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(54) **HOT AIR ENGINE**

HEISSLUFTMOTOR

MOTEUR À AIR CHAUD

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Description

[0001] The present invention relates to a hot air engine comprising at least one compression cylinder connected to a delivery manifold and an inlet manifold for the input and output from the cylinder of an operating fluid, and at least one expansion cylinder connected to an expansion manifold and to an exhaust manifold for the input and output from the cylinder of the operating fluid.

[0002] The engine further comprises a transmission system of the movement of the expansion and compression cylinder pistons to a system for transforming the movement into electric power.

[0003] In particular, each cylinder is connected to each manifold through a valve, so as to allow or prevent the passage of the operating fluid from the cylinder to the manifold and vice versa.

[0004] The one just described is the common configuration of hot air engines known in the state of the art and relating to engines used within external combustion and open circuit thermodynamic cycles, which provide for an inlet phase, a compression phase, a strong heat input phase, an expansion phase of hot gases and an exhaust phase.

[0005] Hot air engines belonging to the past and to an older state of the art are particularly reliable, thanks to the simplicity of the components and the ease of assembly and operation.

[0006] These engines work with large diameter pistons, but have particularly low and unacceptable efficiency for the insertion of said engines into thermodynamic plants for generating electric power.

[0007] High revolution hot air engines are currently being manufactured, such as the Stirling engine, to try to solve efficiency problems, however these engines do not respond adequately to operational and performance needs due to the strong pressure drops during the air flow transfers that evolve in the thermodynamic cycle and also due to the low energy obtainable between the thermal sources.

[0008] All the thermal, fluid and mechanical losses acceptable for an internal combustion engine, as a small part with respect to the power supplied, become too high in percentage for an external combustion air thermodynamic cycle. This results in the need to reduce speeds, decreasing the engine revolutions.

[0009] The decrease in the number of revolutions has evident repercussions on efficiency, so that the engines known in the state of the art cannot obtain a suitable compromise between engine reliability, continuity of operation and energy efficiency.

[0010] Currently, engines can be manufactured to obtain very high efficiency, however the required pressures are particularly high (49-50 bar) and this entails very low reliability and durability, requiring continuous maintenance.

[0011] Furthermore, since the engine object of the present invention can be used inside solar power units

operating also in remote areas, difficult to reach or countries with non-cutting-edge technology, it is particularly advantageous to use elements with easy maintenance and intervention, so that the proposed solution must aim at constructive simplicity.

[0012] Document EP2417343 discloses a heat engine comprising reciprocating compressor and expander elements arranged in a linear, free-piston configuration, a combustor separate from the compressor and expander elements, and a linear energy conversion device provides conversion of solid, liquid, or gaseous fuel into hydraulic, electric, or pneumatic energy by means of subjecting a working fluid to a thermodynamic cycle with substantially constant pressure combustion. The compression and expansion elements are mechanically connected by a rigid rod to permit the compression and expansion elements to reciprocate in unison. The valves may be automatically controlled by an electronic control unit. A heat exchanger may also be used to improve efficiency. The engine is highly efficient and can be used for electric power generation and combined heat and power systems.

[0013] Another energy storage systems is disclosed in document US2015198185, which refers to a compressed gas storage system including a plurality of stages to convert energy into compressed gas for storage, and then to recover that stored energy by gas expansion. The system discloses comprises a reversible compressor/expander having a reciprocating piston. Pump designs for introducing liquid for heat exchange with the gas, are also described. Gas flow valves featuring shroud and/or curtain portions, are also described.

[0014] Document EP0945599 relates to a valve with a rod attached to a flat valve head, which closes an inlet or exhaust passage. The rod is at one edge of the valve head, and is driven in rotation to rotate the head from the closed position to an open position. A spring returns the valve to the closed position. An electronic controller can be used to control the time and degree of opening of the valve.

[0015] Document EP2816013 relates to a hybrid system that comprises: a multifunctional hybrid motor system with pistons, wheels, and associated means including in combination two motor cycles complementary in terms of technology and temperature, one defining an internal combustion engine with at least three cylinders with pistons, and the other defining a so-called external combustion engine with at least three cylinders with pistons driven by the expansion of an active fluid, said hybrid motor system being formed so as to include at least three cylinder/piston pairs, wherein the internal combustion engine operates according to a 4-stroke cycle while the external combustion engine operates according to a 2-stroke cycle, said engine does not include any valves, the pistons of the internal combustion engine and the at least three pistons are arranged so that the energy resulting from the consecutive expansion of the active fluid in the at least three cylinders of the external combustion

engine acts consecutively on said pistons of said 4-stroke internal combustion engine during the compression and exhaust phases. This technical solution makes it possible to recover a portion of the thermal energy discharged by the exhaust gases of the internal combustion engine in order to convert the same into mechanical energy in the external combustion engine.

[0016] There is therefore an unmet need by known engines in the state of the art, to manufacture a very low revolution engine with large pistons which allows to solve the construction, efficiency and flow control problems.

[0017] The present invention achieves the above objects by manufacturing an engine according to claim 1.

[0018] This peculiar configuration allows, as will be described later in detail, to precisely regulate the opening and closing of the valves.

[0019] The engine object of the present invention provides in fact at least four valves (two per cylinder) whose operation, that is when to open/close and for how long, is fully adjustable.

[0020] As will be seen later, the adjustment can take place manually or automatically.

[0021] The fine adjustment of the valves and therefore the correct positioning of the closing element, allows to reduce the dead spaces, i.e. the air volumes inside the cylinders that do not enter the energy generation process.

[0022] The influence of these dead spaces on the evolutionary dynamics of the thermodynamic cycle is important and particularly affects the thermofluid dynamics parameters that are to be obtained for optimizing the efficiency.

[0023] According to a preferred embodiment, the valve seat has a first opening facing towards the manifold and a second opening facing towards the cylinder.

[0024] In particular, the first and second openings are surrounded by a first and a second abutment surface, respectively, since the closing element consists of a plate-like element, so that, during translation, it passes from a condition of maximum approach to the manifold, wherein the surfaces of the plate-like element are in abutment with the first abutment surface, at a condition of maximum approach to the cylinder wherein the surfaces of said plate-like element are in abutment with the second abutment surface.

[0025] In addition to conferring high construction simplicity to the valves belonging to the engine object of the present invention, this embodiment allows to obtain an adjustment of the opening/closing of each valve based on the pressure differential which acts on the two surfaces of the plate-like element.

[0026] The low working pressure allows important simplifications on the seals and on the wear of the cylinder walls: an excellent compromise is obtained between the increase in pressure, which increases the efficiency, and a lowering, which increases the life of the engine.

[0027] According to a preferred embodiment variant, an adjustment system of the timing and the opening angle

of each valve is provided.

[0028] Regardless of the realization of this system, the adjustment of the opening of the valves allows to manufacture a low revolution and high efficiency engine.

[0029] With the same efficiency, the reduction in the number of revolutions allows to obtain an important reduction of the stresses due to the mechanical member speed, in order to achieve continuous engine operation, even 24 hours a day for about 100,000 hours, which represents the operative life of the translational and rotation components.

[0030] However, scheduled maintenance interventions are necessary on more wearable elements, such as the piston rings, but these interventions on the useful life of the machine are not very significant.

[0031] As will become apparent from an illustrated exemplary embodiment, a possible embodiment of the engine object of the present invention, with a peculiar configuration of the arrangement of the compressor and expander cylinder, allows to further reduce the wear of these rings.

[0032] As anticipated, the engine object of the present invention can preferably be provided in combination with a solar power unit for generating electric power.

[0033] In this case, the engine could be connected to a latent heat thermal unit responsible for heating the operating fluid circulating inside the engine cylinders.

[0034] Preferably the operating fluid is made up of air, so as to simplify the engine and the corresponding unit installation, in areas where water is difficult to find.

[0035] Furthermore, the air can absorb heat directly from the thermal unit, avoiding a carrier fluid that carries the necessary heat.

[0036] Finally, the open cycle operation avoids the use of large exchangers for cooling.

[0037] The characteristics described so far and the following ones, therefore, allow the manufacturing of a hot air engine which has high construction simplicity and reliability and which preferably works at air temperatures from 500 °C to 750 °C, maintaining excellent efficiency in terms of energy generation.

[0038] Using 750 °C as the maximum working temperature, the thermal and mechanical stress on the materials is limited: the engine can be built at low cost with common steels and materials.

[0039] In consideration of the operational reliability, the weight of the engine, made up of common steels, becomes an indicator of strength, together with the low number of revolutions, conforms the engine object of the present invention in the similitude of a hydroelectric plant capable of operating for years without maintenance interventions.

[0040] Advantageously, always with the aim of pursuing a high construction and assembly simplicity of the components, the adjustment system consists of a mechanical delay system, which is provided connected between the cylinder of each piston and the corresponding valve.

[0041] This mechanism is able to keep the closing end angles constant for the delivery valve (connected to the delivery manifold) of the compressor cylinder and for the exhaust valve (connected to the exhaust manifold) of the expander cylinder and the opening start angles constant for the inlet valve (connected to the inlet manifold) of the compressor cylinder and for the expansion valve (connected to the expansion manifold) of the expander cylinder.

[0042] At the same time the mechanism is able to adjust, manually or automatically, the opening angle of the valves.

[0043] The mechanical delay system confers flexibility to the engine object of the present invention in relation to the input thermofluid dynamics parameters, such as maximum working pressure of the operating fluid, the temperature of the latent heat thermal unit and the room temperature.

[0044] The mechanical delay system is able to individually adjust the opening angle of the valves by controlling the operation of the engine in the output parameters, such as the number of engine revolutions, the power expressed by the engine to the shaft and the efficiency optimization.

[0045] Lastly, the mechanical delay system is responsible for the important flows adjustment in order to avoid pressures differences in each transfer which lead to significant efficiency drops.

[0046] According to a possible embodiment, which will be described in detail through the use of an illustrated executive example, the mechanical delay system comprises:

a first gear wheel mounted rotatable about an axis,
a second gear wheel, which engages with the first gear wheel so as to rotate in the opposite direction to the first gear wheel,
a first lever system which has an input terminal and an output terminal, so that the input terminal is connected to the second gear wheel, while the output terminal is inserted inside a cam slot provided on an eccentric element.

[0047] In particular, the eccentric element is rotationally fixed and connected to a second lever system, connected in turn to the valve.

[0048] As an alternative to the mechanical delay system, the valve opening adjustment system can include an engine (electric or mechanical)

[0049] In order to maximize the engine efficiency, each cylinder has an external jacket inside which two opposed pistons are mounted, the valves of each cylinder being placed on the external surface of the external jacket of the cylinder, in the area between the heads of the two pistons.

[0050] According to an improvement, the compression cylinder has a smaller diameter than the expansion cylinder.

[0051] In fact, it is simpler and more controllable to divide the compression phase from the expansion phase on two cylinders with different displacements and optimized for the cycle: integrated solutions as in old projects, or as in the known Stirling engine, induce increases in dead spaces and unwanted thermal passages.

[0052] According to a possible variant embodiment, means for setting the adjustment system of the timing and opening angle of each valve can be provided.

[0053] Such means can for example consist of a screw aimed at regulating the stroke or extension of the various components of the mechanical delay system.

[0054] Finally, it is specified that the setting means comprise an interface with one or more electronic units.

[0055] The screw can be connected, for example, to an automatic actuator and/or to a software which calculates the condition of maximum engine efficiency and sets the screw accordingly.

[0056] These and other features and advantages of the present invention will become clearer from the following description of some exemplary embodiments illustrated in the attached drawings wherein:

figures 1a to 1e illustrate some possible embodiments of the hot air engine object of the present invention;

figures 2a to 2g illustrate different views of a preferred embodiment of the valve belonging to the engine object of the present invention;

figure 3 illustrates a possible embodiment of the mechanical delay system belonging to the engine object of the present invention;

figures 4a to 4d show different views of a possible embodiment of the valve opening adjustment system belonging to the engine object of the present invention.

[0057] It is specified that the figures annexed to the present patent application indicate some preferred embodiments of the engine and his components object of the present invention to better understand its advantages and characteristics.

[0058] These embodiments are therefore to be understood for purely illustrative and non-limiting purposes to the inventive concept of the present invention, i.e. that of manufacturing a hot air engine operating at a low number of revolutions which allows to obtain a high energy efficiency, maintaining constructive simplicity and simplicity of the components, easy to be assembled, maintained and repaired.

[0059] With particular reference to Figure 1a, a possible embodiment of the engine object of the present invention is illustrated.

[0060] In particular, the engine includes:

at least one compression cylinder 1 connected to a delivery manifold and to an inlet manifold for the input and output from the cylinder of an operating fluid,

at least one expansion cylinder 2 connected to an expansion manifold and to an exhaust manifold for the input and output from the cylinder of an operating fluid,

a transmission system of the movement of the expansion and compression cylinder pistons to a system for transforming the movement into electric power.

[0061] In the case of figure 1a, the transmission system consists of a piston rod and crank assembly 11 of the compressor cylinder 1 and a piston rod and crank assembly 21 of the expander cylinder 2.

[0062] The piston rod and crank assemblies 11 and 21 are then connected to respective engine shafts 100, which in turn are connected to groups of gears with fly-wheel 200.

[0063] The kinematism of the group of gears with fly-wheel 200 is then used for generating electric power through the connection of the latter with corresponding electric generators 300.

[0064] In the specific case of figure 1a, the electric generator 300 is connected to the power line of the gearbox 200 on the fast shaft; between the generator 300 and the gearbox 200 wall a flywheel is keyed which is powered by the fast shaft.

[0065] The engine components shown in figure 1a, can be supported by a basement (not shown in the figure) which can be built horizontally or vertically, preferably with heavy carpentry to contain the vibrations induced by the dynamics of movement of the pistons.

[0066] The configuration just described is known in the state of the art and can be used in combination with a heating thermal unit of the circulating air, for the production of electric power.

[0067] In this case, the compressor cylinder 1 sucks in the room air, compresses it and sends it to the thermal unit.

[0068] The thermal unit heats the air, the expander cylinder 2 expands the heated air, produces energy through the electric generator 300 and then discharges the air into the surrounding environment.

[0069] Figure 1b illustrates a possible embodiment of the engine object of the present invention according to a schematic diagram.

[0070] According to this configuration, the expander cylinder 2 is positioned in the centre, while two compressor cylinders 1 are positioned on the sides of said expanding cylinder 2.

[0071] In particular, each compressor cylinder 1 has a single piston 13, while the expander cylinder 2 has two pistons 23 positioned symmetrically with respect to each other, so that the pistons 13 of the cylinders 1 are connected to the pistons 23 of the cylinder 2 through a rigid rod 33.

[0072] Each rigid rod 33 is connected to a piston rod crank system, in particular a crank 6 connected with one end to the rigid rod 33 and with the other to the remaining

piston rod crank system 7.

[0073] The piston rod crank system 7 is surrounded by an external crankcase 71 designed to protect and lubricate the system itself.

5 **[0074]** Preferably the two piston rod crank systems 7 are connected to each other through a bevel gear (not shown in figure 1b), so as to be timed.

[0075] This configuration allows to obtain a complete dynamic balancing of the inertia forces.

10 **[0076]** Figure 1c illustrates a further variant embodiment of the engine object of the present invention, similar to the embodiment of figure 1b, but wherein there are specific transmission means between the rigid rod 33 and the piston rod crank system 9.

15 **[0077]** According to the variant illustrated in figure 1c, the transmission means consist of a plurality of rods, in particular a rod 81 pivoted at a point B and connected with its ends to two rods 82, so that the rod 81 is connected to the rigid rods 33 and is set in motion by the movement of the pistons 13 and 23.

20 **[0078]** The rotation of the rod 81 is then transmitted to a pulling rod 83, which rotates the system 9.

[0079] The system 9 can then be connected to the electric power generator 300 in a manner very similar to the system of figure 1a.

25 **[0080]** Figures 1d and 1e show two views of a possible embodiment of the engine object of the present invention.

[0081] The variant illustrated in figures 1d and 1e is completely similar to that illustrated in figure 1b, with some specific configuration.

30 **[0082]** In particular, like figure 1b, a symmetrical structure is provided, with two lateral expander cylinders 2 and a central compressor cylinder 1.

35 **[0083]** Figure 1e also shows the valve groups, which will be described later, in particular, an inlet valve 4' and an exhaust valve 4" for each compression 1 and expansion cylinder 2.

[0084] As for figure 1b, on the axis that joins the two pistons, the crank button 7 is connected from which the piston rod 6 starts to connect to the crank axis.

40 **[0085]** As for the previous variants, the movement of the pistons activates the rotation of two axes 301, each having a gear group 401, which in turn operates a power synchroniser axis 303.

45 **[0086]** The axis 303 is then connected in one of any known ways in the state of the art, to a power generator 400, preferably through a group of reversing gears 401.

[0087] Unlike the engine of figure 1a, the executive variants of figures 1b, 1d and 1e allow to obtain a much lower wear of the elastic bands of the cylinder as they are not subject to the inclination of the piston rod.

[0088] Furthermore, thanks to this configuration, the gears 301 and 401, the axis 303 and the generator 400, are positioned "in a cold zone", i.e. outside the engine.

55 **[0089]** Furthermore, the engine of figures 1b, 1d and 1e can also be mounted vertically allowing to avoid wear following the weight of the pistons and the connecting axis 33 between the two pistons can be guided through

magnetic guides, eliminating frictions.

[0090] Unlike the variant shown in figure 1b, the engine shown in figures 1d and 1e has the expansion chamber divided into two parts 20 and 21.

[0091] This subdivision allows to obtain larger passage sections of the area and at the same time to reduce the residual spaces.

[0092] The engine object of the present invention according to the variants illustrated in figures 1b to 1e, similarly to what is illustrated in figure 1a, provides that the compressor cylinders 1 and the expander cylinder 2 have valve groups, not shown in figures 1b and 1c, for the air input at the arrows indicated with A.

[0093] Regardless of the use and the chosen configuration, both that of figure 1a, 1b, 1c or 1d, and both the compressor cylinder 1 and the expander cylinder 2 have an external jacket, 12, 22 which houses two opposing pistons, as shown in figure 1a the stems 10 and 20 are visible.

[0094] On the centreline of each outer jacket 12, 22, two lights are provided, for the connection of each cylinder with its manifolds, for the input and output of the fluid.

[0095] In figure 1a, in fact, two valve groups 4 are visible, each comprising two valves so as to connect the compressor cylinder 1 with the inlet manifold and with the delivery manifold (not shown in the figures), while the expander cylinder 2 is connected to the expansion manifold and the exhaust manifold (not shown in the figures).

[0096] It is therefore evident that each valve group 4, 4', 4'' allows or prevents the passage of the operating fluid from the cylinder to the manifold and vice versa.

[0097] Figures 2a to 2g illustrate a possible embodiment of the valves.

[0098] In particular, figures 2a to 2c show a side view of the valve, that is, a view of a lateral section of said valve, while figures 2d to 2g show a view according to a plan parallel to the opening of said valve.

[0099] Each valve consists of a valve seat and a closing element.

[0100] The closing element is rotatably mounted with respect to said valve seat, so that the closing condition of the valve corresponds to an overlapping condition of the closing element with respect to the valve seat, while the opening condition of said valve corresponds to a non-overlapping or partially overlapping condition of the closing element with respect to the valve seat.

[0101] The closing element is also mounted in a translatable manner with respect to said valve seat in the direction of the manifold and the cylinder, so that a translation of the closing element allows the passage of the operating fluid even in the overlapping condition of the closing element with the valve seat.

[0102] In figures 2a-2g the closing element consists of a plate-like element 41, such as for example a metal foil 41, mounted inside the valve seat 40.

[0103] The valve seat 40 has a first opening 401 facing the manifold and a second opening 402 facing the cylinder.

[0104] Both the first 401 and the second 402 opening are surrounded by a first 411 and a second 412 abutment surface, respectively.

[0105] In figure 2g the plate-like element 41 is shown in a rotated and non-overlapping condition to the valve seat 40, so that the valve is open.

[0106] The plate-like element 41, or metal foil, in addition to rotating around the axis A, can translate along this axis, so as to pass from a maximum approach condition to the manifold, figure 2a, to a maximum approach condition to the cylinder, figure 2c.

[0107] In the maximum approach condition to the manifold, the foil element 41 is in abutment with the first abutment surface 411, while in the maximum approach condition to the cylinder, it is in abutment with the second abutment surface 412.

[0108] In both these conditions the fluid cannot flow between the manifold and the cylinder, due to the contact between the foil element 41 and the abutment surfaces.

[0109] In the transition, i.e. in the passage between the two conditions, figure 2b, the fluid can flow between the manifold and the cylinder and vice versa, despite the foil element 41 overlapping the valve seat 40, figure 2e.

[0110] It follows that the foil element 41 can position, in closing conditions and with purely vertical movement, towards the cylinder or towards the manifold according to the pressure acting on the surfaces of the foil element 41: it is therefore the pressure differential between the upper and lower face of the foil element 41 which generates the fluid flow block either towards the cylinder or towards the manifold.

[0111] According to this configuration, the operation of the four valves positioned on the compressor 1 and expander 2 cylinders will be described below.

[0112] For the compressor cylinder:

1) valve connected to the delivery manifold. During the compression phase the pressure in the delivery manifold is higher, the foil 41 closes on the second abutment surface 412 and prevents the air transfer into the cylinder towards the manifold; when the two pressures are equal (inside the cylinder and in the delivery manifold) the valve opening mechanism is activated, the foil moves towards the manifold, and the air of the cylinder is discharged into the manifold.

[0113] The displacement of the foil 41 occurs without frictions since the pressures on the opposite faces are equivalent. Even in the event of closure, the pressures are balanced because, when the upper dead centre is reached by the piston, the maximum compression pressure on the foil 41 faces is maintained from the cylinder side, which is the same pressure in the delivery manifold. During the inlet phase of the compressor cylinder 1, the closed valve feels the high pressure in the delivery manifold which keeps the abutment wall 412 closed, blocking the air flow from the manifold to the cylinder.

[0114] 2) valve connected to the inlet manifold. This

valve remains open throughout the inlet phase; during the compression phase the valve is closed and the foil 41 is positioned on the first abutment surface 411 since the pressure in the cylinder is higher than the external one.

[0115] The higher the pressure, the higher the sealing. Here too the opening phase takes place with balanced pressure between the two faces of the foil 41: on one side the ambient pressure on the other the achievement of the ambient pressure (with setting of a slight opening delay) by the residual volume existing between the foil 41 and the cylinder with piston at the upper dead centre; the closing phase evidently takes place with equal pressures in the cylinder and in the ambient.

[0116] Regarding the expander cylinder 2:

1) valve connected to the expansion manifold. The valve opens with balanced pressures, on the one hand the pressure existing in the expansion manifold and on the other the residual pressure induced by the small dead space existing between the valve and the cylinder (the piston is at the upper dead centre). The valve is always closed with balanced pressures between the two faces of the foil 41 since the pressure in the cylinder and in the expansion manifold are identical; the piston then follows its run towards the lower dead centre causing a continuous lowering of the pressure in the cylinder whereby the foil 41 is positioned on the second abutment surface 412 driven by the increasing pressure differential existing between the expansion manifold and the cylinder; during the exhaust phase the pressure in the cylinder is atmospheric and the foil 41 is positioned on the second abutment surface 412 driven by the higher pressure of the expansion manifold.

2) valve connected to the exhaust manifold. The valve opens with balanced pressures, on the side of the exhaust manifold it is ambient pressure, on the side of the cylinder at the end of the stroke, piston at the lower dead centre, it is atmospheric pressure; the closing of the valve provides ambient pressure on the side of the exhaust manifold and also on the cylinder one, so that movement occurs without friction. With the valve closed, the pressure in the cylinder is always higher than the atmospheric pressure, so that the foil 41 is positioned on the first abutment surface 411, avoiding the air flows from the cylinder to the manifold.

[0117] With particular reference to the figures just described, the hot air engine object of the present invention further comprises an adjustment system for the timing and the opening angle of each valve 4.

[0118] According to a first embodiment, this system consists of a mechanical delay system 5, provided connected between the cylinder of each piston and the corresponding valve.

[0119] It follows that up to four mechanical delay sys-

tems 5 may be present, and each mechanical delay system is connected to the gearbox 200 through a shaft 501, while it is connected to each valve through a valve movement rod 502, whose operation will be described later.

[0120] Figure 3 illustrates a possible embodiment of the mechanical delay system, to better understand its operation.

[0121] According to the variant shown in the figures, the mechanical delay system consists of:

- a first gear wheel corresponding to the engine gear 50,
- a second gear wheel corresponding to the gear of the delay system 51,
- a first lever system consisting of three rods 52 and 53,
- an eccentric element, or pull lever, 54,
- a second lever system consisting of a pull rod 55, a pull amplifier 56 and a valve control rod 57.

[0122] The engine gear 50 takes the movement from the axis moved by the piston rods, turning in the opposite direction, and sets the mechanical delay system in motion.

[0123] The gear of the delay system 51 takes the movement from the engine gear 50 turning in the opposite direction to the same and therefore with the same direction as the control of the piston rod.

[0124] This gear is supported by a system which allows it to rotate around the axis of the engine gear 50, anticipating or delaying its timing with respect to the same.

[0125] The adjustment of this rotation can take place, even with the engine running, both with manual and automatic control and modifies the opening degrees of the valve keeping the start or end of the opening constant depending on whether the rotation is clockwise or anticlockwise.

[0126] The rod 52 can consist of both a rod and a support on the side of the gear 51 and has the purpose of creating a fulcrum which rotates at a desired distance from the axis of the gear 51 and which is in the correct timing with the piston movement.

[0127] The rods indicated with the numerical reference 53 are two rods of the desired size, hinged with each other and with the rod 52 and the pull lever 54.

[0128] The pull lever 54 consists of a plate hinged on a fixed fulcrum with a semicircular slot 541 on which the rod terminal 53 slides and a fulcrum 542 which hooks it to the pull rod 55. The position of the rotation fulcrum 543 and the geometry of the slot 541 ensure that the starting or ending angle of the valve opening is kept fixed in a desired adjustment field. The distance between the pivot fulcrum 543 and the pull fulcrum 542 determine the amplitude of the mechanical delay system movement.

[0129] The pull rod 55 is hinged to the pull lever 54 and to the amplifier 56 and transfers the traction movement.

[0130] The pull amplifier 56 is made up of two rods integral with a rotating axis and allows to bring the pull

out of the crankcase of the mechanical delay mechanism and align the pull axis with that of the valve. By playing with the lengths of the two rods it is possible to optimize the valve lift.

[0131] The valve control rod 57 consists of a rod hinged to the amplifier and to the valve group 4.

[0132] According to a possible embodiment, with particular reference to figures 1b and 1c, the valve control rod 57 can be replaced or provided in combination with a wire rope connected to the valve, which chain slides inside a sheath, suitable for facilitating the sliding.

[0133] From what has just been described, it is evident that the delay system can be provided for one, two, three or more valves 4, just as it is possible to provide any number of valves made according to the configuration illustrated in figures 2a to 2g.

[0134] Furthermore, thanks to the described components of the mechanical delay system, the operation of the valves according to this system is described below.

[0135] The valve is kept closed by a spring system which also holds the pull rod 55, the amplifier 56 and the pull lever 57 in position.

[0136] The fulcrum of the rod 52 rotates in synchronization with the movement of the piston.

[0137] When the distance between the fulcrum is less than the sum of the lengths of the two rods 53, these fold back allowing rotation of the rod 52 without generating any pull. When said distance is greater the two rods 53 align and, overcoming the force of the valve spring system, create a traction on the pull lever 54, which transmits it to the system up to the valve.

[0138] The whole system from the engine gear 50 to the axis of the amplifier 56 is arranged in a crankcase, shown in figure 1, which segregates the moving parts and allows their lubrication by splashing.

[0139] Acting on the adjustment and varying the position of the gear of the delay system 51 the rest distance between the rod 52 and the semicircular slot 541 changes thus modifying the angle of starting and ending pull.

[0140] When the pull is higher than the valve opening needs, the excess can be compensated by the closing spring system of the valve itself.

[0141] As an alternative to the delay system, according to a preferred embodiment, the valve opening adjustment system comprises an engine which acts directly on the opening of the valves, as illustrated in figures 4a to 4c.

[0142] The effects obtained by adjusting the opening of the valves are the same as those described above, as well as the operation of the engine object of the present invention, but the means by which the opening is adjusted has changed.

[0143] According to the variant shown in figures 4a to 4c, the adjustment system has an electric or mechanical engine 81, preferably electric of the brushless type, connected with an axis 82 to the valve group 4 through a cam system 83.

[0144] The engine 81 is also connected to the engine described above, so as to provide for the same number

of revolutions of the engine itself.

[0145] For example, an encoder connected to the axis 82 and to the engine power axis described above can be provided.

[0146] In particular, two cams 831 are keyed on the axis 82 connected together with a differential 832,

[0147] The differential 832 can consist, for example, of a double bevel gear.

[0148] A return spring can be provided on the axis 82.

[0149] The axis 82 then acts on the opening of the valves, that is, on the opening of the valve seat, as illustrated in figures 4b and 4c.

[0150] The adjustment of the screw 84 allows to act directly on the differential, for example on the bevel gear 832, so as to obtain, as for the delay system, an adjustment system on the advances and delays of the engine.

[0151] While the invention is susceptible of various modifications and alternative constructions, some preferred embodiments have been shown in the drawings and described in detail.

[0152] It must be understood, however, that there is no intention to limit the invention to the specific illustrated embodiment, but, on the contrary, it intends to cover all the modifications, alternative constructions, and equivalents that fall within the scope of the invention as defined in the claims.

[0153] The use of "for example", "etc.", "or" indicates non-exclusive alternatives without limitation unless otherwise indicated.

[0154] The use of "includes" means "includes, but not limited to" unless otherwise indicated.

Claims

1. Hot air engine comprising

at least one compression cylinder (1) connected to a delivery manifold and an inlet manifold for the input and output from the cylinder (1) of an operating fluid,

at least one expansion cylinder (2) connected to an expansion manifold and to an exhaust manifold for the input and output from the cylinder (2) of an operating fluid,

a transmission system of the movement of the expansion (2) and compression cylinder (1) pistons to a system for transforming the movement into electric power,

being each cylinder (1, 2) connected with each manifold through a valve (4), so as to allow or prevent the passage of the operating fluid from the cylinder (1, 2) to the manifold and vice versa, wherein

each valve has a valve seat (40) and a closing element (41), which closing element (41) is mounted rotatably with respect to said valve seat (40), so that the closing condition of the valve

- corresponds to an overlapping condition of the said closing element (41) with respect to said valve seat (40), while the opening condition of said valve corresponds to a non-overlapping or partially overlapping condition of said closing element (41) with respect to said valve seat (40), being the said closing element (41) mounted in a translatable manner with respect to said valve seat (40) in the direction of the manifold and the cylinder, so that a translation of the said closing element (41) allows the passage of the operating fluid even in the overlapping condition of the closing element (41) with the said valve seat (40), the said valve seat (40) having a first opening (401) facing the manifold and a second opening (402) facing the cylinder, the said first (401) and second (402) opening being surrounded by a first (411) and a second (412) abutment surface, respectively, the said closing element (41) consisting of a plate-like element, so that during translation the said plate-like element passes from a maximum approach condition to the manifold, wherein the surfaces of the plate-like element are in abutment with the said first abutment surface (411), to a maximum approach condition to the cylinder wherein the surfaces of the said plate-like element are in abutment with the said second abutment surface (412).
2. Engine according to claim 1, wherein an adjustment system of the timing and opening angle of each valve (4) is provided.
3. Engine according to claim 2, wherein the said adjustment system consists of a mechanical delay system, which mechanical delay system is provided connected between the cylinder of each piston and the corresponding valve, said mechanical delay system comprising
- a first gear wheel (50) mounted rotatable about an axis,
- a second gear wheel (51), which second gear wheel (51) engages with the first gear wheel (50) so as to rotate in the opposite direction to the first gear wheel (50),
- a first lever system (52, 53) which has an input terminal and an output terminal, so that the said input terminal is connected to the said second gear wheel (51), while the said output terminal is inserted inside a cam slot (541) provided on an eccentric element (54), which eccentric element (54) is fixed in rotation and connected to a second lever system (55, 56, 57), connected in turn to the valve (4).
4. Engine according to one or more of the preceding

claims, wherein each cylinder (1, 2) has an external jacket (12, 22) inside which external jacket (12, 22) two opposed pistons (10, 20) are mounted, the valves (4) of each cylinder (1, 2) being placed on the external surface of the jacket (12, 22) of the cylinder, in correspondence with the area between the heads of the two pistons (10, 20).

5. Engine according to one or more of the preceding claims, wherein the said compression cylinder (1) has a smaller diameter than the said expansion cylinder (2).
6. Engine according to claim 2, wherein setting means of the said adjustment system of the timing and the opening angle of each valve are provided.
7. Engine according to claim 6, wherein the said setting means comprise an interface with one or more electronic units.

Patentansprüche

1. Heißluftmotor, umfassend

mindestens einen Kompressionszylinder (1), der mit einem Zuleitungsverteiler und einem Einlassverteiler für den Eingang und den Ausgang eines Betriebsfluids aus dem Zylinder (1) verbunden ist,

mindestens einen Expansionszylinder (2), der mit einem Expansionsverteiler und einem Abgasverteiler für den Eingang und den Ausgang eines Betriebsfluids aus dem Zylinder (2) verbunden ist,

ein Übertragungssystem der Bewegung der Kolben des Expansions- (2) und Kompressionszylinders (1) auf ein System, um die Bewegung in elektrische Leistung umzuwandeln,

wobei jeder Zylinder (1, 2) durch ein Ventil (4) mit jedem Verteiler verbunden ist, um den Durchgang des Betriebsfluids von dem Zylinder (1, 2) zu dem Verteiler und umgekehrt zu ermöglichen oder zu verhindern,

wobei

jedes Ventil einen Ventilsitz (40) und ein Schließelement (41) aufweist, wobei das Schließelement (41) drehbar gegenüber dem Ventilsitz (40) gelagert ist, sodass der Schließzustand des Ventils einem Überlappungszustand des Schließelements (41) in Bezug auf den Ventilsitz (40) entspricht, während der Öffnungszustand des Ventils einem nicht überlappenden oder teilweise überlappenden Zustand des Schließelements (41) in Bezug auf den Ventilsitz (40) entspricht,

wobei das Schließelement (41) in Bezug auf den

- Ventilsitz (40) in Richtung des Verteilers und des Zylinders verschiebbar montiert ist, sodass eine Translation des Schließelements (41) den Durchgang des Betriebsfluids auch in dem überlappenden Zustand des Schließelements (41) mit dem Ventilsitz (40) ermöglicht, wobei der Ventilsitz (40) eine erste Öffnung (401), die dem Verteiler zugewandt ist, und eine zweite Öffnung (402), die dem Zylinder zugewandt ist, aufweist, wobei die erste (401) und die zweite (402) Öffnung jeweils von einer ersten (411) und einer zweiten (412) Anlagefläche umgeben sind, wobei das Schließelement (41) aus einem plattenartigen Element besteht, sodass das plattenartige Element während einer Translation von einem maximalen Annäherungszustand an den Verteiler, wobei die Oberflächen des plattenartigen Elements an der ersten Anlagefläche (411) anliegen, zu einem maximalen Annäherungszustand an den Zylinder übergeht, wobei die Oberflächen des plattenartigen Elements an der zweiten Anlagefläche (412) anliegen.
2. Motor nach Anspruch 1, wobei ein Einstellsystem der Zeitsteuerung und des Öffnungswinkels von jedem Ventil (4) bereitgestellt ist.
3. Motor nach Anspruch 2, wobei das Einstellsystem aus einem mechanischen Verzögerungssystem besteht, wobei das mechanische Verzögerungssystem zwischen dem Zylinder von jedem Kolben und dem entsprechenden Ventil bereitgestellt ist, das mechanische Verzögerungssystem umfassend
- ein erstes Zahnrad (50), das drehbar um eine Achse gelagert ist,
- ein zweites Zahnrad (51), wobei das zweite Zahnrad (51) mit dem ersten Zahnrad (50) eingreift, um in die entgegengesetzte Richtung zu dem ersten Zahnrad (50) zu drehen,
- ein erstes Hebelsystem (52, 53), das einen Eingangsanschluss und einen Ausgangsanschluss aufweist, sodass der Eingangsanschluss mit dem zweiten Zahnrad (51) verbunden ist, während der Ausgangsanschluss in eine Nockennut (541) eingesetzt ist, die an einem Exzenterelement (54) bereitgestellt ist, wobei das Exzenterelement (54) drehfest und mit einem zweiten Hebelsystem (55, 56, 57) verbunden ist, das wiederum mit dem Ventil (4) verbunden ist.
4. Motor nach einem oder mehreren der vorherigen Ansprüche, wobei jeder Zylinder (1, 2) einen äußeren Mantel (12, 22) aufweist, wobei in dem äußeren Mantel (12, 22) zwei gegenüberliegende Kolben (10, 20) montiert sind, wobei die Ventile (4) von jedem Zylinder (1, 2) auf der Außenfläche des Mantels (12, 22) des Zylinders

entsprechend dem Bereich zwischen den Böden der zwei Kolben (10, 20) platziert sind.

5. Motor nach einem oder mehreren der vorherigen Ansprüche, wobei der Kompressionszylinder (1) einen kleineren Durchmesser als der Expansionszylinder (2) aufweist.
6. Motor nach Anspruch 2, wobei Einstellungseinrichtungen des Einstellsystems der Zeitsteuerung und des Öffnungswinkels von jedem Ventil bereitgestellt sind.
7. Motor nach Anspruch 6, wobei die Einstellungseinrichtungen eine Schnittstelle mit einer oder mehreren elektronischen Einheiten umfassen

Revendications

1. Moteur à air chaud comprenant

au moins un cylindre compresseur (1) connecté à un collecteur de distribution et à un collecteur d'entrée pour permettre l'entrée et la sortie du cylindre (1) d'un fluide de travail,

au moins un cylindre de détente (2) connecté à un collecteur de détente et à un collecteur d'échappement pour permettre l'entrée et la sortie du cylindre (2) d'un fluide de travail,

un système de transmission du mouvement des pistons de cylindre de détente (2) et de cylindre compresseur (1) vers un système de transformation du mouvement en énergie électrique, chaque cylindre (1,2) étant connecté à chaque collecteur par l'intermédiaire d'une soupape (4), de manière à permettre ou à empêcher le passage du fluide de travail du cylindre (1,2) au collecteur et vice versa,

dans lequel

chaque soupape présente un siège de soupape (40) et un élément de fermeture (41), lequel élément de fermeture (41) est monté de manière rotative par rapport audit siège de soupape (40), de sorte que l'état de fermeture de la soupape corresponde à un état de chevauchement dudit élément de fermeture (41) par rapport audit siège de soupape (40), en même temps que l'état d'ouverture de ladite soupape correspond à un état de non-chevauchement ou de chevauchement partiel dudit élément de fermeture (41) par rapport audit siège de soupape (40),

ledit élément de fermeture (41) étant monté de manière mobile par rapport audit siège de soupape (40) en direction du collecteur et du cylindre, de sorte qu'une translation dudit élément de fermeture (41) permette le passage du fluide de travail même dans l'état de chevauchement

- de l'élément de fermeture (41) avec ledit siège de soupape (40), ledit siège de soupape (40) présentant une première ouverture (401) faisant face au collecteur et une seconde ouverture (402) faisant face au cylindre, ladite première ouverture (401) et ladite seconde ouverture (402) étant entourées par une première surface de butée (411) et une seconde surface de butée (412), respectivement, ledit élément de fermeture (41) consistant en un élément en forme de plaque, de sorte que pendant la translation, ledit élément en forme de plaque passe d'un état d'approche maximale vers le collecteur, dans lequel les surfaces de l'élément en forme de plaque sont en butée avec ladite première surface de butée (411), à un état d'approche maximale vers le cylindre dans lequel les surfaces dudit élément en forme de plaque sont en butée avec ladite seconde surface de butée (412).
2. Moteur selon la revendication 1, dans lequel un système de réglage du calage et de l'angle d'ouverture de chaque soupape (4) est fourni.
3. Moteur selon la revendication 2, dans lequel ledit système de réglage consiste en un système de retard mécanique, lequel système de retard mécanique est fourni monté entre le cylindre de chaque piston et la soupape correspondante, ledit système de retard mécanique comprenant
- une première roue dentée (50) montée de manière rotative autour d'un axe, une seconde roue dentée (51), laquelle seconde roue dentée (51) vient en prise avec la première roue dentée (50) de manière à tourner dans le sens opposé à la première roue dentée (50), un premier système de levier (52, 53) qui présente une borne d'entrée et une borne de sortie, de sorte que ladite borne d'entrée soit reliée à ladite seconde roue dentée (51), en même temps que ladite borne de sortie soit insérée à l'intérieur d'une fente de came (541) fournie sur un élément excentrique (54), lequel élément excentrique (54) est fixe en rotation et relié à un second système de levier (55, 56, 57), relié à son tour à la soupape (4).
4. Moteur selon une ou plusieurs des revendications précédentes, dans lequel chaque cylindre (1, 2) présente une chemise externe (12, 22) à l'intérieur de laquelle chemise externe (12, 22) deux pistons opposés (10, 20) sont montés, les soupapes (4) de chaque cylindre (1, 2) étant placées sur la surface externe de la chemise (12, 22) du cylindre, en correspondance avec la zone entre les têtes des deux pistons (10, 20).
5. Moteur selon une ou plusieurs des revendications précédentes, dans lequel ledit cylindre compresseur (1) présente un diamètre plus petit que ledit cylindre de détente (2).
6. Moteur selon la revendication 2, dans lequel des moyens de paramétrage dudit système de réglage du calage et de l'angle d'ouverture de chaque soupape sont fournis.
7. Moteur selon la revendication 6, dans lequel lesdits moyens de paramétrage comprennent une interface avec une ou plusieurs unités électroniques.

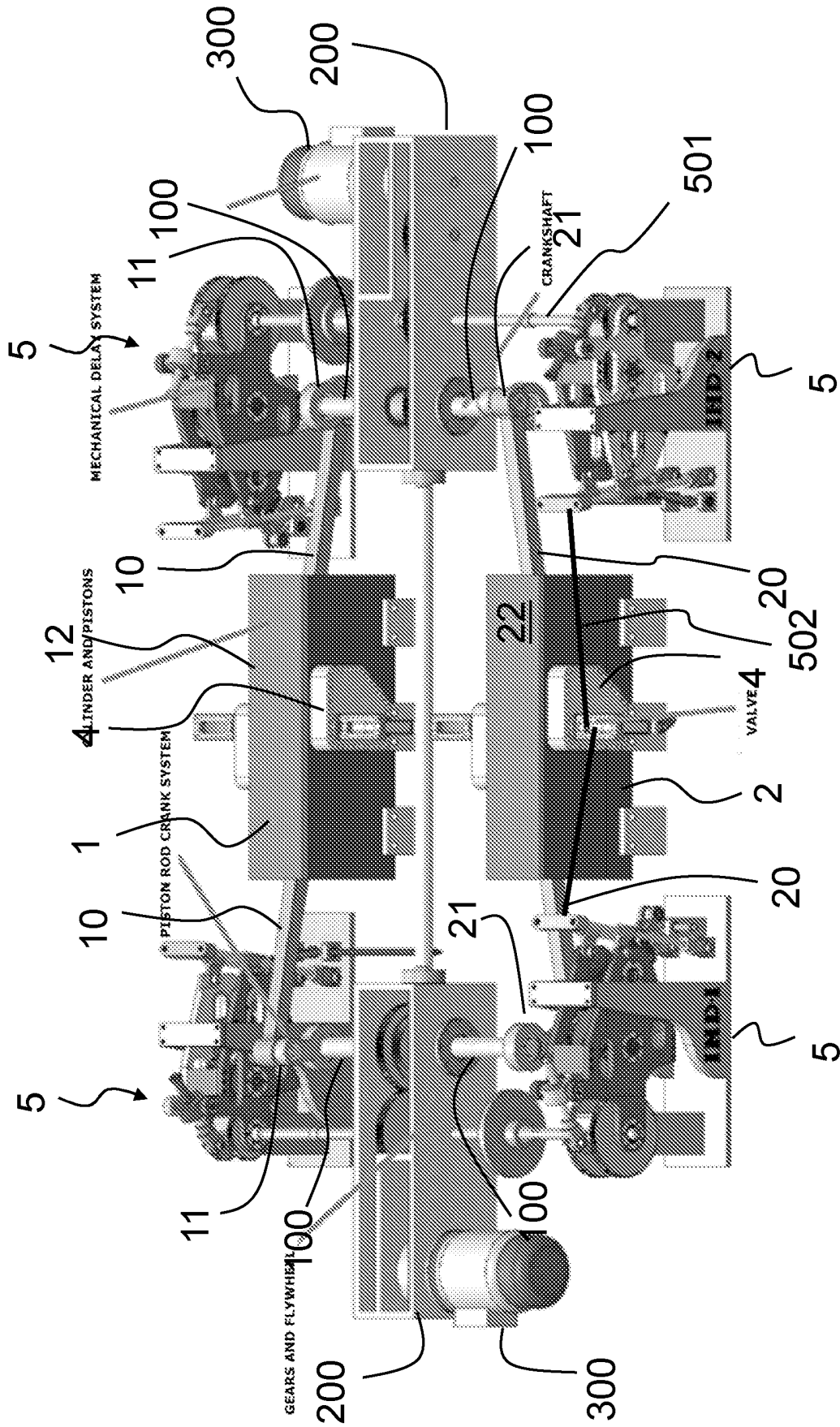


Fig. 1a

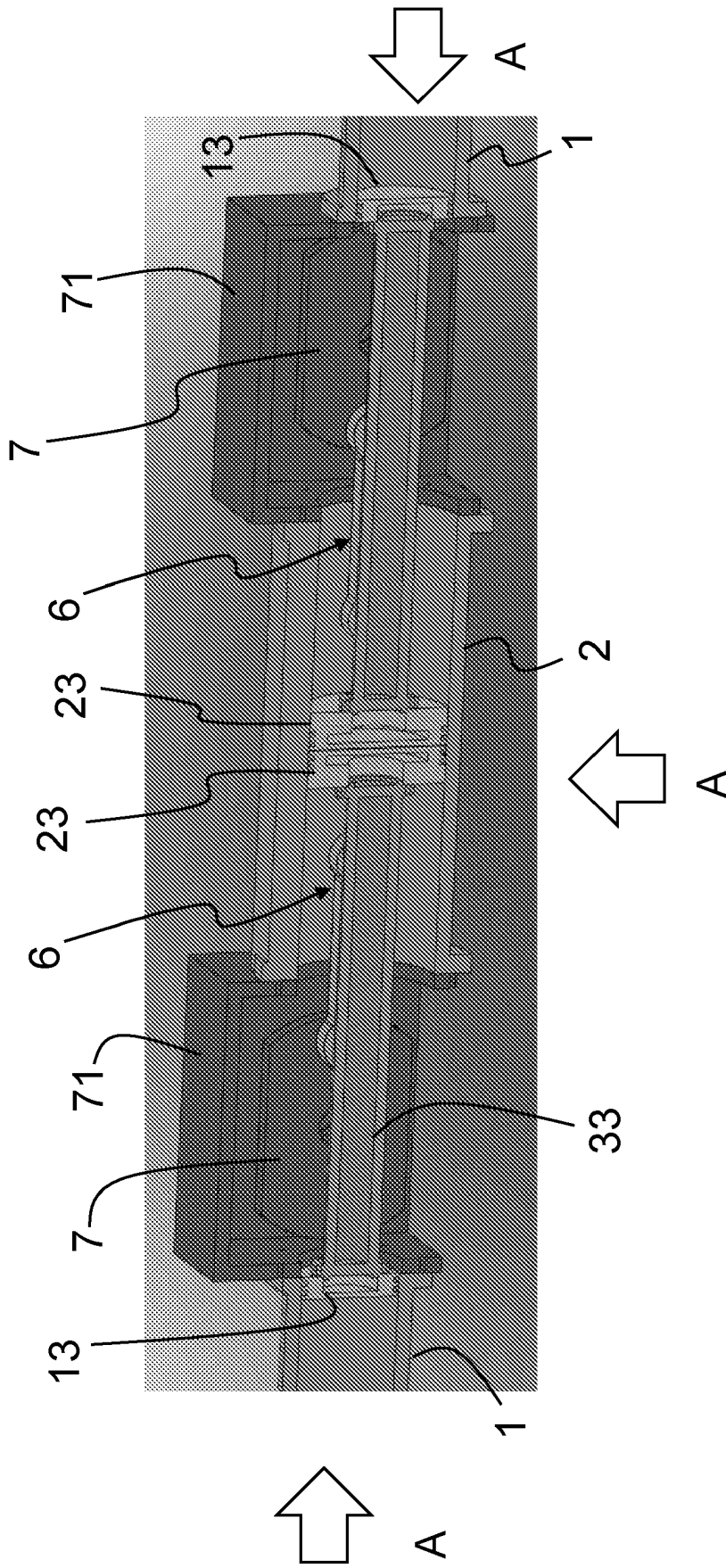


Fig. 1b

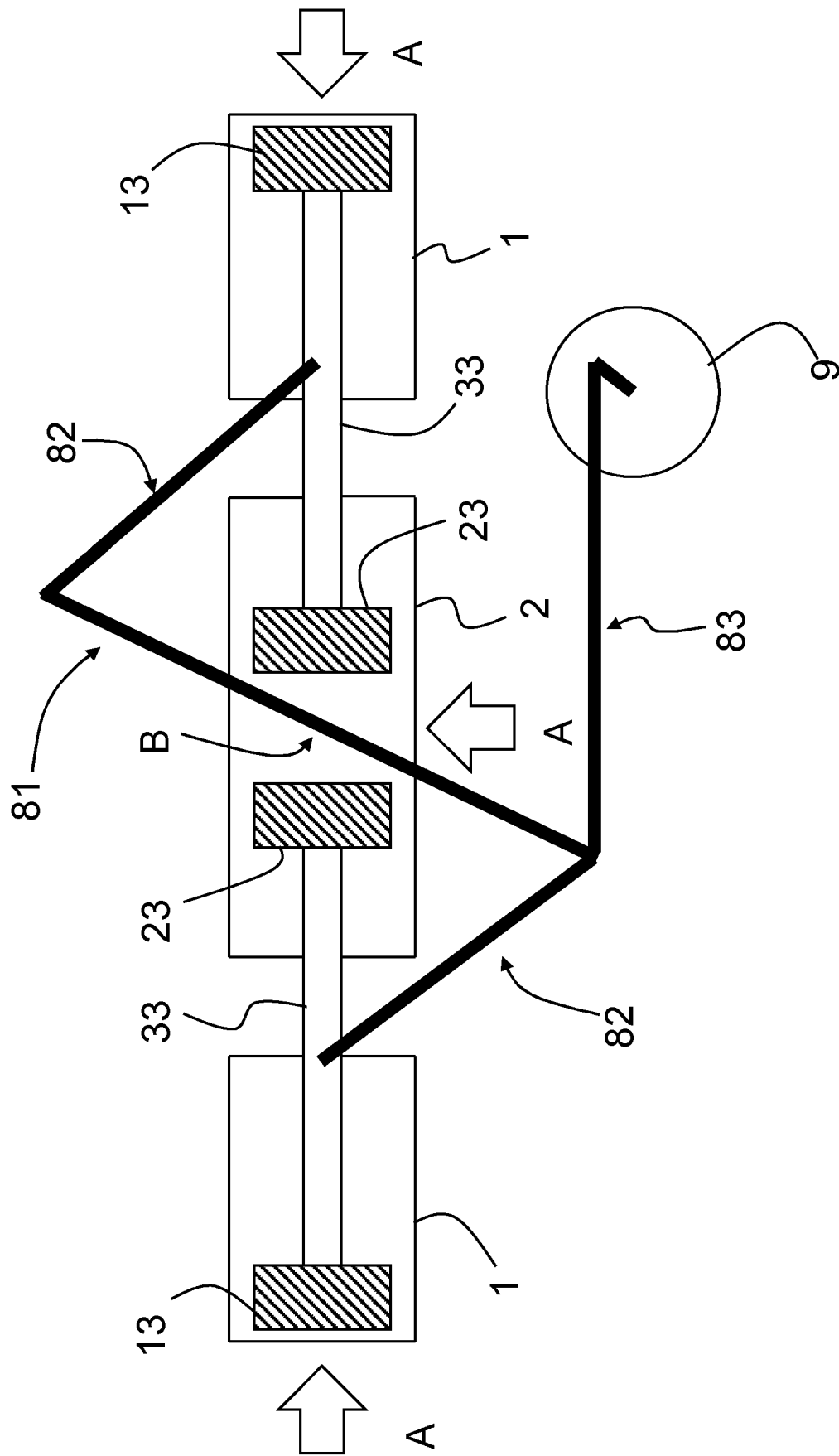
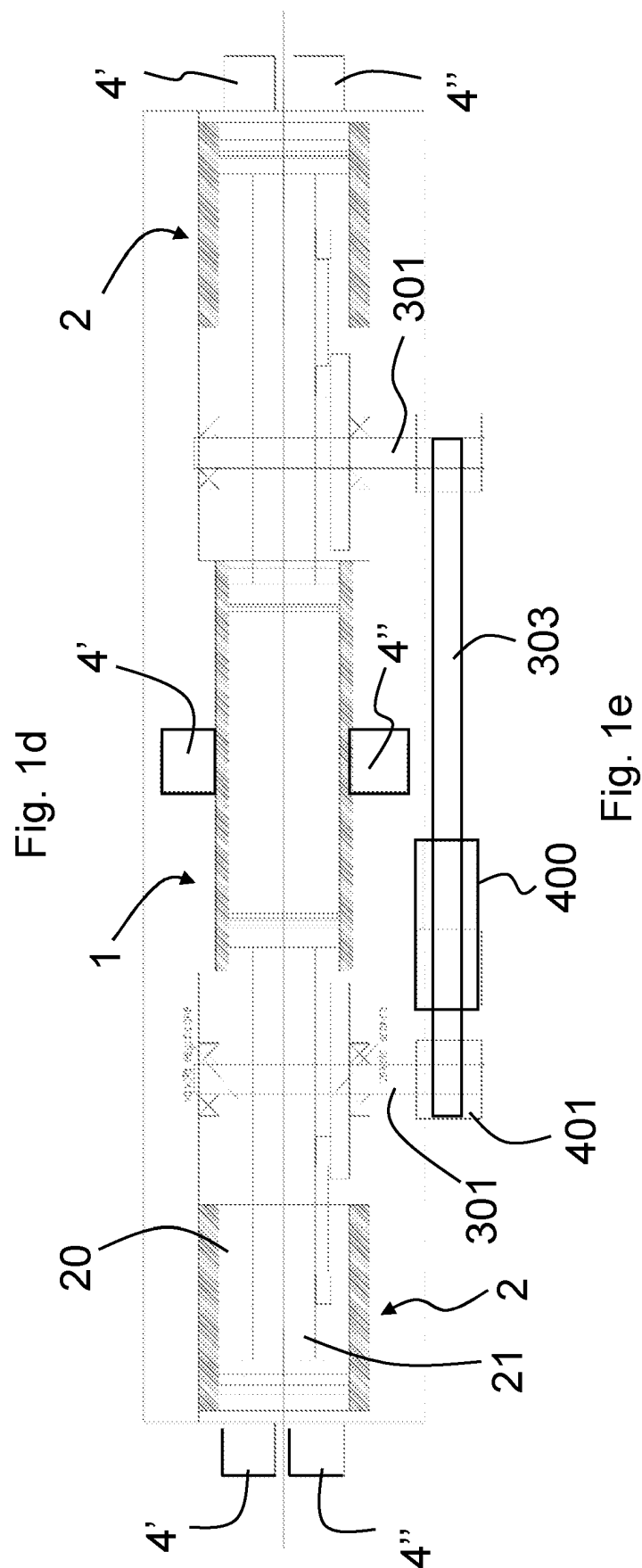
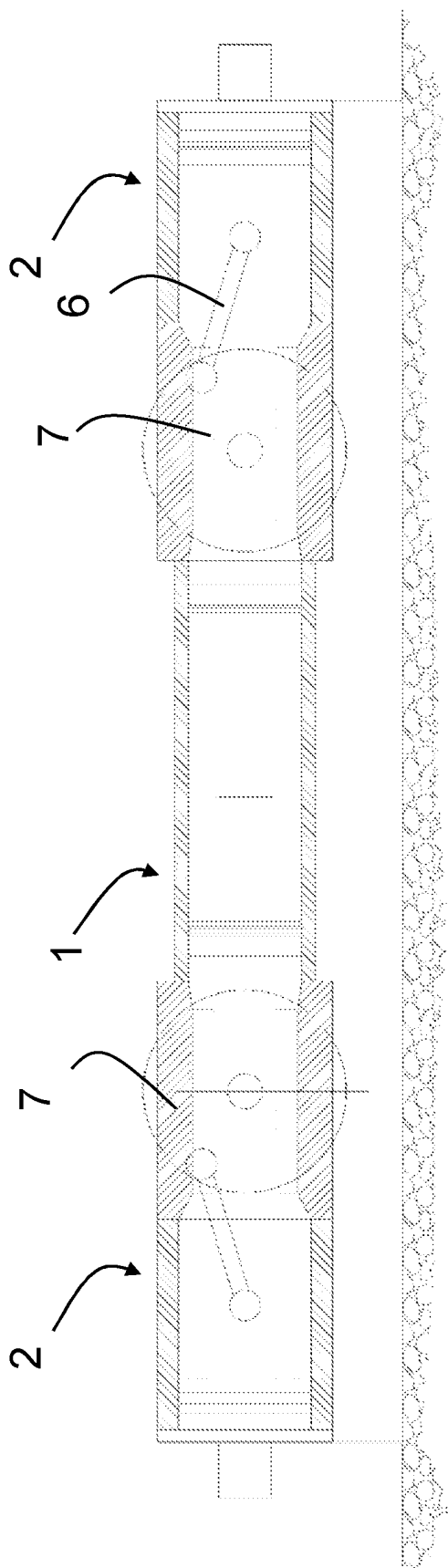


Fig. 1c



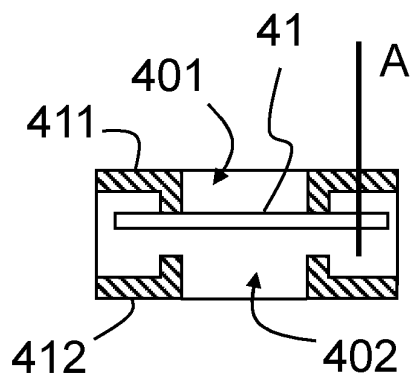


Fig. 2a

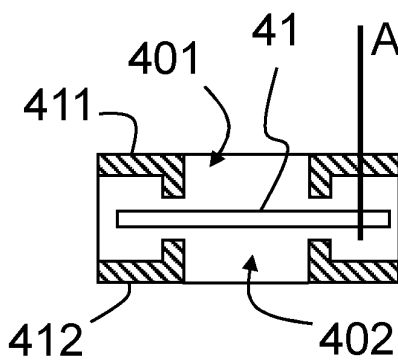


Fig. 2b

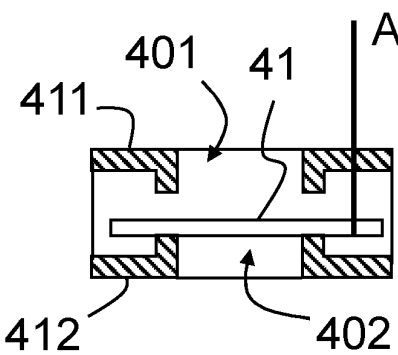


Fig. 2c

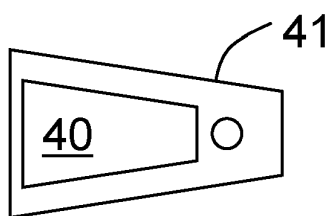


Fig. 2d

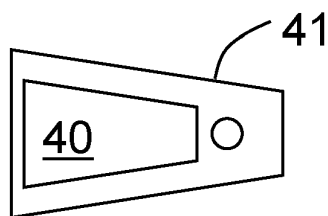


Fig. 2e

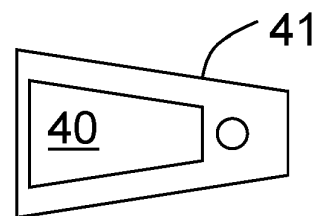


Fig. 2f

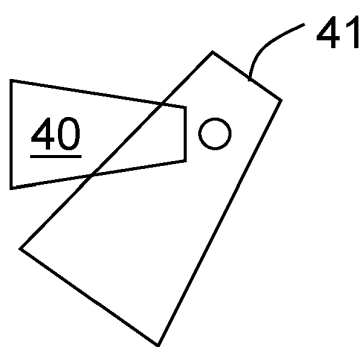


Fig. 2g

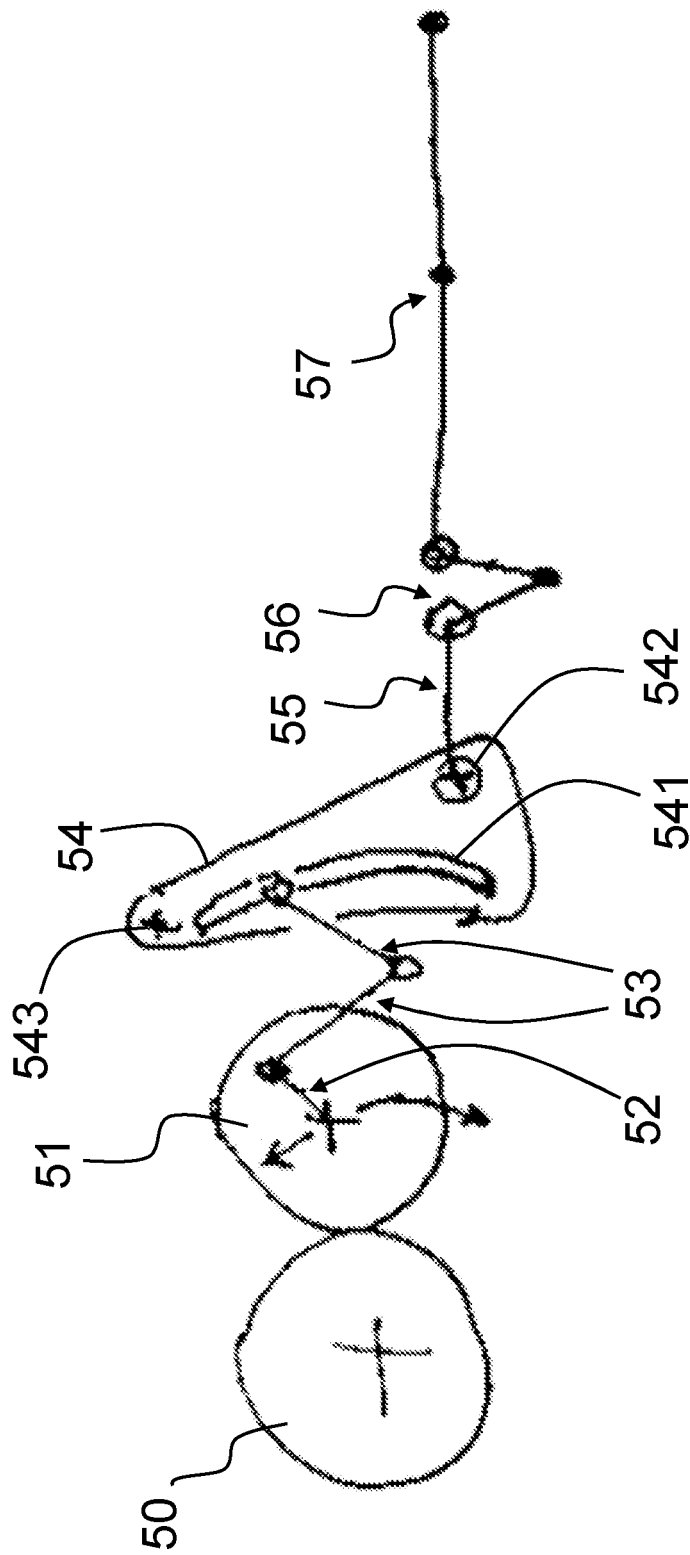


Fig. 3

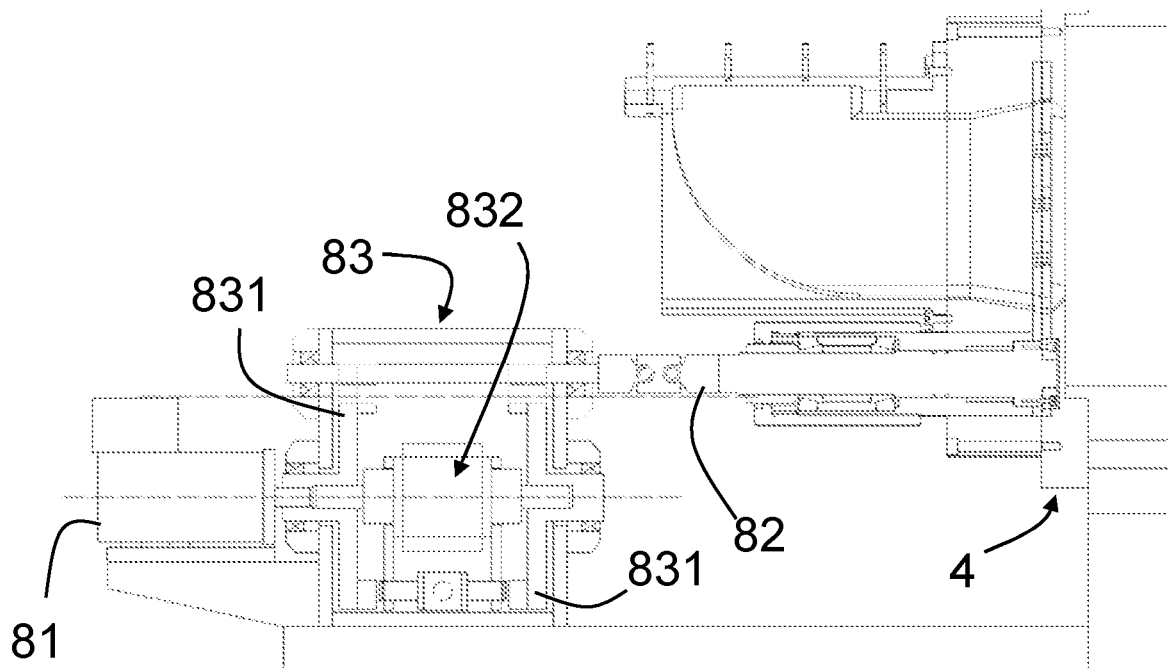


Fig. 4a

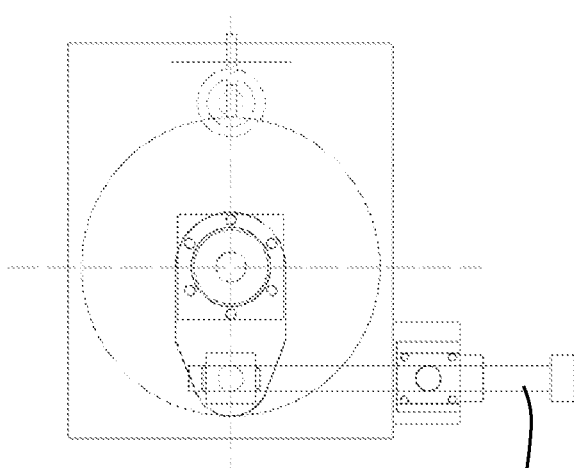


Fig. 4b

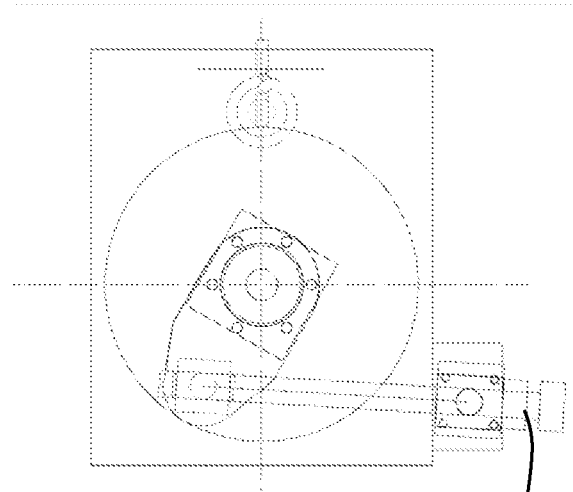


Fig. 4c

REFERENCES CITED IN THE DESCRIPTION

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