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(54) **ECCENTRIC SLIDING VANE EQUILIBRIUM ROTOR DEVICE AND ITS APPLICATIONS**

(57) This invention relates to an eccentric equilibrium rotor device applicable for fluid positive-displacement devices such as compressors, pumps, blowers or motors, having two integrally crossed and equally weighted sliding vanes fixed in the cross-shaped sliding path in the body of the hollow rotor and perpendicular to each other. At the centers of the two slides there are projecting studs provided with coupler rings by which balancing between the inertial force of the motion of the slides is obtained. This invention also relates to a rotary engine using many kinds of fuel, which is constituted by a compressor in coaxial tandem with a gas motor. Both of the said compressor and the gas motor have an eccentric equilibrium rotor with a single sliding vane, and a combustion chamber is provided therebetween and communicates with them.

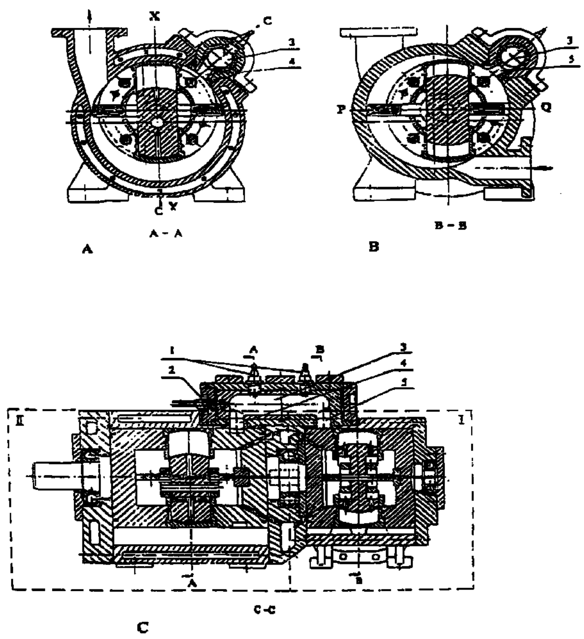

FIG.13

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Description

Field of Technology

[0001] This invention relates to an eccentric sliding vane equilibrium rotor device, and in particular it relates to an eccentric sliding vane equilibrium rotor device such as a fluid displacement compressor, pump, blower, and motor, as well as its applications.

Background of Technology

[0002] In the present technology, the majority of eccentric sliding vane rotors used in pumps, compressors, and pneumatic and hydraulic motors use divided-type sliding vanes, and when the rotors are rotating, the movement of the tips of the sliding vanes pressed against the cylinder wall produces very great friction and the sliding vanes are easily worn down. This increases waste and shortens the life of the motor. Eccentric sliding vane rotor machines once attracted long-term attention in the engineering field and produced many different kinds of improved schemes. In some low-lift oil pumps for aircraft, integrally crossed sliding vanes were used, the contour of the inner wall is formed by splicing together several sections of arcs, and there is some improvement of the stress conditions of the sliding vanes compared with the stress of non-integral sliding vanes. U.S. patents 4,929,159 and 4,958,995 each think of ways to balance the centrifugal force during rotation of the sliding vanes, their structures are comparatively complex, and it is difficult to solve the dynamic pressure of the sliding vanes on the sliding paths. Eccentric sliding vane rotor-type machines are mainly used in small and medium-sized cold engines, and at present there have not been seen reports of successful sliding vane blowers and heat engines.

[0003] Reciprocating piston machines began from the bellows used in China's metallurgical industry of antiquity, and they have continuously developed in the manufacturing of steam engines and internal combustion engines. However, due to the limitations of their inherent structures, the thermal efficiency of steam engines is lower than 22%, the thermal efficiency of gasoline engines is about 26-40%, and the thermal efficiency of diesel engines is about 30-46%, and furthermore, it is most difficult to try to raise the thermal efficiency and relative power. In order to improve traditional heat engines, people have explored many kinds of rotating piston engines, among which the most famous is the Wankel rotary engine which uses a cycloid-shaped cylinder. From the 1960s to the early 1970s, that engine was once mass produced and was used in the automotive industry, but in the 1970s, under the dual assault of the global oil crisis and laws of various countries emphasizing environmental preservation, it was gradually removed from the market, and only a very few makers continue development and production of a small quantity of products in such areas as motor vehicles, military mobile power supplies, and special vehicles and ships. On the other hand, although low-power gas turbines have great relative power, good equilibrium, and little waste from mechanical friction, they are comparatively deficient in power output characteristics such as power required for automobiles and torque of speed interval, and the high-speed interval also requires matched transmission equipment, with the result that the operating cost is expensive. Therefore, it is difficult to serve as a commonly-used engine.

Details of the Invention

[0004] The first aim of the present invention is to design a kind of eccentric sliding vane equilibrium rotor (abbreviated as ESVER) device that can balance the inertial force of the movement between the sliding vanes or between the sliding vanes and the equilibrium units, so as to reduce or eliminate the dynamic pressure of the tips of the sliding vanes on the cylinder wall and of the sliding vanes on the sliding paths, to lower the waste from friction, and to improve the seal environment.

[0005] The second aim of the present invention is to use the ESVER device in a presently-existing sliding vane cold engine, to improve its major performance indicators, such that it can be competitive with and achieve superiority to other fluid displacement cold engines, and to develop blower-type products and other cold engine products using ESVER, so as to expand the scope of use of sliding vane machines.

[0006] The third aim of the present invention is to use the ESVER device to develop many kinds of energy-saving fuel engines; that machine should combine the total advantages of traditional fluid displacement machines and traditional impeller machines, that is, it should have the piston engine's correspondingly fixed compression ratio and expansion ratio under different rotation speeds, as well as rotation speed, torque, and power output characteristics when used in an automobile, and it should also have the impeller machine's separation of compression process and expansion process of the working medium, mutually independent combustion chambers, and characteristics such as high relative power and equilibrium; its thermal efficiency should be higher than that of the present traditional heat engines, and it should be an engine with high performance and low emission of pollutants.

[0007] The ESVER device is realized in the following manner:

[0008] An eccentric sliding vane equilibrium rotor device including a rotor body placed eccentrically inside a cylinder body, eccentricity *e*, and a radial sliding path evenly spaced on the rotor, characterized in that: the rotor body has a hollow part, there is at least one pair of equally-weighted members moving perpendicular to each other in the radial sliding path of the rotor body, and at least one of them is an integrally intersected sliding vane; there are central studs or shaft holes on said equally weighted members crossing the centers of mass of said equally-weighted members and running parallel with the axis of the rotor body, and they are connected by a movement restraining unit; and the inertial force of the movement of said equally-weighted members is mutually balanced through said movement restraining unit.

[0009] The ESVER device of the present invention also can be realized through the following schemes:

[0010] The central studs or shaft holes of said equally-weighted members are connected by a rigid, flexible or pliable movement restraining unit, said movement restraining unit is a coupling ring, and the coupling ring is fitted outside the central studs of said equally-weighted members, so as to constrain the optimal center distance between the two central studs to *e*. Said movement restraining unit has a connecting rod protruding in both directions and running parallel to the studs, two protruding studs are located on both sides of the connecting rod body, and their optimal center distance is *e*. One of said equally-weighted members is an integrally intersected sliding vane, the other is a member causing a balancing action, and they can form a single-sliding vane-type eccentric equilibrium rotor device. Said equally-weighted members both are integrally intersected sliding vanes, and they can form a dual-sliding vane or four-sliding vane or six-sliding vane or multiple-sliding vane-type eccentric equilibrium rotor device. Said integrally intersected sliding vane is constituted by a sliding vane frame and a sliding vane sealing unit or scaling unit assembly; the sliding vane frame includes two sliding vane bodies, a linking cross member between the two sliding vane bodies, and a protruding stud or shaft hole in the center of the linking cross member; the sliding vane frame can be a single component, or it can be an integrated member composed by suitably processing a plurality of components, and the eccentric sliding vane equilibrium rotor device has at least one sliding vane frame; the sliding vane sealing unit or sealing unit assembly includes an elastic element and a linkage unit, a T-shaped sealing unit or wear-resistant spring-type sealing unit sealing the tip of the sliding vane, and a self-expanding-type sealing sheath or self-expanding-type quasi-surface contact sealing sheath sealing the entire sliding vane body. Said rotor body can have a half-hollow part or have a single hollow part or have a plurality of hollow parts. Application of said eccentric sliding vane equilibrium rotor device in all kinds of compressors, pumps, blowers, and motors results in an energy-saving multiple-fuel rotary engine, utilizing an eccentric sliding vane-type equilibrium rotary compressor and an eccentric sliding vane-type equilibrium rotary gas motor being cascaded coaxially, and being connected by a combustion chamber therebetween.

<u>Description of the Drawings</u>

[0011]

Figure 1 is a concept drawing of the first embodiment, being a dual-sliding vane ESVER compressor, vacuum pump or pneumatic motor;

Figure 2 is a comparative drawing of pressure distribution of sliding vanes and cylinder wall in the present technology and the ESVER device;

Figure 3 is an explanatory drawing of a planar isochordal curve and its characteristics;

Figure 4 is a concept drawing of a sliding vane in an ESVER machine;

Figure 5 is a concept drawing of seven kinds of ESVER sliding vanes and sealing schemes;

Figure 6 is a schematic of the layout of hollow rotor bodies and sliding vanes of traditional ESEVERs;

Figure 7 is a concept drawing of the second embodiment, being a dual-sliding vane ESVER blower and large-scale pneumatic motor;

Figure 8 is a concept drawing of the third embodiment, being a dual-sliding vane ESVER fluid pump and hydraulic motor;

Figure 9 is a schematic of the fourth embodiment, being a four-sliding vane ESVER;

Figure 10 is a concept drawing of the fifth embodiment, being a single-sliding vane ESVER heat engine motor or compressor;

Figure 11 is a stereo view of the sixth embodiment, being a dual-sliding vane ESVER with restraining unit as connecting rod;

Figure 12 is a concept drawing of the seventh embodiment, being a multistage expansion ESVER steam motor;

Figure 13 is a concept drawing of the eighth embodiment, being an ESVER energy-saying multiple-fuel rotary engine;

Figure 14 is an elementary diagram of the operation of the ESVER engine.

<u>Preferred Embodiments of the Invention</u>

[0012] Figure 1 is the first preferred embodiment of the present invention; it is a dual-sliding vane ESVER compressor, vacuum pump or gas motor. In Figure 1, there is a pair of integrally intersected and mutually perpendicular equally-weighted sliding vanes placed in the sliding path of the rotor body, sliding vane S1 situated in the vertical position and sliding vane S2 situated in the horizontal position (composed of two units S2' and S2'' spliced together). The rotor body is a two-unit spliced type, and there is a cavity in the center. 51 resembles the letter "I" being symmetric top and bottom, the two parts top and bottom are the sliding vane body, the narrow center part is a linking cross member, and on both sides of the center part of the linking cross member, there are central studs a1' and a1'' extending outward, running parallel with the axis of the rotor body and following the central axis of the sliding vane; sliding vane S2 (S2' and S2'') resembles two narrow letters "I" (in Figure 1-A, only the cross section of the linking cross member can be seen), the widths of its sliding vane body and linking cross member being only half those of the vertical sliding vane, and the sum of the weights of the two horizontal sliding vanes being comparable to that of the vertical sliding vane. The two horizontal sliding vanes are spliced together, the central part forms a rectangular hole, and each has a central stud a2' and a2'' extending inward, running parallel with the axis of the rotor body and following the central axis of the sliding vanes. Since sliding vanes S1 and S2 are centrally axi-symmetric components with even weight distribution, their centers of mass are necessarily on the point of intersection of each central axis and the central horizontal sectional plane of the cylinder body. The central horizontal sectional plane of the cylinder body also is the plane of motion of the centers of mass of the sliding vanes. The diameters of the central studs of the sliding vanes are both d, R1 and R2 are two coupling rings, they are separately mounted on the outsides of the two pairs of central studs, their internal diameters $D = e + d$, generally $d < e$, and they cause the maximum center distance of the two central studs to be e.

[0013] The above-mentioned rotor with sliding vanes and coupling ring is eccentrically installed into an approximately isochordal curve-shaped cylinder body, and the eccentricity is e. A sealing arc is processed out at the location of contact of the rotor with the cylinder body; a seal slot is processed out at the top part of the sliding vane, and a graphite or polytetrafluoroethylene seal F is inserted so as to be capable of sliding freely following the radial direction. The entire rotor also can rotate freely from the front and back cylinder heads and bearing support. When the moment of external force drives the rotor to rotate clockwise at angular velocity w, an air inlet on the right side draws in air, the air is compressed in a displacement chamber, and then it is exhausted from an air outlet on the left side. Following rotation of the rotor, the sliding vanes are substantially performing planetary movement; that is, the centers of mass of the sliding vanes revolve around, the central axis (virtual axis) of the coupling ring at angular velocity w_g, and at the same time the sliding vanes also rotate around their own central studs at angular velocity w, furthermore, the angular velocities of the rotation and revolution have a relationship of $w_g = 2w$; the axis of rotation of the sliding vanes and the central axis of the central studs (or shaft holes) overlap each other, the sliding vanes (or equilibrium units) and coupling ring jointly compose a planetary rotational system with the central axis of the coupling ring as the axis of rotation, the inertial force of movement of this group of equally-weighted sliding vanes is mutually balanced through the coupling ring, there is no longer dynamic pressure of the tops of the sliding vanes on the cylinder wall and the sliding vanes on the sliding path in general, the stress conditions of the sliding vanes achieves improvement, the frictional waste achieves lowering, and at the same time a better sealing environment is obtained. When the air inlet is connected to a fixed container, that machine is a vacuum pump; when air having a specific pressure taken into the cylinder body from the outside drives the rotors to rotate and moving force is output from the shaft, that machine is a pneumatic motor.

[0014] Figure 2 shows a comparison of pressure distribution of the sliding vanes on the cylinder wall in the present technology and an ESVER device; the traditional divided-type sliding vanes all have dynamic pressure on the entire cylinder wall (Figure 2-A), the traditional intersected-type sliding vanes partially have dynamic pressure on the lower half of the cylinder wall (Figure 2-B), and when the sliding vanes in the ESVER device do not have a seal installed, the tips of the sliding vanes very rarely contact the cylinder wall, and the cylinder wall does not receive dynamic pressure (Figure 2-C).

[0015] Figure 3 is a planar isochordal curve and its characteristics; four ends of a pair of sliding vanes in the above-mentioned rotor during planetary rotational movement created the basic form of the cylinder body of the ESVER machine -- the planar isochordal curve; it can be seen that the isochordal curve is a kind of cycloid. Figure 3-A shows one planar isochordal curve when $\lambda = B/e = 4$; Figure 3-B shows a family of planar isochordal curves when A changes from 2 to 8.

[0016] The Cartesian coordinate equations of an isochordal curve are:

$$X = (B - e \,.\, \mathrm{Sin}\,\Theta) \,.\, \mathrm{Cos}\,\Theta$$

$$y = (b - e \,.\, \mathrm{Sin}\,\Theta) \,.\, \mathrm{Sin}\Theta$$

Its polar coordinate equation is: $p = B - e \,.\, \mathrm{Sin}\Theta$.

[0017] In the above formulas, B and e generally are constants, and Θ is the angle variable, among which:

B -- called polar radius, equal to one half of the horizontal chord length, the polar diameter length is $2B$.

e -- eccentricity, is the distance of the central axis of the rotor body offset from the central axis of the cylinder body, it is also the optimal center distance between the central studs of the said equally-weighted members (integrally intersected sliding vanes or equilibrium units).

Θ - rotational angle of the rotor body, it is also the rotational angle of the integrally intersected sliding vanes.

λ -- called radial deflection ratio, $\lambda = B/e$.

[0018] An isochordal curve has two important characteristics:

(1) Any chord length crossing the polar core is identically equal to the fixed length $2B$. Based on this characteristic, that family of curves is called isochordal curve, that characteristic ensures that a sliding vane having a fixed length of $2B$ can freely rotate around the polar core (that is, the central axis of the rotor) in a cylinder body having an isochordal curve as the main outline of the inner wall, and the theoretical gap between the tip of the sliding vane and the cylinder wall at any rotational angle can be identically equal to zero or maintain a constant minimum value.

(2) The track of any chord center point P (usually also the center of mass of the sliding vane) crossing the polar core is a circle with a diameter of e; therefore the distance between the center points of any two chords crossing the polar core o and being perpendicular to each other is identically equal to e. This characteristic provides the theoretical basis of utilizing a rigid coupling ring or other rigid, flexible or pliable coupling unit to link up the central axes (axes of revolution) of a group of said equally-weighted members, to constrain their movement, and to make the inertial force of their movement mutually balanced.

[0019] Figure 4 is a concept drawing of an integrally intersected sliding vane in an ESVER machine; an integrally intersected sliding vane in an ESVER machine is mainly constituted by a sliding vane frame and a sealing unit. In order to distinguish from other types of sliding vanes, the main part of a sliding vane having a central stub or shaft hole used in an ESVER is called the sliding vane frame. As shown in Figure 4-A, the sliding vane frame assumes the shape of the letter "I", the entirety is composed of three parts, being a central stud *a*, a linking cross member *b*, and two sliding vane bodies *v* and *v*'; four units can be used, two units per group spliced relatively as in Figure 4-B, to constitute the pair of mutually perpendicular ESVER sliding vanes used in Figure 7 and Figure 8. Since the sliding vane frame receives cyclic loading, fatigue-resistant, robust materials and skilful manufacturing should be adopted, and the central studs and inside of the sliding vane body should be wear-resistant; to make the inertial moments of the sliding vane frame on the *O-O* axis and the *M-N* axis both zero, they must have the optimal mass distribution and equilibrium effect, otherwise a linkage unit should be installed between each group of sliding vanes to make them become an integrated whole, a seal slot is opened at the tip of the sliding vane body, and a seal F made of wear-resistant material is installed therein; a seal slot can also be opened on the end face of the sliding vane body, and an end face seal or angle piece can be fitted (all kinds of sealing schemes of Wankel rotary engines can serve as reference). A rippled spring can be installed in the seal slot in order to reinforce the sealing effect of the seal when at low rotational speed.

[0020] Figure 5 is seven different kinds of ESVER sliding vanes and sealing schemes.

[0021] Figure 5-A is a sliding vane without a sealing ring; the sliding vane is constituted only by a sliding vane frame, and it can be used in fluid pump-type machines; since leaks are easily produced and it requires comparatively high processing precision, it is generally not recommended.

[0022] Figure 5-B is a simple seal ribbon scheme; a seal slot is processed out on the tip of the sliding vane body, a ribbon-shaped seal called a seal ribbon is inserted therein, the seal ribbon can expand and contract radially following the sliding vane so as to compensate for gaps and wear. Advantages: simple, easy to manufacture, suitable for all kinds of compressors, pumps, blowers, and motors; Figure 1 uses this scheme.

[0023] Figure 5-C is a T-shaped sealing unit scheme; a T-shaped slot is processed out on the tip of the sliding vane and a T-shaped sealing unit is inserted therein, the sealing unit can slide radially, but its wear compensation is a limited value. An approximately isochordal curve-shaped cylinder body is selected to match, the machine is subjected to a period of breaking-in operation, the seal gap tends toward a stable value, and the sealing unit and the inner wall of the cylinder wall come into quasi-contact condition. It is suitable for sealing a high-rotational speed ESVER machine of large dimensions.

[0024] Figure 5-D is a wear-resistant spring-type sealing unit scheme; a spring of composite material is fixed to the tip of the sliding vane body, an approximately isochordal curve-shaped cylinder body is selected for best match, and the inner wall of the cylinder body is spray-coated with polytetrafluoroethylene.

[0025] Figs. 5-E, F, G, and H are self-expanding sealed sliding vanes, and they are recommended schemes for experimental engines. Their common features are: the main sliding face of the sliding vane is constituted by a single sliding vane-sheathing sealing unit, a part with expanding angle in the form of a "jaw" has flexibility, under pressure the two outer surfaces of the "jaw" can return to a parallel state and it can be inserted into the sliding path of the rotor body, and a sufficient gap is left between the sealing sheath and the sliding vane body so as to prevent gripping during thermal expansion of the components. Sealing of the two side faces of the sliding vane and compensation for wear are ensured by flexibility and self-expanding property of the sliding vane-sheathing sealing unit, and a flexible element can be installed inside the sliding vane body so as to increase the pressure of the tip of the sliding vane sheath on the cylinder wall; the sliding vane sheath can expand and contract radially, and it can form a seal between the tip of the sliding vane and the cylinder wall and compensate for wear.

[0026] Figure 5-E is a simple self-expanding-type sealing sheath scheme; it can be used on the earliest experimental machine so as to observe the sealing effect and wear conditions, a wedge-shaped angular piece sealing sheath can also be matched so as to reinforce the seal of the end face of the sliding vane.

[0027] Figure 5-F is a masthead-shaped self-expanding sealing sheath scheme;- the angle at the top surface of the sealing unit is changed to a pin roller, the sliding friction is changed to rolling friction, and a fixed wear-resistant unit of hard alloy or corundum can also be installed on the top.

[0028] Figs, 5-G and H are self-expanding quasi-surface contact sealing sheath schemes; a wear-resistant pin that can rotate at a specific angle is installed on the tip of the sealing sheath, the linear contact of the sealing unit is changed to approximately columnar surface to columnar surface contact, or it is called quasi-surface contact sealing, and such is convenient for forming oil film lubrication and is useful for reducing or avoiding the formation of cracks on the cylinder wall. Figure 5-G shows the radial axis of the sliding vane and the symmetric axis of the cylinder body positioned overlapping as in Figure 13-B, and at this time the pressure between the sliding vane and the cylinder wall is about zero degrees; Figure 5-H shows when the radial axis of the sliding vane and the symmetric axis of the cylinder body are positioned perpendicularly as in Figure 13-A, and at this time the pressure between the sliding vane and the cylinder wall has about reached the maximum value.

[0029] Figure 6 is a typical ESVER hollow rotor body and sliding vane placement scheme; the sliding vanes in the drawing are all simplified to the forms in Figure 5-A, and the sealing units and coupling rings are omitted and are not drawn; different hollow rotor bodies and sliding vanes can have different kinds of combinations, but here only typical examples are presented,

[0030] Figure 6-A is a half-hollow rotor body, sliding vane and coupling ring placement scheme; the drawing shows a half-hollow ESVER device consisting of one half-hollow rotor body, two sliding vanes, and one coupling ring (abbreviated as 2S1R); in the drawing, S1 and S2 respectively are identical equally-weighted vertical and horizontal sliding vanes, a coupling ring R is installed around the outside of the central stud a of the two sliding vanes, and it is required that the inertial moments of the sliding vanes on the *O-O* axis and *M-N* axis both be zero in order to be able to ensure good equilibrium of the whole rotor; one consisting of two bearing supports has a half-hollow rotor body with a cross-shaped sliding groove and a half axle, the sliding vanes and coupling ring assembly can be conveniently installed into the half-hollow rotor body from the right side; that structure is simple, and it is suitable for compact-type cold engine products such as electric freezers and air conditioners.

[0031] Figure 6-B is two spliced-type hollow rotor body ESVER devices one with a single sliding vane and one with dual sliding vanes; it is the most typical ESVER device, and there are many kinds of sliding vane and coupling ring placement schemes; for example two-vane two-ring type, abbreviated as 2S2R, as in Figure 1, Figure 7, and Figure 8; one-vane two-ring type -- IS2R, as in Figure 10 and Figure 13.

[0032] Figure 6-C is a four-sliding vane-type ESVER device; in the drawing, there are two kinds of sliding vanes, two vanes of each kind, two vanes vertically as one pair, the four sliding vanes in the rotor body are evenly spaced at a mutual angle of 45°, and thus is constituted one four-vane two-ring ESVER device, abbreviated as 4S2R; it is required that the inertial moments of the sliding vanes on the *O-O* axis and *M-N* axis both be zero in order to be able to ensure good equilibrium of the whole rotor. With four vanes, there are also schemes such as four-vane three-ring type -- 4S3R, as in Figure 9, and four-vane four-ring type -- 4S4R.

[0033] Fig 6-D is a six vane three ring-type ESVER device; the spliced sliding vanes situated on the two sides in the four vane three ring-type rotor in Figure 9 are respectively made independent, their sliding vane bodies are extended to equal width with the rotor body, the six sliding vanes are evenly spaced, each vane is at a mutual angle of 30°, and thus is constituted a six vane three ring-type ESVER device as in Figure 6-D.

[0034] In regard to ESVER devices, there are the following several points which require explanation:

(1) An ESVER is a planetary rotational mass system constituted by many components, and it is not a simple rigid body; it can be proven using mathematical dynamics or geometric methods. Although the center of mass of the whole eccentric rotor mass system is biased from the rotational axis, during rotation the center of mass always maintains relative stasis, and thereby it becomes an eccentric equilibrium rotor. The core concept of the ESVER device is: there is at least one pair of equally-weighted members (integrally intersected sliding vanes or equilibrium units) moving perpendicular to

each other in the evenly spaced radial sliding path of the rotor, said equally-weighted members both have rotating axes crossing the centers of mass of said equally-weighted members and running parallel with the axis of the rotor, there are central studs or shaft holes on said equally-weighted members following said rotating axes, and they are connected by a movement restraining unit; and during rotation of the rotor body, said equally-weighted members perform mutually balanced planetary movement, and their inertial force is mutually balanced through said movement restraining unit.

(2) The main characteristic of the ESVER device is: the central stud or shaft hole of said equally-weighted members is connected by a rigid, flexible or pliable (such as an endless chain or wire cable ring) movement restraining unit, and the specific connection methods are determined according to the structures, dimensions, and working conditions of the actual machines.

(3) A coupling ring is the most simple central shaft movement restraining unit to use; when the diameters of the central studs of the equally-weighted members are equal and are d, the optimal inner diameter of the coupling ring is $D = e + d$, generally $d < e$; the surface of the inner ring of the coupling ring must be wear-resistant, the entirety requires high strength and high tenacity.

(4) A shaft hole can also be formed in the location of the central shaft of said equally-weighted members, and then a shaft pin can be pressed in and fixed; or a shaft bearing can be installed in the shaft hole. Said movement restraining unit thus has a connecting rod protruding in both directions and running parallel to the studs, two protruding studs are located on both sides of the connecting rod body, and their optimal center distance is e; the two shaft journals of the connecting rod respectively can be fitted with the shaft bearing, and they can rotate freely.

(5) In an ESVER machine, an isochordal curved, approximately isochordal curved or standard round columnar cylinder body (theoretical cylinder radius $R_{B0} = /(B^2 + e^2)$) can be used, and experience proves: the ESVER operates freely and stably in a round cylinder, it has good equilibrium, sealing property, and manufacturability.

(6) One of a pair of mutually perpendicular sliding vanes can be turned into an equilibrium unit or equilibrium guide pillar which purely causes an equilibrium effect, and it can form a single sliding vane-type eccentric equilibrium rotor device.

(7) In actual machines, a pair of mutually perpendicular sliding vanes can be used to form a machine type dividing the cylinder body into four displacement chambers, and two pairs or three pairs of mutually perpendicular evenly spaced sliding vanes can also be used to form machine types dividing the cylinder body into eight or twelve displacement chambers, such as in Figure 6-C and D; it is also possible to manufacture machines having more than twelve chambers or machine types with odd numbers of sliding vanes, but the structures are too complex and the use value is not great.

(8) As future ESVER machines gradually increase in speed and increase in external dimensions, it is better to use high-strength alloys and precision casting methods for the sliding vanes to make them into hollow units (approximating gas turbine blade processing), or high-strength light-weight materials for aircraft airfoils are used with such processes as gluing, welding or riveting to make them into composite sliding vanes, so as to make them have high fatigue strength and as little weight as possible.

(9) The ESVER is suitable for use in the development of all kinds of cold engines such as compressors, pumps, blowers, and pneumatic and hydraulic motors, it can reduce energy consumption, reduce relative weight, and extend the lifetime of use; such machine has good potential for increase of speed and capacity of the rotors, it also has enormous potential for increase of capacity by enlarging the external dimensions of the machine body, it can increase the displacement volume of sliding vane-type machines by multiples, even ten times or several tens of times, and it will be useful for expanding the scope of application of sliding vane-type machines.

(10) The ESVER also should be suitable for use in high-thermal efficiency rotor steam or gas motors having a working medium of high-temperature high-pressure steam or combustion gas and converting thermal energy into mechanical energy, and it can be used in the development of many types of engines having high thermal efficiency.

[0035] Figure 7 is the second embodiment of the present invention, being a dual-sliding vane ESVER blower and large-scale pneumatic motor; in this, for one pair of integrally intersected sliding vanes, four identical sliding vanes relatively spliced together to become as in Figure 4-B are used, and between them are used two coupling rings, mutually balanced. Sliding vanes of the types in Figs. 5-B, C, and D can be used to manufacture a blower. That structure also can be used in the manufacture of a dual-sliding vane ESVER steam or gas motor, only the working medium is changed to pressurized steam or combustion gas. In order to reduce the corrosive action of high-temperature water vapor and reduce waste from friction, all components such as cylinder body, cylinder cap, rotor body, sliding vane groove, and sliding vane set should be spray coated with polytetrafluoroethylene, and if the temperature of the combustion gas is too high, the cylinder body should be water cooled. This structure can be cascaded in multiple stages to manufacture a high-pressure compressor, or to serve as an intermediate experimental machine for a multistage ESVER high-pressure steam motor; it can also be independently used in a blast furnace blower or a drive motor for blast furnace coal gas overpressure power generation or low-heat steam power generation.

[0036] Figure 8 is the third embodiment of the present invention, being a dual-sliding vane ESVER fluid pump and hydraulic motor; the structure is the same as in Figure 7, and since the fluid cannot be compressed, the inlet and outlet should be modified; the sliding vanes in Figs. 5-A, B, and C can be used during manufacturing. When external mechanical force drives the rotor to rotate clockwise, the fluid is drawn in from the hole on the right and is discharged from the hole on the left, and this is a fluid pump or quantum pump; when pressurized oil is fed in from the hole on the right and the rotor is driven to rotate clockwise to output mechanical force, that machine is an oil motor; when pure water in a water reservoir is used to propel it to rotate, that machine is a water motor; if many cylinders in tandem cause the water inlets and outlets to be in staggered placement and balance well the water pressure on the main shaft bearing, it is also possible to manufacture a water-saying ESVER "water turbine". When used in an oil transfer pump, in order to reduce pulsing of the flow rate, a four-vane machine scheme can be used or an accumulator can be placed in the channel; that scheme is suitable for use in cases of special applications such as thick oil pumps, gas-fluid two-phase pumps for mixed transfer of petroleum and natural gas, and water-oil two-phase pumps. In order to reduce the corrosive action of water and reduce waste from friction, the whole cylinder body, cylinder cap, rotor body, sliding vane groove, and sliding vane set should be spray coated with polytetrafluoroethylene or they should be manufactured using corrosion-resistant materials.

[0037] Figure 9 is a concept drawing of the fourth embodiment, being a four-sliding vane three-ring-type gas compressor; two groups of mutually perpendicular integrally intersected sliding vanes are placed evenly spaced in the rotor body, it is required that the weight distribution of equally-weighted sliding vanes S3 and S4 placed at 45° angles in the drawing can ensure that the center of mass is situated at the point of intersection of the central shaft and the central horizontal sectional plain of the cylinder body, and the inertial force of the two sliding vanes can be balanced using one coupling ring R1 between them; sliding vanes S1 and S2 are mutually balanced through coupling rings R2 and R3; four-vane machines have many kinds of structural schemes, and because the cylinder body is divided into eight chambers, it is useful in increasing the compression ratio and reducing redundant compression.

[0038] Figure 10 is the fifth embodiment, being a single-sliding vane ESVER gas motor (when backward-rotating, it is a compressor); there is only one sliding vane in the rotor, another sliding vane is converted into an equally-weighted guide pillar, and the two top surfaces of the guide pillar no longer extend from the round columnar surface of the rotor body, by this the length of the sealing line is reduced, and it can have comparatively greater compression ratio or expansion ratio; when used as a compressor, a cheek valve generally must be placed at the gas outlet, or an exhaust groove is opened on the round columnar surface of the rotor, and when arriving at the predefined compression ratio, the gas inside the compression chamber is jointly exhausted through the exhaust groove and the gas outlet; at other rotational angles, the gas outlet is closed by the round columnar surface of the rotor. When used as a gas motor, the length of the gas intake groove opened on the round columnar surface of the rotor body or the corresponding rotational angle determines the gas expansion ratio. This scheme can independently manufacture products, but the main purpose is to serve as an intermediate experimental version of an ESVER engine.

[0039] Figure 11 is a stereo view of the sixth embodiment, being a dual-sliding vane ESVER with restraining unit as connecting rod; the drawing shows that there is a shaft hole in the central position of sliding vanes S1 and S2, the central shaft movement restraining unit is a connecting rod L protruding in both directions and running parallel with the studs, and the optimal center distance of the two studs is equal to e. The two shaft journals of the connecting rod respectively should be able to be fitted with the central shaft hole and be able to rotate freely, and the inertial force of the movement of the two sliding vanes can be mutually balanced through this connecting rod. That scheme is suitable for use in mass-produced products in which the central shaft hole of the sliding vanes can be directly pressure cast.

[0040] Figure 12 is a concept drawing of the seventh embodiment, being a multistage expansion ESVER steam motor; high-temperature high-pressure steam supplied from furnace Q first enters the first stage in the center, after the action of expansion it enters steam superheater H to raise the temperature, furthermore it continues to expand up to the last stage outside, and the discharged spent steam and water are recirculated back to the furnace and are converted into high-temperature high-pressure steam for reuse. The main structural characteristics of that machine are: a plurality of ESVER pneumatic motors placed coaxially becomes in a symmetrical placement, the high-pressure cylinder has a small bore and is situated in the center, the cylinder bores at each stage extending in both directions are gradually increased, the low-pressure cylinder has the greatest bore and is situated at the outermost side of the two sides, adjacent cylinder bodies are placed respectively apart at 180°, the gas inlets and outlets between each stage are placed staggered and symmetrically, and as long as the diameter and length of the rotor are suitably designed, the radial gas pressure acting on the main shaft bearing of the rotor can be reduced or eliminated. The radial pressure of the gas on the rotor in the high-pressure stage of that machine can achieve comparatively better equilibrium, and since comparatively better thermodynamic periodic duty can be selected, operation at low speed also can have comparatively better thermal efficiency. Under conditions of gradual reduction of global petroleum resources, the use of coal gas and nuclear energy as alternate energy supplies to drive large-scale ships could be a condition for development and manufacturing of large-scale multistage ESVER steam engines. Reverse operation of that scheme can be used in manufacturing high-pressure compressors.

[0041] Figure 13 is a concept drawing of the eighth embodiment; it uses an ESVER device to develop an energy-saving multiple-fuel rotary engine; the structural principles and embodiments of the ESVERs previously described were mainly preparations made for developing ESEVER engines. Many kinds of engines can be formed by using the afore-described ESVER gas compressor and ESVER gas motor cascaded coaxially and connecting a combustion chamber therebetween. Figure 13 is an engine designed using a single-sliding vane ESVER device; Figure 13-A is a horizontal sectional view of a single-sliding vane gas motor, Figure 13-B is a horizontal sectional view of a single-sliding vane compressor, and Figure 13-C is a vertical sectional view of the whole machine.

[0042] A single-sliding vane ESVER compressor (Figure 13-C-I) and a gas motor (Figure 13-C-II) having the same structure except that the widths of the cylinder body and sliding vanes are increased up to f times (f = 1.2-2, in this drawing f = 1.4) are cascaded coaxially, and the symmetric central axes PQ and XY of the horizontal sections of the cylinder bodies of the two machines are perpendicular to each other. There is provided a long round columnar combustion chamber 3 on the bisector of the angle of the two central axes and a vertical axis tangential to the rotor and the cylinder body and running parallel to the cylinder body, a fuel injection nozzle 2 is provided on the left end of the combustion chamber, and it can inject many kinds of fuel, and there are two spark plugs 1 above the combustion chamber. The capacity of the combustion chamber, speaking of the compressor, has a compression ratio of 8, and speaking of the gas motor, its expansion ratio is 11.2 (8 x 1.4). On the lower right side of the combustion chamber, there is provided a gas inlet channel 5 connected with the compressor, and on the lower left side of the combustion chamber, there is provided a gas outlet channel 4 connected with the gas motor. A gas inlet port is provided on the lower right side of the compressor; on the round columnar surface of the compressor rotor, there are opened two gas inlet grooves following in the clockwise direction starting from the two sides of the sliding vane and continuing for about a 75° rotational angle; a gas outlet port is provided on the upper left of the gas motor; on the round columnar surface of the gas motor rotor, there are opened two gas outlet grooves following in the counter-clockwise direction starting from the two sides of the sliding vane and continuing for about a 105° rotational angle.

[0043] Figure 14 is an elementary concept diagram of the operation of the ESVER engine; (A-A) and (B-B) in the drawing correspond respectively to the A-A and B-B sectional views in Figure 13, and they respectively represent the gas motor and gas compressor components. Above them, there is drawn an enlarged combustion chamber, and they are connected with the compressor and the gas motor using gas inlet and outlet channels beneath both the left and right ends thereof. A fuel injection nozzle is drawn on the left end of the combustion chamber and there are two spark plugs at the top. The rotor in Figure 14 is simplified as rotor bodies having gas inlet and outlet grooves opened thereon and flat sliding vanes that can move freely, and the other structures are not drawn. When this engine rotates following the clockwise direction, the sliding vanes and rotor bodies always divide the cylinder body into two to three independent and sealed deflection chambers. The compressor completes the gas-drawing and compression processes, the gas engine completes the expansion work and exhaust process, and their detailed working processes are as shown in the drawing; assuming the two sliding vanes at the start are in the horizontal position, the rotational angle of the sliding vanes is zero degrees as in Figure 14~A. When the starting motor drives the tandem master axle to rotate following the clockwise direction, the half crescent-shaped spaces at the upper halves of the compressor sliding vanes are gradually reduced following the rotation and the gas is compressed, and when they rotate to about a 55° angle and the gas inside the compression chamber is compressed to about 0.4MPa, the gas inlet groove on the round columnar surface of the rotor and the gas inlet channel of the combustion chamber connect together as in Figure 14-B, and fresh air starts to enter the compression chamber. At the same time, the combustion gas inside the combustion chamber which is not yet exhausted and has a pressure of 0.25-0.35MPa is squeezed through the gas outlet channel into the expansion chamber of the gas motor, and the rotational angle of the simultaneously open gas inlet channel connecting the combustion chamber with the compressor and gas outlet channel connecting with the gas motor is as large as about 10° (this angle still requires experimental optimization), and it is called the combustion chamber scavenging iteration angle. Following continued rotation of the rotor, the squeezed out gas freely expands and works inside the chamber at the lower right of the gas motor as in Figure 14-C. During this process, the gas outlet channel of the combustion chamber being connected to the gas engine is closed by the round columnar surface of the rotor and is kept at about a, 75° rotational angle. At the same time as this, the gas inside the compressor is continuously pressed into the combustion chamber, and the sealed adiabatic compression process is gradually completed. When the original left ends of the sliding vanes enter the rotor sealing zone as a result of the compression and the gas inlet and outlet channels are both scaled shut, the fuel injection nozzle injects fuel (fuel injection can be earlier, and the optimal early angle of fuel injection requires experimental confirmation), and the spark plugs spark as in Figure 14-D; during the period when the sparks ignite and burn, the temperature and pressure inside the combustion chamber are raised under nearly isovolumetric conditions. When it further winds past about a 20°-30° angle and the sliding vanes of the compressor and gas motor rotate to about a 160° angle, the gas outlet groove on the round columnar surface of the rotor body of the gas motor connects the combustion chamber and the expansion chamber of the gas engine as in Figure 14-E, high-pressure combustion gas is continuously led into the expansion working chamber of the gas motor and drives the sliding vanes to rotate on a horizontal line past a 180° angle, furthermore the combustion gas kept at 90°-100° counting from the start of expansion is led into the interconnecting angle, the pressure of the gas expansion continuously drives the sliding vanes to move right up to the next round of scavenging of the combustion chamber, the entirety of the combustion gas is squeezed into the expansion chamber, the gas outlet channel of the combustion chamber is again closed, the gas inside the expansion chamber of the gas motor continues to expand and work following rotation right up to when the sliding vanes again reach the horizontal positions, and when the capacity of the expansion chamber reaches the maximum value, as in Figure 14-F, the pressure inside the expansion chamber is close to atmospheric pressure, and the potential energy of the pressure of the gas has been used to the greatest extent. Following that, the sliding vanes continue to rotate, and when they wind past a 360° angle, the expansion chamber and gas outlet port are connected, and the spent gas is exhausted as in Figure 14-B. At the same time as completing one half rotor capacity of exhaust, the other half rotor capacity also starts the next process of expansion work.

[0044] It can be seen that: each time the tandem main axle of the machine rotates one revolution, the compressor completes two rounds of processes of air intake and compression, the combustion chamber completes two rounds of processes of aeration, explosion and combustion, and outputting high-pressure working gas, and the combustion motor completes two rounds of processes of expansion work and exhausting spent gas; that is, each time the main axle of the engine rotates one revolution, it completes two working cycles of air intake, compression, and combustion and expansion work, and exhausting spent gas.

[0045] There are the following several points which require further explanation:

(1) The four strokes of air intake, compression, expansion, and exhaust of reciprocating engines and Wankel engines are undertaken in the same cylinder body; air intake and compression of an ESVER engine are undertaken in a first cylinder body, and expansion and exhaust are undertaken in a second cylinder body. Two rotors coaxially cascaded and connected by an independent combustion chamber therebetween have good equilibrium, and together with the sliding vanes, they form an "impeller" having "blades" with flexible length of working surface. Such structural placement is closer to that of a gas turbine; on the other hand, in small and medium-sized machine types and in general internal combustion engines, the substance of the operation of their working media and thermomotive conversion still pertain to fluid displacement machines, and viewed from the substance of its structural placement and thermo-motive conversion, the ESVER engine is a new type of heat engine between a traditional reciprocating engine and an impeller machine.

(2) To continuously raise the thermal efficiency of engines is an eternal theme of research and development of heat engines; the present invention defines the ratio of maximum expansion capacity of a gas motor and the maximum gas intake capacity of a compressor as 1.2-2 (the specific value is determined by the extent of pressurization of the inlet gas), and this is useful in fully utilizing the potential energy of the pressure in the combustion gas, lowering the temperature of the exhaust gas, and raising the thermal efficiency of the whole engine. It was discovered in experimental studies of rotary machines that due to the unidirectional fluid characteristics of the gas working medium, and the fact that there is no resistance of gas inlet and outlet valves, their exhaust temperatures are higher than those of traditional reciprocating piston engines, the exhaust temperature of a Wankel-type rotary engine during full load operation is about 900°C, and the thermal energy carried away with the exhaust gas occupies about 43% of the total thermal energy; although the exhaust temperature of a reciprocating engine is somewhat lower, the thermal energy carried away with the spent gas is considerably visible. In thinking of ways to convert the partial energy in the spent gas into useful work, using a gas turbocharger is one method. The

present invention lowers the exhaust temperature to 500°C or lower by increasing the capacity for expansion work, fully utilizing the potential energy of compression in the combustion gas and allowing it to fully expand, and by this alone it raises the thermal efficiency by 10% or higher. Because there are no moving parts at all inside the independent combustion chamber, it is possible to have comparatively better models of combustion chambers and area-volume ratio, it is convenient in manufacturing using high temperature-resistant materials, and it is convenient in spray coating heat-insulating layers or using low heat-conducting ceramic combustion chambers; since the combustion frequency of the combustion chamber is four times that of common single-cylinder four-stroke engines, the utilization rate of the combustion chamber is very high, the loss of dissipated heat is reduced, the temperature and pressure of combustion is comparatively higher when equal quantities of fuel are injected, and it is useful for full combustion of the fuel, improving the quality of the exhaust gas, and reducing pollution; there are also many diverse schemes of such machine types, they can more fully utilize the thermal energy of combustion, and they can further increase the thermal efficiency.

(3) The ESVER engine has superior dynamic equilibrium performance, vibration is little, waste from friction is little, and mechanical efficiency is high, and these advantages are especially prominent at high rotational speed.

(4) Change of curvature at all points on the approximately isochordal curved internal contour is very little, and change of the normal wedge angle (or called pressure angle) of the points of contact of the sealing unit with the cylinder wall; the cylinder body of a Wankel-type rotary engine is approximately shaped like the number "8", and the curve has two points of inflection, in contrast, the cylinder body of the ESVER engine is comparatively easier to manufacture, and it is comparatively easy to seal; in the present invention, there are designed a self expanding-type sealing sheath and quasi-surface contact self expanding-type sealing sheath (Figs. 5-G and H) to substitute for the doctor blade line contact seal of the Wankel engine in order to form a gas pressure gradient in the lengthwise direction of the sealing surface, and it should have a comparatively better sealing effect as well as avoid the production of cracks on the cylinder surface.

(5) Since the pressure of the gas on the sliding vanes inside the cylinder body is greater than on the arm of force between the rotors, the ESVER engine has very good torque output characteristics and extremely low fuel consumption during medium and low speeds.

(6) Once it is possible to begin development of multiple-cylinder cascaded high-output medium- and low-speed ESVER spark plug ignition-type diesel engines, suitable placement of a good number of cylinder inlet and outlet ports should be designed so as to make the radial gas pressure acting on the round columnar surface of the rotor mutually balanced, to make the stress on the main shaft bearing of the rotor be in the least condition; as for high-output engines, following the increase of linear dimensions of the engine, the ratio between the length of the sealing line and the working capacity will be gradually reduced, the sealing effect will be even better, and it can serve as an internal combustion engine for car or ship.

(7) This machine uses an injection-type fuel supply system, it is convenient for testing the use of many kinds of fuels, and it is also convenient for utilizing computer technology to optimize the fuel injection and combustion processes so as to conserve fuel.

Testing and Outlook

[0046] The first ESVER experimental compressor uses steel sliding vanes and a double coupling ring, it was test operated at three rotational speeds of 825, 1460, and 260Orpm, and the amounts of emissions were respectively 2.2, 4, and 7m^3/min; during testing, the ESVER operated stably and freely, there were no marks from contact friction on the tips of the sliding vane frames and the inner wall of the gas cylinder, there was low vibration and low waste, and this demonstrates good potential for raising the speed and capacity of the rotors and potential for increasing the external dimensions of the machine body; the rotational speed can be changed using the same components such as cylinder body and rotor to develop a series of products.

[0047] The second ESVER experimental compressor also uses steel sliding vanes; the amount of emissions was 11.5m^3/min when at 1470rpm, and the amount of emissions was 22m^3/min when at 2920rpm. Specimens such as a compact-type experimental compressor, vacuum pump, and fuel-less compressor, a medium-sized compressor having 3Om^3/min emissions and 0.8MPa pressure, a blower having about 150-300m^3/min emissions, as well as an oil transfer pump and gas-liquid two-phase pump are presently under test development.

[0048] Since an ESVER device is a kind of eccentric equilibrium rotating piston, it has the major characteristics of a fluid displacement machine; it is also similar to a completely balanced eccentric turbine (the blades can expand and contract), and at the same time it has a few of the major characteristics of turbine machines, therefore it can be suitable for developing many kinds of commonly used mechanical products similar to the two types described above. Since its structure is simple and the manufacturability is comparatively better, the ESVER device will first be used in all kinds of products such as compressors, pumps, blowers, and pneumatic motors (including large-scale gas motors using blast furnace coal gas overpressure power generation), furthermore it may gradually promote expansion of the scope of application, and through continuous improvements of structures, materials, and manufacturing techniques, its rotational speed and external dimensions may be gradually increased, and the ESVER may be used in such fields as ships and power stations to flying machines, and it also may form a new type of mechanical system between traditional piston machines and traditional turbine machines.

Claims

1. An eccentric sliding vane equilibrium rotor device including a rotor body placed eccentrically inside a cylinder body, eccentricity *e*, and a radial sliding path evenly spaced on the rotor body, characterized in that: the rotor body has a hollow part, there is at least one pair of equally-weighted members moving perpendicular to each other in the radial sliding path of the rotor body, and at least one of them is an integrally intersected sliding vane; there are central studs or shaft holes on said equally-weighted members crossing the centers of mass of said equally-weighted members and running parallel with the axis of the rotor body, and they are connected by a movement restraining unit; and the inertial force of the movement of said equally-weighted members is mutually balanced through said movement restraining unit.

2. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that the central studs or shaft holes of said equally-weighted members are connected by a rigid, flexible or pliable movement restraining unit.

3. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that said movement restraining unit is a coupling ring, and the coupling ring is fitted outside the central studs of said equally-weighted members, so as to constrain the optimal center distance between the two central studs to *e*.

4. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that said movement restraining unit has a connecting rod protruding in both directions and running parallel to the studs, two protruding studs are located on both sides of the connecting rod body, and their optimal center distance is *e*.

5. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that one of said equally-weighted members is an integrally intersected sliding vane, the other is a member causing a balancing action, and they can form a single-sliding vane-type eccentric equilibrium rotor device.

6. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that said equally-weighted members both are integrally intersected sliding vanes, and they can form a dual-sliding vane or four-sliding vane or six-sliding vane or multiple-sliding vane-type eccentric equilibrium rotor device.

7. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that said integrally intersected sliding vane is constituted by a sliding vane frame and a sliding vane sealing unit or sealing unit assembly; the sliding vane frame includes two sliding vane bodies, a linking cross member between the two sliding vane bodies, and a protruding stud or shaft hole in the center of the linking cross member; the sliding vane frame can be a single component, or it can be an integrated member composed by suitably processing a plurality of components, and the eccentric sliding vane equilibrium rotor device has at least one sliding vane frame; the sliding vane sealing unit or sealing unit assembly includes an elastic element and a linkage unit, it has a T-shaped sealing unit or wear-resistant spring-type scaling unit sealing the tip of the sliding vane, and a self-expanding-type sealing sheath or self-expanding-type quasi-surface contact sealing sheath sealing the entire sliding vane body.

8. An eccentric sliding vane equilibrium rotor device according to Claim 1, characterized in that said rotor body can have a half-hollow part or have a single hollow part or have a plurality of hollow parts.

9. Use of eccentric sliding vane equilibrium rotor devices according to Claim 1 in various kinds of compressors, pumps, blowers, and motors.

10. An energy-saving multiple-fuel rotary engine, utilizing an eccentric sliding vane-type equilibrium rotary compressor and an eccentric sliding vane-type equilibrium rotary gas motor being cascaded coaxially, and being connected by a combustion chamber therebetween.

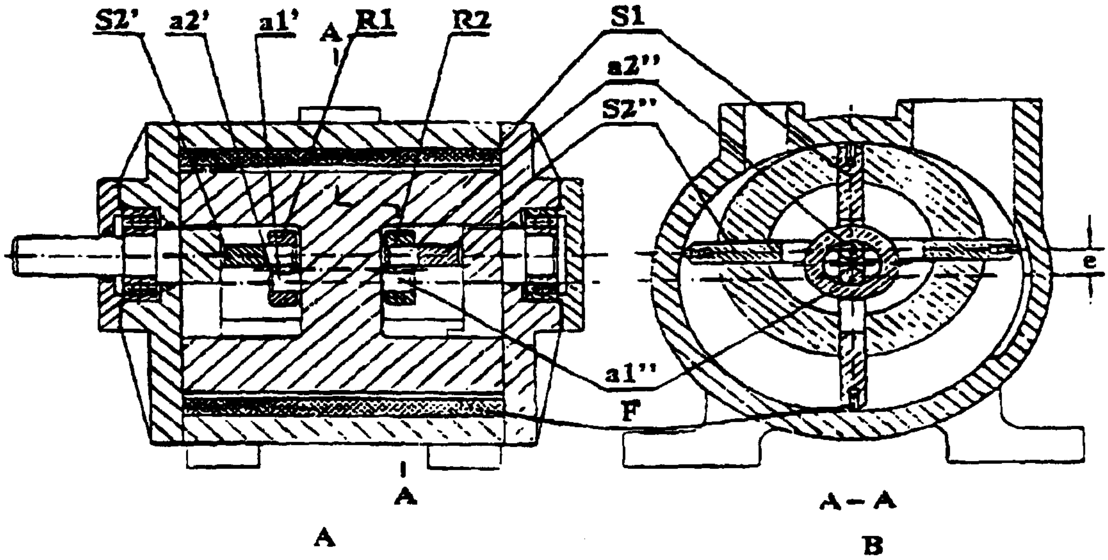


FIG.1

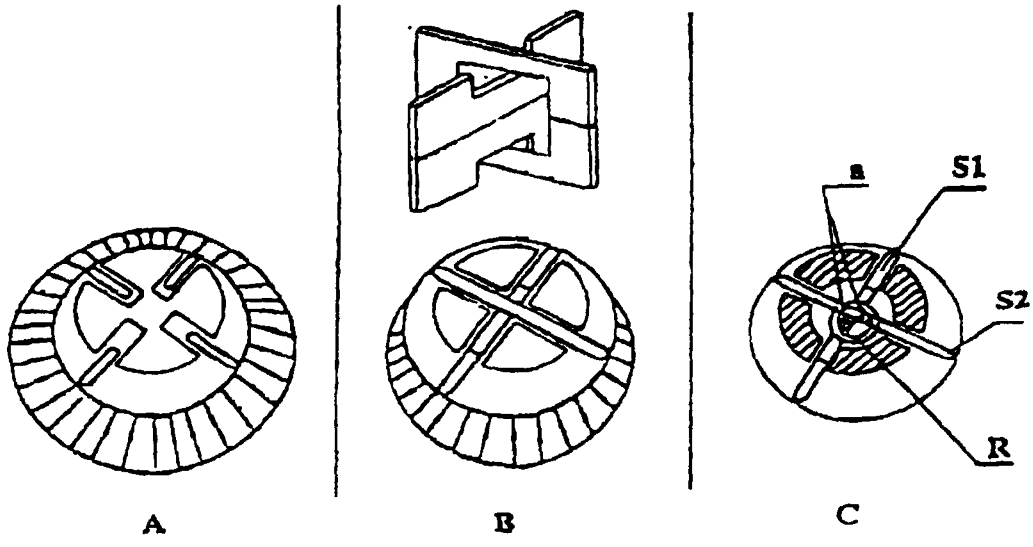
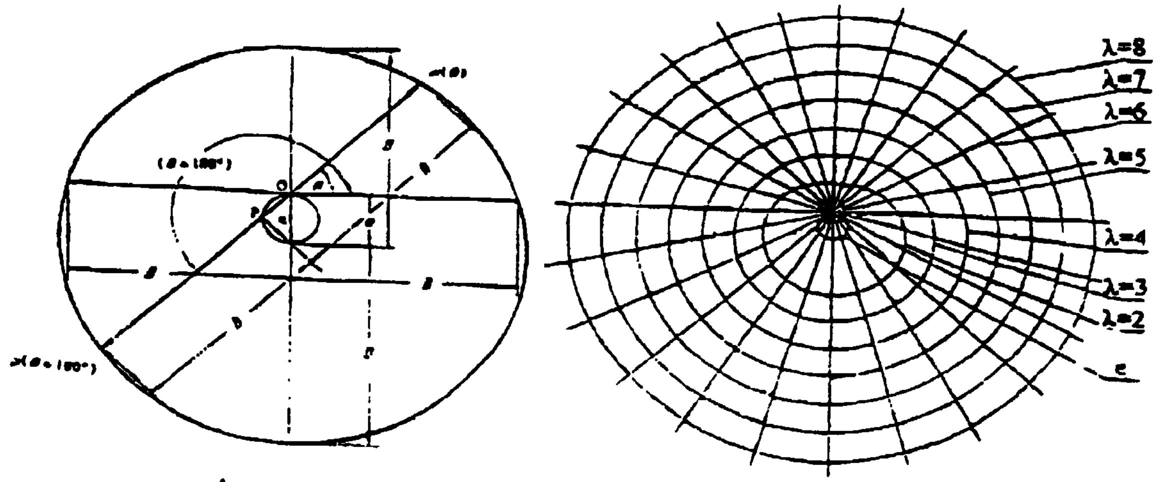


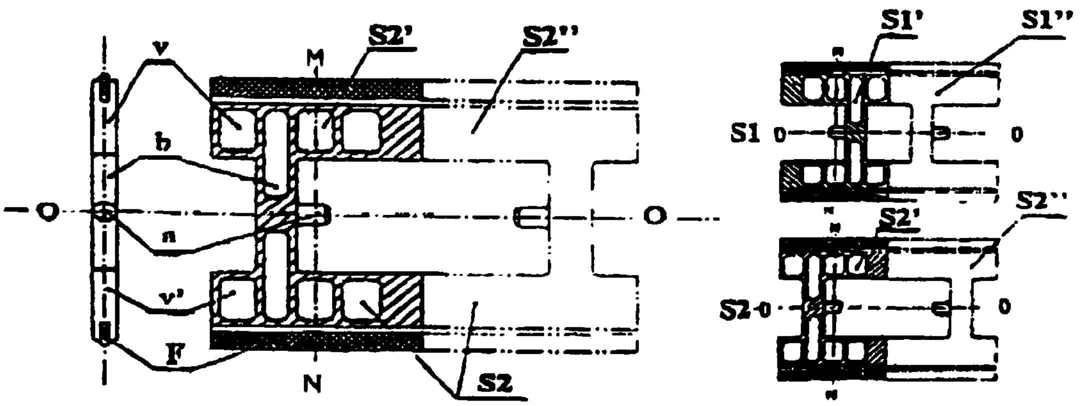
FIG.2



A

B

FIG.3



A

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FIG.4

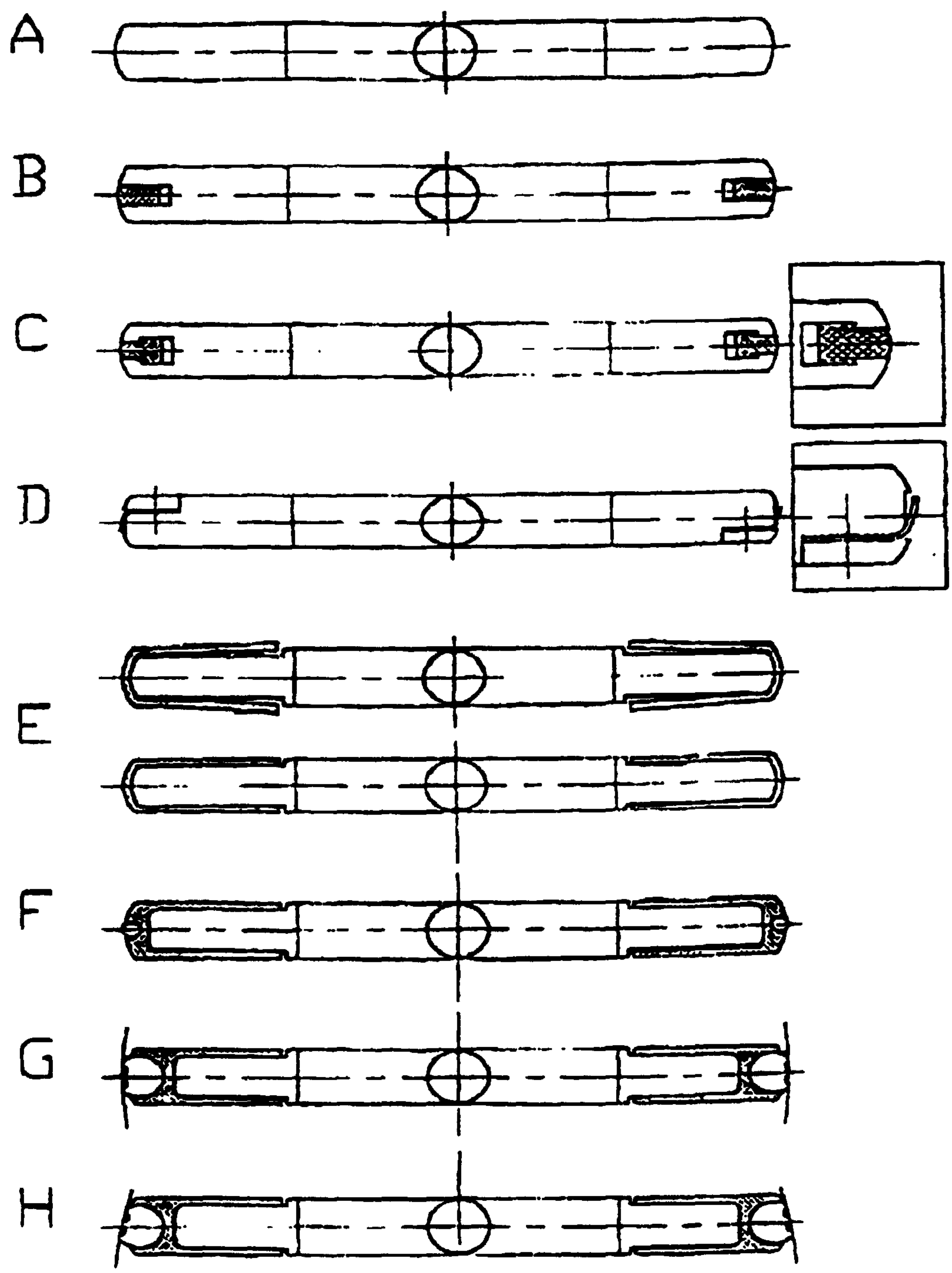


FIG.5

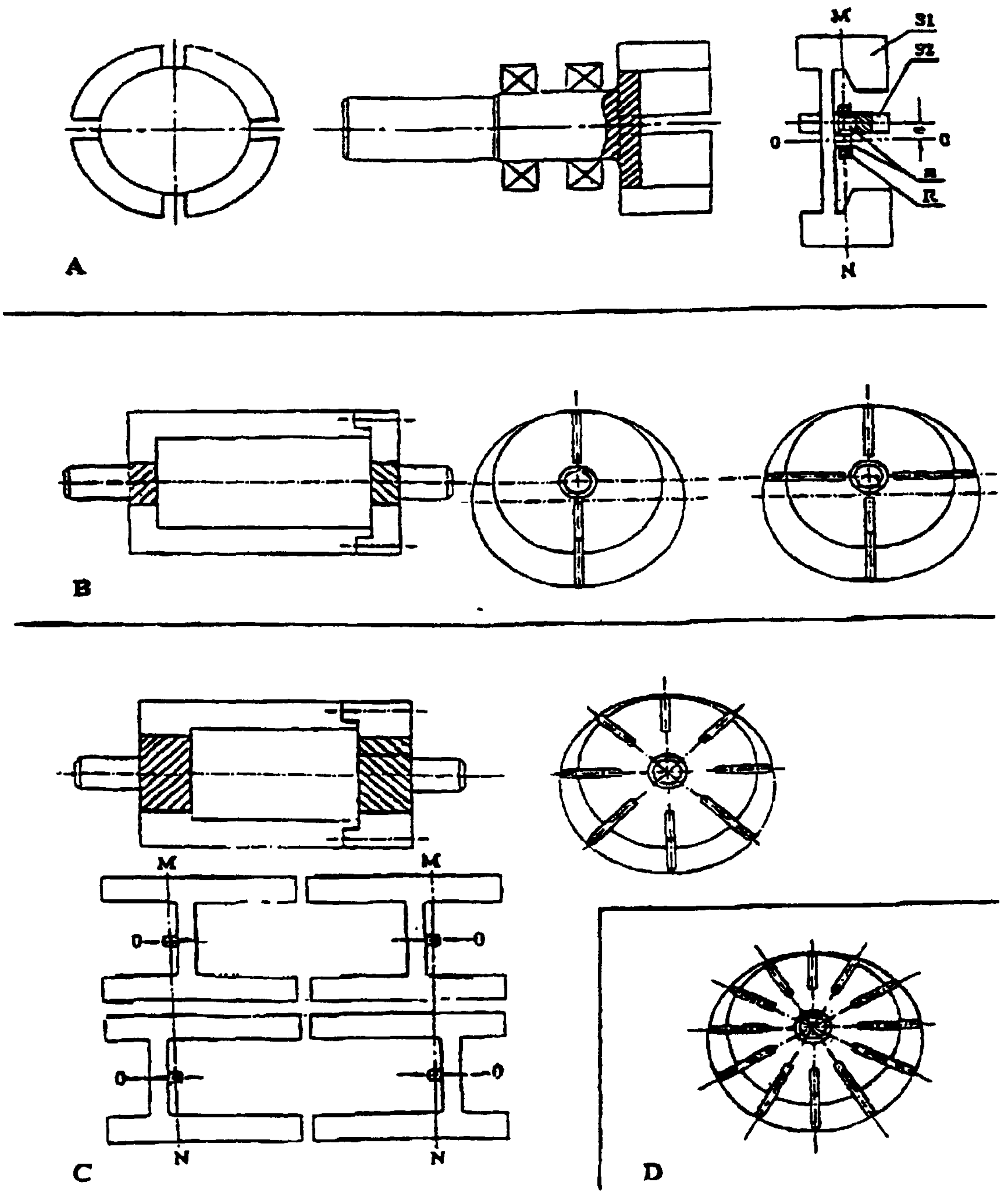


FIG.6

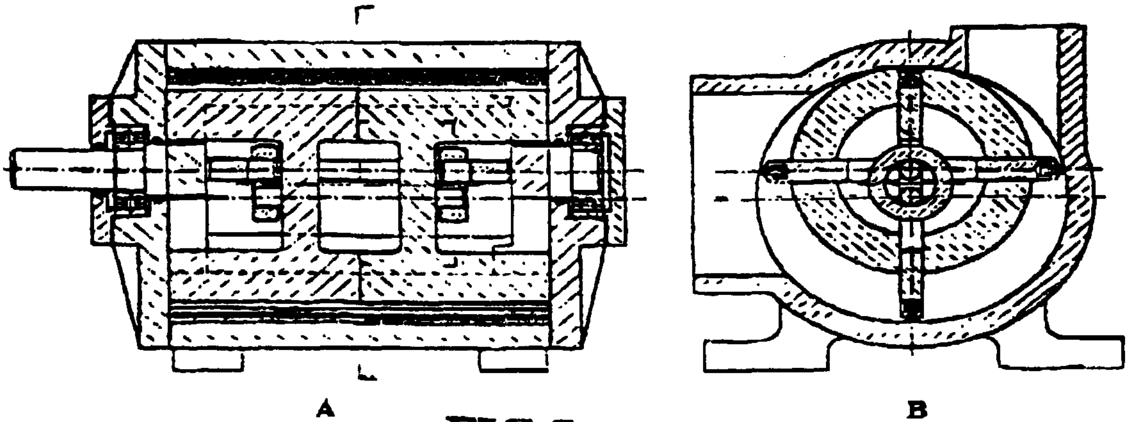


FIG.7

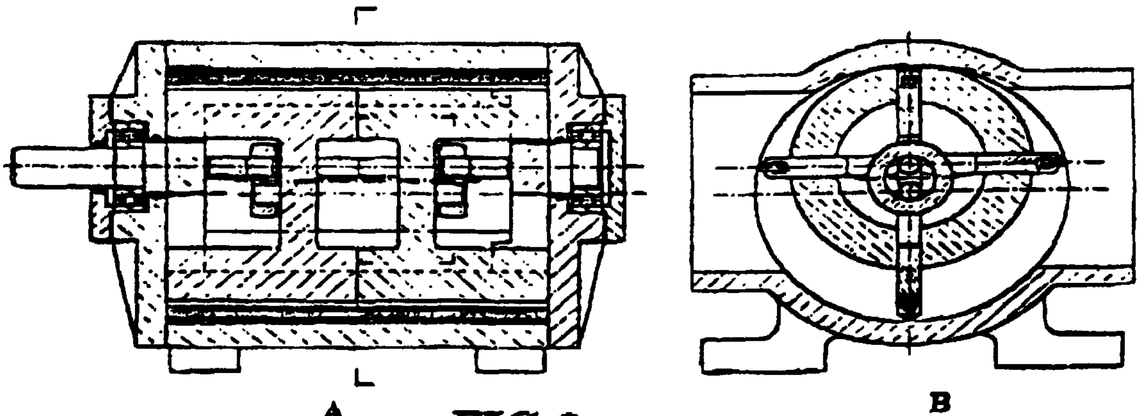
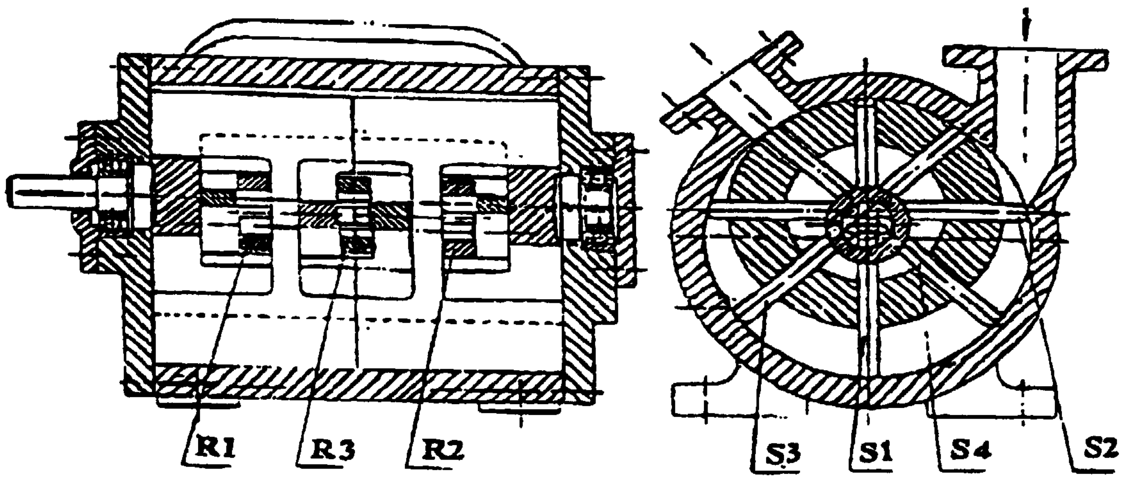


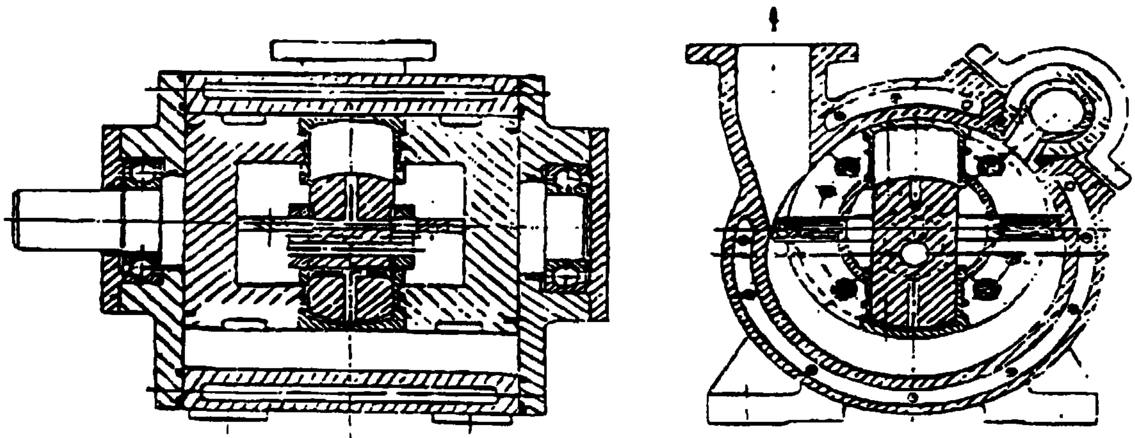
FIG.8



A

B

FIG.9



A

B

FIG.10

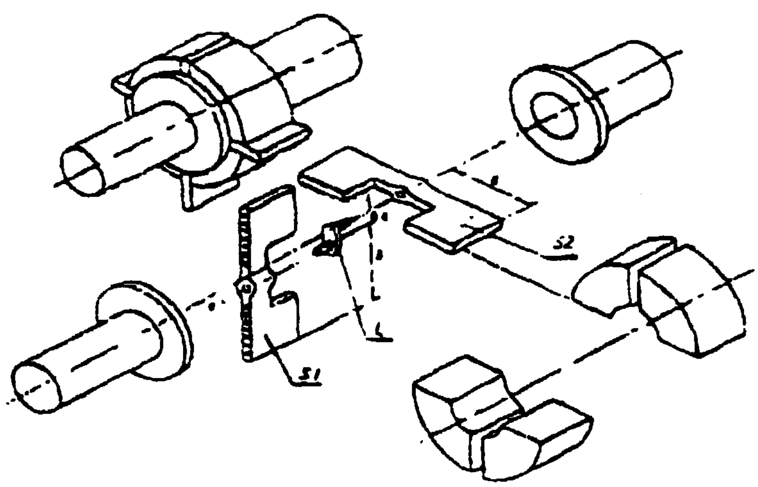


FIG11

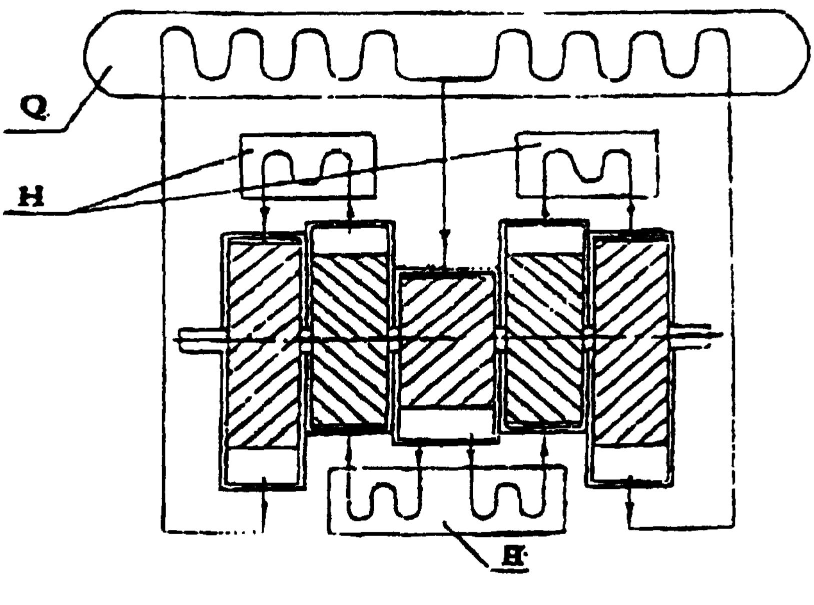


FIG12

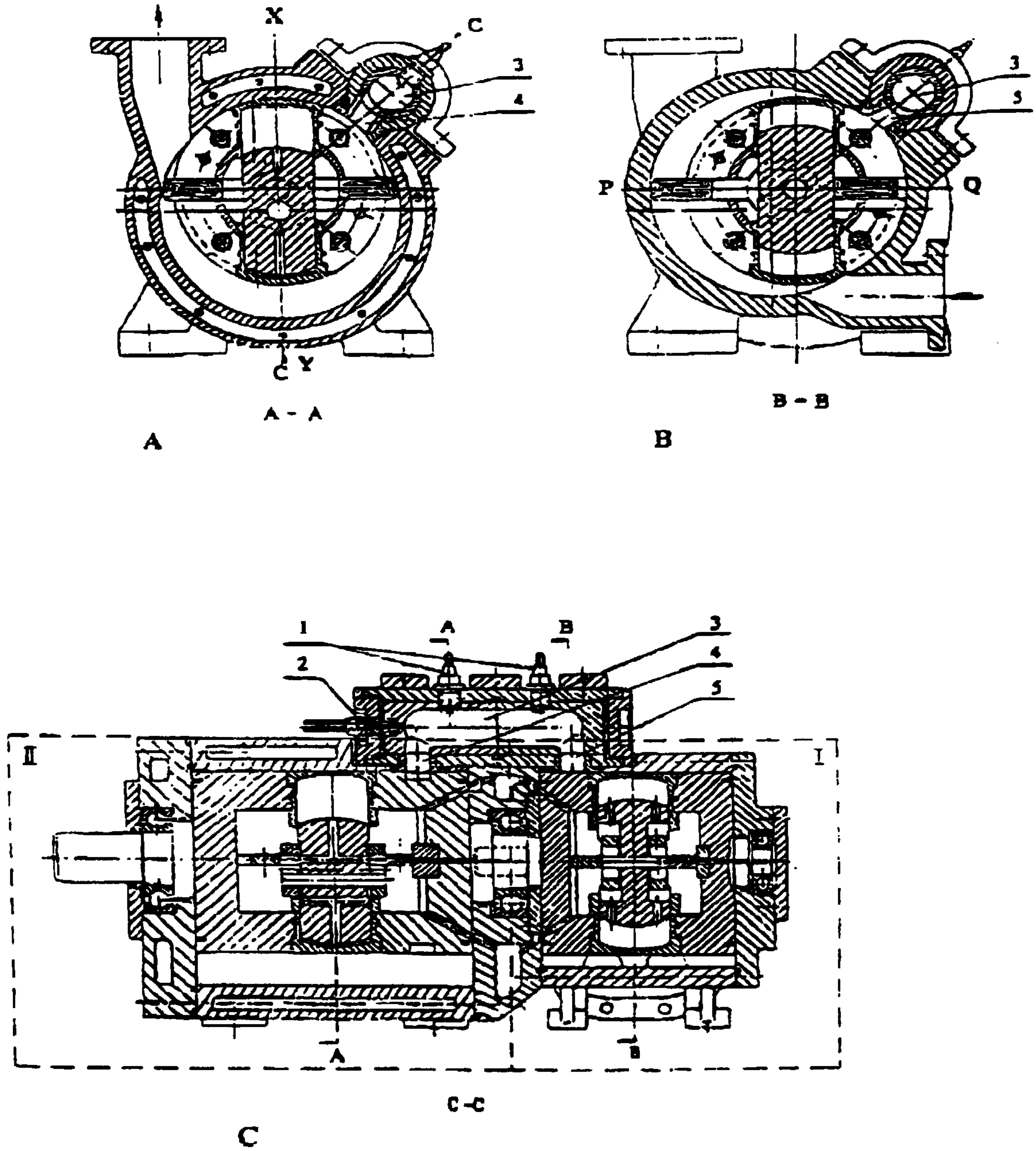


FIG.13

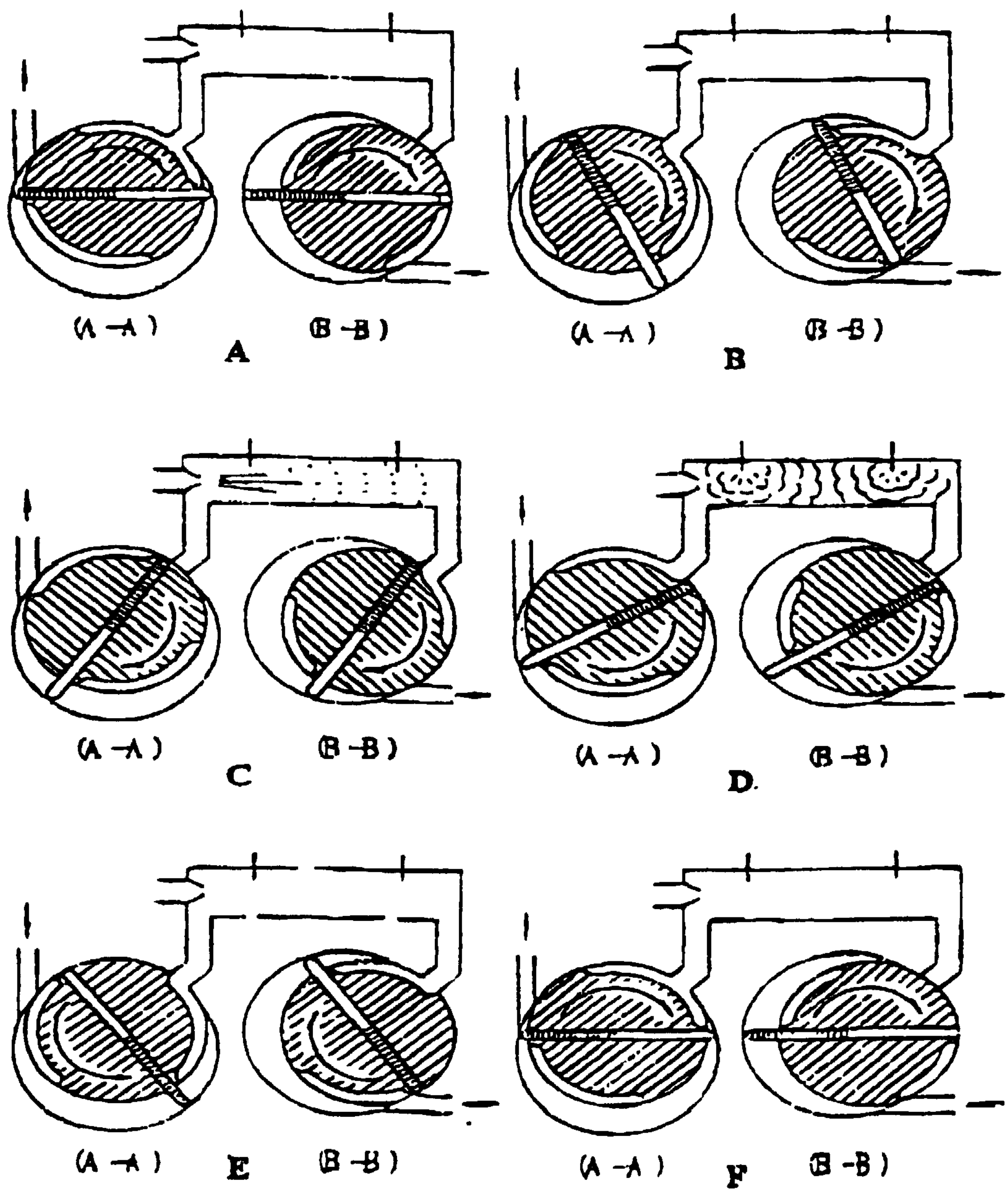


FIG.14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN 98/00078

A. CLASSIFICATION OF SUBJECTMATTER

IPC[6] F04C 18/344, 2/344, F01C 1/344

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCH

Minimum documentation searched (classification system followed by classification embolus)

IPC[6] F04C 2/34,2/344,18/34,18/344,F01 C1/34,1/344

Documentation searched other than minimum documentation to the extent that such documents are included in the field searched

CHINESE INVENTION 1985-1997, CHINESE UTILITY MODELS 1985-1997

Electronic data base consulted during the international search (name of date base and, where practicable, search terms used)

COMPRESSOR, PUMP, ENGINE, VANE BALANCE PIN PROJECTION

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4,958,995 (EAGLE INDUSTRY CO., LTD.) 25 SEPTEMBER 1990(25.09.90) SEE TOTALITY	1~10
A	US,A,4,929,159 (HITACHI LTD.) 29 MAY 1990 (29.05.90) SEE TOTALITY	1~10
A	US,A,4,410,305 (WAYNE C. SHANK , THOMAS C. EDWARDS) 18 OCTOBER 1983 (18.10.83) SEE TOTALITY	1~10

[X] Further documents~ are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention can not be considered novel or can not be considered to involve an inventive step when the document is take alone

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Date of the actual completion of the international search	Date of mailing of the international search report
2 September 1998(02.09.98)	17 SEP 1998 (17.09.98)
Name and mailing address of the ISA/CN Chinese Patent Office No. 6 Xitucheng Road, Jimen Bridge, Haidian District 100088 BEIJING, P.R of CHINA Facsimile No. 86-10-62019451	Authorized officer ZHANG MING Telephone No. 86-10-62093722

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN 98/00078

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