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(54) **MACHINE FOR USE AS ROTARY COMBUSTION ENGINE OR COMPRESSOR**

(57) The present disclosure relates to a machine for use as an engine or compressor (1). The machine (1) comprises a cylindrical housing (10) extending along a longitudinal axis (C), and housing plates (30) arranged against a respective longitudinal end of the cylindrical housing (10). The machine (1) further comprises a rotor (20) arranged inside the cylindrical housing (10), wherein the rotor (10) rotates around a rotational axis (R) that is parallel to but offset with respect to the longitudinal axis (C). The machine (1) further comprises a plurality of sealing plates (22, 22a-c), wherein two neighboring sealing plates (22, 22a-c) defines a closed chamber (25a, 25b, 25c) and wherein the first housing plate (30) is biased against the cylindrical housing (10) and axially displaceable along the longitudinal axis (C) to enable expansion of the closed chamber (25a, 25b, 25c) along the longitudinal axis (C).

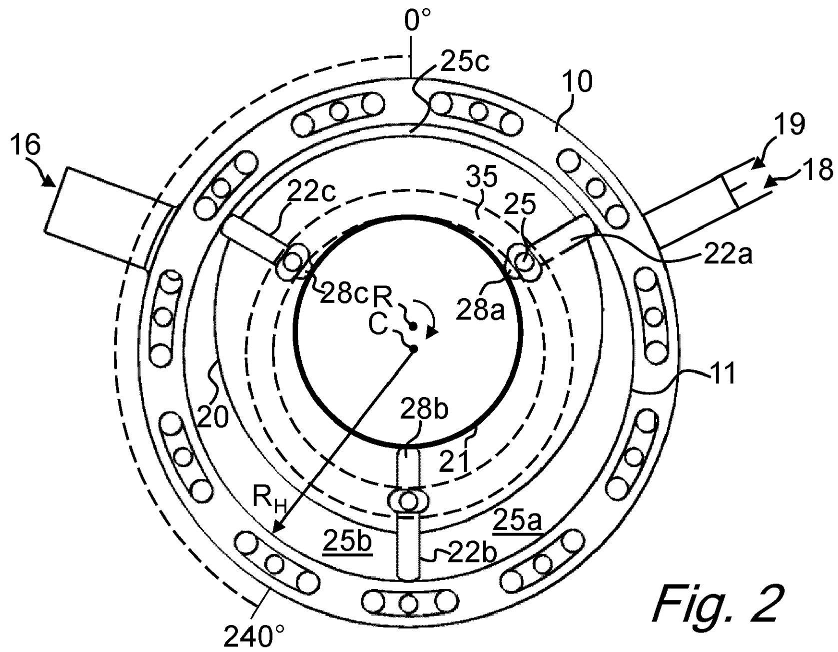

Fig. 2

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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to a machine for use as a combustion engine or compressor.

BACKGROUND OF THE INVENTION

[0002] Molecular hydrogen, also referred to as hydrogen gas, (H_2) can be used as a multipurpose fuel in a large variety of applications. For example, molecular hydrogen can react with molecular oxygen, also referred to as oxygen gas, (O_2), which is abundant in the air, in an exothermic reaction that produces water (H_2O) as the only residual product. Accordingly, molecular hydrogen is sometimes preferred to carbon based fuels, such as diesel or gasoline, as the residual products do not include carbon dioxide (CO_2). In addition, molecular hydrogen can be compressed and cooled, even to the point of liquification, allowing molecular hydrogen to be stored at great energy-to-volume densities, making molecular hydrogen suitable for energy storage or even use as fuel for e.g. propelling space rockets.

[0003] Molecular hydrogen can also be used in combustion engines to power land, sea or airborne vehicles or to power generators for production of electricity. There exist different types of combustion engines that are suitable for combustion of hydrogen and oxygen. For example, US patent application number 3,995,421 describes a hydrogen engine comprising a rotor body rotating around an eccentric shaft of a cylindrical housing. The rotor body comprises a plurality of sealing plates that are slidable in grooves, in and out, of the rotor body in a radial direction relative the eccentric shaft wherein each sealing plate seals against the inside of the cylindrical housing to form multiple sealed combustion chambers. As the rotor rotates, the sealed combustion chambers undergo compression and expansion as hydrogen gas and oxygen gas is injected and ignited. The combustion of hydrogen and oxygen drives the rotor and the residual product, water vapor, is extracted when a combustion chamber is compressed. The rotor is connected to an axel which can be connected to e.g. a generator for the generation of electricity or to the drivetrain of a vehicle to propel the vehicle.

[0004] A drawback with this type of combustion engine for combustion of hydrogen gas and oxygen gas is that the efficiency in many implementations is quite poor. While hydrogen may offer excellent fuel efficiency that rivals of exceeds that of diesel or petrol combustion engines it has proven difficult to achieve this efficiency in practice. The hydrogen combustion engines that do exist are poorly optimized and offer a lower than desirable fuel efficiency.

SUMMARY OF THE INVENTION

[0005] In view of the drawbacks of existing solutions there is a need for an improved rotary combustion engine that overcomes the drawbacks of existing solutions and enhances combustion efficiency. It is a purpose of the present invention to provide such an improved combustion engine and according to a first aspect of the invention there is provided a machine for use as a combustion engine or compressor comprising a cylindrical housing extending along a longitudinal axis, the cylindrical housing having an inner surface defining an inner volume. The machine further comprises a first and second housing plate arranged against a first and second longitudinal end of the cylindrical housing, respectively, and a rotor arranged inside the cylindrical housing. The rotor being configured to rotate around a rotational axis wherein the rotational axis is parallel to but offset with respect to the longitudinal axis. Additionally, the machine comprises a plurality of sealing plates, configured to be movable relative the rotor in a radial direction relative said rotational axis to seal against the inner surface of the cylindrical housing. Any two neighboring sealing plates defines a closed chamber together with the first housing plate, the second housing plate and the inner surface of the cylindrical housing, and the first housing plate is biased against the cylindrical housing so as to be axially displaceable along the longitudinal axis to enable expansion of the closed chamber along the longitudinal axis.

[0006] The machine of the first aspect can act as an improved combustion engine or as a new type of highly efficient compressor. When the machine is used as a combustion engine the closed chambers may be referred to as closed combustion chambers.

[0007] The machine of the first aspect of the invention can also be used as a compressor, pump or vacuum pump. When used as a compressor, pump, vacuum pump or hydraulic pump the combustion chambers may be referred to as pump chambers. By providing an external rotational force to the rotor (e.g. via a rotational shaft coupled thereto) the sealing plates will start to rotate inside the cylindrical housing. By arranging a compressor outlet port in a region of the cylindrical housing where the pump chambers are compressed and inlet port in a region of the cylindrical housing where the pump chambers are expanded a medium introduced via the inlet port will be compressed and expelled via the compression port. Alternatively, by arranging a vacuum port in a region of the cylindrical housing where the pump chambers are expanded and outlet port in a region of the cylindrical housing where the pump chambers are compressed a medium can be extracted (pumped out) via the vacuum port will be expelled via the outlet port. Accordingly, the machine can also be used as a compressor, pump or vacuum pump. Exemplary implementations of a compressor, pump or vacuum pump is as a heat pump or air conditioning unit for temperature control.

[0008] In the below, the machine will be assumed to be used as a combustion engine unless it is stated otherwise. However, a pump or compressor having the same features as the combustion engine is also envisaged.

[0009] With a rotor that rotates around a rotational axis that is offset from the longitudinal (central) axis of the cylindrical housing, the rotor will form zones of compression and expansion inside the cylindrical housing referred to as combustion chambers. As fuel and oxidant is injected and combusted inside these combustion chambers the rotor will be forced to rotate. The rotational torque of the rotor can be transferred to a rotational shaft which in turn is used to power e.g. a vehicle or drive a generator for the generation of electricity.

[0010] Compared to e.g. a Wankel engine the rotary combustion engine of the present invention has multiple benefits. Firstly, the rotor rotates around a fixed rotational axis and does not rotate about an eccentric axis which is the case for the Wankel engine. The Wankel engine is therefore subject to much greater wear and requires more frequent maintenance since a gear construction is used to achieve complex rotary motion. Secondly, the rotor of the present invention allows a cylindrical housing to be used, compared to the oval elliptic housing required for Wankel engines, which means that the engine of the present invention is easier to produce with enhanced accuracy.

[0011] Another benefit of the present invention comes from the first housing plate being biased against the cylindrical housing and being able to move along the longitudinal axis to allow expansion of the combustion chambers also in a direction parallel to the longitudinal axis. This allows the combustion chamber to expand to a greater extent than what is possible for other combustion engines, which has been shown to improve efficiency. Preferably, the first housing plate is elastically biased against the cylindrical housing meaning that it will push back against the rotor and contribute to compressing the combustion chamber(s) as well. As fuel and oxidant is periodically injected and combusted inside the engine the housing plate will move back and forth, so as to allow greater expansion of the expanding combustion chambers and also provide additional compression for shrinking combustion chambers. This effect enables the engine to be more efficient as well as achieving more complete exhaustion of residual combustion products.

[0012] It is understood that it is sufficient that only one out of the two housing plates is biased against the cylindrical housing so as to be axially displaceable along the longitudinal axis to achieve these beneficial effects. However, in some implementations, both housing plates are biased against the cylindrical housing so as to be axially displaceable along the longitudinal axis. During expansion, the housing plates moves in opposite directions and when a combustion chamber shrinks the housing plates moves against each other. The person skilled in the art realizes that any arrangement used to bias the first housing plate against the rotor or sealing plates, or arrangement used to bias a sealing plate against any of the housing plates can be replicated on both longitudinal sides of the rotary combustion engine of the present invention.

[0013] According to some implementations, the rotary combustion engine further comprises an outer housing plate attached to the cylindrical housing and a biasing arrangement arranged between the outer housing plate and the first housing plate, elastically pressing the first housing plate against the cylindrical housing.

[0014] The outer housing plate may be rigidly attached to the cylindrical housing. For example, the outer housing plate acts as a lid for the cylindrical housing wherein the first housing plate is sized and adapted to be arranged fully inside the cylindrical housing, between the rotor and the outer housing plate. The biasing arrangement comprises one or more elastic elements (e.g. a coil spring, torsion spring or similar) arranged to press the housing plate against the rotor and the sealing plates.

[0015] In some implementations, the biasing arrangement comprises a plurality of elastic units interacting with the outer housing plate and arranged in a circular pattern around the longitudinal axis, each elastic unit being elastically displaceable and configured to bias the housing plate in a direction parallel with the longitudinal axis.

[0016] With multiple elastic units arranged in a circular pattern, an even force distribution is achieved around the housing plate. Optionally, one or more supporting pins are arranged on the rear side of the housing plate (opposite to the inner surface of the housing plate that faces the combustion chambers) and the support pins are received inside corresponding apertures of the outer housing plate. By ensuring that the pins are received tightly inside the corresponding apertures this arrangement may prohibit the housing plate from rotating and/or ensure that the housing plate moves mainly linearly along the longitudinal axis and does not pivot.

[0017] According to some implementations, the biasing arrangement further comprises an intermediate plate arranged in abutment with the plurality of elastic units on one side and in abutment with an outer surface of the first housing plate on a second side, opposite to the first side. Optionally, a conical ring is arranged between the first housing plate and the intermediate plate, wherein the inner surface of the conical ring is concave and the outer surface of the first housing plate is convex.

[0018] For example, the outer surface of the first housing plate has the shape of a truncated cone and the inner surface of the conical ring is concave with a shape corresponding to the truncated cone shape of the housing plate. The conical ring is preferably provided with a split, making it C-shaped and allowing it to expand and contract when engaging a convex housing plate.

[0019] According to some implementations, the plurality of elastic units comprise rigid elements that are spring loaded in a direction transverse to the longitudinal axis, wherein each rigid element comprises an abutment surface that is oblique relative the transverse direction, and wherein the intermediate plate comprises a plurality of grooves configured to receive the abutment surface of each elastic unit, respectively.

[0020] The elastic unit can be made elastic in a direction perpendicular to the longitudinal axis even if the elastic element (e.g. a coil spring, torsion soring or similar) is arranged to be compressed in a direction perpendicular to the longitudinal axis. This may be achieved using a rigid element that has a surface that is oblique to the central axis and the rigid element is configured to engage an oblique surface in the intermediate plate. For instance, the rigid element is triangular and the intermediate plate is provided with corresponding triangular grooves that engage the triangular rigid element. As the intermediate plate moves away from the rotor the triangular grooves press the triangular elements which slides relative the groove and compress the elastic element in a direction perpendicular to the longitudinal axis.

[0021] In one example implementation, ten or more rigid elements and associated elastic elements are arranged around the longitudinal axis. For example, fifteen rigid elements are arranged with an oblique surface that is tilted about 26 degrees relative to the transverse axis. Each rigid element is loaded by a spring, and with this tilt of the oblique surface, the rigid elements the compressive force of each spring will effectively be doubled. Accordingly, by selecting an appropriate tilt of the oblique surface of the rigid element interacting with the intermediate plate and the spring the compressive force can be tuned.

[0022] According to some implementations, each sealing plate is split into a first plate portion and a second plate portion. The second plate portion is moveable relative the first plate portion in at least a direction parallel with the longitudinal axis and a biasing element is arranged between the first and second plate portions, exerting a force on the second plate portion in at least the longitudinal direction against the first housing plate.

[0023] That is, the second plate portion is moveable relative to the first plate portion so as to follow the housing plate, even the housing plate moves back and forth along the longitudinal axis due to expanding combustion chambers. This facilitates sealing between the combustion chambers since the sealing plate expands to cover the new longitudinal extension of the combustion chamber when the housing plate moves.

[0024] It is understood that some leakage may still occur between combustion chambers as gaseous elements may travel between the rotor and housing plate when the sealing plate is in its extended state and furthest from the rotational axis. Surprisingly, this leakage is miniscule and does not to a large extent impede the efficiency. That is, despite this leakage, the combustion engine's efficiency is still improved compared to previous engines and the benefits associated with this design greatly outweigh the miniscule leakage between neighboring combustion chambers.

[0025] Optionally, the first plate portion comprises an elongated protrusion or elongated groove and the second plate portion comprises the other one of an elongated protrusion or groove, wherein the elongated protrusion is inserted into the elongated groove to make the first and second plate portions slidable with respect to each other.

[0026] An interconnecting groove and protrusion enable the first and second plate portion to be connected to each other, and e.g. rotate together around the rotational axis, while still enabling the second plate portion to slide along at least the longitudinal axis relative the first plate portion and follow the housing plate. In some implementations, the elongated protrusion and elongated groove are configured to enable the plate portions to slide relative to each other in a direction that is oblique relative to the radial direction and longitudinal direction. That is, enable the plate portions to slide relative to each other in an oblique direction having both a radial and a longitudinal component.

[0027] For example, the second plate portion is formed a right angled triangular cut-out of the rectangular sealing plate. A hypothenuse surface of the triangular cut-out faces the first plate portion and the groove and/or protrusion is arranged on the hypotenuse surface allowing the second plate portion to slide relative the first plate portion and seal against the movable housing plate.

[0028] In some implementations, one of the first plate portion and second plate portion comprises a recess, and the other one of the first and second plate portion comprises a protrusion that is received in the recess, and wherein the elastic element is arranged in the recess. The elastic element which forces the second plate portion to move relative the first plate portion is preferably integrated in a recess formed in one of the first and second plate portion. This protects the elastic element and does not require any adaptations of the rotor to make room for the elastic element. One of the first and second plate portion is provided with a protrusion which fits inside the recess of the other one of the first and second plate portion while still leaving an empty space in which the elastic element can be placed. This means that the elastic element will press against the inner walls of the recess and the protrusion so as to force the first and second plate portions apart, whereby the second plate portion is forced against the housing plate.

[0029] In some implementations, the rotary combustion engine comprises an elongated follower associated with each sealing plate, each follower extending longitudinally through a first opening in the first plate portion and a second opening in the second plate portion, and protruding from at least one longitudinal side of the sealing plate. The rotary combustion engine further comprises a groove arranged on an inside of at least the first housing plate, the groove being configured to receive the follower protruding out of each sealing plate, wherein the groove defines a closed path for guiding the movement of the sealing plates radially relative the rotor.

[0030] The follower is rotatable to the sealing plate allowing the follower to turn relative to the sealing plate.

As the combustion cycle continues inside the cylindrical housing, the rotor will rotate and force the sealing plates to move together with the rotor. The follower protruding from each sealing plate engages a groove in the first housing plate which guides the sealing plate in and out of the rotor. In some implementations, an equivalent groove is formed in the second housing plate and the follower protrudes and engages this groove as well.

[0031] In some implementations, a diameter of the second opening in the second plate portion is larger compared to a diameter of the first opening in the first plate portion. With a larger opening diameter in the second plate portion compared to the opening diameter of the first plate portion the second plate portion can move without being obstructed by the rod. For example, the cross-sectional shape of the second opening is that of a geometric stadium, with the straight sides extending perpendicular to the rotational axis, allowing the second plate portion to move in at least the radial direction with respect to the rod.

[0032] In some implementations, each sealing plate portion is rigid and made of a metal material, preferably a metal coated with titanium aluminum nitride, TiAlN. Other components of the combustion engine, such as at least one of the rotor, cylindrical housing, rotational shaft, first and second sealing plate, outer sealing plate and the biasing arrangement may also be made of rigid material, such as a metal material, preferably a metal material coated with TiAlN.

[0033] In some implementations, each sealing plate comprises an apex sealing element extending along an apex of the sealing plate, the apex sealing element being biased against the inner surface of the cylindrical housing.

[0034] With the apex of the sealing plate it is meant the side of the sealing plate that is arranged most distally from the rotational axis and is facing the inner surface of the cylindrical housing. While it is envisaged that the sealing plates can be manufactured with high accuracy so as to slide along the inner surface of the cylindrical housing with low friction and still providing a seal it may be desirable to provide apex sealing elements that are biased towards the inner surface of the cylindrical housing to further facilitate sealing. The apex sealing element could be made of an elastic material, e.g. a rubber material meaning that the sealing element as such is elastic and enables biasing against the inner surface of the cylindrical housing. Alternatively, the apex sealing element is rigid (e.g. made of a metal material optionally coated with TiAlN) and biased using one or more biasing elements arranged between the apex sealing element and the sealing plate.

[0035] In some implementations, a transverse cross-section of the rotor along the longitudinal axis is the shape a curved polygon, preferably a Reuleaux triangle, with one sealing plate at each vertex of the curved polygon.

[0036] That is, the rotor has a three-dimensional shape of an extruded curved polygon. In a curved polygon, two vertexes are connected with a curved surface. Preferably the radius of curvature of the surface connecting two vertexes has a radius of curvature which is greater than the radius of the inner volume in the cylindrical housing. Preferably, the radius of curvature of the curved surface(s) of the rotor is at least 20%, at least 50% or at least 100% greater than the radius the radius of the inner volume in the cylindrical housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] These and other aspects of the invention will now be described in more detail, with reference to the appended drawings showing exemplary embodiments of the present invention, wherein:

Figure 1 is a perspective view of a rotary combustion engine according to some embodiments, with the housing plates removed.

Figure 2 is a cross-sectional view of the cylindrical housing, rotor and sealing plates of the engine, illustrating the individual combustion chambers.

Figure 3 depicts the inner surface of a housing plate according to some implementations.

Figure 4 shows an outer housing plate and a biasing arrangement together with the housing plate according to some implementations.

Figure 5a is a schematic cross-sectional view of the arrangement of the outer housing plate, the biasing arrangement and the housing plate.

Figure 5b illustrates an elastic unit between the intermediate plate and the outer housing plate.

Figure 5c illustrates an elastic unit between the intermediate plate and the outer housing plate when the intermediate plate and hosing plate moves away from the rotor to allow a combustion chamber to expand.

Figure 6 depicts a detailed view of a sealing plate according to some implementations.

Figure 7 depicts the details of the first and second plate portion that together form a sealing plate according to some implementations.

Figure 8 shows further details of the surface of the second plate portion that faces the first plate portion.

Figure 9 depicts an elastic element used to bias the second plate portion against the first plate portion according to some implementations.

Figure 10 illustrates schematically how the second plate portion moves relative to the first plate portion according to some implementations.

Figure 11a shows a detailed view of the sealing elements arranged on each sealing plate according to some implementations.

Figure 1 1b shows a detailed side view of the sealing element arranged on each sealing plate according to some implementations.

Figure 12 shows how a wave spring can be used to bias the sealing element of each sealing plate against the inner surface of the cylindrical housing according to some implementations.

DETAILED DESCRIPTION OF CURRENTLY PREFERRED EMBODIMENTS

[0038] Fig. 1 shows a perspective view of a machine according to some implementations. The machine in fig. 1 is used as an rotary combustion engine 1. The rotary combustion engine 1 is sometimes referred to as a pistonless rotary combustion engine 1 since it does not contain any traditional reciprocating pistons. The rotary combustion engine 1 may be used with a variety of different fuels, such as diesel or petroleum, but the rotary combustion engine 1 is especially well suited for use with molecular hydrogen as fuel and concentrated oxygen or atmospheric oxygen (from the air) as the oxidant.

[0039] In the following detailed description the rotary combustion engine 1, or pistonless rotary combustion engine 1, will sometimes be referred to simply as the engine 1, and, as described in the above, the engine 1 can also be used as a pump or vacuum pump if an external torque is exerted on the rotational shaft.

[0040] The engine 1 comprises a substantially cylindrical housing 10 extending along a longitudinal (central) axis, parallel to the rotational axis R, having an inner cylindrical surface defining an inner volume. The longitudinal axis extends in the center of the inner volume. The engine 1 further comprises a first and second housing plate arranged against the respective longitudinal ends of the cylindrical housing 10 to completely seal the inner volume of the cylindrical housing 10, however, in fig. 1 the housing plates have been removed to show the inside of the cylindrical housing 10.

[0041] The engine 1 further comprises a rotor 20 arranged inside the cylindrical housing 10. The rotor 20 is configured to rotate about the rotational axis R that extends parallel to, but offset from, the central longitudinal axis of the cylindrical housing 10. The offset can e.g. be 1 cm when the inner radius of the cylindrical housing is 10 cm. Preferably, the absolute offset distance is scaled with the size of the engine 1. That is, if the dimension of the engine 1 is scaled A times compared to a reference design with 1 cm offset distance the offset distance is also scaled with the factor A.

[0042] As the rotor 20 rotates about the rotational axis R it creates regions of compression and expansion inside the cylindrical housing 10. To seal off the regions, also called combustion chambers or pump chambers, the rotor 20 further comprises a plurality of sealing plates 22 that slide in and out of the rotor 20 in the radial direction about the rotational axis R. The sealing plates 22 are in contact with the inner surface of the cylindrical housing 10 and the housing plates which forms a seal. Thus, the sealing plates 22 form a plurality of sealed-off circumferentially arranged combustion chambers that will move along a circumferential trajectory when the rotor 20 rotates inside the cylindrical housing 10. As the rotor 20 rotates about the rotational axis R, which is offset from the longitudinal axis of the cylindrical housing, the volume of each combustion chamber will increase and decrease as the combustion chamber moves around the rotational axis R.

[0043] When used an engine, fuel and oxidant (e.g. molecular hydrogen and oxygen/air) is injected into the cylindrical housing 10 via the fuel injection system 18 and oxidant injection system 19 and the mixture is ignited. The exothermic reaction creates an expansive force that presses against the rotor 20 and the sealing plates 22 which forces the rotor 20 to rotate around the rotational axis R. The rotor 20 is attached to a rotational shaft 21 that extends outside of engine 1 such that the rotational energy of the rotor 20 can be transferred to an external device via the shaft 21. For example, the shaft 21 is connected to the drivetrain of a vehicle to propel the vehicle or the shaft 21 is connected to an electrical generator for the generation of electricity.

[0044] It is understood that while the operation of the engine 1 has now been described in detail the skilled person realizes that by applying a torque to the rotational shaft 21 so as to turn the rotor 20 inside the cylindrical housing 10 the engine 1 will instead act as a compressor, that receives a medium (e.g. a gas or liquid) as an input, compresses the medium and expels compressed medium.

[0045] Fig. 2 shows a cross-section of the engine 1 according to some implementations. The cross-section being in a plane that is transverse to the longitudinal axis C and/or the rotational axis R. The cylindrical housing 10 extends along the longitudinal axis C and has an inner surface 11. The inner surface 11 defines an inner volume with a radius R_H around the longitudinal axis C. For example, the radius R_H is 10 cm.

[0046] The rotor 20 is arranged inside the cylindrical housing 10 and arranged to rotate clockwise around the rotational axis R. The rotational axis R is offset from, but parallel to the longitudinal axis C. The cross-sectional shape of the rotor 20 is that of a Reuleaux triangle having three vertexes. However, it is envisaged that the rotor 20 can have other cross-sectional shapes such as any general curved polygon shape (of which the Reuleaux triangle is merely one example) or even a circular shape.

[0047] Three slits 28a-c are provided provided at each vertex of the rotor 20 wherein each slit 28a-c is configured to receive a respective sealing plate 22a-c. Each sealing plate 22a-c is configured to be slidable in and out of the respective slit 28a-c in a radial direction from the rotational axis T to seal against the inner surface 11 of the cylindrical housing 10. The surface of the sealing plate 22a-c that is radially most distant from the rotational axis R is referred to as the apex surface of the sealing plate 22a-c. It is this surface that comes into contact with, and seals against, the inner surface 11 of cylindrical housing 10.

[0048] Accordingly, the rotor 20 comprises a slit 28a-c associated with each sealing plate 22a-c whereby each sealing plate 22a-c can slide in and out of the respective slit 28a-c. Each slit 28a-c is preferably sized to receive substantially the whole sealing plate 22a-c such that the sealing plate 22a-c is received fully inside the rotor 20 when the associated vertex passes its closest point to the inner surface 11. For example, in the rotor position shown in fig. 2 sealing plates 22a and 22c are substantially fully inside the respective slit 28a, 28c rotor 20 as this portion of the rotor 20 makes its closest approach to the inner surface 11 of the cylindrical housing 10. By comparison, sealing plate 22b extends out from slit 22b as this part of the rotor 20 has just passed its maximum distance from the inner surface 11. As will be described in further detail below, the sealing plates 22a-c may comprise a follower 25 which engages a groove 35 provided in at least one of the two housing plates (see fig. 3). This groove 35 may be circular with a center point on the longitudinal axis C (which is offset from the rotational axis R).

[0049] The sealing plates 22a-c, rotor 20, inner surface 11 as well as the housing plates (not shown) define a plurality of combustion chambers 25a-c that are sealed from each other. For example, sealing plates 22a and 22b, rotor 20, inner surface 11 as well as the housing plates (not shown) form combustion chamber 25a and sealing plates 22b and 22c, rotor 20, inner surface 11 as well as the housing plates (see fig. 3) form combustion chamber 25b. As the rotor 20 rotates, each combustion chamber 25a-c undergoes compression and expansion. For example, as the rotor 20 rotates clockwise in fig. 2, combustion chamber 25a will be forced to expand by the ignition of fuel and oxidant injected via the fuel injection system 18 and oxidant injection system 19 respectively. As the rotor 20 continues to rotate clockwise, the volume of combustion chamber 25a will decrease which forces the residual combustion products (e.g. water vapor in the case of combustion of hydrogen and oxygen) out of the engine 1 via an exhaust outlet 16. Combustion chamber 25a then returns to the starting position and is again forced to expand by combustion. This process is repeated for each combustion chamber 25a-c which drives the engine and causes a continuous torque on the rotational shaft 21 which can be used to e.g. drive a generator for electricity production.

[0050] The rotational axis R is displaced from the longitudinal axis C in a 0° angular direction around the longitudinal axis C. Going clockwise from this direction, the fuel and oxidant injection systems 18, 19 inject fuel and oxidant into the cylindrical housing at about 30° to 90°, such as at about 60°. When instead used as compressor, the compression medium intake replaces the fuel and oxidant injection systems 18, 19. The exhaust outlet 16 is preferably arranged angularly far away from the fuel and oxidant inlets, such as between 240° and 360°. Preferably, the exhaust outlet 16 is spread out to span a substantial range of angles, such as extending from 240° to about 360° to achieve complete expelling of residual products. When instead used as compressor, the compression medium outlet replaces the exhaust outlet 16.

[0051] Fig. 3 shows a perspective view of a housing plate 30 configured to seal a longitudinal end of the cylindrical housing. The housing plate 30 is installed with its inner surface 31 facing the inner volume of the cylindrical housing and the rotor located therein. On an outer surface of the housing plate 30, being opposite the inner surface 31, one or more pins 37 are arranged so as to project out from the outer surface. The one or more pins 37 may be received in corresponding apertures formed in an outer housing plate to prevent the housing plate from rotating with the shaft and/or the rotor as will be described in detail in the below.

[0052] The housing plate 30 may be substantially circular and shaped like a disc. The radius of the housing plat 30 may equal to the radius of the inner surface in the cylindrical housing (e.g. a radius of 10 cm) such that the housing plate 30 can be inserted into the cylindrical housing 10 and create a seal against the cylindrical housing 10 along the periphery of the housing plate 30. Alternatively, the radius of the sealing plate 30 is larger than the cylindrical housing radius (e.g. larger than 10 cm) meaning that the housing plate seals against the cylindrical housing with its inner surface.

[0053] The housing plate 30 comprises a groove 35 configured to receive a follower 25 extending from a sealing plate so as to control the radial movement of the sealing plate. Preferably, the groove 35 is circular having its center on the longitudinal axis. The sealing plate 30 also comprises an opening 33 configured to receive the rotational shaft connected to the rotor so as to allow transfer of rotational energy to/from the rotor inside of the cylindrical housing.

[0054] The housing plate is not rigidly attached to the cylindrical housing but biased against the cylindrical housing so as to be axially displaceable along the longitudinal axis to enable expansion of the closed combustion chamber also along the longitudinal axis.

[0055] Fig. 4 depicts an exemplary embodiment of a biasing arrangement 50 suitable for biasing the housing plate 30 against the cylindrical housing. The biasing arrangement 50 comprises a plurality of elastic units 51a, 51b that exert an elastic force upon the housing plate 30 pressing it against the rotor inside the cylindrical housing. The biasing arrangement 50 may e.g. be configured to interact with the outer housing plate 40 which is rigidly attached to the cylindrical housing. This enables the housing plate 30 to axially move between the outer housing plate 40 and the rotor while the housing plate 30 is still biased against the rotor.

[0056] To prohibit the housing plate 30 from rotating with the rotor the outer surface 32 of the housing plate 30 may comprise a plurality of pins 37 that engage apertures (not shown) formed in an inner surface of the outer housing plate 40.

[0057] The biasing arrangement 50 comprises a plurality of elastic units 51a, 51b arranged in a circular pattern around the longitudinal axis C. The elastic units 51a, 51b are arranged so as to be biased against the outer surface 32 of the first housing plate 30, either directly against the outer surface 32 or indirectly, with one or more intermediate elements placed between the outer surface 32 and the elastic units 51a, 51b. As will be described in further detail in the below, each elastic unit 51a, 51b may be realized with a triangular element which is biased in a radial direction, perpendicular to the longitudinal axis C, while still biasing the housing plate 30 against the rotor.

[0058] The elastic units 51a, 51b engage an intermediate plate 52 located between the elastic units 51a, 51b and the first housing plate 30. The outer surface of the intermediate plate 52 comprises a plurality of grooves 53, each groove 53 being associated with, and configured to receive, an elastic unit 51a, 51b that is elastically loaded against to force the intermediate plate 52 against the housing plate. It is understood that by configuring the shape of the grooves 53 and/or the shape of elastically loaded elastic units 51a, 51b it is possible to bias the intermediate plate 52 away from the outer sealing plate 40 and against the first housing plate 30.

[0059] For example, each groove 53 may be shaped like a triangular groove, having an engagement surface that is oblique to the radial direction and longitudinal axis C. When this type of groove 53 engages a triangular rigid element biased in the radial direction, movement of the intermediate plate 52 along the longitudinal axis C will cause displacement of the triangular rigid element along the radial direction.

[0060] The outer surface 32 of the first housing plate 30 is convex, e.g. shaped like a truncated cone. Between the intermediate plate 52 and the housing plate 30 there is located a conical ring 55 having an inner surface that is concave and adapted to receive the convex outer surface 32 of the first housing plate 30. The conical ring 55 is split at one location allowing it to elastically expand and contract. For example, the conical ring 55 is shaped from a single piece of material that is bent to form a ring.

[0061] Fig. 5a depicts schematically a cross-section of the outer housing plate 40, the biasing arrangement 50, the first housing plate 30 and the cylindrical housing 10. The rotor 20 is arranged inside the cylindrical housing 10 and an axel 21 is attached to the rotor 20 and extends out of the cylindrical housing so as to transfer rotational energy from the rotor 20 to an external device.

[0062] The first housing plate 30 is arranged with its inner surface 31 facing the rotor 20 so as to seal against the rotor 20 and sealing plates. The first housing plate 30 has a diameter adapted to allow the first housing plate 30 to fit inside the cylindrical housing 10 and an opening 33 allowing the rotational shaft 21 to pass through the first sealing plate 30. Preferably, one or more sealing rings (e.g. O-rings made of a compressible material) are arranged around the rotational shaft 21 and between the rotational shaft 21 and at least one of housing plate 30, intermediate housing plate 52, and outer housing plate 40 to form a seal. The inner surface 31 of the first sealing plate 30 also has a groove 35 for engaging a follower of each sealing plate, to guide the sealing plate as it slides in and out of the rotor 20.

[0063] The first housing plate 30 has a convex outer surface 32 which is received in a concave inner surface 56 of the conical ring 55. The conical ring 55 is provided with at least one cut allowing it to expand and contract radially when the outer housing plate 30 moves in back and forth along the longitudinal axis C. The outer surface 57 of the intermediate plate 52 has a plurality of grooves 53 configured to receive an elastic unit 51a, 51b attached to the outer sealing plate 40. Each elastic unit 51a, 51b comprises a triangular rigid element 59 that has an engagement surface that contacts a surface 58 in the corresponding groove 53 and an elastic element 54 (e.g. a spiring). The rigid element 59 is also in contact with the outer housing plate 40. The engagement surface and the surface 58 in the groove 53 are substantially parallel and both are oblique to the longitudinal axis C and the radial direction of the longitudinal axis C. This allows the rigid element to be biased in the radial direction against the intermediate plate 52 and the sliding interaction between the engagement surface and the surface 58 in the groove 53 translates the radially biasing force to a biasing force parallel with the longitudinal axis C. Each elastic unit 51a, 51b may be provided with an elastic spring 54, such as a coil spring, that biases the rigid element in the radial direction so as to bias the intermediate plate 52, and by extension also the conical ring 55 and the first sealing plate 30, along the longitudinal axis C against the rotor 20.

[0064] Fig. 5b shows a rigid element 59 according to some implementations when the intermediate plate 52 and the housing plate is forced away from the outer housing plate 40 towards the rotor. By comparison, fig. 5c shows the rigid 59 element when the intermediate plate 52 has moved away from the rotor towards the outer housing plate 40. The rigid element has a width W and a height H wherein the ratio between width W and height H dictates to which extent the spring element 54 is compressed when the intermediate plate 52 moves towards the outer housing plate 40. For example, the ratio W/H may be about 2 meaning that for a displacement of X cm of the intermediate plate 52 towards outer housing plate 40 the spring element 54 is compressed 2X cm, effectively doubling the spring force. In general, the ratio W/H = A and the spring force of the spring element 54 is adjusted with a factor of A. In one exemplary embodiment, fifteen elastic units are used, each comprising a spring element 54 having a compressive force of 8 kg with a rigid element 59 having width/height ratio of about 1.77 giving a total biasing force of 15 X 1.77 X 8 = 212.4 kg.

[0065] As seen in fig. 5b and fig. 5c the end of the spring element 54 which engages the rigid element 59 moves along the longitudinal axis when the intermediate plate moves relative the outer housing plate 40. The spring element 54 may be loose inside the groove so as to follow the rigid element 59 or it is envisaged that the spring element 54 bends as the rigid element moves relative the intermediate plate 52.

[0066] Fig. 6 is a perspective view of a sealing plate 22 according to some implementations. The sealing plate 22 is substantially flat and has a top surface, also referred to as the apex, that faces the inner surface of cylindrical housing and a bottom edge that faces the rotor when the sealing plate 22 is used in the engine. The apex surface is provided with an apex sealing element 27 that protrudes from the apex surface of the sealing plate 22 so as to facilitate a gas tight seal against the inner surface of the cylindrical housing even when the rotor rotates and the sealing plate 22 slides against the inner surface and slides in and out of the rotor. The apex sealing element 27 may be made of an elastically deformable material such as rubber. It is also envisaged that the sealing element 27 is made of a rigid material, such as a metal and preferably metal coated with titanium aluminum nitride, TiAlN, and provided with one or more biasing elements that biases the apex sealing element 27 against the inner surface of the cylindrical housing. Optionally, two or more apex parallel sealing elements 27 may be provided side-by-side along the top edge of the sealing plate 22 to further facilitate a gas tight seal.

[0067] Each sealing plate 22 comprises an opening extending through the sealing plate 22 and a follower 25 arranged inside the opening so as to protrude from the sealing plate 22 on at least one longitudinal side of the sealing plate 22. The protruding part of the follower 25 is arranged inside the groove provided in the first and/or second housing plate meaning that when the rotor rotates, the follower 25 will follow the groove which in turn forces the sealing plate 22 in and out of the rotor. When the rotor with the sealing plates 22 rotates around the longitudinal axis, each follower 25 will turn relative the corresponding sealing plate 22, meaning that the rod 25 is rotatably arranged inside the opening of the sealing plate 22. Optionally, the protruding portion of the follower 25 is provided with a groove engagement element 26 that is received inside groove of the first or second sealing plate. The groove engagement element 26 may be in the form of a cuff or ring.

[0068] The sealing plate 22 comprises a first plate portion 23 and a second plate portion 24 wherein the second plate portion 24 is movable relative the first plate portion 23. The second plate portion 24 is movable at least along the longitudinal direction so as to push against the inside of the housing plate, which is biased against the sealing plate moveable allowing the combustion chamber of the engine to expand along the longitudinal axis.

[0069] The second plate portion 24 is also movable in the radial direction. This is achieved by the first plate portion 23 and second plate portion 24 being split along an oblique splitting plane whereby the second plate portion 24 is substantially triangular. The first and second plate portions 23, 24 are slidable relative to each other along the oblique splitting plane. As the second plate portion 24 slides relative the first plate portion 23, the second plate portion 24 will move along both the radial direction (to or from the rotational axis) and along the longitudinal axis (to or from the housing plate).

[0070] Fig. 7 shows further details of the first and second plate portion 23, 24. The first plate portion 23 comprises a protrusion 231 and the second plate portion 24 comprises a groove 241 that is configured to receive the 231 to hold the second plate portion 24 against the first plate portion 23 while still allowing the second plate portion 24 to slide relative the first plate portion 23 along the extension of the groove 241 and elongated protrusion 231. For example, the protrusion 231 is a T-shaped ridge and the groove 241 is a corresponding T-shaped groove 231 that receives the T-shaped ridge. It is understood that the arrangement of the groove 241 and protrusion 231 may be reversed, with the second plate portion 24 having the protrusion 231 and the first plate portion 23 having the groove 241.

[0071] The first plate portion 23 comprises a first opening 233 and the second plate portion 23 comprises a second opening 243. The openings 233, 243 cooperate to form a single opening extending through the sealing plate to receive a follower for engagement with the groove of the housing plate.

[0072] The second plate portion 24 further comprises a recess 242 and the first plate portion 23 comprises a protrusion 232 that is received inside the recess 242. The protrusion 232 forms a ledge upon which an elastic element can be placed. The elastic element will be compressed by the protrusion 232 and the side walls of the recess 242 to bias the second plate portion 24 along the longitudinal axis C towards a housing plate. This causes the second plate portion to abut the housing plate which facilitates a gas tight sealing.

[0073] As seen in fig. 7 slits 244, 234 may be provided in the top edge of both the first plate portion 23 and the second plate portion 24. These slits are used for receiving sealing elements that facilitate enhanced sealing against the inner surface of the cylindrical housing 10. The slits 244, 234 are configured to receive the sealing elements even when the second plate portion 24 moves in the radial and/or longitudinal direction.

[0074] Fig. 8 depicts a side view of the side of the second plate portion 24 that faces the first plate portion 23. The second plate portion 24 comprises a groove 241 that cooperates with an elongated protrusion provided on the first plate portion. Additionally, as stated in the above, the first plate portion comprises a protrusion 232 that is arranged inside a recess 241 provided in the second plate portion 24. The protrusion 232 supports an elastic element 60 which biases the second plate portion 24 in the radial direction, away from the rotational axis and towards the housing plate.

[0075] The elastic element 60 is preferably in the form of a double torsion spring as shown in further detail in fig. 9. The double torsion spring comprises two coil springs 61, 62 connected by a curved plate element 63. Each coil spring 61, 62 is formed by a coiled plate having a first end and a second end. The first end of each coil spring 61, 62 is connected to a respective end of the curved plate element and the second end of each coil spring is free, and may glide against a surface of the respective coiled plate as the elastic element 60 is compressed.

[0076] Turning back to fig. 8, it is also shown that the second opening 243 in the second plate portion 23 is larger in diameter compared to the first opening in the first plate portion. The first opening in the first plate portion is adapted to receive the follower 25 and allow it to rotate relative the first plate portion. That is, the diameter of the first opening is substantially that of the follower 25 whereas the diameter of the second opening is larger. This allows the second plate portion 24 to move relative the follower 25 in the radial direction and longitudinal direction so as to press against the housing plate. For example, when the second plate portion 24 is in its retracted position the follower 25 rests against a surface of the second opening 243 facing the rotational axis and when the second plate portion 24 is in its extended position (e.g. to follow the housing plate) the follower is in follower position 25', wherein the follower 25 rests against a surface of the second opening 243 facing away from the rotational axis.

[0077] The second plate portion 24 also comprises slits 244 for receiving sealing elements 27. The sealing elements 27 are abutting the inner surface of the cylindrical housing and when the second plate portion 24 is in its extended position, the top most portion of the second plate portion 24 (i.e. the portion comprising the slits 244) may come into contact with the inner surface of the cylindrical housing.

[0078] Fig. 10 shows schematically a comparison between a sealing plate 22' at its minimum longitudinal extension, also referred to as the retracted position, and a sealing plate 22" at its maximum longitudinal extension, also referred to as its extended position. In use, it is understood that each sealing plate 22', 22" is placed inside a slit provided in a rotor, as shown in fig. 1 and fig. 2.

[0079] Irrespective of the longitudinal extension of the sealing plate 22', 22" the sealing plate 22', 22" comprises an apex sealing element 27 which abuts (and slides along) the inner surface of the cylindrical housing so as to seal off a combustion chamber. Sealing plate 22' may represent the state of one of the sealing plates when oxidant and fuel is injected into a combustion chamber defined partially by the sealing plate 22'. The oxidant and fuel is ignited causing an increase in pressure which causes the combustion chamber to expand. Expansion of the combustion chamber is in part realized by rotation of the rotor, bringing the combustion chamber to a point along the rotation where the sealing plate 22' extends further out from the rotor. In addition, the combustion chamber also expands along the longitudinal axis C due to displacement of the second plate portion 24 relative the first plate portion 23 and the second plate portion 24 pushing the biased housing plate 30 away from the rotor. Since the housing plate 30 is biased towards the second plate portion 24 there is always a seal formed between the inside of the housing plate 30 and the second plate portion 24.

[0080] The sealing plate 22" being in its state of maximum longitudinal extension has the second plate portion 24 displaced relative the first plate portion 23. The displacement is caused by the second plate portion 24 sliding relative the first plate portion 23 in a direction oblique to both the rotational axis R and the transverse/radial axis T that is perpendicular to the rotational axis R.

[0081] The displacement along the rotational axis R causes a displacement of the biased housing plate 30. Comparing the sealing plate 22' (retracted position) with the sealing plate 22" (expanded position) reveals that that the housing plate 30 has been displaced a distance d. In both the expanded and retracted positions, the second plate portion 24 still seals against the housing plate, prohibiting gases from flowing from one combustion chamber to a neighboring combustion chamber. Additionally, the groove 35 provided in the housing plate 30 is sufficiently deep so as to engage the follower 25 even at the maximum displacement such that the sealing plates 22', 22" are continuously guided by the groove 35 and disengage from the groove.

[0082] The displacement along the transverse/radial axis T results in the second plate portion 24 engaging the apex sealing element 27 with the slits provided at the radial top most portion of the second plate portion 24 (see e.g. fig. 8). At its largest displacement in the transverse/radial direction T the radial top most portion of the second plate portion 24 may contact the inner surface of the cylindrical housing together with the apex sealing elements 27.

[0083] The person skilled in the art will appreciate that the relationship between the maximum displacement in the direction of the rotational axis R and the maximum displacement along the transverse/radial axis T can be modified by adjusting the angle α of the interface between the first and second plate portion 23, 24. The angle α of the interface is measured in the T/R-plane spanned by the transverse/radial axis T and the axis of rotation R. For example, if the angle α of the interface is 45° the displacement will be equal along the transverse/radial axis T and along the rotational axis R. On the other hand, if the angle α of the interface is small, e.g. 10° or 5° the displacement along the transverse/radial axis T will be smaller compared to the displacement along the rotational axis R.

[0084] To maintain a seal between the combustion chambers that are separated by sealing plates 22', 22", it is preferable that the apex sealing element(s) 27 are also moveable parallel to the rotational axis R so as to follow the moving housing plate 30. In some embodiments, moving the apex sealing element(s) 27 is achieved with an arrangement as shown in fig. 11a and fig. 11b.

[0085] In fig. 11a two apex sealing elements 27a, 27b are arranged on the apex surface of the same first plate portion 24. Each sealing element 27 is biased using a respective longitudinal biasing element 71a, 71b biasing the respective apex sealing elements in opposite directions against opposite housing plates 30. The longitudinal biasing element 71a is attached at one end to the first plate portion 24 and at the other end to the corresponding apex sealing element 27a pushing the apex sealing element 27a to one of the housing plates 30. Also, the longitudinal biasing element 71b is attached at one end to the first plate portion 24 and at the other end to the corresponding apex sealing element 27b pushing the apex sealing element 27b to the other one of the housing plates 30. In this way, one or both of the housing plates 30 may be movable and biased and the apex sealing elements 27a, 27b will be biased and forced against inside of each respective housing plate 30 to form a seal for the combustion chambers. The longitudinal biasing element 71a, 71b may be a spring such as coil spring, spiral spring, or similar. Fig. 11a shows one pair of apex sealing elements 27a, 27b. However, it is envisaged that two or more pairs, such as three or more pairs, may be provided on each sealing plate to further facilitate better sealing between combustion chambers.

[0086] In addition to biasing each apex sealing element 27 in the direction of the rotational axis with a longitudinal biasing element 71a, each apex sealing element 27 is also biased in the transverse direction against the inner surface of the cylindrical housing with one or more transverse biasing element(s) 72 shown in fig. 11b. The transverse biasing element(s) 72 may, like the longitudinal biasing element 71a, be realized with a spring, such as coil spring, spiral spring, or similar.

[0087] In some implementations, it is envisaged that the apex sealing element 27 is biased in both the transverse direction T and in the direction of the rotational axis R by a single biasing element. One example of such a single biasing element is a wave spring 70 as shown in fig. 12.

[0088] The wave spring 70 comprises an undulating plate portion 70a that extends along a main axis and is placed between the apex sealing element 27 and first plate portion 23 to act as the at least one transverse biasing element. The undulating plate portion 70a has a plurality of undulations and may have a substantially sinusoidal shape. Preferably, the undulating plate portion 70a has substantially the same width as the apex sealing portion 27. In this way, each top peak of the undulating plate portion seals against the apex sealing element and each bottom peak of the undulating plate portion seals against the first plate portion 23 so as to prohibit oxidant, fuel or residual combustion products from travelling between combustion chambers by going under the apex sealing element 27, between the apex sealing element 27 and the first plate portion 23.

[0089] The undulating plate portion 70a can be resiliently compressed in the transverse/radial direction such that the apex sealing element 27 is biased against the inner surface of the cylindrical housing.

[0090] Additionally, the wave spring 70 comprises a longitudinally biasing section 70b that is connected to the undulating portion 70a. The longitudinally biasing section 70b extends perpendicular to the main axis of the undulating plate portion 70a and comprises a torsion spring and optionally one or more undulating structures. That is, the wave spring 70 may be formed as a single piece that is substantially L-shaped. Having a longer undulating plate portion 70a that extends along substantially the entire longitudinal extension of the apex sealing element 27 so as to bias it against the inner surface of the cylindrical housing and a shorter longitudinally biasing section 70b biasing the apex sealing element 27 against the inside of a housing plate.

[0091] Fig. 13 depicts a cross sectional view of a one-way valve 80 that can be used with the machine when used as e.g. a heat pump. The one-way valve 80 allows a fluid (e.g. from the outlet of the machine) to travel along a flow direction F, from an inlet pipe 81 to an outlet pipe 83. The inlet pipe 81 has an open end forming a cone shaped or concave mouth. The mouth is shaped and adapted to receive a sphere 82 arranged between the inlet pipe 81 and outlet pipe 83 which, when arranged in the mouth of the inlet pipe 81, fluidly seals the hollow pipe 81 to close the one-way valve 80. When the sphere 82 is moved away from the mouth of the inlet pipe 81, the fluid can flow around the sphere 82 to enter a fluid channel 84 in the outlet pipe 83 arranged in-line with the inlet pipe 81. Notably, the outlet pipe 83 comprises one or more fluid channels 84 displaced from the central elongation axis of the outlet pipe 83 such that, even if the sphere 82 is pressed against the outlet pipe 83 it does not completely seal all fluid channels 84 to allow fluid to flow from the inlet pipe 81, around the sphere 82 and into the outlet pipe 84 when the one-way valve 80 is open. Downstream, the one or more fluid channels 84 of the outlet pipe can converge to a single channel.

[0092] The inlet pipe 81 and outlet pipe 83 are arranged in-line, and the outlet pipe 83 is movable relative the inlet pipe 81 such that by moving the outlet pipe 83 towards the inlet pipe 81 the sphere 82 is pressed against the mouth of the inlet pipe 81 by the outlet pipe 83 to close the one-way valve 80. The inlet pipe 81, outlet pipe 83 and sphere 82 are housed inside a sleeve 86 that allows the outlet pipe 83 to move to/from the inlet pipe 81 to close/open the one-way valve 80.

[0093] To control movement of the outlet pipe 83 relative the inlet pipe 81, a mechanical actuator may engage the outlet piper 83 and move it relative the inlet pipe 81. In some implementations, the outlet pipe 83 comprises, or is made of, a magnetic material wherein the outlet pipe 83 is surrounded with a conductive coil 85. By controlling an electric current supplied to the coil 85, the coil 85 generates a magnetic field which exerts a force on the outlet pipe 83 that moves the outlet pipe 83 to/from inlet pipe 81 to close/open the one-way valve 80. Accordingly, a compact electrically actuated one-way valve 80 suitable for use with the machine has now been described.

[0094] Fig. 14 shows schematically the machine 100 used as a heat pump. The machine 100 may be identical to the machine or combustion engine described in connection to fig. 1 - 12 in the above. A first and second one-way valve 80a, 80b are connected in parallel to the outlet of the machine 100 (where compressed medium exits the machine 100) and a third and fourth one-way valve 80c, 80d are connected in parallel to the inlet of the machine 100 (where compression medium is pulled into the machine 100). Each one-way valve 80a-d may be the electrically actuated one-way valve 80 as described in fig. 13. By selectively opening and closing the one-way valves 80a-d the machine 100 can be used as a heat pump for either heating or cooling an internal space. The internal space may be an indoor environment of a building or e.g. the interior of a vehicle. An internal heat exchanger 88 is arranged inside the internal space and an external heat exchanger 87 is arranged in an exterior space (e.g. outdoors).

[0095] When operating in cooling mode the second and fourth one-way valve 80b, 80d are opened and the first and third one-way valve 80a, 80c is closed. Compression medium therefore exits the machine 100 and enters the external heat exchanger 87 via the second one-way valve 80b where some heat is dissipated. The medium then exits the external heat exchanger 87 and passes an expansion valve formed of two opposite and parallel one-way valves 80e, 80f allowing the medium to expand and cool. When the medium passes from the external heat exchanger 87 to the internal heat exchanger 88 the external-to-internal one-way valve 80e is open and the internal-to-external one-way valve 80f is closed. The cooled medium then enters the internal heat exchanger 88 where it absorbs heat from the internal environment which cools the internal environment. The medium then exits the internal heat exchanger 88 and reenters the machine 100 via the fourth one-way valve 80d.

[0096] When operating in heating mode the second and fourth one-way valve 80b, 80d are closed instead and the first and third one-way valve 80a, 80c are open. The compressed medium exits the machine 100 and passes through the first one-way valve 80a to enter the internal heat exchanger 88. The compressed and heated medium heats the internal space, exits the internal heat exchanger 88 and is expanded in expansion valve formed of the two parallel but opposite one-way valves 80e, 80f. When the medium passes from the internal heat exchanger 88 to the external heat exchanger 87 the external-to-internal one-way valve 80e is closed and the internal-to-external one-way valve 80f is open. The expansion cools the medium whereby the medium is transferred to the external heat exchanger 87 wherein the medium is heated by the external environment. The medium is then reintroduced into the machine 100 via the third one-way valve 80c.

[0097] Thus, by controlling the opening and closing of the one-way valves 80a-f it is possible to use the machine 100 as a heat pump.

[0098] The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. On the contrary, many modifications and variations are possible within the scope of the appended claims. For example, different shapes of the rotor can be used, with more or less than three sealing plates. While the engine is especially suitable for combustion of hydrogen and oxygen other fuel and oxidant mixtures can be used, such as gasoline or diesel together with air or oxygen. As another example, it is envisaged that for any embodiment of the engine or compressor only one, or both, of the housing plates are biased against the rotor and the sealing plates. Any housing plate which is not biased against the rotor and sealing plates may then be rigidly attached to the cylindrical housing. In the claims, the word "comprising" does not exclude the presence of other elements or steps than those listed in the claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

Claims

1. A machine (1) for use as a combustion engine or compressor, comprising:

    a cylindrical housing (10) extending along a longitudinal axis (C), the cylindrical housing (10) having an inner surface (11) defining an inner volume,
    a first and second housing plate (30) arranged against a first and second longitudinal end of the cylindrical housing (10), respectively,
    a rotor (20) arranged inside the cylindrical housing (10), the rotor (10) being configured to rotate around a rotational axis (R), the rotational axis (R) is parallel to but offset with respect to the longitudinal axis (C),
    a plurality of sealing plates (22, 22a-c), configured to be movable relative the rotor (20) in a radial direction relative said rotational axis (R) so as to seal against the inner surface (11) of the cylindrical housing (10),
    wherein any two neighboring sealing plates (22, 22a-c) defines a closed chamber (25a, 25b, 25c) together with the first housing plate (30), the second housing plate (30) and the inner surface (11) of the cylindrical housing (10), and
    wherein the first housing plate (30) is biased against the cylindrical housing (10) so as to be axially displaceable along the longitudinal axis (C) to enable expansion of the closed chamber (25a, 25b, 25c) along the longitudinal axis (C).

2. The machine (1) according to claim 1, further comprising:

    an outer housing plate (40) attached to the cy-

lindrical housing (10), and
a biasing arrangement (50) arranged between the outer housing plate (40) and the first housing plate (30), elastically pressing the first housing plate (30) against the cylindrical housing (10).

3. The machine (1) according to claim 2, wherein the biasing arrangement (50) comprises:
a plurality of elastic units (51a, 51b) arranged in a circular pattern around the longitudinal axis (C), each elastic unit (51a, 51b) being elastic in a direction parallel with the longitudinal axis (C) and configured to interact with the outer housing plate (40).

4. The machine (1) according to claim 3, wherein the biasing arrangement (50) further comprises:
an intermediate plate (52) arranged in abutment with the plurality of elastic units (51a, 51b) on one side and in abutment with an outer surface (32) of the first housing plate (30) on a second side, opposite to the first side.

5. The machine (1) according to claim 4, wherein a conical ring (55) having a concave inner surface (56) is arranged between the intermediate plate (55) and first housing plate (30), and wherein the outer surface (32) of the first housing plate (30) is convex.

6. The machine (1) according to any of claims 3-5, wherein the plurality of elastic units (51a, 51b) comprise rigid elements that are spring loaded in a direction transverse to the longitudinal axis (C), wherein each rigid element comprises an abutment surface that is oblique relative the transverse direction, and wherein the intermediate plate (52) comprises a plurality of grooves (53) configured to receive the abutment surface of each elastic unit (51a, 51b), respectively.

7. The machine (1) according to any of the preceding claims, wherein each sealing plate (22, 22a-c) is split into a first plate portion (23) and a second plate portion (24) and wherein the second plate portion (24) is moveable relative the first plate portion (23) in at least a direction parallel with the longitudinal axis (C), and
a biasing element (60) arranged between the first and second plate portions (23, 24), exerting a force on the second plate portion (24) in at least the longitudinal direction against the first housing plate (30).

8. The machine (1) according to claim 7, wherein the first plate portion (23) comprises an elongated protrusion (231) or elongated groove and the second plate portion (24) comprises the other one of an elongated protrusion or elongated groove (241), wherein the elongated protrusion (231) is inserted into the elongated groove (241) to make the first and second plate portions (23, 24) slidable with respect to each other.

9. The machine (1) according to claim 8, wherein the elongated protrusion and elongated groove (231, 241) are configured to enable the plate portions (23, 24) to slide relative each other in a direction that is oblique relative to the radial direction and longitudinal direction.

10. The machine (1) according to any of claims 7-9, wherein one of the first plate portion (23) and second plate portion (24) comprises a recess (242), and the other one of the first and second plate portion (23, 24) comprises a protrusion (232) that is received in the recess (242), and wherein the elastic element (60) is arranged in the recess.

11. The machine (1) according to any of claims 7 - 10, further comprising:

a follower (25) associated with each sealing plate (22, 22a-c), each follower (25) extending longitudinally through a first (233) opening in the first plate portion (23) and a second opening (243) in the second plate portion (24), and protruding from at least one longitudinal side of the sealing plate (22, 22a-c), and
a groove (35) arranged on an inside of at least the first housing plate (30), the groove being configured to receive the follower (25) protruding out of each sealing plate (22, 22a-c), wherein the groove (35) defines a closed path configured to control the movement of the sealing plates (22, 22a-c) radially relative the rotor (20).

12. The machine (1) according to claim 11, wherein a diameter of the second opening (243) in the second plate portion (24) is larger compared to a diameter of the first opening (233) in the first plate portion (23).

13. The machine (1) according to any of claims 7 - 12, wherein each plate portion (23, 24) is rigid and made of a metal material, preferably a metal coated with titanium aluminum nitride, TiAlN.

14. The machine (1) according to any of the preceding claims, wherein each sealing plate (22, 22a-c) comprises an apex sealing element (27) extending along an apex of the sealing plate (22, 22a-c), the apex sealing element being biased against the inner surface (11) of the cylindrical housing (10).

15. The machine (1) according to any of the preceding claims, wherein a transverse cross-section of the rotor (20) is a curved polygon, preferably a Reuleaux triangle, with one sealing plate (22, 22a-c) at each vertex of the curved polygon.

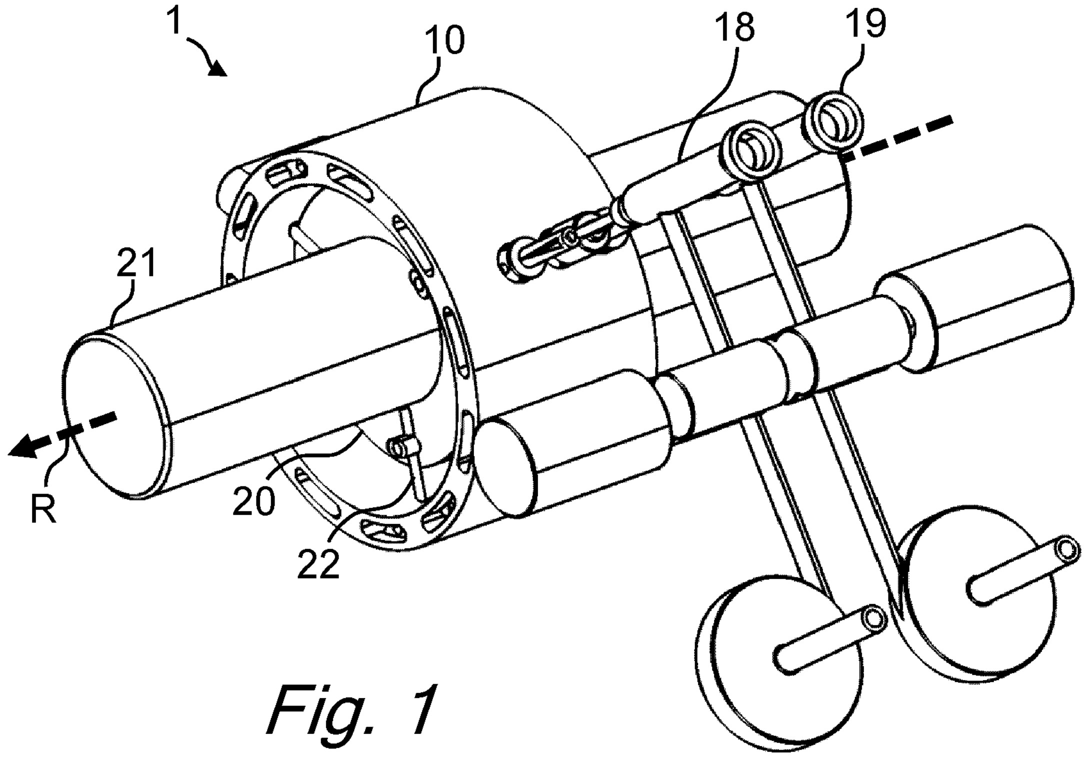
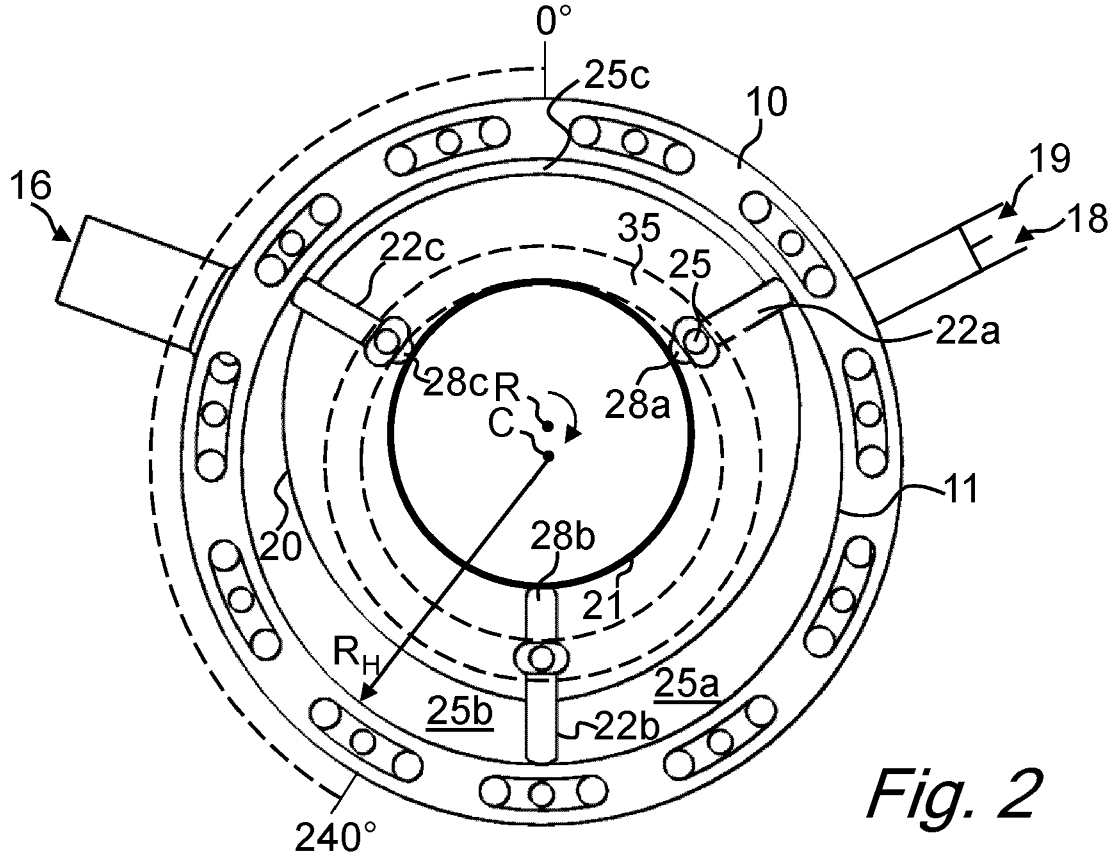

1
10
18
19
21
R
20
22

Fig. 1


0°
25c
10
16
19
18
22c
35
25
22a
28c
R
28a
C
11
20
28b
21
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25a
25b
22b
240°

Fig. 2

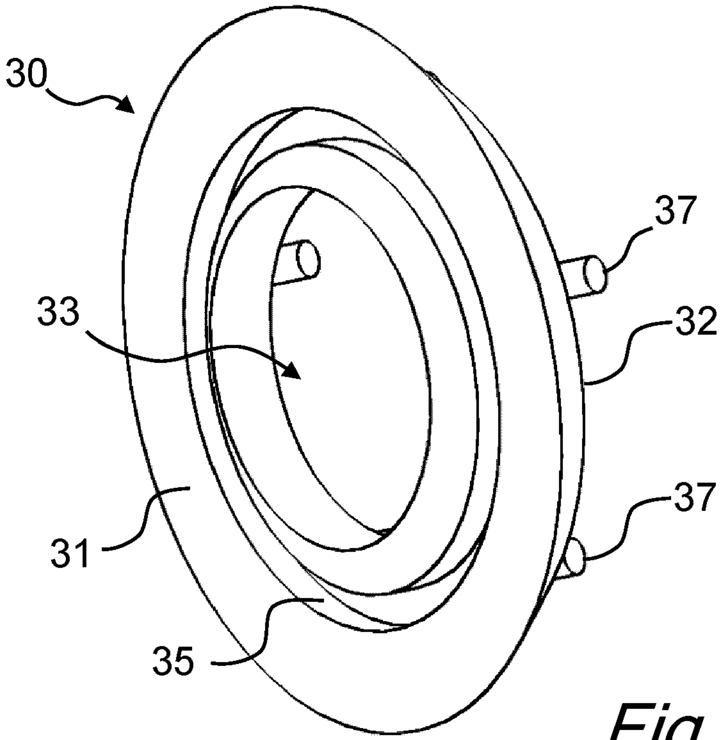

Fig. 3

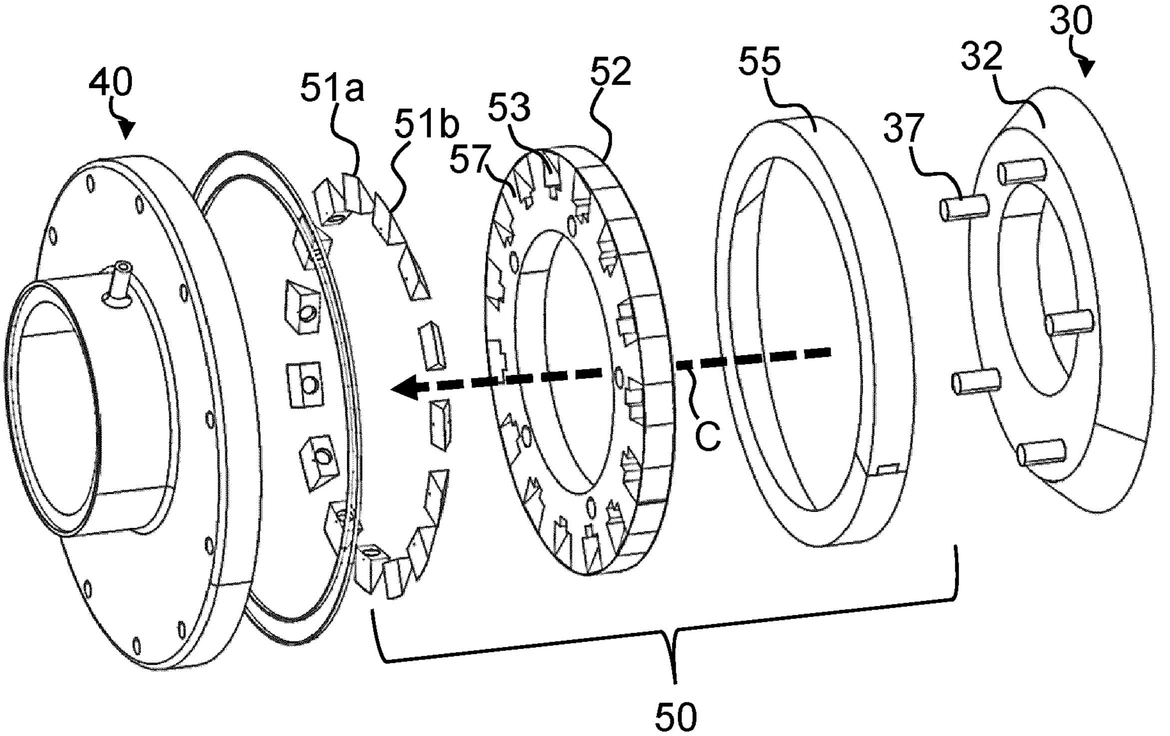

Fig. 4

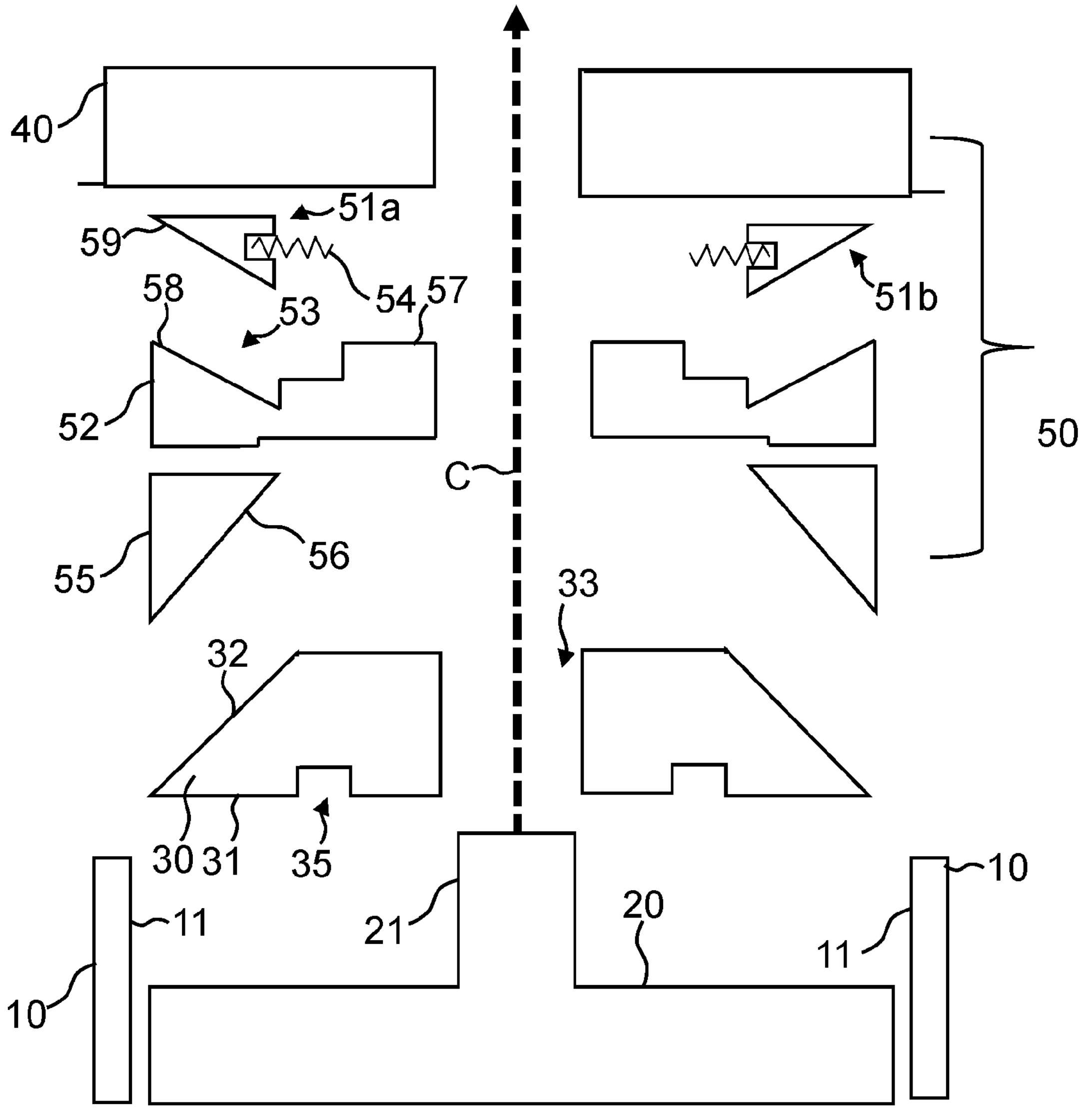

Fig. 5a

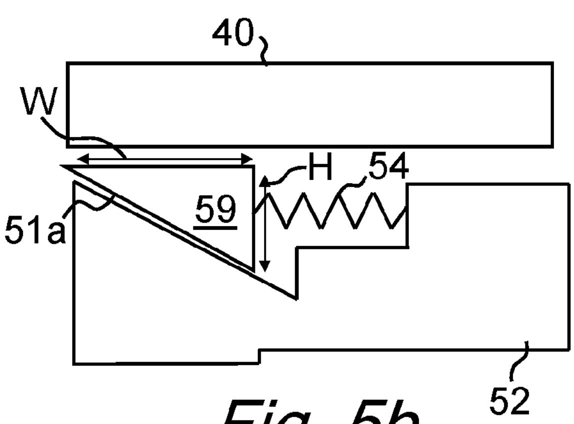

Fig. 5b

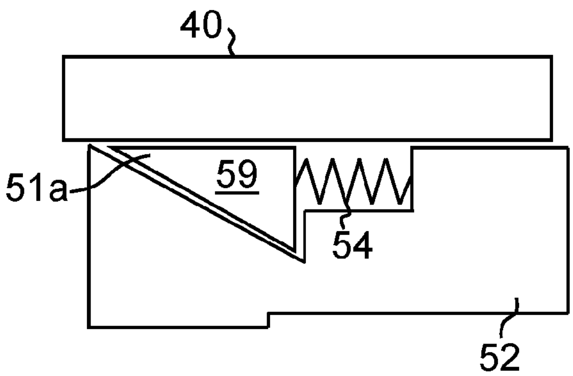

Fig. 5c

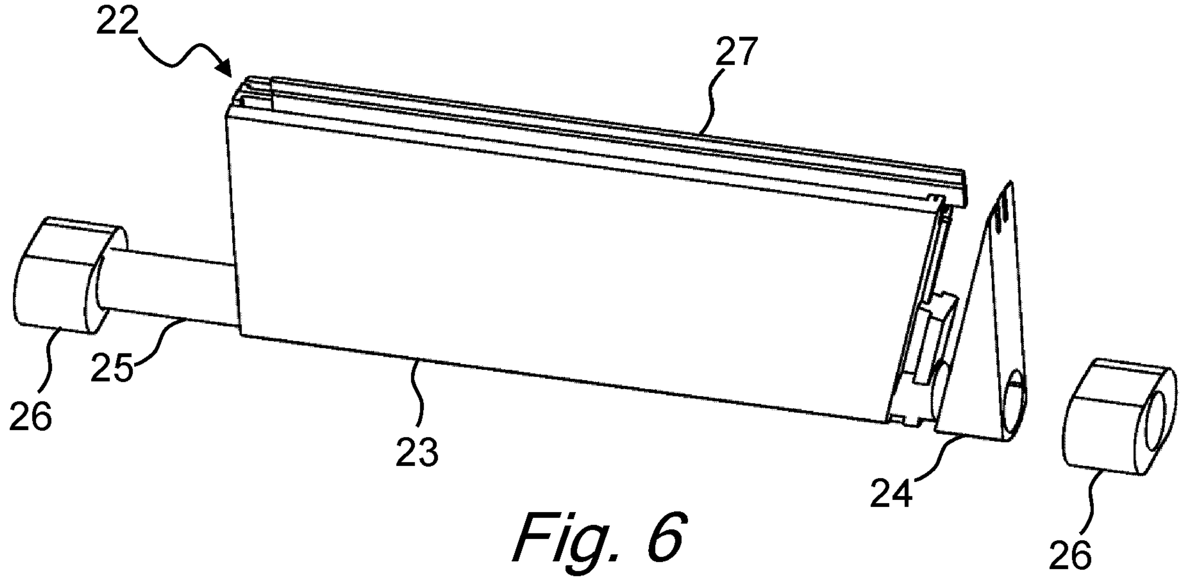

Fig. 6

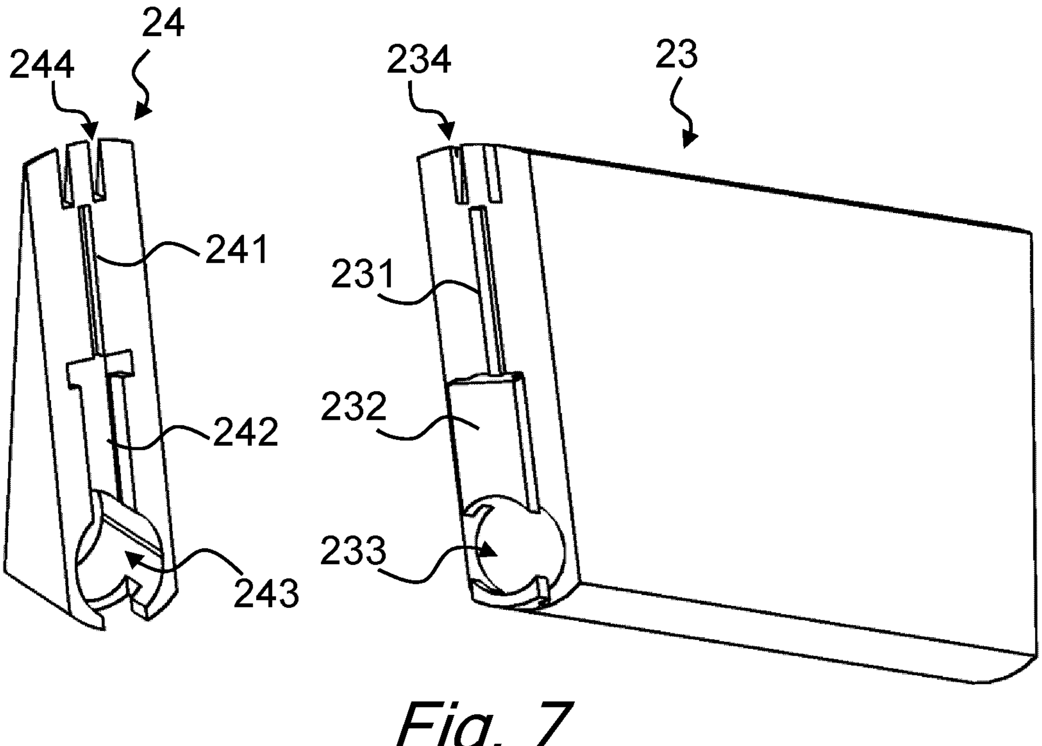

Fig. 7

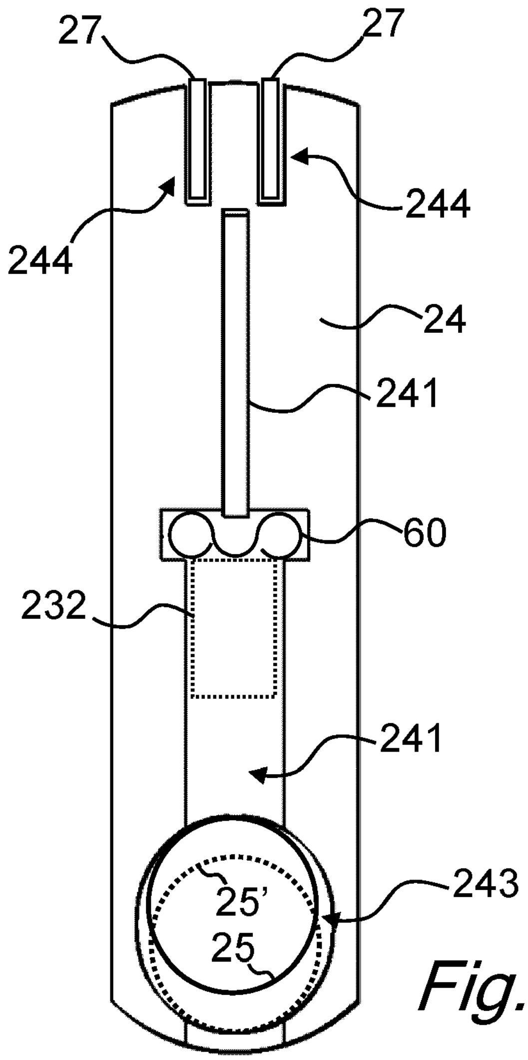

Fig. 8

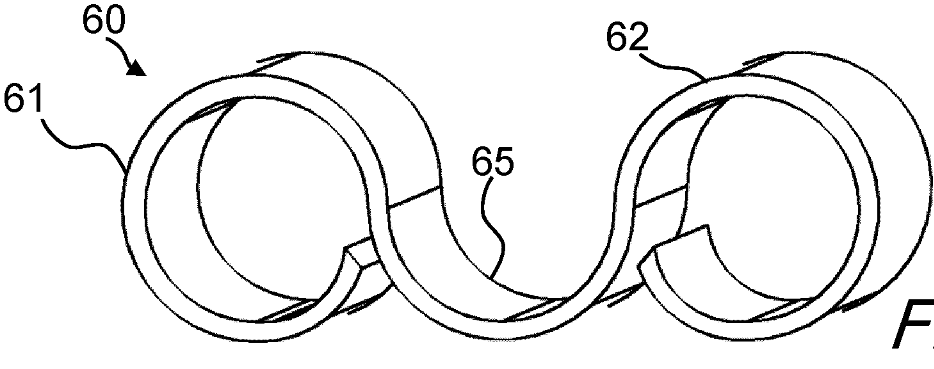

Fig. 9

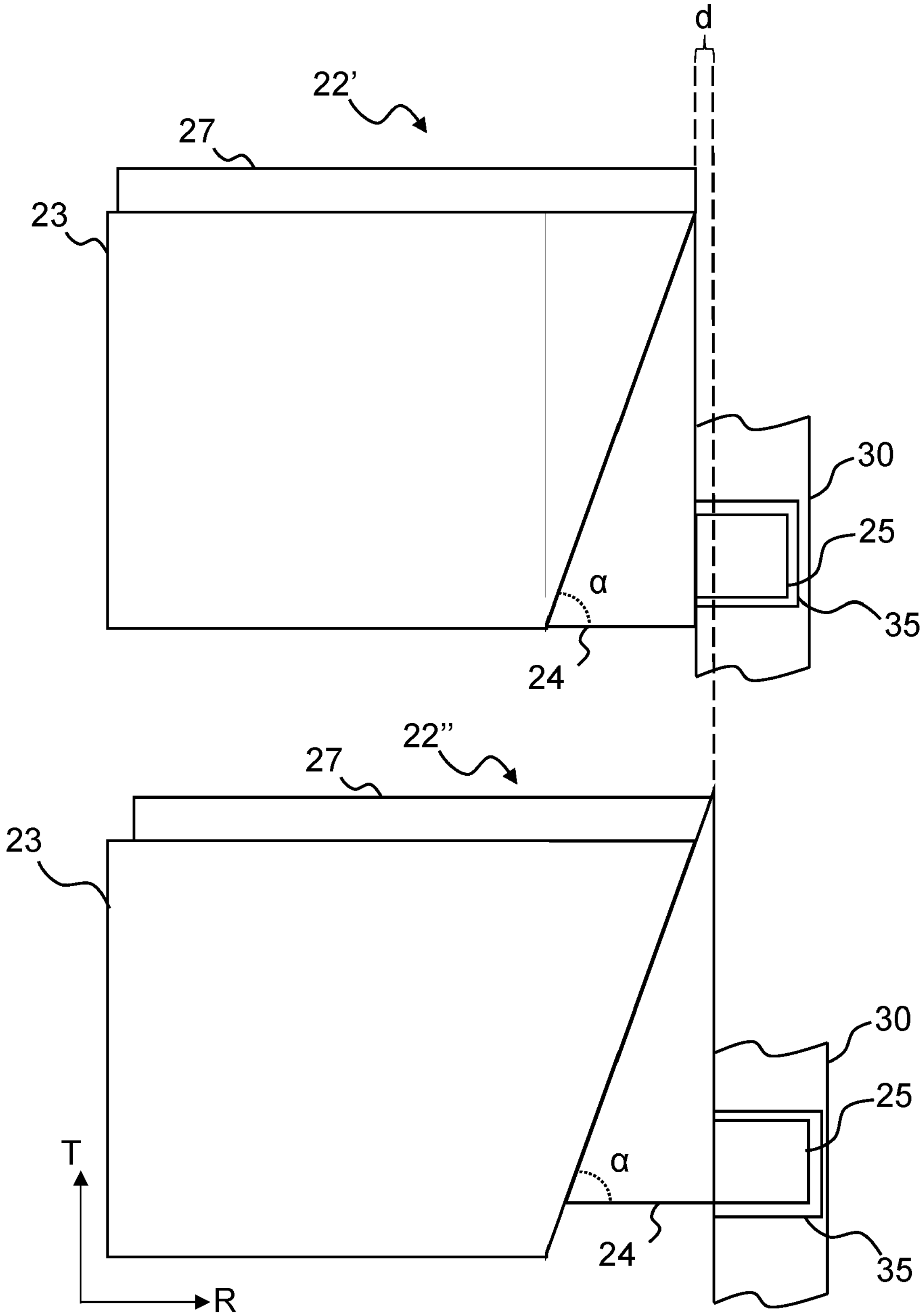

Fig. 10

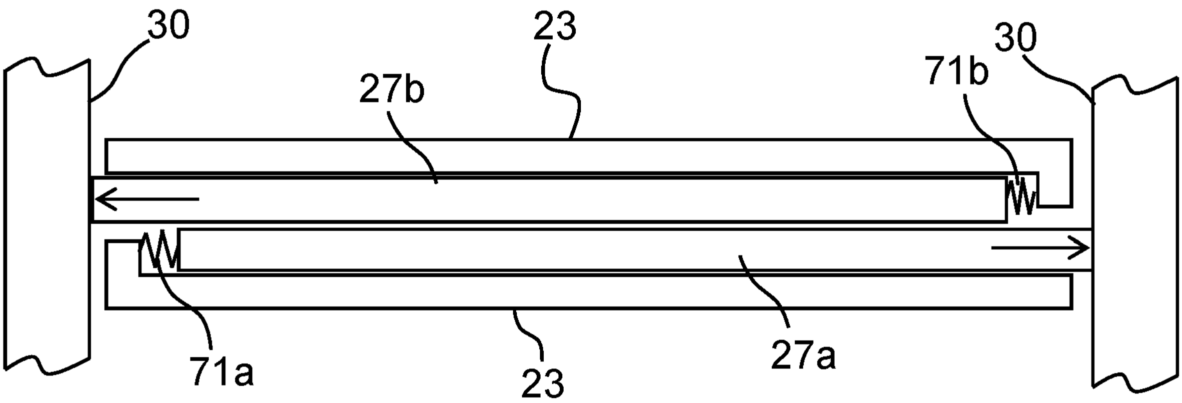

Fig. 11a

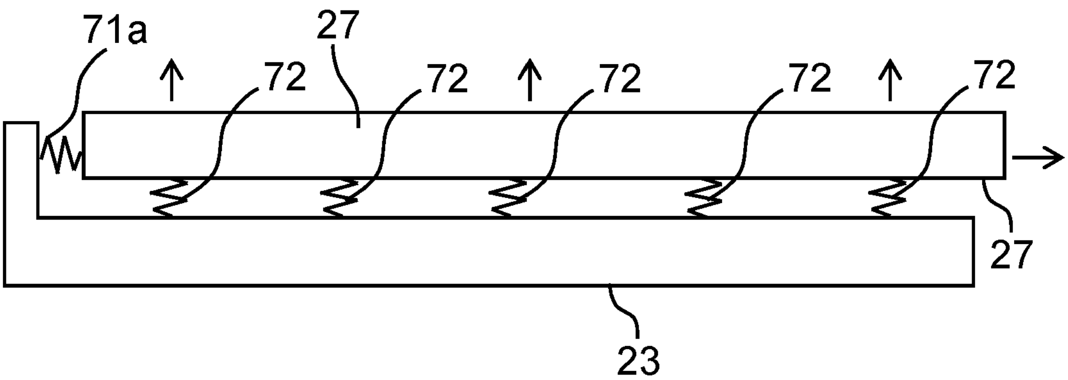

Fig. 11b

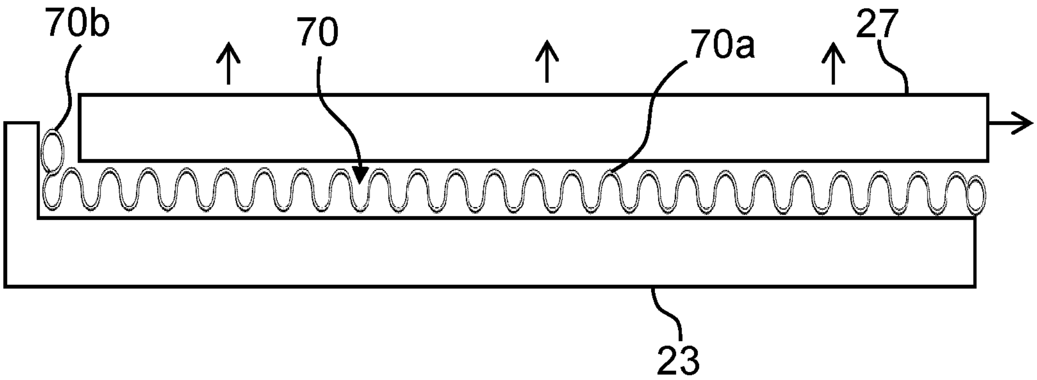

Fig. 12

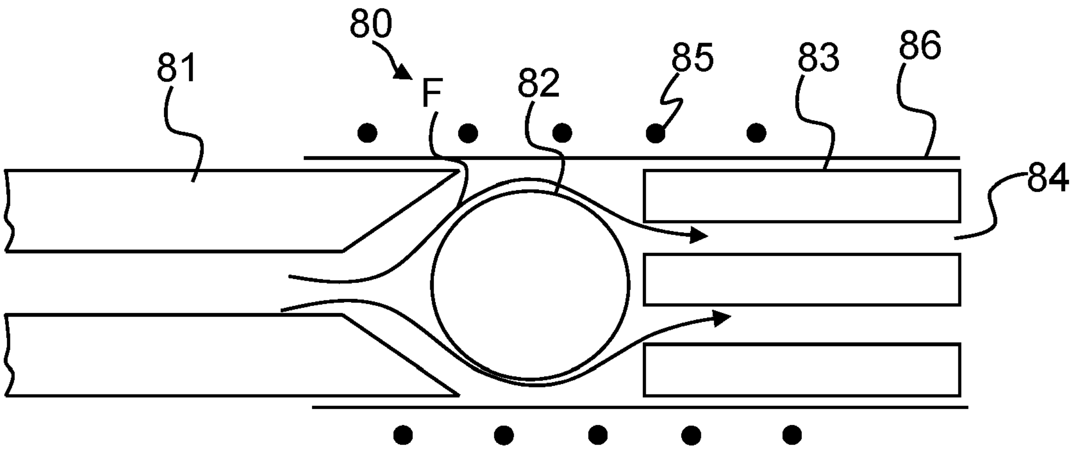
80
81
F
82
85
83
86
84

Fig. 13

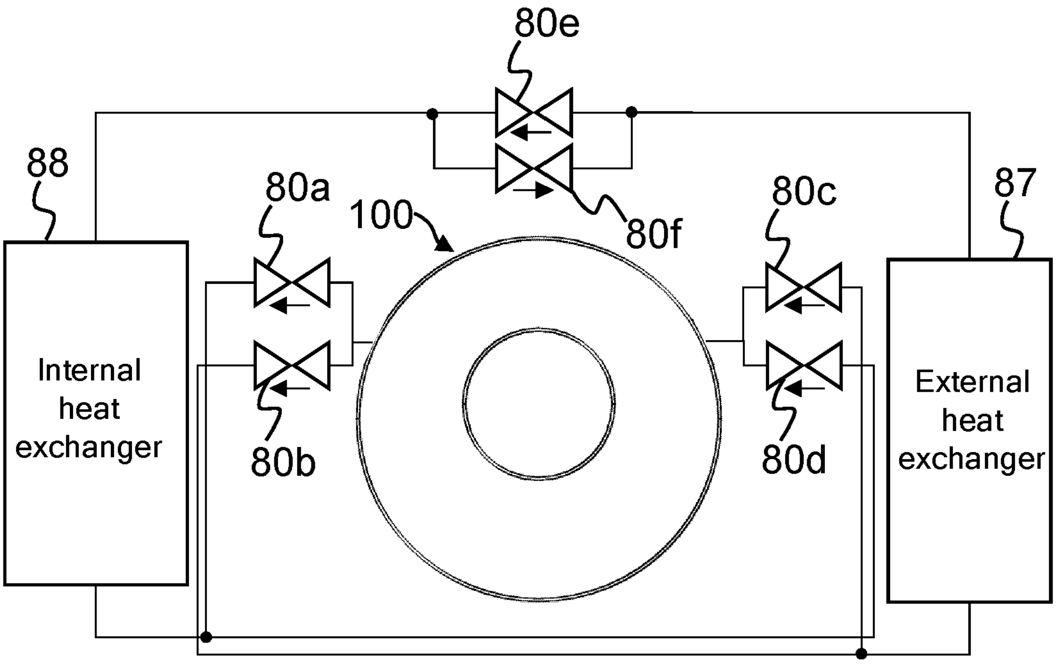
80e
88
80a
100
80f
80c
87
Internal heat exchanger
80b
80d
External heat exchanger

Fig. 14

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Place of search	Date of completion of the search	Examiner
Munich	22 October 2023	Durante, Andrea

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