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(54) **ENERGY TRANSFORMATION DEVICE AND PUMP AND MOTOR UTILISING SAID DEVICE**

(57) An energy transformation device comprising a rotary part, a non-rotary part, and a fluid running between said parts, where the rotary part includes a compartment that accommodates the non-rotary part, the compartment has a bottom wall and a circumferential perimeter with a curvature defined by a periodic function having maxima and minima, the non-rotary part comprises a partition arranged traversing a first point on the curvature and an opposite second point on the curvature, a manifold having a first manifold part and a second manifold part arranged on opposite sides of the partition, which manifold parts have respective at least one fluid inlet and/or at least one fluid outlet, which partition in response to rotation of the rotary part delimits an intake pressure chamber and an outlet pressure chamber when the maxima and minima of the curvature of the rotary part pass by an end of the partition.

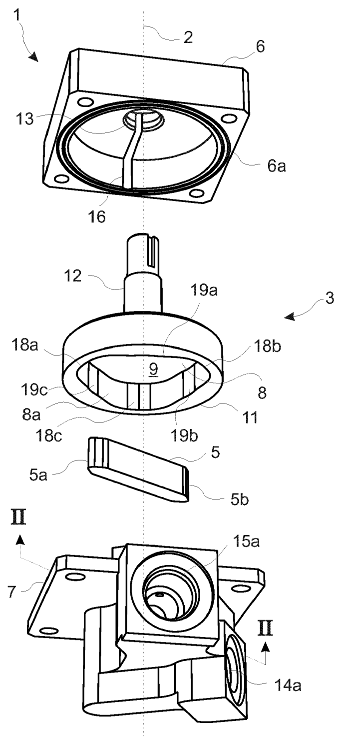

Fig. 1a

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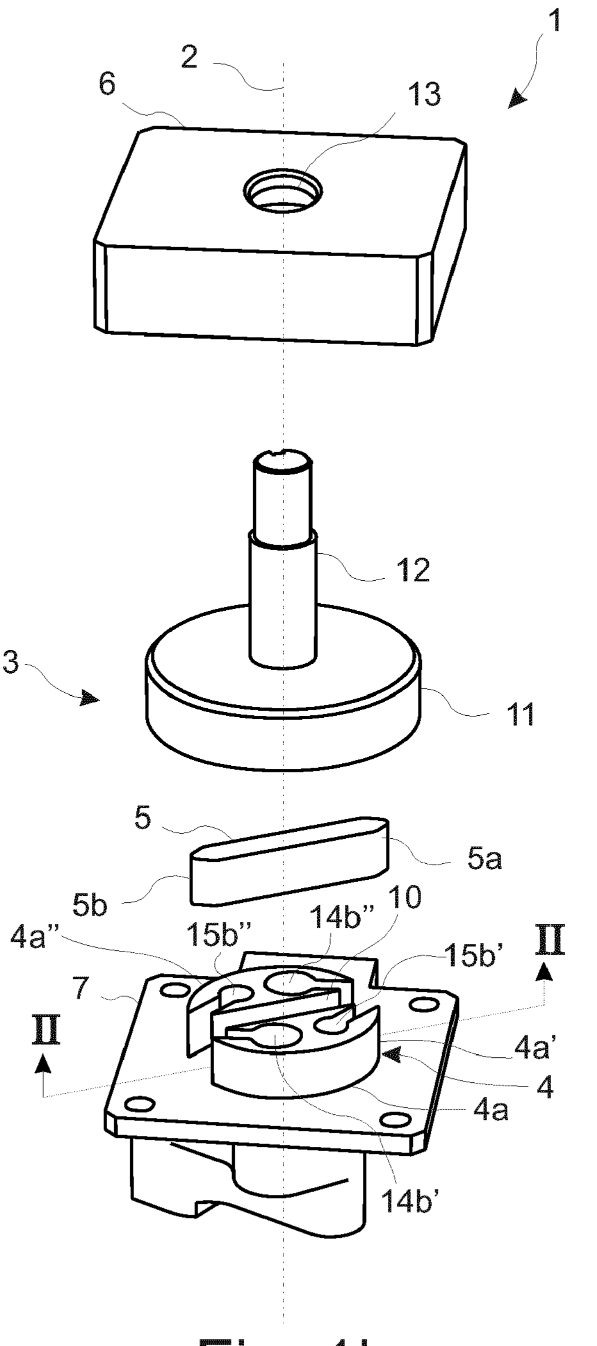

Fig. 1b

Description

[0001] The invention relates to an energy transformation device adapted for transferring a fluid, where the energy transformation device comprises a rotary part, and a non-rotary part.

[0002] Energy transformation devices, which are simple and low cost, like e.g. external gear pumps, generate a high level of noise (95 decibel and above is not impossible) partly due to cavitations, which can also destroy surfaces inside the pump or motor. Designs that generate less noise and less or no cavitations are more complex and costly to produce. In addition, known hydraulic pump and motor designs are relatively large in size.

[0003] Robotics is the technology dealing with the design, construction, and operation of robots in automation. Such robot arms have become increasingly popular and common in the industry to use in manufacturing processes, like shaping, loading CNC mills, assembling or packing products. Due to the vicinity between man and machine, low noise level is important.

[0004] The latest robot arm systems have classical structural design, and use strain wave gears as actuators. However, these arms are still relatively bulky, and heavy, which are not advantageous in the close proximity of man and machine. In addition, the robot arms are hardly affordable for small and medium-sized enterprises.

[0005] Efforts to improve the external gear pumps and minimize cavitation and noise have been made. For example, the external gear pump Silence Plus from Bosch Rexroth AG, Stuttgart, Germany has curved and helical gears, which minimizes the voids at the points the gears meshes and thereby lowers cavitation. However, these added features also makes this pump more challenging to produce and more expensive than a ordinary gear pump, as the helical features increases the production costs, along with a reduction in the maximum pressure generated by the pump.

[0006] In addition, gear pumps can due to the meshing of gears be damaged by pumping solids, especially large solids. When solids are present in the fluid they may act as abrasives, causing damage to the gears and increasing downtime.

[0007] Some energy transformation devices such as vane pumps or vane motors with vanes on a rotational shaft positioned eccentrically inside a more or less circular or elliptical cavity use centrifugal force or springs to maintain contact between the vanes and the inside walls of the cavity. The centrifugal force or the spring presses the vanes against the wall creating a fluidly tight contact. When the rotating speed of the vanes drops under a certain limit the contact between the vanes and the wall cannot be maintained by the centrifugal force or the springs. That means an energy transformation device that does not work well at low speeds or low revolutions per minute and cannot pump small amounts of fluids. Examples of such pumps or motors are obtainable from e.g. Permco, Streetsboro, OH, USA.

[0008] In other energy transformation devices such as axial piston pumps or motors, a rotating shaft with an oblique plate or cam plate, where the oblique plate upon rotation will drive circular arranged pistons to move within cylinders pumping fluid. Valves to open up for fluids to enter and leave the cylinders are necessary. That means a complicated, expensive and bulky energy transformation device. Examples of such pumps or motors are obtainable from e.g. Bosch Rexroth AG, Stuttgart, Germany.

[0009] Each piston in the axial piston pumps or motors can only transfer fluid one way at the time either out of the its cylinder or into its cylinder. When a cylinder is totally full or totally empty there is no transfer of fluid at all.

[0010] The drawbacks and disadvantages of the above-mentioned prior art energy transformation devices such as hydraulic or pneumatic transformation devices, pumps, or motors are according to the invention remedied by,
in a first aspect providing a low-noise energy transformation device,
in a second aspect providing an energy transformation device that when operated produce a very low level of pulsations or vibrations with high amplitudes,
in a third aspect, providing an energy transformation device in form of a pump or motor that has a simple construction and is produced at a low cost,
in a fourth aspect, providing an energy transformation device in form of a pump or motor that is reliable and durable,
in a fifth aspect, providing an energy transformation device in form of a lightweight pump or motor,
in a sixth aspect, according to the invention, providing an energy transformation device in form of a pump or motor that does not produce cavitations,
in a seventh aspect, according to the invention, providing an energy transformation device in form of a pump that can pump solids, and
in an eighth aspect, providing an energy transformation device in form of a pump or motor that is compact.

[0011] The novel and unique features according to the invention whereby these and other aspects are achieved consist in the fact that

- the rotary part includes a compartment that accommodates the non-rotary part,
- the compartment has a bottom wall and a first circumferential perimeter with a first curvature defined by a periodic function having first maxima and first minima,
- the non-rotary part comprises

- at least one partition arranged traversing a first point on the first curvature and an opposite second point which second point is located on any of

    - the first curvature,
    - a second curvature of a second circumferential perimeter, where the second curvature is defined by a periodic function having second maxima and second minima,
    - a second curvature of a second circumferential perimeter without second maxima and second minima, or
    - the non-rotary part, and

- a manifold having a first manifold part and a second manifold part arranged on opposite sides of the at least one partition, which manifold parts have respective at least one fluid inlet and/or at least one fluid outlet,

- which at least one partition in response to rotation of the rotary part delimits an intake pressure chamber and an outlet pressure chamber when the first maxima and the first minima of the first curvature of the rotary part pass by an end of the at least one partition.

[0012] Within the scope of the present invention, the term energy transformation device means a device that is able to transform rotational energy to kinetic energy of a flowing fluid and/or vice versa. Due to the technical features of the energy transformation device this can be achieved in an energy transformation device that is produced at a low cost, is compact, has small energy losses in the transformation process, and does not produce much vibrations, pulsations of fluid, and noise during use.

[0013] The fluid can be a liquid like e.g. hydraulic fluid or air or a gas like e.g. pneumatic fluid.

[0014] The invention contemplates to provide embodiments comprising just a first curvature, embodiments comprising first and second curvatures and embodiments comprising first and second curvatures, where at least one of the curvatures have periodic functions having maxima and minima.

[0015] The periodic function of the first curvature and the periodic function of the second curvature can have a periodicity corresponding to one revolution of the rotary part or corresponding to the distance between first maxima and second maxima, respectively.

[0016] A first maximum and a first minimum of the first curvature of the first perimeter mean a relative maximal and minimal distance from the centre of the rotation axis of the rotary part, respectively.

[0017] A second maximum and a second minimum of the second curvature of the second perimeter mean a relative minimal and maximal distance from the centre of the rotation axis of the rotary part, respectively.

[0018] With only a first curvature, when the first point on the first curvature being a first maximum preferably the second point on the first curvature is a first minimum, and vice versa. With both a first curvature and a second curvature, when the first point on the first curvature being a first maximum preferably the second point on the second curvature is a second minimum, and vice versa. The advantage is that both the first point and the second point will guide the partition in the same direction reducing energy losses.

[0019] The first manifold part and a second manifold part can be arranged to form a groove to guide the at least one partition to move longitudinally but not rotationally relative the manifold. The depth of the groove and the height of the at least one partition can be the same and correspond to the height of the first circumferential perimeter and/or the second circumferential perimeter to seal the pressure chambers from each other and/or to seal one end of a pressure chamber from another end of the same pressure chamber.

[0020] The energy transformation device comprises the rotary part with the compartment accommodating the partition and the manifold with the fluid inlet and fluid outlet. That means few items that all are simple and economical to mill. To mill the rotary part so that the compartment has a first circumferential perimeter with a first curvature defined by a periodic function or a first and second curvature defined by a periodic function is also simple and economical. The partition just has to have the length corresponding to the distance across the compartment of the rotary part so that the partition traverses two opposite points of the first curvature or of the first curvature and the second curvature. The manifold with the fluid inlet and outlet is also simple to fabricate. There is no need for advanced and hard-to-produce 3D curvatures that are bent and curved at the same time like e.g. the curved and helical gears in the external gear pump Silence Plus from Bosch Rexroth AG mentioned above. In addition, the number of complicated sharp inward corners - like e.g. between the teeth in a gear wheel, where the angle and distance have to be correct - is reduced. The corner between the bottom wall and the first circumferential perimeter and/or second circumferential perimeter of the compartment of the rotary part is a sharp inside corner but that corner is technically simple to mill. The parts of the energy transformation device are simple to fabricate and can be produced at a low cost.

[0021] The fluid is transferred from the fluid inlet into the intake pressure chamber between the manifold and a first maximum of the first curvature or between the manifold and a second maximum of the second curvature. The intake pressure chamber becomes during rotation an outlet pressure chamber that transfers the fluid into the fluid outlet without compression of the fluid during the process. No compression of the fluid means small losses in energy in the process of transferring the fluid. Of course, if there is a certain pressure on the fluid outlet side that has to be achieved then the energy transformation device has to transfer the fluid against that pressure, which will involve some compression. But there is no inherent compression due to the design of the energy transformation device as it is in a gear pump, where fluid is compressed between the teeth where the two cogwheels engage with each other. In addition, the energy transformation device will cause little or no cavitation, since there is no or only an inferior drop in pressure that will create the voids. That means less noise as well as less damage and wear on the parts in the energy transformation device.

[0022] The lack or reduced level of compression and meshing of gears also mean that the energy transformation device as a pump is excellent in transporting fluids comprising solids like food.

[0023] The first circumferential perimeter of the compartment of the rotary part has a first curvature with a periodic function, or the first circumferential perimeter has a first curvature with a periodic function and the second circumferential perimeter has a second curvature with a periodic function, where the two periodic functions can have the same angular frequency, have the same amplitude, and be 180° out phase with each other. The at least one partition is placed in the manifold and the rotary part can move around the stationary manifold and the partition. The partition traverses the compartment between two opposite points of the first curvature or of the first curvature and the second curvature, so that the length of the partition is dimensioned so that both ends of the partition abuts each their opposite point of the first curvature or of the first curvature and the second curvature and so that both ends of the partition and the two opposite points of the first curvature or of the first curvature and the second curvature create fluidly tight seals. That both ends of the at least one partition creates fluidly tight seals means an energy transformation device that can accurately transfer even very small amounts of fluid compared to e.g. a vane pump or motor using centrifugal force to maintain contact between the vanes and the inside walls of the cavity. Another advantage is that each end of the partition can be used to transfer fluid into the intake pressure chamber and out of the outlet pressure chamber of the energy transformation device. So one partition is used to transfer fluid in two places, which means an energy transformation device that is compact and has a high energy density compared to an axial piston pump or motor.

[0024] Thus by arranging the at least one partition so that the opposite ends of said at least one partition point on a first point and an opposite second point of the first curvature or on a first point of the first curvature and on an opposite second point of the second curvature the volume of the intake pressure chamber and the outlet pressure chamber is changed and adjusted so as to provide a smooth transfer of the fluid so that extremely little or no noise at all is produced when the rotary part rotates around the non-rotary part. Moreover the repetition of first curvature and/or the second curvature with the periodic function ensures that the energy transformation device operates in a consistent manner.

[0025] The first curvature and/or the second curvature will during motion displace the at least one partition to reciprocate within the manifold, which means that just a small mass, the mass of the partition, is moved reciprocatingly in a simple, repeating movement. Since both ends of the partition are arranged traversing two opposite points of the first curvature or of the first curvature and the second curvature, there is no fluid pushed in front of the partition i.e. between the partition and the first curvature and/or the second curvature, so there is no fluid that has to be compressed causing energy losses.

[0026] The non-rotary part of the energy transformation device according to the present invention can comprise at least one partition arranged traversing a first point on the first curvature and an opposite second point on a second curvature of a second circumferential perimeter, where the second curvature e.g. can be a circle. The energy transformation device with such a non-rotary part can be produced at a low cost.

[0027] The non-rotary part of the energy transformation device according to the present invention can comprise at least one partition arranged traversing a first point on the first curvature and an opposite second point on the non-rotary part. The energy transformation device with such a non-rotary part can be produced at a low cost.

[0028] The rotary part can have a shaft, a cogwheel, a wheel for a cog or notched belt, or magnetic means to transfer the rotation of the rotary part outside of the energy transformation device. A shaft attached to the centre of the rotary part will e.g. transfer the rotational movement of the rotary part out of the energy transformation device. The rotational movement of the rotary part can e.g. also be transferred by a magnetic liquid rotary mechanism like Ferrofluidic seals made by the Ferrotec Corporation, Santa Clara, CA, USA. The skilled person will understand how this is done and will also understand that there might be other ways to transfer the rotation of the rotary part outside of the energy transformation device. If the rotary part has a shaft the shaft can be placed eccentrically on the rotary part e.g. enabling that the rotational movement of the rotary part can be transformed to a longitudinal movement.

[0029] If the non-rotary part comprises at least three or preferably at least four partitions arranged traversing at least three or at least four first points on the first curvature and at least three or at least four opposite second points on the second curvature defined by a periodic function preferably having second maxima and second minima, the at least three or at least four partitions can be angularly unevenly distributed. The advantage is that the pressure chambers can open up to or connect to the fluid inlet or fluid outlet at different times distributing any vibrations and/or pulsations due to flow of fluid between the pressure chambers and the fluid inlet or fluid outlet evenly during one revolution of the rotary part. Evenly distributed vibrations and/or pulsations will make the rotation of the energy transformation device very smooth and gentle.

[0030] The non-rotary part can comprise at least three or preferably at least four partitions arranged traversing at least three or at least four first points on the first curvature having at least four, preferably at least five and more preferably at least six first maxima and at least three or at least four opposite second points on the second curvature defined by a periodic function preferably having at least four, preferably at least five and more preferably at least six second maxima and at least four, preferably at least five and more preferably at least six second minima. With many partitions and maxima/minima the output of fluid in response to one revolution of the rotary part will be high. Each maximum can form a pressure chamber. This embodiment with many pressure chambers will have the advantage that the effect of compression of fluids, particularly pneumatic fluids, can be minimised, which will increase the precision of the output of the energy transformation device.

[0031] In an embodiment according to the invention, the first curvature substantially can circumscribe the second curvature.

[0032] With the first curvature substantially circumscribing the second curvature, the first and second curvatures can be substantially concentric.

[0033] With the first curvature substantially circumscribing the second curvature an energy transformation device with a high torque, when used as e.g. a motor and with a high output of fluid per revolution of the rotary part when used as e.g. a pump.

[0034] In an embodiment according to the invention, the compartment can have an overall triangular outline or can have an overall annulus shape.

[0035] With an overall triangular outline of the compartment, there is not necessarily a second curvature. The curvature surrounding the overall triangular compartment is still called first curvature for consistency's sake even though there is no second curvature.

[0036] A triangular outline of the compartment with one partition can correspond to that there are three pressure chambers angularly displaced from each other. Of the three pressure chambers one or two can each be parted by the partition in an intake pressure chamber and an outlet pressure chamber. Into the intake pressure chamber(s) and out of the outlet pressure chamber(s) there can flow fluid. With a triangular outline, which means that the angular displacement between the pressure chambers can be more or less 120°, the transfer of fluid will be substantially constant causing only low amplitude vibrations and little noise. That means, if the energy transformation device is used as a pump, the pumping will be constant or substantially constant or, if the energy transformation device is used as a motor, the torque will be constant or substantially constant.

[0037] The transfer of fluid will be substantially constant because with an overall triangular outline of the compartment the three pressure chambers are more or less evenly angularly distributed so that when the transfer of fluid into one intake pressure chamber decreases the transfer of fluid into another intake pressure chamber increases with the same amount and when the transfer of fluid out of one outlet pressure chamber decreases the transfer of fluid out of another outlet pressure chamber increases with the same amount and vice versa. The substantially constant transfer of fluid means pulsations in the overall flow of fluid are substantiallyeliminated.

[0038] The compartment can alternatively have an overall annulus shape or ring shape with a first circumferential perimeter with a first curvature defined by a periodic function having first maxima and first minima, and a second circumferential perimeter with a second curvature defined by a periodic function having second maxima and second minima. That means that both the first circumferential perimeter and the second circumferential perimeter can have curvatures defined by a periodic function having maxima and minima.

[0039] With an annulus-shaped compartment, the at least one partition arranged traversing two opposite points of the first curvature and the second curvature, respectively, can be arranged traversing two opposite points of the curvature of the first circumferential perimeter and of the second circumferential perimeter, respectively.

[0040] With an overall annulus shape of the compartment several partitions can be arranged angularly spaced apart inside the annulus-shaped compartment. With each extra partition the pumping efficiency and pumping outlet are increased. Each partition can be positioned inside the compartment in a radial direction from the rotation axis of the rotary part. That means short partitions with little mass, which reduces energy losses, since the reciprocating movement of the partitions due to the maxima and minima of the first and second curvatures means continual acceleration and retardation of the partitions.

[0041] In the embodiment with the compartment having an overall annulus shape, the manifold can comprise sub-manifolds, where the manifold can be accommodated in the compartment having an annulus shape. The annulus-shaped manifold can have at least one set of a respective first manifold part and a respective second manifold part arranged on opposite sides of each of the at least one partition, which set of manifold parts can have respective at least one fluid inlet and/or at least one fluid outlet, and where each set of manifold parts is a sub-manifold. Each of the at least one partition with surrounding manifold parts and at least one fluid inlet and at least one fluid outlet can then function as its own more or less independent energy transformation device within the overall energy transformation device.

[0042] Many partitions will enable an energy transformation device, when used e.g. as a pump, with substantially constant pumping, low amplitude vibrations and pulsations as well as a very high output compared to the rotational speed of the rotary part, and an energy transformation device when used e.g. as a motor, with an even rotation of the rotary part and a high torque.

[0043] The annulus-shaped compartment can be supplemented by one or more other annulus-shaped compartments preferably all of the annulus-shaped compartments being concentric, where at least one, preferably all, of the other annulus-shaped compartments can have the above-mentioned features of the annulus-shaped compartment. Such an energy transformation device will have, when used e.g. as a pump, substantially constant pumping, even lower amplitude vibrations and pulsations and even higher output compared to the rotational speed of the rotary part, and when used e.g. as a motor, an even rotation and even higher torque.

[0044] The one or more other annulus-shaped compartments can have more maxima and minima as well as correspondingly more fluid inlets and fluid outlets the further away from the centre the one or more other annulus-shaped concentric compartments are situated. That will further increase the amount of transported fluid when the energy transformation device is used as a pump and of the torque whenenergy transformation device is used as a motor.

[0045] In an embodiment of the invention, the first curvature of the first circumferential perimeter and/or the second curvature of the second circumferential perimeter can be a closed curve or two opposite closed curves.

[0046] With the first curvature and/or the second curvature being (a) closed curve(s) the rotary part can continuously keep on to rotate in the same direction and does not need to shift direction. The positions of the pressure chambers as delimited by the ends of the partitions are well-defined, as well.

[0047] With the first curvature and the second curvature being two opposite closed curves as for the annulus embodiment, many partitions with each their sub-manifold with fluid inlet and fluid outlet can be positioned in the annulus compartment resulting in an even rotation and a very high torque if the energy transformation device is used e.g. as a motor or in substantially constant pumping, low amplitude vibrations and a very high output compared to the rotational speed if the energy transformation device is used as e.g. a pump.

[0048] In an embodiment of the present invention, at least a part of the first curvature and/or the second curvature can include a sine and/or a cosine curve, which will enable the at least one partition to be moved or controlled smoothly and gently without the risk of having the at least one partition and the rotary part to get stuck. The sine and/or cosine curve can alter the first curvature and/or the second curvature from e.g. a simple circle into a wave curvature or undulate curvature that might or might not be closed to provide repeated and consistent transmission of energy.

[0049] The sine and/or cosine curve can be understood as superpositioned on top of a circle or alternatively on top of another shape. The geometrical outline, around which the sine and/or cosine curve describing the first curvature and/or the second curvature is/are positioned, can be defined as the outline of a circle or alternative thereto.

[0050] The first curvature and/or the second curvature can also be a pure sine or cosine curve, or modifications of such regarding period, and amplitude.

[0051] With the first curvature and/or the second curvature being a pure sine or pure cosine curve the inclinations of the first curvature and/or the second curvature between the maxima and minima are not so steep compared to first curvature and/or the second curvature having plateaus. Less steep inclinations mean that the partition or partitions will move more smoothly causing less friction and less energy loss.

[0052] In an embodiment of the invention, the at least one of the first maxima and/or second maxima and/or first minima and/or second minima can have a plateau or a plateau can be arranged at the peak of at least one of the first maxima and/or second maxima and/or a plateau can be arranged at the bottom of at least one of the first minima and/or second minima.

[0053] A plateau will eliminate that pressurized fluid from one pressure chamber passes over to another pressure chamber causing ripples in the overall pumping of the fluid.

[0054] The plateau can preferably have a length corresponding to the width of a fluid outlet and/or inlet. In that case, in that moment when the rotary part in its rotation around the non-rotary part has a plateau positioned opposite a fluid outlet or a fluid inlet both ends of the plateau will seal with the opposite edges of the mouth of the fluid outlet or fluid inlet. One of the opposite edges of the mouth of the fluid outlet or fluid inlet can be the end of the partition.

[0055] The plateau can preferably have a length corresponding to the 60% of the width of a fluid outlet and/or fluid inlet, preferably 70% of the width of a fluid outlet and/or fluid inlet, more preferably 80% of the width of a fluid outlet and/or fluid inlet, and most preferably 90% of the width of a fluid outlet and/or fluid inlet. Even though the plateau does not have a length corresponding to the whole width of a fluid outlet and/or fluid inlet, the ripples in the overall pumping of the fluid and pulsation can be almost totally eliminated.

[0056] If the plateau is narrower than the width of a fluid outlet or fluid inlet, there will be a position of the rotary part relative the non-rotary part, where the plateau is positioned opposite that fluid outlet or fluid inlet without sealing any of the edges of the mouth of that fluid outlet or fluid inlet. In this situation, fluid can flow from one pressure chamber through the opening between the one edge of the mouth of that fluid outlet or fluid inlet and the corresponding edge of the plateau via that fluid outlet or fluid inlet and through the opening between the other edge of the mouth and the corresponding other edge of the plateau into the next pressure chamber. When there is such a fluid contact there might be a pressure equalising between the two pressure chambers causing ripples in the overall fluid transfer, and although such embodiments are within the scope of the present invention they may be less preferred in such application.

[0057] In an embodiment of the invention, the at least one partition can have tapered ends and/or rounded ends, or tapered and asymmetric ends.

[0058] Tapered ends can cause the contact between the at least one partition and the first curvature and/or the second curvature of the rotary part to be well-defined and consequently simpler to seal. In addition, tapered ends will increase the volume of the pressure chambers and the amount of transferred fluid as well as lower the friction between the ends of the at least one partition and the first curvature and/or between the ends of the at least one partition and the second curvature.

[0059] With rounded edges of the ends of the partitions, the length of the at least one partition will not decrease as fast due to wear compared to a partition without rounded edges. Rounded edges will also mean better sealing ability between a partition and the first curvature of the rotary part and/or between a partition and the second curvature of the rotary part.

[0060] With the at least one partition having tapered and asymmetric ends the fluid can more easily be transferred out of the outlet pressure chamber and into the at least one fluid outlet. Asymmetric ends of a partition will be especially useful for pumping fluid with solids, since the flow of fluid and solids out of the outlet pressure chamber and into the at least one fluid outlet will be enhanced so that solids will not get stuck between the partition and the first curvature of the rotary part and/or between the partition and the second curvature of the rotary part.

[0061] In an embodiment of the invention, the at least one partition can include two partition parts in elongation of each other and mutually connected by means of a spring member, or the at least one partition can be biased by a spring.

[0062] With a spring member in between the two partition parts or with two spring members acting on each partition part, maybe independently, the duration of life of the partition can be even more extended.

[0063] With a spring member in between the two partition parts, the distance between two opposite points of the first curvature of the first perimeter and/or the second curvature of the second perimeter of the compartment does not need to be constant, which makes production of the rotary part simpler and more economical.

[0064] When using a partition with a spring member in between the two partition parts in a compartment having an overall triangular outline, the first minima and/or the second minima can preferably have plateaus. The first maxima and/or the second maxima can be without plateaus. For the fluid outlet(s) and fluid inlet(s) to be sealed so that fluid cannot pass from one pressure chamber to another pressure chamber in a compartment having an overall triangular outline, it is the first minima of the first curvature that can have plateaus, preferably with a width corresponding to the width of the mouths of the fluid outlets and fluid inlets. With the first maxima being without plateaus the first maxima can be made higher/deeper, increasing the volume of the pressure chambers and the overall fluid transfer per revolution.

[0065] When using a partition with a spring member in between the two partition parts in a compartment having an overall annulus shape, the first minima of the first curvature of a first perimeter and the second minima of the second curvature of a second perimeter can have plateaus.

[0066] Alternatively, the first maxima of the first perimeter and/or the second maxima of the second perimeter can be without plateaus.

[0067] For the fluid outlets and fluid inlets to be sealed so that fluid cannot pass from one pressure chamber to another pressure chamber in a compartment having an overall annulus shape, it is the first minima of the first curvature of the first perimeter and the second minima of the second curvature of the second perimeter that can have plateaus, preferably with a width corresponding to the width of the mouths of the fluid outlets and fluid inlets.

[0068] With the first maxima of the first perimeter and the second maxima of the second perimeter being without plateaus the first maxima of the first perimeter and the second maxima of the second perimeter can be made higher/deeper, increasing the volume of the pressure chambers and the overall fluid transfer per revolution.

[0069] When using a partition biased by a spring in a compartment having an overall annulus shape, the second circumferential perimeter can be without the second maxima and second minima. Such a rotary part can be produce very easily and at a low cost. More fluid is transferred at the first maxima and first minima of the first curvature than at the second maxima and second minima of the second curvature in an energy transformation device having an annulus compartment.

[0070] In an embodiment of the invention, the compartment can have a constant diameter or the compartment with an annulus shape can have a constant radial width.

[0071] That the diameter of the compartment with an overall triangular shape can be constant means that the diameter can be the same for all diameters across the compartment irrespective of the angle position of the rotary part.

[0072] That the width of the compartment with an overall annulus shape can be constant means that the width across the annulus or the radial width across the annulus can be the same for all such widths across the compartment irrespective of the angle position of the rotary part.

[0073] Generally, the at least one partition can move between two opposite points of the first curvature or of the first curvature and the second curvature, respectively. To keep up the energy transformation between the rotational energy of the rotary part and the kinetic energy of the running fluid using a partition of a fixed length, both ends of the partition have to contact opposite points of the first curvature or of the first curvature and the second curvature, respectively, during a whole revolution and thus the distance between opposite points for all opposite points has to be the same. That is equivalent to that a first maximum of a certain height at one point of the first curvature is arranged opposite a first minimum or second minimum of the same depth at the opposite point of the first curvature or second curvature, respectively. If there is e.g. a first maximum of the first curvature at one end of the at least one partition there can be a corresponding first minimum or second minimum of the first curvature or second curvature, respectively, at the other end of the at least one partition. A plateau e.g. at the first maximum then can mean that the corresponding first minimum or second minimum has a plateau of the same length or width. A partition of a fixed length is simple to fabricate and mass-produce, and to provide as a spare part.

[0074] The compartment can have a constant diameter or crosswise width even though there are first maxima and/or second maxima and first minima and/or second minima. That requires that a first maximum of the first curvature at one point of the first curvature of the rotary part be arranged opposite an opposite first minimum of the first curvature with the same depth/height and the same width, and vice versa. Accordingly, the radial distance between the first point on the first curvature and the opposite second point on the first curvature is substantially constant.

[0075] The compartment with an annulus shape can have a constant width even though there are first maxima, second maxima, first minima and second minima. That requires that a first maximum of the first curvature be arranged opposite an opposite second minimum of the second curvature with the same depth/height and the same width, and vice versa.

[0076] The advantage of having a constant diameter or crosswise width of the compartment or a constant width of the compartment with an annulus shape is that both ends of each of the partition(s) will always be able to create a fluidly tight seal with the first circumferential perimeter and/or the second circumferential perimeter. With a constant diameter of the compartment or a constant width of the annulus, there is no need to part the partition in two with a spring in between, in order to seal. That makes a reliable construction and a partition that can be produced at a low cost.

[0077] In an embodiment of the invention, the length of the at least one partition can correspond substantially to the constant diameter or the constant width.

[0078] Such a partition is able to create fluidly tight seals with the first circumferential perimeter and/or the second circumferential perimeter at both ends of the partition.

[0079] In an embodiment of the invention, the first curvature can have at least three first maxima and at least three first minima and/or the second curvature can have at least three second maxima and at least three second minima.

[0080] Already with three first maxima and/or three second maxima and three first minima and/or three second minima there can be a constant flow of fluid from the fluid inlet to the fluid outlet even with only one partition. That will be a reliable construction that can be produced at a low cost. A constant flow causes less turbulence, friction and noise, which mean a more efficient energy transformation device, such as a pump or a motor.

[0081] With more than three first maxima and three second maxima and three first minima and three second minima and with more than one partition the flow can still be constant and the transferred fluid will be higher, since each partition with its corresponding at least one fluid inlet and at least one fluid outlet contributes to the transferral of fluid.

[0082] With a compartment having an overall annulus shape, the number of partitions is ideally even and the number of first maxima and the number of second maxima (as well as the number of first minima and the number of second minima) is 1.5 times the number of partitions. That will give a constant flow of fluid and more partitions will result in a higher flow of fluid per revolution of the rotary part.

[0083] As an example an external motor e.g. an external engine or electric motor with a low revolution per time unit will normally hardly be able to drive a conventional pump to pump a high amount of fluid, however this can be achieved by using e.g. the external electric motor to drive the energy transformation device in form of a pump of the present invention with many partitions and number of maxima and minima.

[0084] In another example, the energy transformation device of the present invention, when used as a motor driven by fluid, has many partitions and a large number of maxima. Such an energy transformation device in the form of a motor will have a high torque compared to fluid-driven conventional motors of the same size. Using such a motor of the present invention, it will also be possible to control the angular position of the outgoing shaft connected to the rotary part to a very high degree.

[0085] In an embodiment of the invention, the at least one fluid inlet can be larger than the at least one fluid outlet.

[0086] Suction of fluid under atmospheric conditions is limited since the pressure difference between the inlet and the outlet of the associated device such as e.g. the pump housing in which the energy transformation device of the present invention operates can never be higher than one atmosphere. The amount of fluid that can be transported into e.g. a pump will therefore be limited by the physical dimensions of the tube on the suction side or intake side of the pump.

[0087] If e.g. the energy transformation device according to the present invention is to be used as, in or for a pump it can be advantageous to design the fluid inlet as big as possible even at the expense of the fluid outlet. On the other hand, a too small fluid outlet will result in a pressure drop over the fluid outlet requiring more energy to operate or drive the energy transformation device. The ideal ratio between the sizes of the fluid inlet and of the fluid outlet may in some embodiments be a compromise.

[0088] The ideal ratio between the sizes for the actual situation can easily be determined by tests and trials.

[0089] The energy transformation device of the present invention may be modified in that the non-rotary part includes the compartment so that the rotary part is accommodated in the non-rotary part, and the compartment has a bottom wall and a first circumferential perimeter with a first curvature defined by a periodic function having first maxima and first minima is substituted by the compartment has a bottom wall and the rotary part has a first circumferential perimeter with a first curvature defined by a periodic function having first maxima and first minima.

[0090] This energy transformation device is a variation of and an alternative to the energy transformation device described above, implementing same technical features and with the same advantages like no cavitations, low production costs and being very compact compared to the output of fluid per time unit.

[0091] The invention also relates to a pump for driving a fluid comprising the energy transformation device of the present invention as defined above arranged in a pump housing having a pump inlet connected to the fluid inlet of the energy transformation device and a pump outlet connected to the fluid outlet of said energy transformation device, and a rotary shaft to rotate the rotary part in relation to or relative the non-rotary part.

[0092] Such a pump will be quiet, efficient, reliable, compact and lightweight. Such a pump will also pump fluid substantially or even completely without producing cavitations and noise.

[0093] To reduce leakage of fluid in the gap between the surface of the manifold and/or the partition and the surface of the rotary part preferably the bottom wall of the rotary part between the at least one fluid inlet and the at least one fluid outlet and between the intake pressure chamber and the outlet pressure chamber, a plate preferably fastened to the manifold, can be positioned between the manifold and the rotary part. Another advantage by incorporating the plate between the manifold and the rotary part is that the plate will minimise or eliminate the axial pressure from the fluid outputs and/or the fluid inputs acting on the rotary part in the axial direction away from the fluid outputs and/or the fluid inputs causing friction between the rotary part and the housing, thereby reducing said friction.

[0094] The invention also relates to a motor for driving a rotary shaft comprising the energy transformation device of the present invention as defined above, which energy transformation device being arranged in a motor housing having a pump outlet connected to the fluid inlet of the energy transformation device and a pump inlet connected to the fluid outlet of said energy transformation device, and a rotary shaft driven by the rotary part in relation to or relative the non-rotary part.

[0095] Such a motor will be quiet, efficient, reliable, compact and lightweight. Such a motor will also drive the shaft substantially or even completely without producing cavitations and noise inside the motor.

[0096] To reduce leakage of fluid in the gap between the surface of the manifold and/or the partition and the surface of the rotary part, preferably the bottom wall of the rotary part between the at least one fluid inlet and the at least one fluid outlet, and between the intake pressure chamber and the outlet pressure chamber, a plate, preferably fastened to the manifold can be positioned between the manifold and the rotary part. Another advantage by incorporating the plate between the manifold and the rotary part is that the plate will minimise or eliminate the axial pressure from the fluid outputs and/or the fluid inputs acting on the rotary part in the axial direction away from the fluid outputs and/or the fluid inputs causing friction between the rotary part and the housing, thereby reducing said friction.

[0097] The invention will be explained in greater details below, giving further advantageous features and technical effects and describing exemplary embodiments with reference to the drawing, in which

Fig. 1a shows an exploded perspective view of an embodiment of the invention in the form of a first energy transformation device seen from below,

Fig. 1b shows the same seen from above,

Figs. 2a - d show a sectional view of the first energy transformation device taken along line II - II in Fig. 1b,

Fig. 3a is a graph illustrating the variation in flow of fluid out of the first and second inlets, respectively, or alternatively into the first and second outlets, respectively,

Fig. 3b shows an assembled sectional view of the first energy transformation device shown in Figs. 2a - d with an asymmetrical partition,

Fig. 4a shows an exploded perspective view of an embodiment of the invention in the form of a second energy transformation device seen from below,

Fig. 4b shows the same seen from above,

Figs. 5a to 5d show an assembled sectional view of the second embodiment of the energy transformation device taken along line V - V in Figs. 4a and 4b, and

Figs. 6a and 6b show a modified version of the first energy transformation device.

[0098] In the perspective, exploded views of Figs. 1a and 1b, the first energy transformation device 1 is shown from two different angles. In Fig. 1b the first energy transformation device 1 has also been rotated approximately 180° around a rotational axis 2 compared to Fig. 1a to show all sides of the first energy transformation device 1.

[0099] The first energy transformation device 1 comprises a rotary part 3 adapted to rotate around the rotational axis 2, a manifold 4, a partition 5 with two ends 5a,5b, as well as a first 6 and a second 7 housing part. The manifold 4 is integral with the second housing part 7.

[0100] The rotary part 3 has a compartment 8 with a rim 8a defining a first curvature 8a with an overall triangular outline or shape having first maxima 18a,18b,18c and first minima 19a,19b,19c. In this embodiment of the invention the term "first curvature" does not require that there is a "second curvature". The compartment 8 has a bottom wall 9.

[0101] The partition 5 is positioned in a groove 10 of the manifold 4. The partition 5 can be arranged longitudinally movable in other ways than by means of the groove 10. E.g. the bottom wall 9 of the compartment 8 can have a ridge fitting into a groove in the partition 5.

[0102] In operative conditions, the partition 5 can move in the groove 10 longitudinally but not rotationally in relation to or relative the manifold 4. During use the manifold 4 and the partition 5 are positioned in the compartment 8, as shown in Figs. 2a - d.

[0103] The height of the partition 5 can be substantially the same as the depth of the groove 10 and can be substantially the same as the depth of the compartment 8 so that fluid cannot flow between the partition 5 and the bottom wall 9 of the compartment 8, or the bottom of the groove 10 except for the thin film of fluid that can be used and/or normally is used as lubrication between the parts inside the energy transformation device.

[0104] The rotary part 3 has an outer circular shape 11 and a shaft 12 extending from the bottom wall 9 of the rotary part 3 away from the compartment 8. The outer circular shape 11 and the shaft 12 are concentric around the rotational axis 2.

[0105] The first 6 and the second 7 housing parts together with an O-ring 6a form a fluidly tight cavity enclosing the rotary part 3 except the shaft 12, the manifold 4 and the partition 5.

[0106] The distance across the compartment 8 through the rotational axis 2 is always substantially and completely the same. The length of the partition 5 corresponds to this distance across the compartment 8, so that the ends 5a and 5b of the partition 5 each creates a fluidly tight connection with the first curvature 8a irrespective of the relative rotational position between the rotary part 3 and the partition 5.

[0107] The ends 5a,5b of the partition 5 are advantageously tapered and rounded. That the ends 5a,5b are tapered provides well-defined borders between the ends 5a,5b and the first curvature 8a that will give a more reliable fluid tightness. That the ends 5a,5b are rounded means that the ends 5a and 5b create fluidly tight connections with the first curvature 8a even after long time of use and wear. Rounded ends 5a,5b can also have the advantage of improving the sealing between the ends 5a,5b and the first curvature 8a.

[0108] The rotation of the rotary part 3 is transferred out of or into the first energy transformation device 1 by the shaft 12 through an opening 13 in the first housing part 6. There maybe bearings and seals (not shown) between the shaft 12 and the first housing part 6.

[0109] The second housing part 7 comprises an inlet connector 14a and an outlet connector 15a fluidly connected to first 14b' and second 14b" inlets and first 15b' and second 15b" outlets, respectively.

[0110] The inlet connector 14a and outlet connector 15a can be connected to external pipes or external connectors in a fluidly tight way.

[0111] The direction of the fluid through the first energy transformation device 1 can be reversed, which is especially useful if the first energy transformation device 1 is used as a motor so that the motor can rotate in both directions. When the direction of the fluid is reversed, the inlet connector 14a and the first 14b' and second 14b" inlets become the outlet connector 14a and the first 14b' and second 14b" outlets, and the outlet connector 15a and the first 15b' and second 15b" outlets become the inlet connector 15a and the first 15b' and second 15b" inlets.

[0112] The first housing part 6 may have a groove 16 so that fluid can lubricate between the first housing part 6 and the rotary part 3. The groove 16 will also drain any superfluous fluid away from the shaft 12 and lower the pressure around the shaft 12 reducing the risk that the sealing (not shown) between the first housing part 6 and the shaft 12 breaks. The skilled person will understand how to feed the groove with lubrication fluid. Preferably, the lubrication fluid can be the fluid, which is driven by, or the fluid to drive the energy transformation device, preferably the hydraulic fluid if the fluid is hydraulic fluid.

[0113] In The enlarged sectional views of Figs. 2a - 2d for the energy transformation device 1 taken along line II - II in Fig. 1b is shown for different positions of the rotary part 3, and consequently also for the partition 5.

[0114] Figs. 2a - 2d show the first housing part 6, the rotary part 3, the manifold 4 and the partition 5 in an assembled view to illustrate the pumping action when rotating the rotary part 3 or the rotational action of the rotary part 3 when pumping fluid between the inlet connector 14a and the outlet connector 15a.

[0115] In the sequence of drawings shown in Figs. 2a to 2d the rotation of the rotary part 3 is clockwise around the stationary manifold 4 of the stationary non-rotary part.

[0116] When assembled, the compartment 8 is divided in three pressure chambers - a first 17a, a second 17b, and a third 17c pressure chamber - which each, during rotation of the rotary part 3, establishes and ends fluid connection with the first 14b' and second 14b" inlets and the first 15b' and second 15b" outlets.

[0117] Flow of fluid in through the inlet connector 14a and the first and second inlets 14b',14b" and out through the first and second outlets 15b',15b" and the outlet connector 15a will cause the rotary part 3 to rotate and vice versa. Flow of fluid in the reverse direction will cause the rotary part 3 to rotate in the opposite direction and vice versa.

[0118] As shown in Fig. 2a, the first pressure chamber 17a has a fluid connection with the second outlet 15b" and the volume of the combined first pressure chamber 17a and second outlet 15b" is about to decrease in size. At the same time the first pressure chamber 17a is just about to establish a fluid connection with the first inlet 14b'.

[0119] In the position shown in Fig. 2b the rotary part 3 has rotated approximately 45° clockwise compared to the position shown in Fig. 2a. At the same time the partition 5 has moved upwards with the orientation of the drawing following the changes of the positions of the first maxima 18a,18b,18c and the first minima 19a,19b,19c of the first curvature 8a. Of course both ends 5a,5b of the partition 5 still have fluidly tight connections with the first curvature 8a so that fluid cannot flow between the partition 5 and the first curvature 8a.

[0120] The first pressure chamber 17a is divided by the partition 5 in two parts, which are the of the first pressure chamber's first part 17a' and of the first pressure chamber's second part 17a".

[0121] A first combined volume of the first pressure chamber's first part 17a' and the second fluid outlet 15b" in the position shown in Fig. 2b is smaller than a second combined volume of the first pressure chamber 17a and the second outlet 15b" in the position shown in Fig. 2a. If the energy transformation device is used as a pump the difference in fluid volume of the first combined volume and the second combined volume has been forced or pumped out of the energy transformation device as fluid. If the energy transformation device is used as a motor the difference in fluid volume of the first combined volume and the second combined volume has forced the rotary part 3 to rotate the approximately 45° between the positions shown in Figs. 2a and 2b.

[0122] At the same time, the combined volume of the first pressure chamber's second part 17a" and the first inlet 14b' in the position shown in Fig. 2b is larger than the volume of just the first inlet 14b' in Fig. 2a.

[0123] The fluid that was in the first pressure chamber 17a in the position shown in Fig. 2a has in the position shown in Fig. 2c been totally transported out of the compartment 8. In stead the first pressure chamber 17a in the position shown in Fig. 2c has been filled with fluid from the first inlet 14b'.

[0124] So there is a transport of fluid into the energy transformation device 1 and out of the energy transformation device 1 at the same time.

[0125] In the position shown in Fig. 2d the first pressure chamber 17a and the first inlet 14b' are fluidly disconnected from each other. There is no transport of fluid into or out of the first pressure chamber 17a between the positions shown in Figs. 2c and 2d.

[0126] The second pressure chamber 17b is not connected to any input or output in the position shown in Fig. 2a. In the position shown in Fig. 2b the second pressure chamber 17b has just established fluid connection with the first outlet 15b' but no fluid has been transported out of or into the second pressure chamber 17b between the positions shown in Figs. 2a and 2b.

[0127] In the position shown in Fig. 2c the second pressure chamber 17b is divided in a second pressure chamber first part 17b' and a second pressure chamber second part 17b" by the partition 5. Between the positions shown in Figs. 2b and 2c a little less and between the positions shown in Figs. 2b and 2d a little more than half of the fluid in second pressure chamber 17b has been transported out of the first outlet 15b'. At the same time fluid has been transported into the second pressure chamber's second part 17b" via the second inlet 14b".

[0128] Between the positions shown in Figs. 2a and 2b, the third pressure chamber 17c is filled via the second inlet 14b". The fluid in the third pressure chamber 17c is then moved to fluid connection with the second outlet 15b", as seen in Fig. 2d, through which eventually, but not shown in the sequence of Figs. 2a to 2d, the fluid leaves the third pressure chamber 17c.

[0129] It is clear that transportation of fluid into and out of the first 17a, second 17b and third 17c pressure chambers takes place at different times.

[0130] One example of a mathematical expression of the radius ($r(\theta)$) of the first curvature 8a in the embodiment having the overall triangular shape, where the numbers given can be in any length unit is:

$$r(\theta)=\begin{cases}27.0, 0° \le \theta < 20°,\\ (22.5+0.096+2.25)+2.25*\sin(4.5*\theta)+0.096*\cos(9*\theta), 20° \le \theta < 60°,\\ 22.5, 60° \le \theta < 80°, \text{ and}\\ (22.5+0.096+2.25)+2.25*\sin(4.5*(\theta-20°))+0.096*\cos(9*(\theta-20°)), 80° \le \theta < 120°.\end{cases}$$

[0131] The mathematical expressions of the radius for 120° ≤ θ < 240° and for 240° ≤ θ < 360° are repetitions of the radius for 0° ≤ θ < 120°.

[0132] Fig. 3a shows a first graph 20 that illustrates the variation in flow of fluid out of the first inlet 14b' as a function of the rotation of the rotary part 3 and a second graph 21 that illustrates the variation in flow of fluid out of the second inlet 14b" also as a function of the rotation of the rotary part 3. Alternatively, the first graph 20 shows the variation in flow of fluid into the first outlet 15b' and the second graph 21 shows the variation in flow of fluid into the second outlet 15b", respectively. Fig. 3a shows the variations in the flow of fluid during three full revolutions of the rotary part 3.

[0133] The variation in the flow of fluid from the first inlet 14b' is 180° out of phase compared to the variation in the flow of fluid from the second inlet 14b".

[0134] Likewise, the variation in the flow of fluid into the first outlet 15b' is 180° out of phase compared to the variation in the flow of fluid into the second outlet 15b".

[0135] The total flow of fluid into or out of the energy transformation device 1 according to the present invention is constant, or at least almost constant and shown by a third graph 22.

[0136] Fig. 3b shows the first energy transformation device 1 with the same sectional view and rotating in the same direction as shown in Figs. 2a - d but with a partition 23 having an asymmetrical profile. With the asymmetrical partition 23 fluid can be transferred out of the pressure chamber 24 and into the outlet 25 more easily and with less turbulence and resistance. The asymmetrical profile can comprise two convex shapes 26 at the ends of the partition. The convex shapes 24 direct the fluid into the outlet 25 further reducing fluid turbulence and flow resistance. With an asymmetrical partition 23 with asymmetrical ends 23a,23b, the plateau of the first minima and the first maxima of the first curvature of the rotary part can be made longer. Alternatively, with an asymmetrical partition 23 the width of an opening 25a of the outlet 25 and the width of an opening 27a of the inlet 27 are kept the same by positioning an edge 25b of the opening 25a of the outlet 25 further away from the partition 23 and by positioning an edge 27b of the opening 27a of the inlet 27 closer to the partition 23.

[0137] A second embodiment of the invention is shown in Figs. 4a, 4b as well as 5a - 5d.

[0138] Figs 4a and 4b show in an exploded perspective view the second energy transformation device 101 from two different perspectives. In Fig. 4b the first energy transformation device 101 has been rotated approximately 90° around a rotational axis 102 compared to Fig. 4a.

[0139] The second energy transformation device 101 comprises a first 106 and a second 107 housing part, which together enclose a rotary part 103, a non-rotary part 104 with a manifold 104a and six partitions 105.

[0140] The second housing part 107 has a circular opening 113 for a rotational shaft 112 attached to the rotary part 103. The shaft 112 and the circular opening 113 may be sealed to each other with seals (not shown).

[0141] Instead of the second housing part 107 having the circular opening 113, the circular opening 113 can be in the first housing part 106 and the shaft 112 is then on the other side of the rotary part 103. Alternatively, the rotary part 103 has shafts 112 on both sides and the first 106 and the second 107 housing part both have a circular opening 113 for each of the shafts 112.

[0142] The rotary part 103 has an outer circular shape 111.

[0143] The rotary part 103 has an overall annular compartment 108 with a first rim defining a first curvature 108a, a second rim defining a second curvature 108b and a bottom wall 109. The rotary part rotates around a rotational axis 102. The first curvature 108a and the second curvature 108b have wave-like curvature with a well-defined periodicity. The first curvature 108a and the second curvature 108b can have plateaus at the first maxima 118a and at the second maxima 118b and plateaus at the first minima 119a and at the second minima 119b. The angular periodicity of the two curvatures 108a,b are the same. The distance in the radial direction between the curvatures 108a,b is constant or substantially constant and corresponds to the length of the partitions 105, so that one end 105a of the partition 105 abuts the first curvature 108a and the other end 105b abuts the second curvature 108b.

[0144] Alternatively, each partition 105 is divided in two parts and has a spring in between (not shown). In that embodiment the distance in the radial direction between the first curvature 108a and the second curvature 108b does not need to be constant.

[0145] The second housing part 107 comprises a first connector 114a and a second connector 115a fluidly connected to a first opening 114b and a second opening 115b, respectively. The first opening 114b ends in a first circular groove 114c and the second opening 115b ends in a second circular groove 115c. The first circular groove 114c and the second circular groove 115c are concentric, or substantially concentric.

[0146] The second housing part 107 comprises a first O-ring 107a that seals against the first housing part 106. The second housing part 107 comprises second O-rings 107b that together with the manifold 104a seal so that fluid cannot flow directly between the first circular groove 114c and the second circular groove 115c, and cannot flow around the manifold 104a into the rotary part 103.

[0147] The manifold 104a of the second energy transformation device 101 comprises a flat first ring 104'. On one side of the first ring 104' and preferably integral with the first ring 104' there are six blocks 104b together forming a second ring 104c interrupted by six grooves 110 as well as a first 110a and a second 110b channel on each side of each groove 110.

[0148] The height of the partitions 105 can be substantially the same as the depth of the grooves 110 and can be substantially the same as the depth of the compartment 108 so that fluid cannot flow between the partitions 105 and the bottom wall 109 of the compartment 108, or the bottom of the groove 110, except for the thin film of fluid that can be used and/or normally is used as lubrication between the parts inside the energy transformation device 101.

[0149] The number of blocks 104b can be fewer or more than six. The number of grooves 110 and partitions will of course decrease or increase, too, as well as the number of first maxima 118a and first minima of the first curvature 108a, the number of second maxima and second minima of the second curvatures 108b will decrease or increase correspondingly.

[0150] In one preferred embodiment, the number of first maxima, the number of first minima, the number of second maxima, and the number of second minima are each 1.5 times the number of partitions 105, and thus the number of blocks 104b.

[0151] In the grooves 110 the partitions 105 are limited to only move in their lengthwise direction and further controlled in their position by the first curvature 108a and second curvature 108b.

[0152] Each first channel 110a has a first hole 110a' through the flat first ring 104' at the same radial distance from the rotational axis 102 as the first circular groove 114c. Fluid can flow between the first circular groove 114c and each first channel 110a independent of each other.

[0153] Each second channel 110b has a second hole 110b' through the flat first ring 104' at the same radial distance from the rotational axis 102 as the second circular groove 115c. Fluid can flow between the second circular groove 115c and each second channel 110b independent of each other.

[0154] The first housing part 106 has a groove 116a so that fluid can lubricate between the first housing part 106 and the rotary part 103. The groove 116a will also drain any superfluous fluid away from the shaft 112 and lower the pressure around the shaft 112 reducing the risk that the sealing (not shown) between the second housing part 107 and the shaft 112 breaks leaks. The second housing part 107 has grooves 116b,116c so that fluid can lubricate between the second housing part 107 and the rotary part 103. The skilled person will understand how to feed the grooves with lubrication fluid.

[0155] In Figs. 5a - 5d the enlarged sectional view of the second energy transformation device 101 is taken along line V - V in Figs. 4a and 4b, and shown for different positions of the rotary part 103 and consequently also for the partitions 105.

[0156] Figs. 5a - 5d show the second housing part 107, the rotary part 103, the manifold 104a and the six partitions 105 in an assembled view to illustrate the pumping action when rotating the rotary part 103 or the rotational action of the rotary part 103 when pumping fluid between the first connector 114a and the second connector 115a.

[0157] The curvature of the first curvature 108a has nine first maxima 118a and nine first minima 119a. Likewise, the curvature of the second curvature 108b has nine second maxima 118b and nine second minima 119b.

[0158] The first maxima 118a of the first curvature 108a is radially opposite the second minima 119b of the second curvature 108b and vice versa.

[0159] The first curvature 108a and the circular second ring 104c of the stationary manifold 104a form outer pressure chambers 117a and the second curvature 108b and the circular second ring 104c form inner pressure chambers 117b.

[0160] In a clockwise rotation of the rotary part 103, the outer pressure chambers 117a and the inner pressure chambers 117b are filled with fluid through the first holes 110a' and the first channels 110a and emptied of fluid through the second channels 110b and the second holes 110b'.

[0161] In a counter-clockwise rotation of the rotary part 103, the outer pressure chambers 117a and the inner pressure chambers 117b are filled with fluid through the second holes 110b' and the second channels 110b and emptied of fluid through the first channels 110a and the first holes 110a'.

[0162] In the sequence of drawings shown in Figs. 5a to 5d the direction of rotation of the rotary part 103 is clockwise around the stationary manifold 104a.

[0163] There are six pumping stations 120a - 120f each with one corresponding partition 105. Each pumping station comprises a sub-manifold and a partition 105. Each sub-manifold comprises one half of a block 104b and another half of another block, where the blocks 104b are located on each side of the partition 105 forming a groove 110 for the partition 105.

[0164] In the position of Fig. 5a in the pumping station 120a, the partition 105 divides the outer pressure chamber 117a in a first 117a' and a second 117a" outer pressure chamber part. At the shown moment the emptying speed of the first outer pressure chamber part 117a' through the second channel 110b and the second hole 110b' is more or less at the top. At the same time the filling speed of the second outer pressure chamber part 117a" through the first channel

110a and a first hole 110a' is equally high and also as close to the top.

[0165] In the position of Fig. 5b the emptying and filling speeds of the first 117a' and second 117a" outer pressure chamber parts, respectively, have gone down a little. But at the same time fluid from the first inner pressure chamber part 117b' has started to flow into the second channel 110b and the second hole 110b', and on the other side of the partition end 105a a second inner pressure chamber part 117b" has just started to be filled with fluid from the first channel 110a and the first hole 110a'.

[0166] In the position of Fig. 5c and even more in the position of Fig. 5d the fluid flow from the first outer pressure chamber part 117a' into the second channel 110b and the second hole 110b' has gone down further, and so has the flow of fluid into the second outer pressure chamber part 117a". In Fig. 5d there is no flow at all into or out of the outer pressure chamber 117a. But at the same time the flow of fluid from the second inner pressure chamber part 117b" into the second channel 110b and the second hole 110b' and the flow of fluid from the first channel 110a and the first hole 110a' into the first inner pressure chamber part 117b' have increased.

[0167] The flow of fluid in the first station 120a is in phase with the flow of fluid in the third 120c and fifth 120e stations.

[0168] At the same time, the flow of fluid in the second 120b, fourth 120d and sixth 120f stations has an 180° phase shift to the flow of fluid in the first 120a, third 120c and fifth 120e stations.

[0169] That means that when the flow into the second channels 110b and second holes 110b' of the first 120a, third 120c and fifth 120e stations is at the highest the corresponding flow into the second channels 110b and second holes 110b' of the second 120b, fourth 120d and sixth 120f stations is at the lowest and vice versa.

[0170] There is also a 180° degree phase shift between the flow out of the first channels 110a and first holes 110a' of the first 120a, third 120c and fifth 120e stations and the flow out of the first channels 110a and first holes 110a' of the second 120b, fourth 120d and sixth 120f stations.

[0171] The result is a totally constant flow of fluid through the energy transformation device according to the invention. When the flow of fluid through one station 120a-f decreases there is another station 120a-f where the flow increases as much.

[0172] A constant flow causes less turbulence, friction and noise, which mean a more efficient pump or motor.

[0173] Since the first 120a, the third 120c and the fifth 120e stations are in phase, pressure chambers will open up to the outlets or inlets of the first 120a, the third 120c and the fifth 120e stations simultaneously. By positioning the first 120a - the sixth 120f stations with uneven angular distribution of pressure chambers will not open simultaneously to the inlets or outlets of the stations. With e.g. six stations 120a - 120f, nine first maxima 118a and nine second maxima 118b, as in the positions of Fig. 5a - 5d, the second station 120b can be positioned 60° from the first station 120a, the third 120c and the fourth 120d stations can be positioned 120° - 13.3° away from the first 120a and the second 120b station, respectively, and the fifth 120e and the sixth 120f stations can be positioned 240° + 13.3° away from the first 120a and the second 120b station, distributing the locations of pressure chamber openings to an inlet of a station to every 6.7° and to an outlet of a station to every 6.7°. Any ripples or pulsations in the flow of fluid when pressure chambers open up to an inlet or outlet of a station is evenly distributed during one revolution of the rotary part 103.

[0174] A modification of the first energy transformation device is presented and described in relation to Figs. 6a and 6b.

[0175] Fig. 6a shows the modified energy transformation device 201 in a perspective view and in Fig. 6b the view is straight from the front. The modified energy transformation device 201 is shown without housing parts.

[0176] The modified energy transformation device 201 comprises a rotary part 203, a manifold 204, a partition 205 with partition parts 205',205" with ends 205a'.

[0177] In the following the energy transformation device 201 is described under the assumption that the rotary part 203 rotates clockwise, even though the rotary part 203 can as easily rotate counter-clockwise, in an alternative embodiment.

[0178] The manifold 204 has a circular compartment 208 with a bottom wall 209. The rotary part 203 positioned in the compartment 208 and has a rim 208a defining a first curvature 208a having first maxima 218a,218b,218c and first minima 219a,219b,219c. The first maxima 218a,218b,218c and the first minima 219a,219b,219c have plateaus. The first curvature 208a has an overall triangular outline or shape.

[0179] The partition parts 205',205" can be connected with each other by a rigid middle part (not shown) so that the partition parts 205',205" move as one part, or the partition parts 205',205" can be biased against the first curvature 208a by springs (not shown).

[0180] During use, the partition parts 205',205" are positioned in openings 210 of the circumferential wall or manifold 204. In the openings 210 the partition parts 205',205" can move longitudinally but not rotationally in relation to or relative the manifold 204.

[0181] The height of the partition parts 205',205" can be substantially the same as the height of the openings 210 and can be substantially the same as the height or thickness of the rotary part 203 so that fluid cannot flow between the partition parts 205',205" and the bottom wall 209 of the compartment 208, or above the partition parts 205', except for the thin film of fluid that can be used and/or normally is used as lubrication between the parts inside the energy transformation device.

[0182] The rotary part 203 has a shaft 212. The circular compartment 208 and the shaft 212 are concentric around the rotational axis 202.

[0183] The distance across the rotary part 203 through the rotational axis 202 can always be the same. The length between the ends 205a' of the partition parts 205',205" corresponds to this distance across the rotary part 203, so that the ends 205a' of the partition parts 205',205" each creates a fluidly tight connection with the first curvature 208a irrespective of the relative rotational position between the rotary part 203 and the partition parts 205',205".

[0184] The ends 205a' of the partition parts 205',205" are advantageously tapered and rounded. That the ends 205a' are tapered provides well-defined borders between the ends 205a' and the first curvature 208a that will give a more reliable fluid tightness, even after long time of use and wear.

[0185] In the position of Fig. 6b the partition part 205' divides a first pressure chamber 217a in a first pressure chamber's first part 217a' and a first pressure chamber's second part 217a". During a revolution of the rotary part 203 the partition parts 205' and 205" will divide in addition to the first pressure chamber 217a also the second pressure chamber 217b and third pressure chamber 217c in the same way as described for the first embodiment in Figs. 2a - d.

[0186] The rotation of the rotary part 203 is transferred out of or into the first energy transformation device 201 by the shaft 212.

[0187] The manifold 204 comprises inlets 214 and outlets 215 for letting fluid into and out of pressure chambers between the manifold 204 and the rotary part 203. When the direction of the fluid is reversed, the inlets 214 become the outlets 214, and the outlets 215 become the inlets 215.

[0188] The invention also relates to an alternative energy transformation device according to the present invention, where the rotary part is replaced by a reciprocating part, where the first circumferential perimeter and the second circumferential perimeter are opened to a first elongated perimeter and a second elongated perimeter, respectively, where the first elongated perimeter and the second elongated perimeter are substantially parallel. Upon movement of the reciprocating part, the first maxima and first minima of the first curvature and the second maxima and second minima of the second curvature will move the partition to and fro between the curvatures. Apart from the reciprocating part, the first elongated perimeter and the second elongated perimeter, the alternative energy transformation device is substantially the same as the energy transformation device described above with all the stated advantages.

Claims

1. An energy transformation device (1,101,201) adapted for transferring a fluid, where the energy transformation device (1,101,201) comprises a rotary part (3,103,203), and a non-rotary part (4,104,204), **characterised in that**

- the rotary part (3,103) includes a compartment (8,108) that accommodates the non-rotary part (4,104),
- the compartment (8,108) has a bottom wall (9,109) and a first circumferential perimeter (8a,108a) with a first curvature (8a,108a) defined by a periodic function having first maxima (18a,18b,18c,118a) and first minima (19a,19b,19c,119a),
- the non-rotary part (4,104,204) comprises

    - at least one partition (5,23,105,205) arranged traversing a first point on the first curvature (8a,108a,208a) and an opposite second point, which second point is located on any of

        - the first curvature (8a,108a,208a),
        - a second curvature (108b) of a second circumferential perimeter (108b), where the second curvature (108b) is defined by a periodic function having second maxima (118b) and second minima (119b),
        - a second curvature (108b) of a second circumferential perimeter (108b) without second maxima and second minima, or
        - the non-rotary part (4,104,204), and

    - a manifold (4a,104a,204a) having a first manifold part (4a',104a',204a') and a second manifold part (4a",104a",204a") arranged on opposite sides of the at least one partition (5,23,105,205), which manifold parts have respective at least one fluid inlet (14b',14b",25,114b,214) and/or at least one fluid outlet (15b',15b",27,115b,215),
    - which at least one partition (5,23,105,205) in response to rotation of the rotary part (3,103,203) delimits an intake pressure chamber (17a",17b",117a",117b", 217a") and an outlet pressure chamber (17a',17b', 117a',117b',217a') when the first maxima (18a,18b,18c, 118a,218a,218b,218c) and first minima (19a,19b,19c, 119a,219a,219b,219c) of the first curvature (8a,108a, 208a) of the rotary part (3,103,203) pass by an end of the at least one partition (5,23,105,205).

2. An energy transformation device (1,101,201) according to claim 1, **characterised in that** the first curvature (8a,108a,208a) substantially circumscribes the second curvature (108b).

3. An energy transformation device (1,101,201) according to claim 1 or 2, **characterised in that** the compartment (8,108,208) has an overall triangular outline or has an overall annulus shape.

4. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the first curvature (8a,108a,208a) and/or the second curvature (108b) is/are a closed curve or two opposite closed curves.

5. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** at least a part of the first curvature (8a,108a,208a) and/or the second curvature (108b) include(s) at least a sine and/or a cosine curve.

6. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** at least one of the first maxima (18a,18b,18c,118a,218a,218b, 218c), and/or second maxima (118b), and/or first minima (19a,19b,19c,119a,219a,219b,219c), and/or second minima (119b) has a plateau.

7. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the at least one partition (5,23,105,205) has tapered ends (5a,5b,105a,105b,205a') and/or rounded ends, or tapered and asymmetric ends (23a,23b).

8. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the at least one partition (5,23,105,205) includes two partition parts in elongation of each other and mutually connected by means of a spring member or the at least one partition (5,23,105,205) is biased by a spring.

9. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the compartment (8,208) has a constant diameter or that the compartment (108) with an annulus shape has a constant width.

10. An energy transformation device (1,101,201) according to claim 9, **characterised in that** the length of the at least one partition (5,23,105,205) corresponds substantially to the constant diameter of the compartment (8,208) or the constant width of the compartment (108).

11. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the first curvature (8a,108a,208a) has at least three first maxima (18a,18b,18c,118a,218a,218b,218c) and at least three first minima (19a,19b,19c,119a,219a,219b,219c) and/or the second curvature (108b) has at least three second maxima (118b) and at least three second minima (119b).

12. An energy transformation device (1,101,201) according to any of the preceding claims, **characterised in that** the at least one fluid inlet (14b',14b",27,114b,214) is larger than the at least one fluid outlet (15b',15b",27,115b, 215).

13. An energy transformation device (1,101,201) according to any of the preceding claims 1 - 12 modified in that the non-rotary part (204) includes the compartment (208) so that the rotary part (203) is accommodated in the non-rotary part (204),
and
the compartment has a bottom wall and a first circumferential perimeter with a first curvature defined by a periodic function having first maxima and first minima is substituted by the compartment (208) has a bottom wall (209) and the rotary part has a first circumferential perimeter (208a) with a first curvature (208a) defined by a periodic function having first maxima (218a,218b,218c) and first minima (219a,219b,219c).

14. A pump for driving a fluid **characterised in that** the pump comprises

- the energy transformation device (1,101,201) according to any of the preceding claims 1 - 13, which energy transformation device (1,101,201) is arranged in a pump housing (6,7,106,107) having a pump inlet (14a,114a) connected to the fluid inlet (14b',14b",27,114b,214) of the energy transformation device (1,101,201) and a pump outlet (15a,115a) connected to the fluid outlet (15b',15b",27,115b,215) of said energy transformation device (1,101,201), and
- a rotary shaft (12,112,212) to rotate the rotary part (3,103,203) in relation to the non-rotary part (4,104,204).

15. A motor for driving a rotary shaft **characterised in that** the motor comprises

- the energy transformation device (1,101,201) according to any of the preceding claims 1 - 13, which energy transformation device (1,101,201) being arranged in a motor housing (6,7,106,107) having a pump outlet (15a,115a) connected to the fluid inlet (14b',14b",27,114b,214) of the energy transformation device (1,101,201) and a pump inlet (14a,114a) connected to the fluid outlet (15b',15b",27,115b,215) of said energy transformation device (1,101,201),
- a rotary shaft (12,112,212) driven by the rotary part (3,103,203) in relation to the non-rotary part (4,104,204).

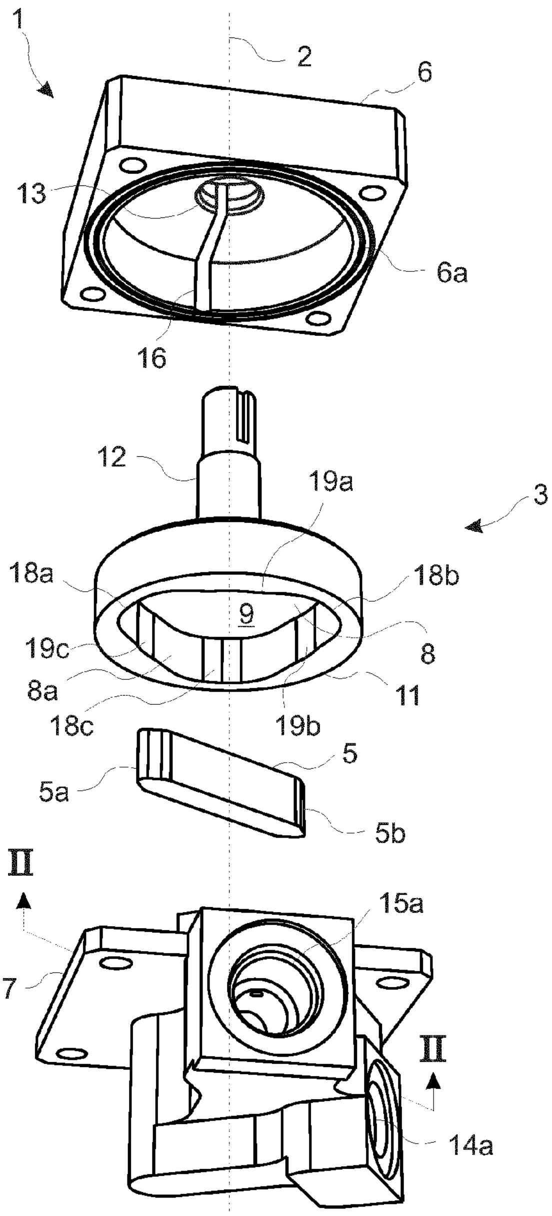

Fig. 1a

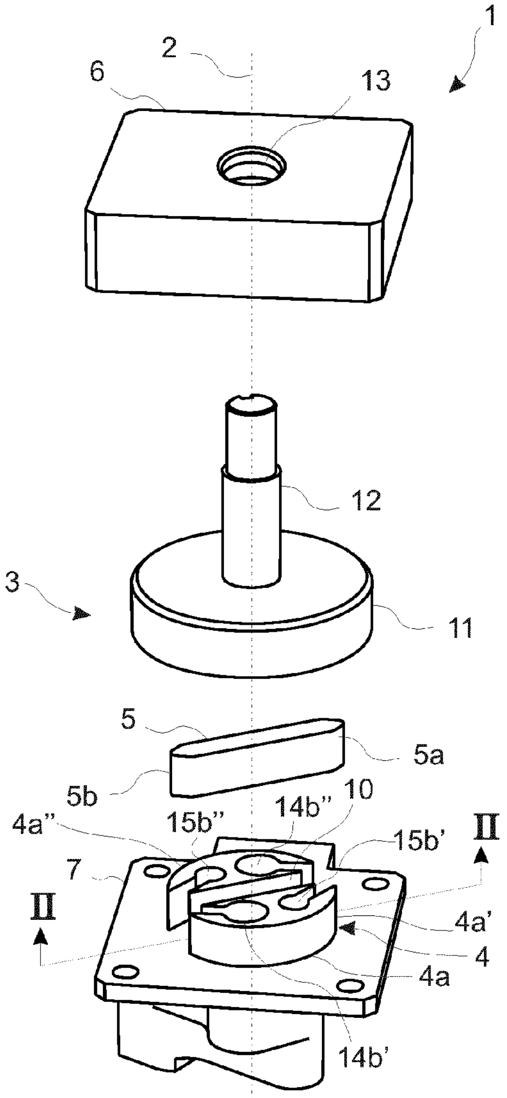

Fig. 1b

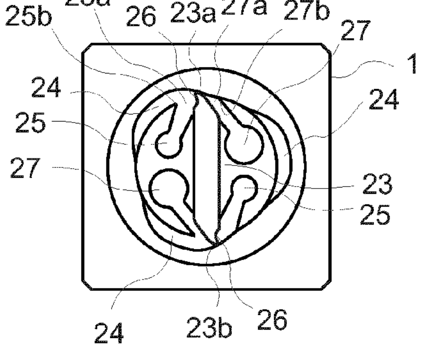

Fig. 3b

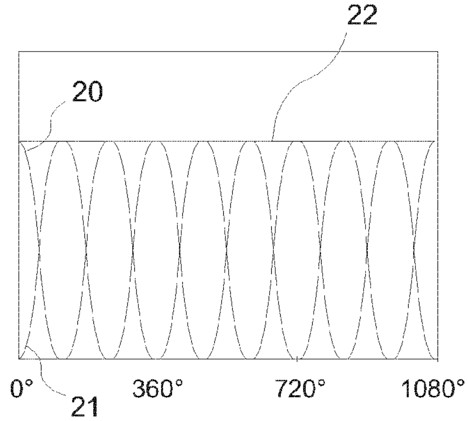

Fig. 3a

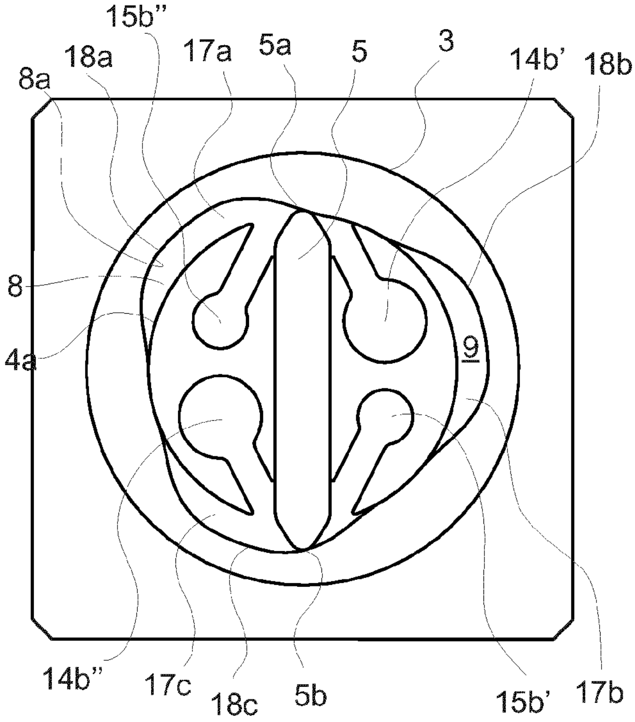

Fig. 2a

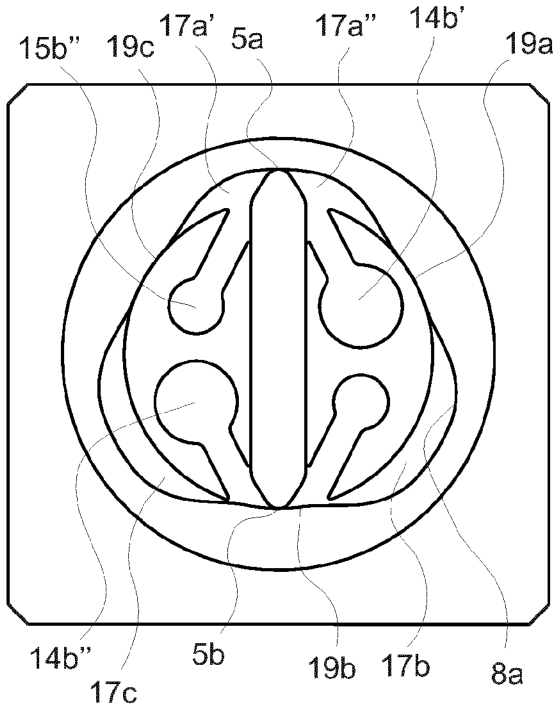

Fig. 2b

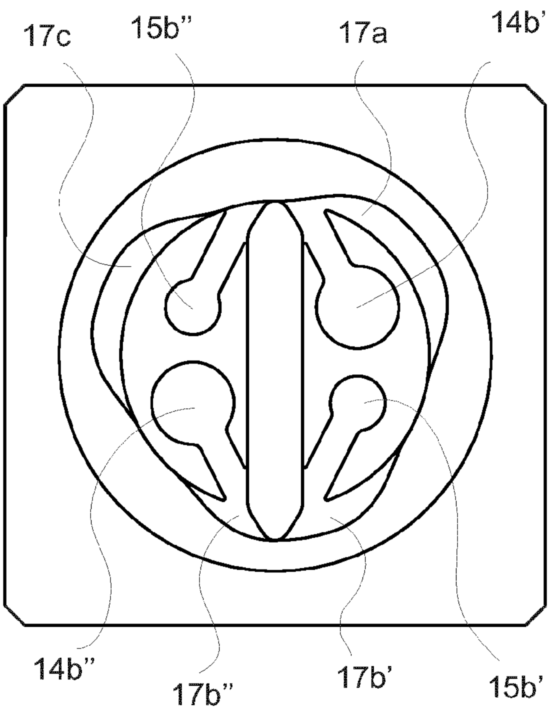

Fig. 2c

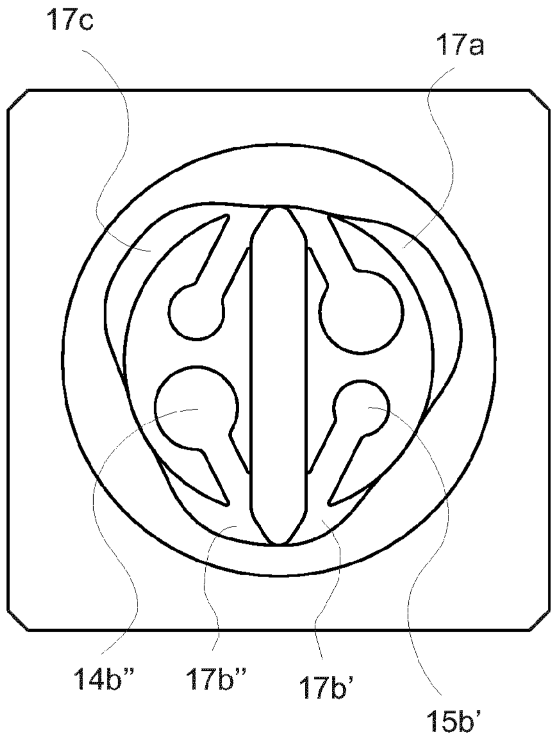

Fig. 2d

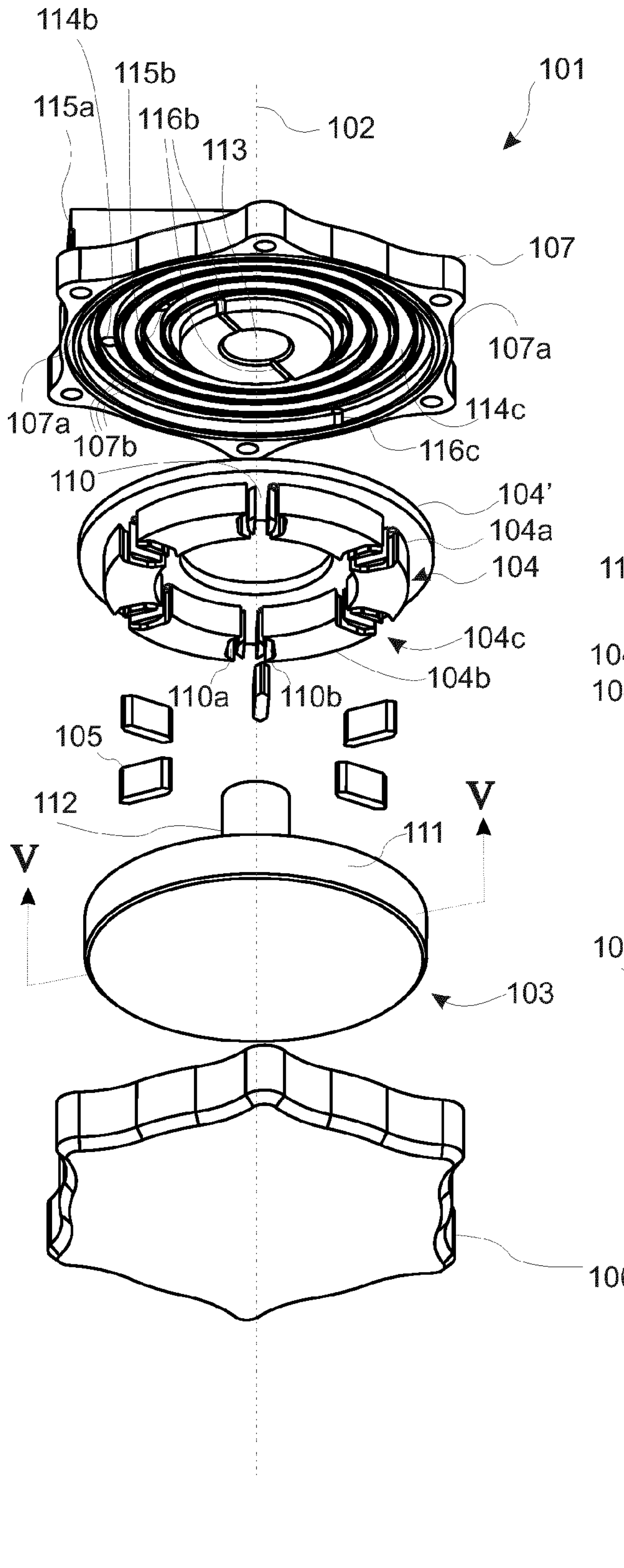
114b
115b
115a
116b
113
102
101
107
107a
107a
107b
114c
116c
110
104'
104a
104
104c
110a
110b
104b
105
112
V
111
V
103
106

Fig. 4a

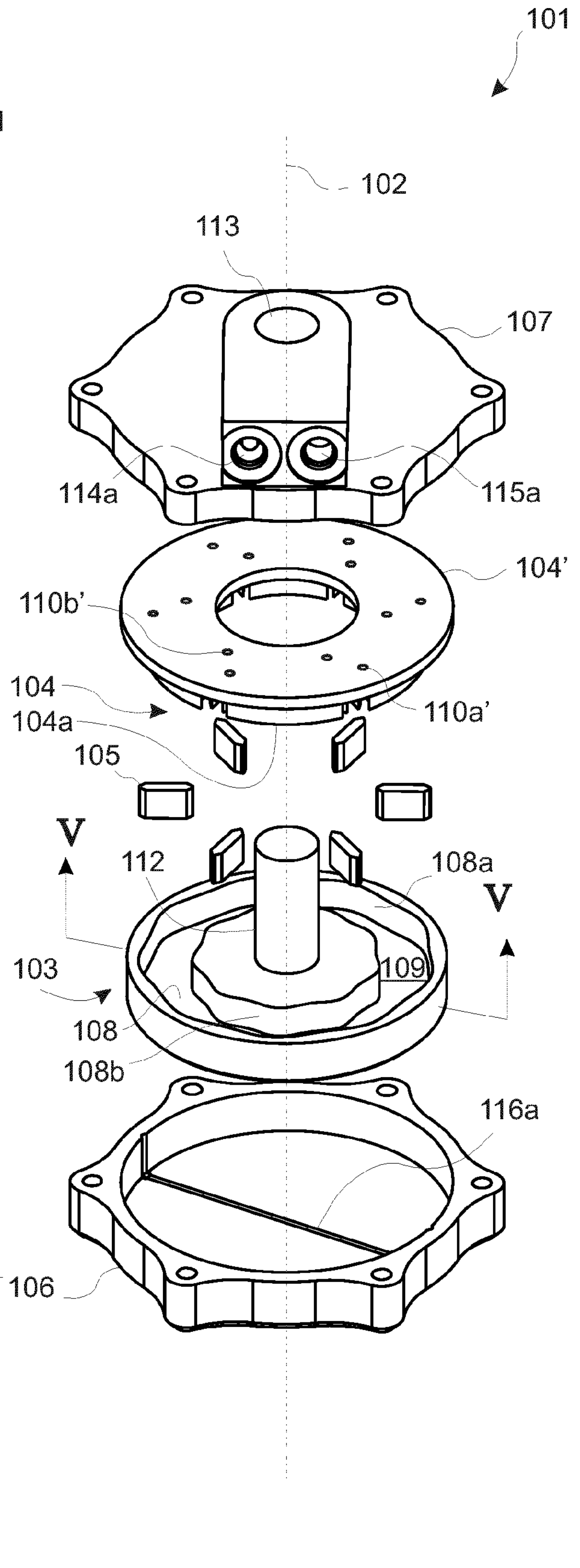
101
102
113
107
114a
115a
104'
110b'
104
104a
110a'
105
V
112
108a
V
103
109
108
108b
116a

Fig. 4b

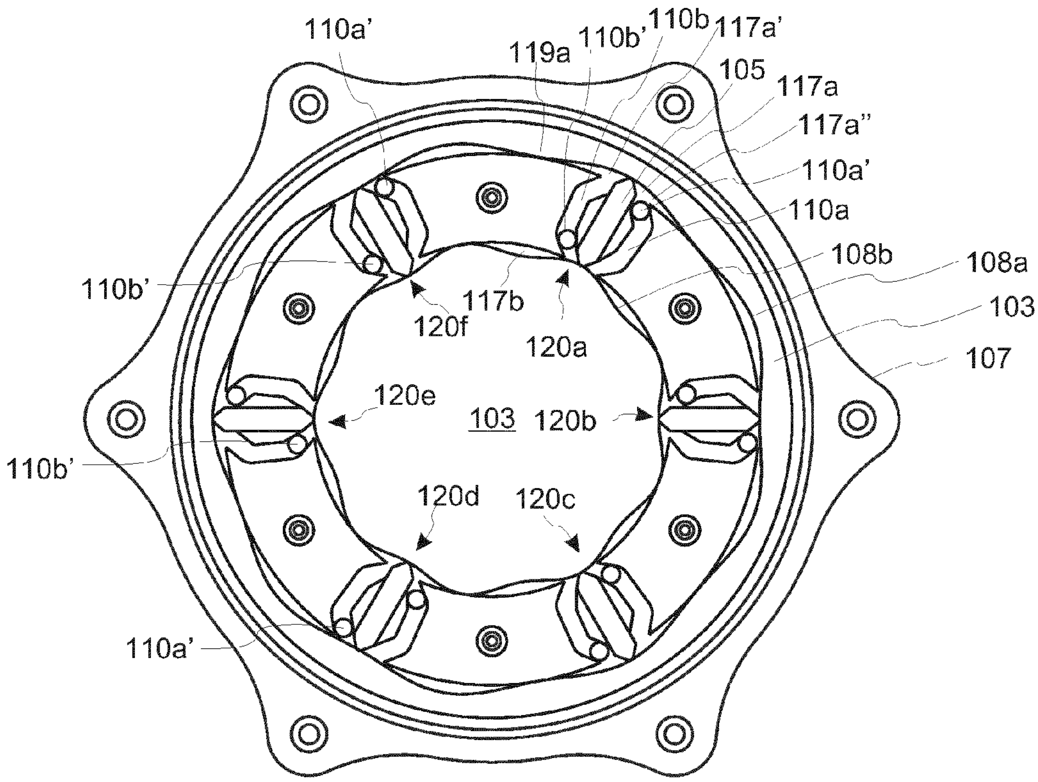
110a'
119a
110b'
110b
117a'
105
117a
117a''
110a'
110a
108b
108a
103
107
110b'
117b
120f
120a
120e
103
120b
110b'
120d
120c
110a'

Fig. 5a

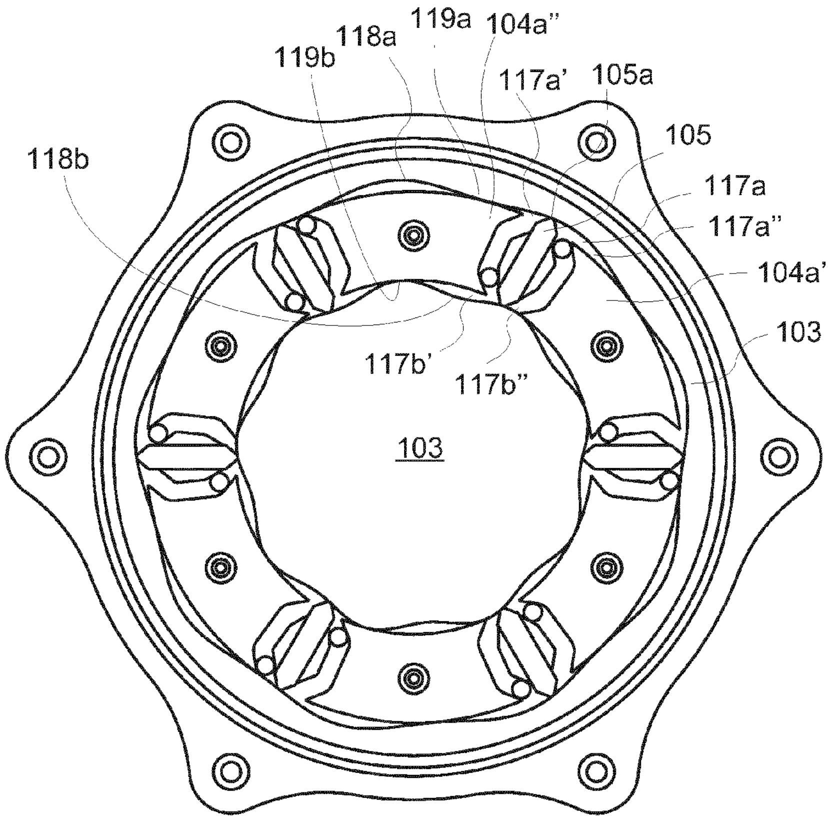
119b
118a
119a
104a''
117a'
105a
118b
105
117a
117a''
104a'
103
117b'
117b''
103

Fig. 5b

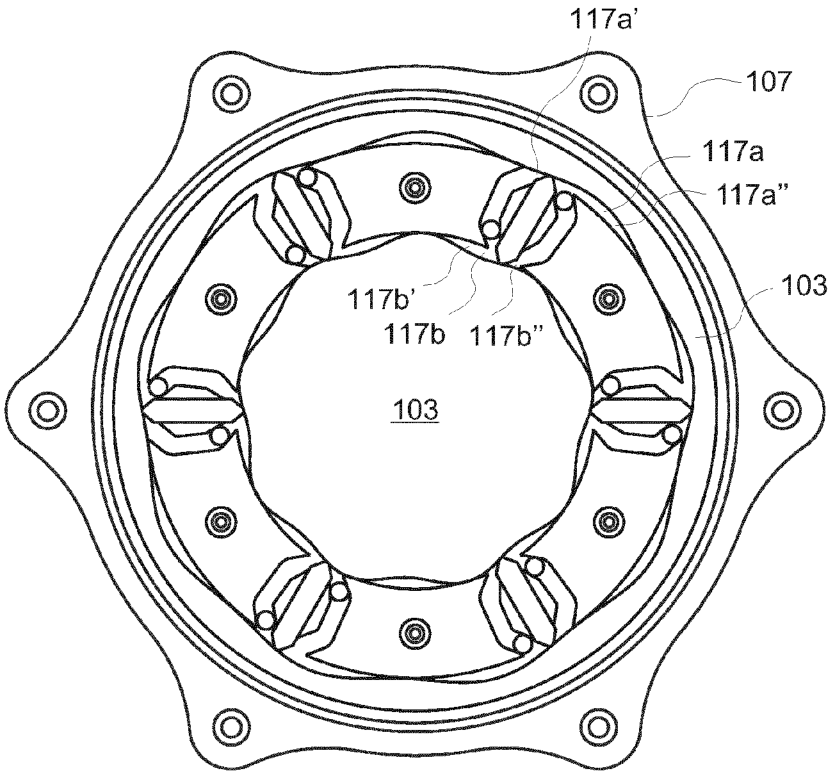
117a'
107
117a
117a"
103
117b'
117b
117b"
103

Fig. 5c

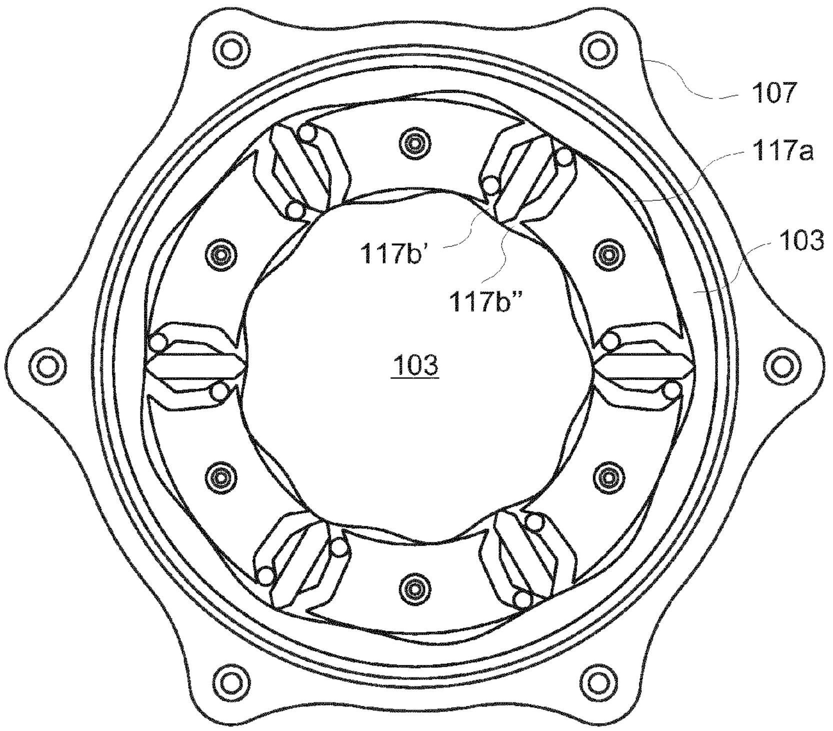
107
117a
103
117b'
117b"
103

Fig. 5d

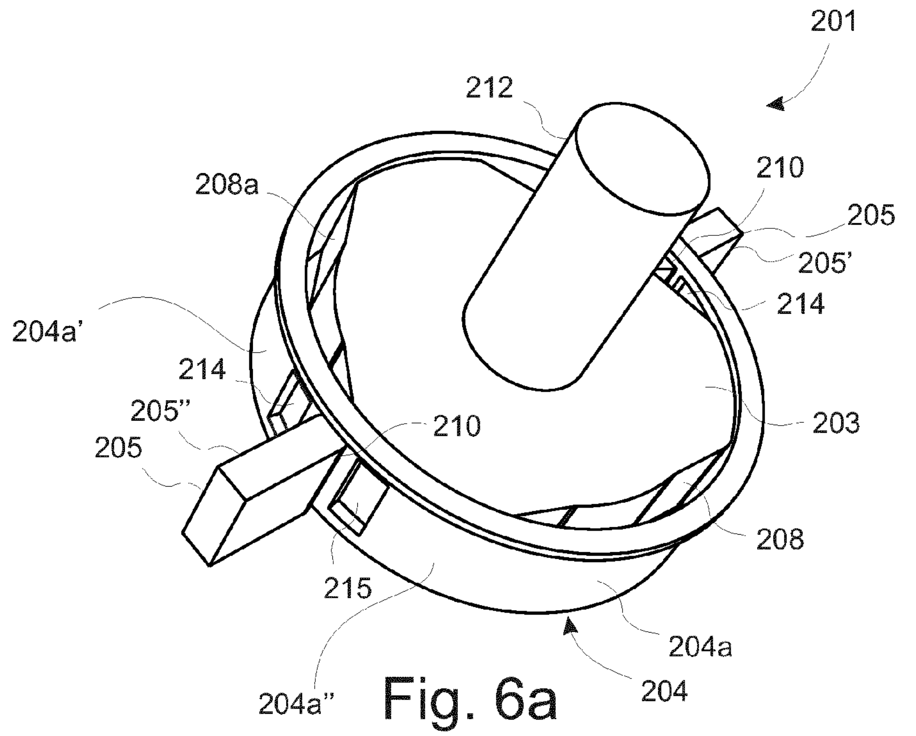
201
212
210
208a
205
205'
214
204a'
214
205"
210
203
205
208
215
204a
204
204a"

Fig. 6a

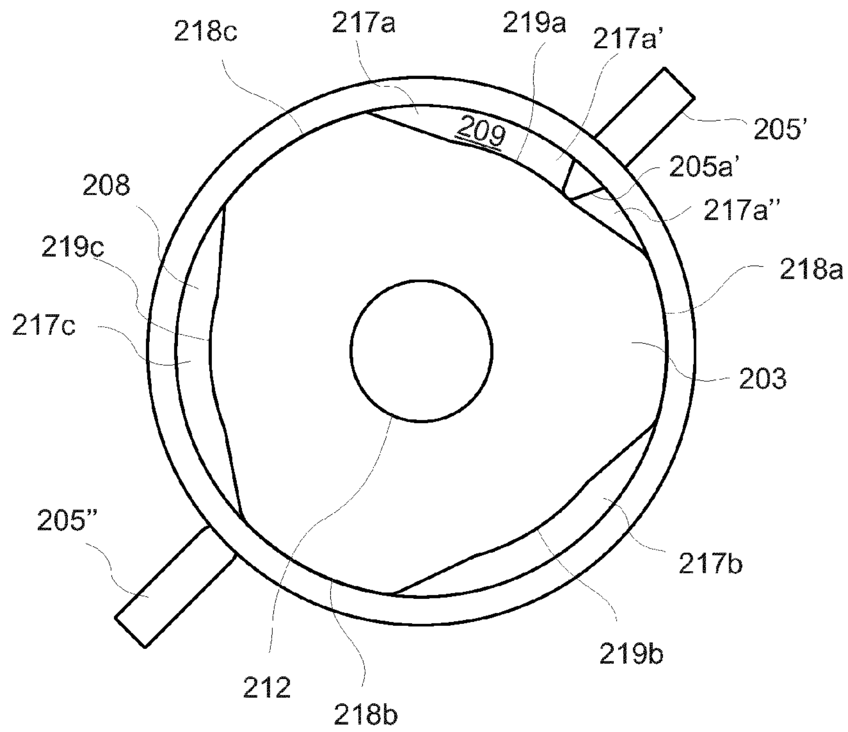
218c
217a
219a
217a'
209
205'
205a'
208
217a"
219c
218a
217c
203
205"
217b
219b
212
218b

Fig. 6b

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EUROPEAN SEARCH REPORT

Application Number
EP 16 18 9979

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 3 642 390 A (OSTBERG BERNHARD NILS) 15 February 1972 (1972-02-15) * column 1, line 1 - line 8; figures 1,5 * * column 5, line 36 - line 44 * * column 2, line 7 - line 9 * -----	1-5,7-14 6,15	INV. F01C1/02 F04C2/344
X	GB 2 497 840 A (RICHSTONE LTD [KR]; RICHSTONE LTD [JP]) 26 June 2013 (2013-06-26) * page 6, line 5 - line 20; figure 22 * * page 12, line 25 - page 13, line 5 * -----	1-5,7-14	
A	US 3 304 879 A (HANSON ELLIOTT F) 21 February 1967 (1967-02-21) * column 1, line 35 - line 40; figures 3,4 * -----	1-15	
Y	US 2006/059904 A1 (SHEVKET ALPER [GB]) 23 March 2006 (2006-03-23) * figure 1a * -----	6,15	

TECHNICAL FIELDS SEARCHED (IPC)

F01C
F04C
F03C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 January 2017	Grilli, Muzio

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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24-01-2017

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 3642390	A	15-02-1972	DE	1946794	A1	10-09-1970
			FR	2017937	A1	22-05-1970
			GB	1258983	A	05-01-1972
			IE	34277	B1	02-04-1975
			JP	S5120727	B1	28-06-1976
			SE	364552	B	25-02-1974
			SE	371864	B	02-12-1974
			US	3642390	A	15-02-1972
GB 2497840	A	26-06-2013	CN	103233891	A	07-08-2013
			DE	102012023000	A1	27-06-2013
			GB	2497840	A	26-06-2013
			JP	5643923	B2	24-12-2014
			JP	2013130132	A	04-07-2013
			KR	20130073015	A	02-07-2013
			US	2013183171	A1	18-07-2013
US 3304879	A	21-02-1967	NONE			
US 2006059904	A1	23-03-2006	US	2006059904	A1	23-03-2006
			WO	2008075134	A1	26-06-2008

EPO FORM P0459

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