
IS
MS
OS
B2
B1
B2
12
11
RD
30
31
32

FIG. 2a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cdt2
14
13b
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RD
12
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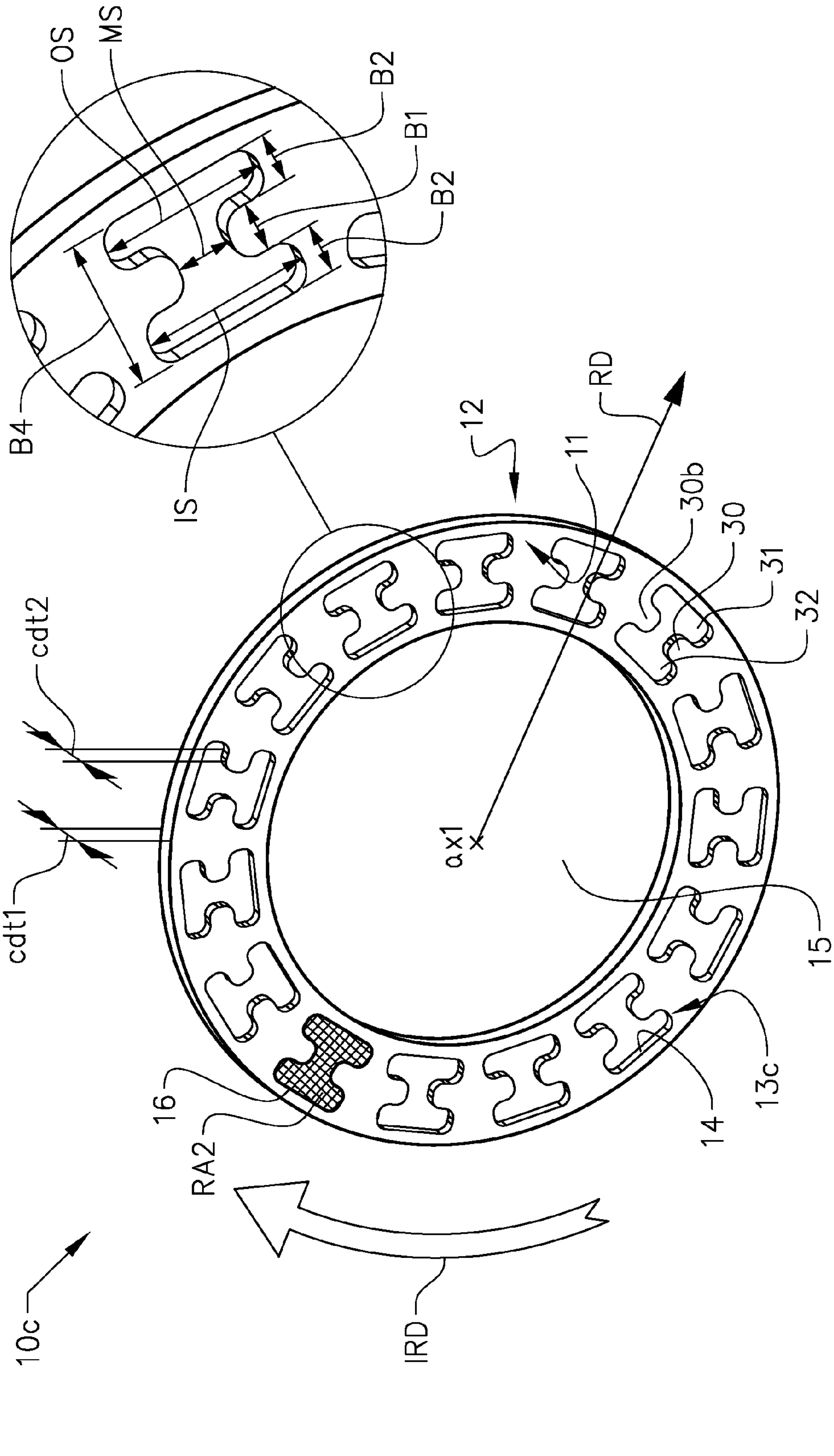
B1
B2
OS
MS
B4

FIG. 2b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IS
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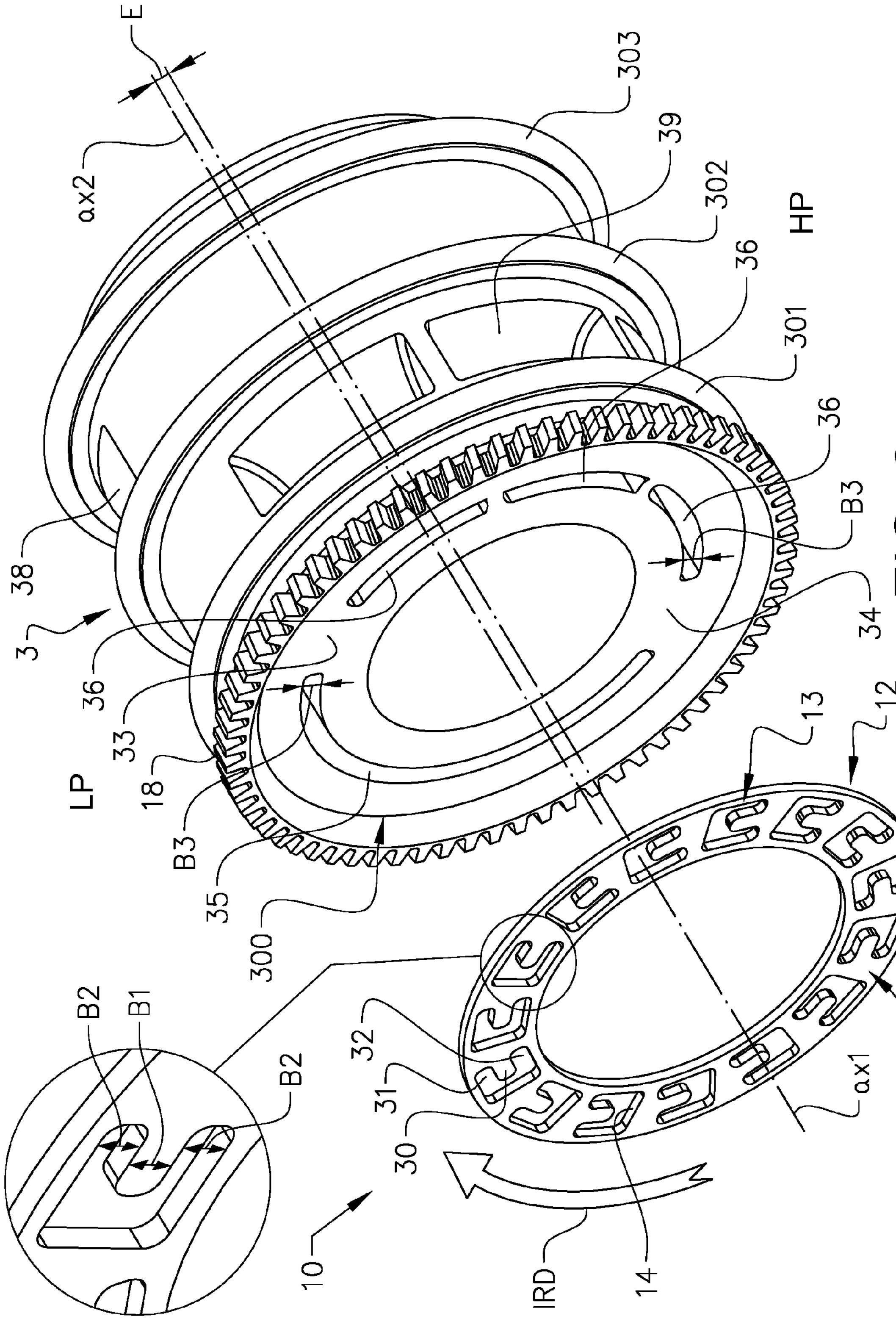
B2
B1
B2

FIG. 2c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αx2
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302
HP
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301
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18
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300
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13
12
11
αx1
32
31
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14
IRD
10
B2
B1
B2

FIG. 3

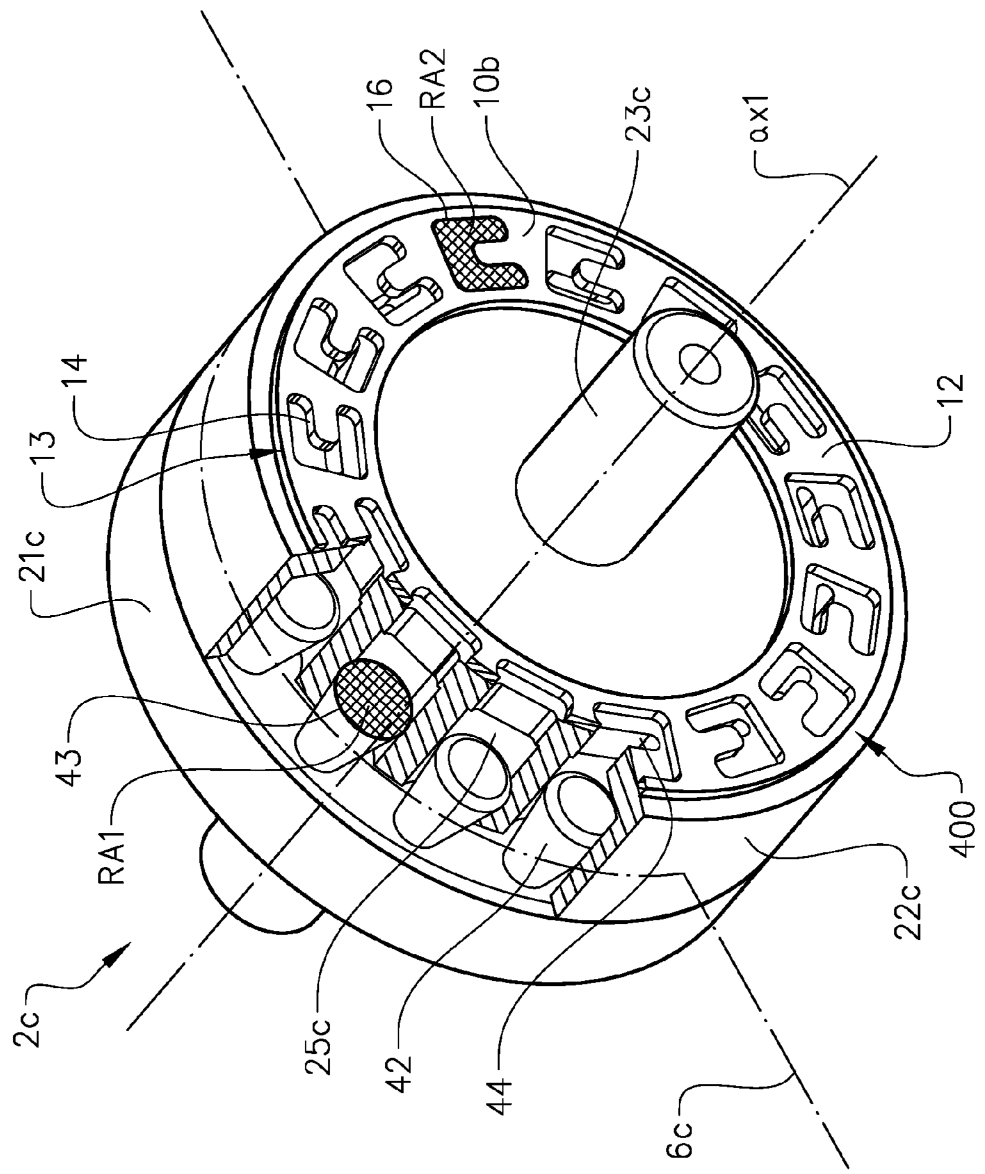
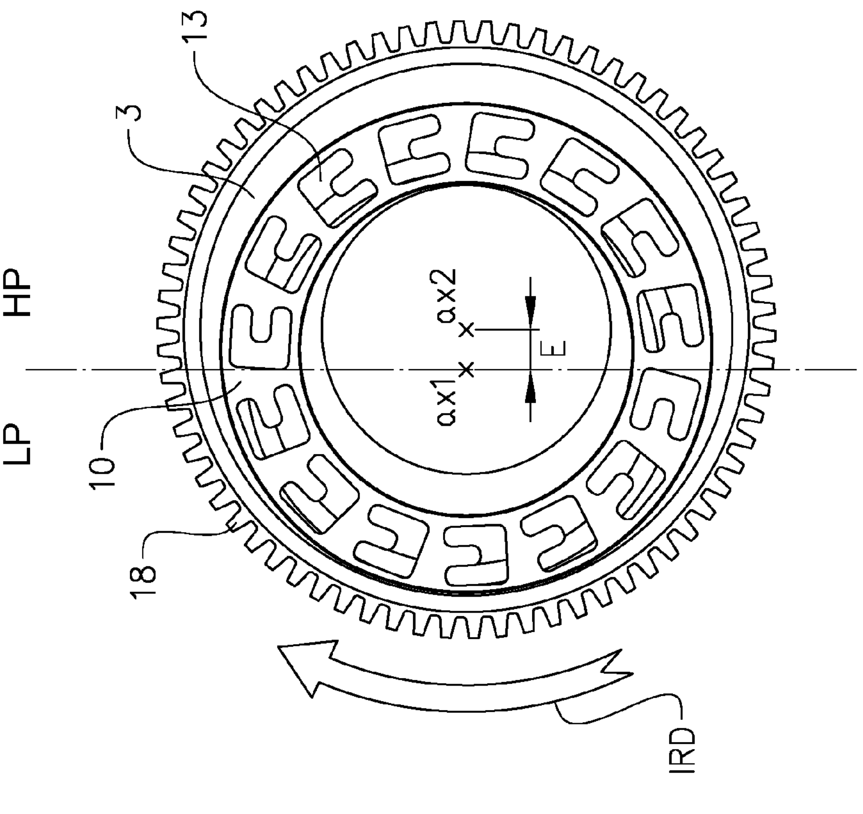


FIG. 4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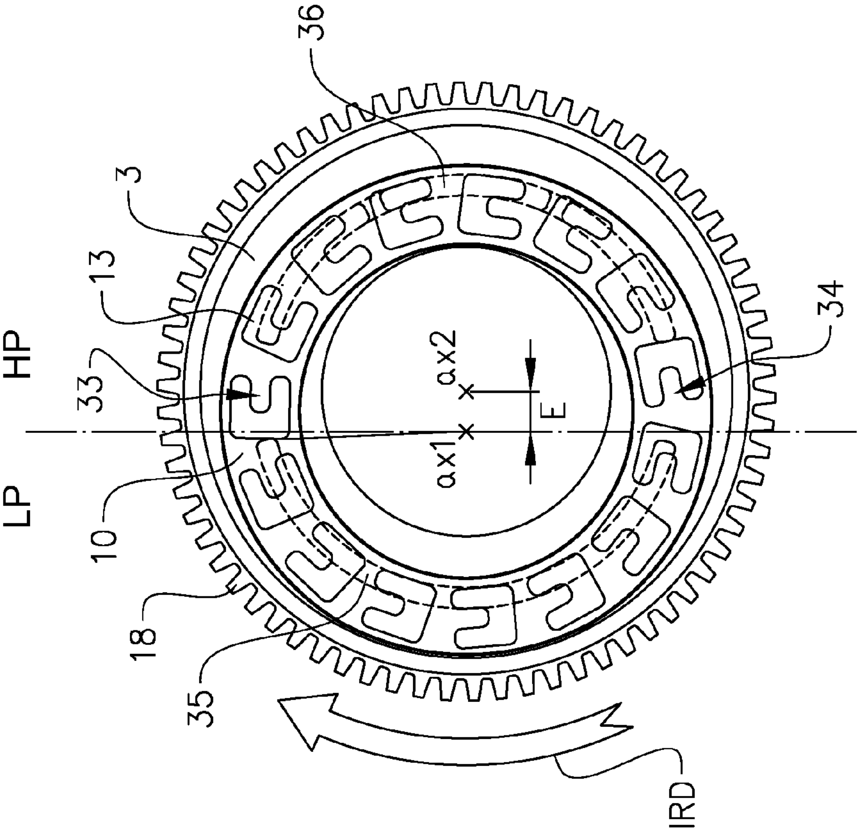
10
18
ax1
ax2
E
IRD

FIG. 5a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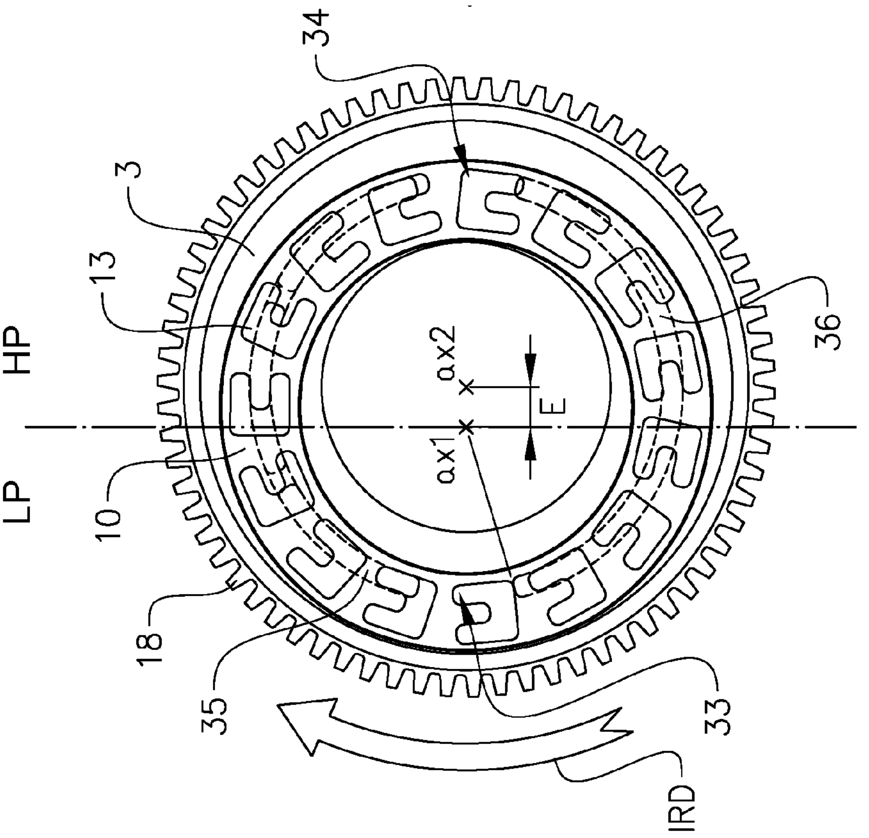
35
34
ax1
ax2
E
IRD

FIG. 5b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HP
LP
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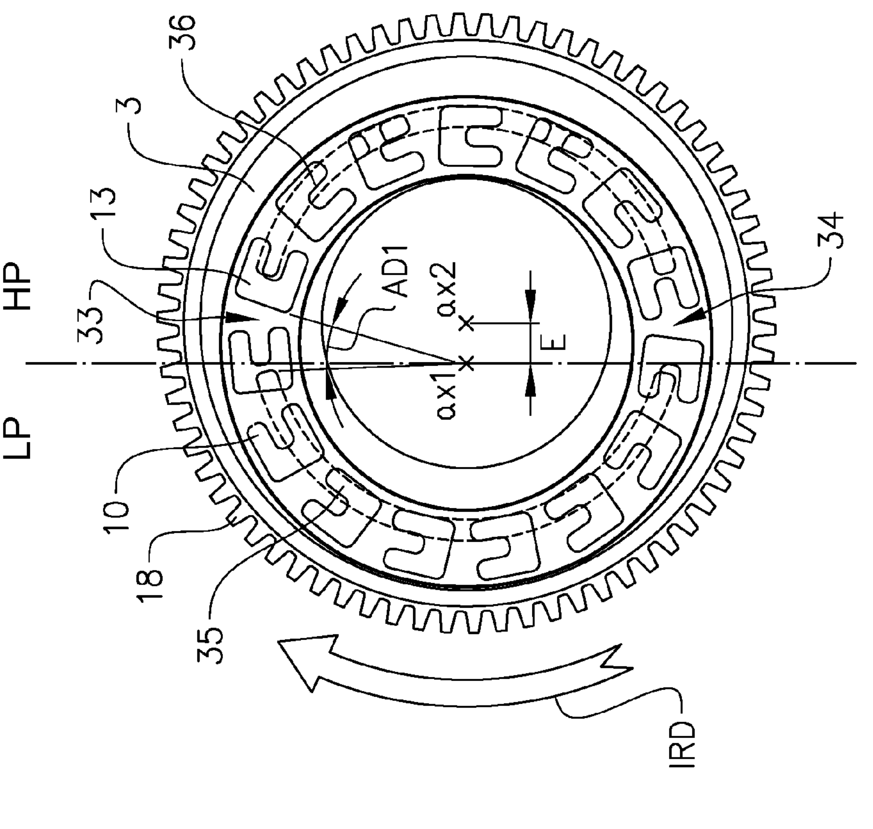
αx2
αx1
E
36
33
IRD

FIG. 5d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HP
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αx1
E
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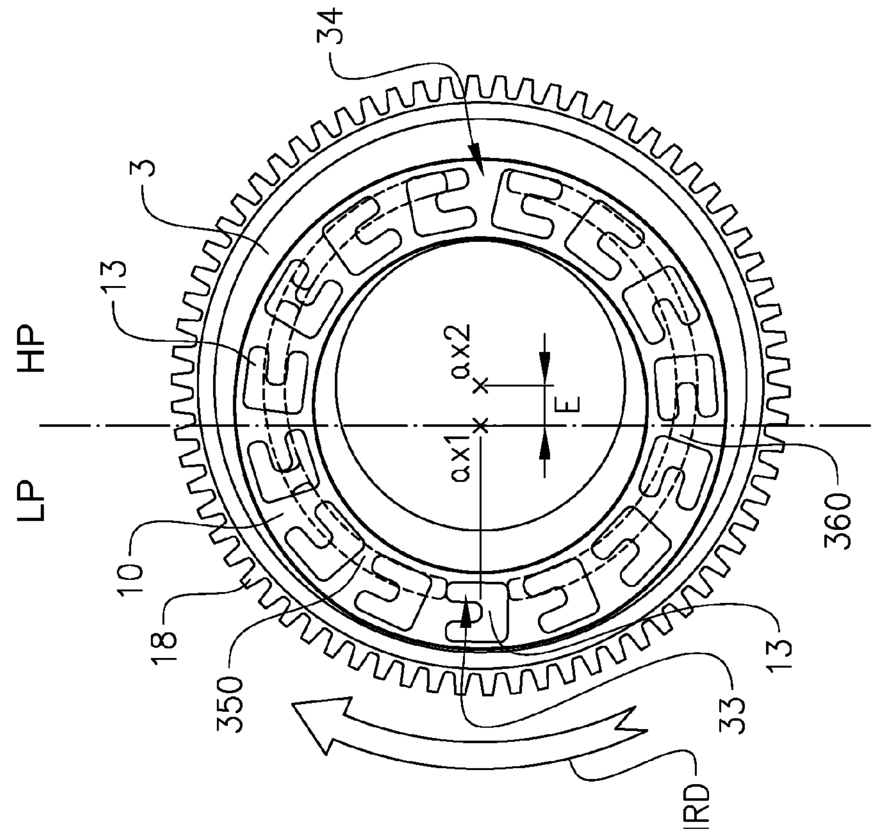
18
35
34
IRD

FIG. 5c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HP
LP
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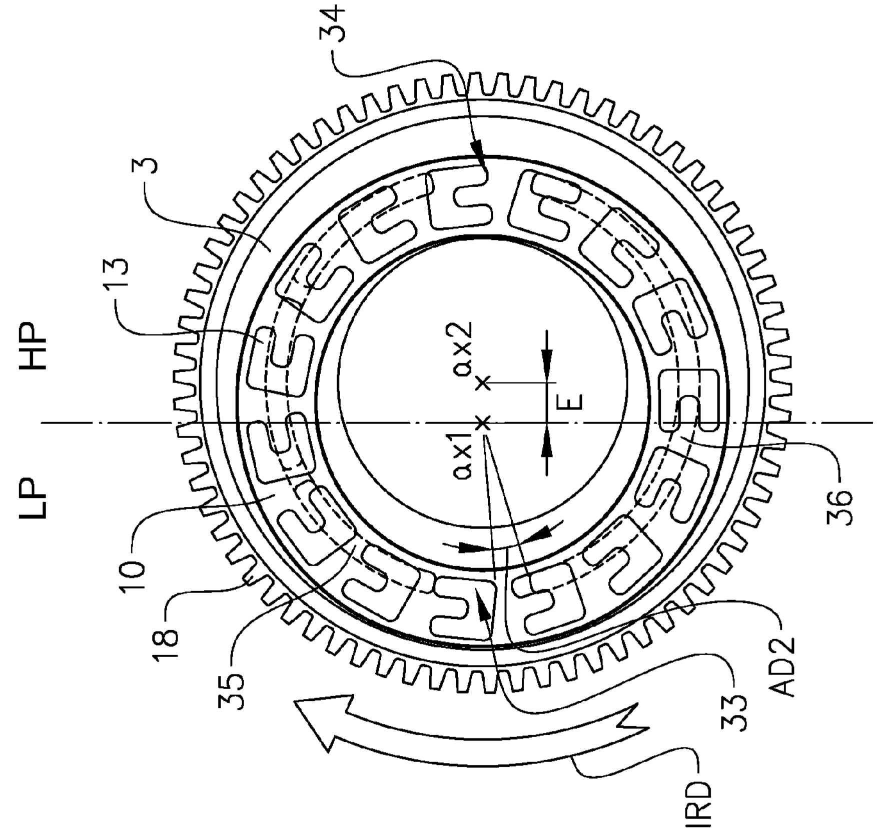
13
360
IRD
ax1
ax2
E

FIG. 5f


34
3
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HP
LP
10
18
35
33
AD2
36
IRD
ax1
ax2
E

FIG. 5e

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EUROPEAN SEARCH REPORT

Application Number
EP 15 18 7889

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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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F04B
F01B
F03C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 March 2016	Pinna, Stefano

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