June 24, 1969 JEAN-FRANCOIS G. ROY 3,451,345

COMPRESSION-DEPRESSION MACHINE HAVING ROTARY PISTONS

Filed Nov. 21, 1967

Sheet 1 of 2

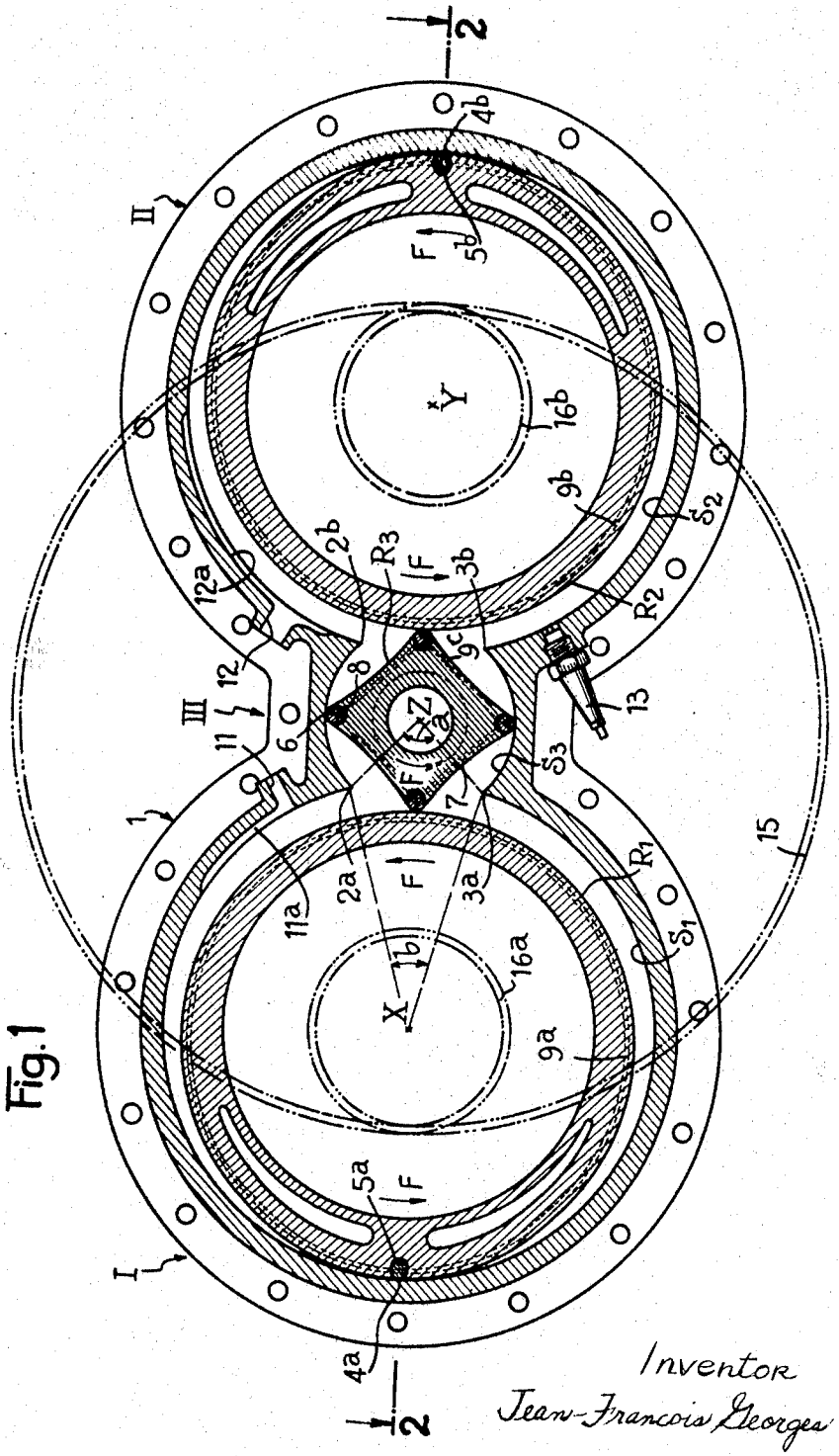


Fig. 1

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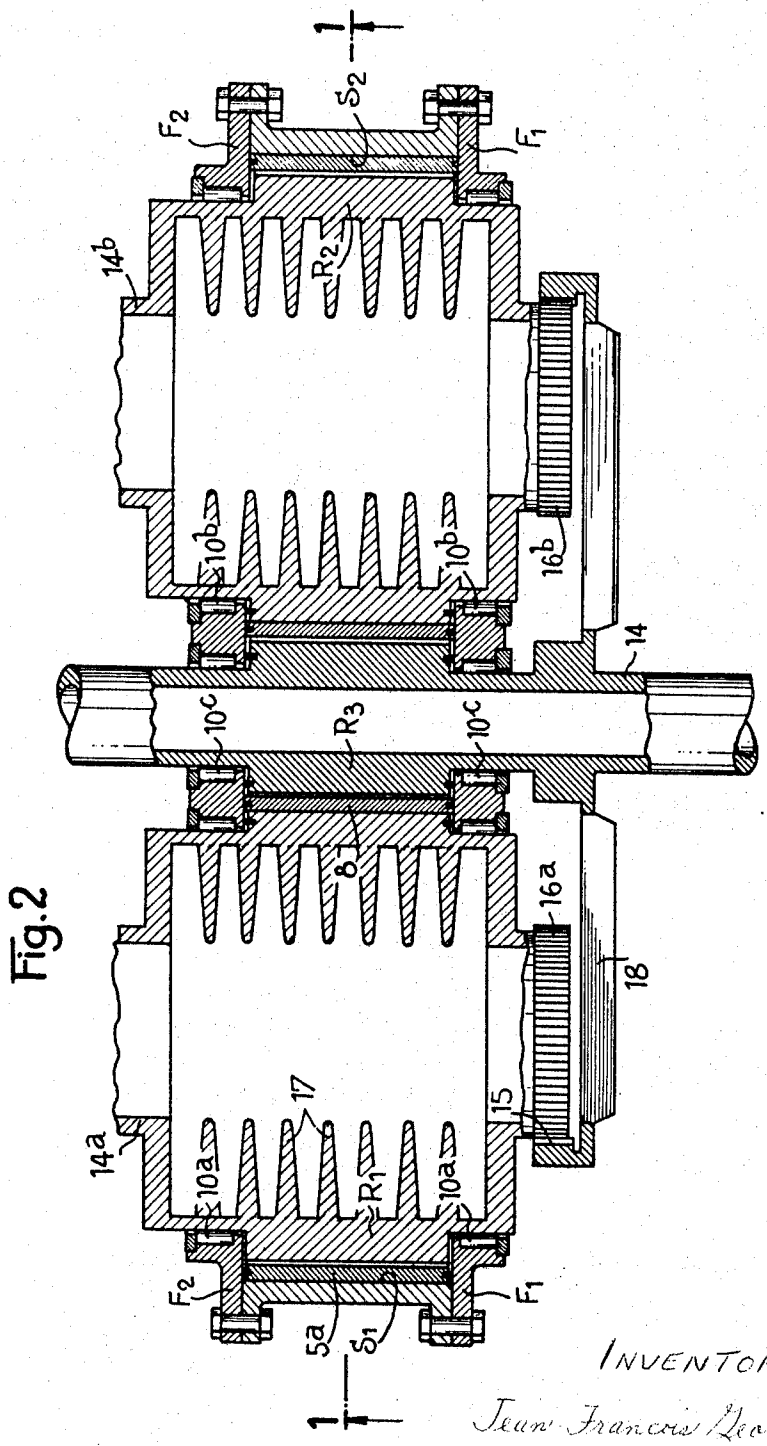


Fig.2

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COMPRESSION-DEPRESSION MACHINE HAVING ROTARY PISTONS

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ABSTRACT OF THE DISCLOSURE

A machine affording chambers of variable volume of utility as a pump, compressor or motor and including a plurality of rotary pistons having eccentric portions and rotating about parallel shafts and coacting to create said chambers, the machine being characterized in that a connecting mechanism interconnecting the pistons is such that the speeds of rotation of two adjacent pistons are different and the ratio between the numbers of different eccentric portions of the two adjacent pistons is the inverse of the ratio between the speeds of rotation of the two adjacent pistons.

The object of the present invention is to provide a machine affording chambers of variable volume of utility as a pump, compressor or motor, said machine comprising an enclosure provided with suitable intake and exhaust ports and in which are movable a plurality of rigid rotary pistons which co-act to create chambers, the pistons rotating in the same direction and with predetermined speeds about parallel axes which are fixed relative to the enclosure, said axes being embodied by shafts interconnected by a suitable mechanism, each piston comprising at least one eccentric portion which moves in a cavity of the enclosure whose shape corresponds, apart from a minimum clearance, to a portion of the surface of revolution generated by the or each eccentric portion of the piston, the axis of each cavity consequently coinciding with the axis of rotation of the corresponding piston, the cavities communicating in pairs, the various couples of adjacent pistons being such that the eccentric portion or portions of each thereof extend successively and alternately at least partially into the adjacent cavity whereas the portions thereof which are less eccentric allow the passage of the eccentric portions of the adjacent piston, said machine being so arranged that said connecting mechanism connecting the shafts of the pistons is such that the speeds of rotation of two adjacent pistons are different, the ratio between the numbers of different eccentric portions of two adjacent pistons being in the inverse of the ratio between the speeds of rotation of said two adjacent pistons.

The ratios of the speeds of rotation must therefore be rational numbers.

When a piston comprises a plurality of eccentric portions, the latter have identical shapes. In the various stages of the movement, each of the eccentric portions is either in contact, apart from the clearance, with the corresponding cavity or in an adjacent cavity; and the shapes of the less eccentric portions of each piston are such that they allow at least the passage of the more eccentric portions of the adjacent pistons and possibly remaining in contact therewith.

The condition of contact between pistons mentioned hereinbefore—which also embraces the case of the provision of minimum clearance—defines the shape of the pistons so that they contribute to the formation of the chambers. The chambers can be created between two successive zones of contact between the enclosure and pistons. Therefore, when the zones of contact are between two distinct pistons, these pistons must remain in contact with each other, apart from a clearance, or at least with intermediate pistons which also remain in contact.

In the design of a machine according to the invention, the shape and eccentricity of the eccentric portions, of each piston must therefore be defined, whence results the shape of the corresponding cavities, then the respective numbers of their eccentric positions, which are equal for each couple of pistons to within a multiple of the denominator and numerator of the rational number corresponding to the ratio of their speeds of rotation. Lastly, the distance between the axes of the pistons completing the definition of the assembly remains to be chosen, and in this respect a certain condition of compatibility must be ascertained so that the eccentric portions of each piston can in fact exist.

In the embodiment described in detail hereinafter, in which the pistons and cavities are cylindrical, the latter consisting of portions of circular cylinders, the aforementioned condition of compatibility is expressed for each couple of adjacent cavities and pistons by the relation $a+b/n \leq 2\pi/d$, wherein the letters a and b designate the angles at the centre to which the section of the cavities corresponds respectively in the first and second cavity, d the number of teeth of the first piston and n the ratio between this number and the number of teeth of the second piston. If the relation is not satisfied, the eccentric portion of one of the pistons at least cannot be situated at a distance from the axis comparable with the radius of the corresponding cavity and therefore in contact with the latter. If there is egality, a generatrix of contact is obtained in each of the eccentric portions which therefore have a pointed shape. If there is a complement of egality, this is manifested by a widening of the eccentric portions so that there is a certain latitude as to the choice of the shape of the eccentric portions; in this case, it is possible for example to widen so much more the zones of contact between the pistons and cavities—which permits moreover removing the same amount from the points presented by the enclosure at the junction of the cavities, without this altering the definition of the chambers, whereby the passage from one cavity to the other of the fluid traveling through the chambers is facilitated. Irrespective of the shape adopted for the eccentric portions, their choice finally defines the shape of the less eccentric portions of adjacent pistons in accordance with the aforementioned condition of contact between pistons.

The fact of adopting for the pistons and cavities cylindrical shapes axially defined by two planes perpendicular to the axes, favours the machining of the device, but this must not be considered as a limitative feature of the invention. Under these conditions, the zones defining the chambers are constituted by portions of their end faces, in addition to the eccentric portions of the pistons.

Sealing means such as sealing elements can be provided to eliminate possible clearances of the zones defining the chambers and in fact ensure the contact of these zones. However, on the end faces the sealing can be partly ensured without contact by the intervention of labyrinths, this being an advantage of the purely rotary movement. Further, the simplicity of the movement allows higher operational speeds, this tendency being here only limited by the possible presence of sealing elements of contact. Also, machinings of higher precision tending to minimize the importance of the part played by the sealing elements, can be adopted. These two advantages therefore result in a complementary manner in the possible elimination of the sealing elements, the corresponding gain as concerns friction compensating the resulting very small loss

as concerns the compression ratio, particularly as the operational speed is high. In this respect, the present invention should lend itself to the construction of compression-depression machines deriving from the piston and the turbine their respective advantages.

From a conformist point of view, and in order not to presume on the foregoing advantage, the zones of contact of the illustrated embodiment are shown equipped with sealing elements. However, it must be understood that this is not a limitative feature of the invention.

Apart from the foregoing general features, relating to the principle of the invention, two interesting technical features should be mentioned. They concern simplifications afforded by the invention, first, in the gear device which ensures that the ratios of the speeds of rotation of the pistons remains constant and, secondly, in the internal cooling of these pistons.

Further features and advantages of the invention will be apparent from the ensuing description with reference to the accompanying drawings.

The described embodiment concerns a four-stroke engine.

In the drawings:

FIG. 1 is a cross-sectional view, taken along line **1—1** of FIG. 2, of an engine or motor according to the invention, and

FIG. 2 is a sectional view taken along line **2—2** of FIG. 1.

Three judiciously disposed rotors constitute a four-stroke engine without intervention of valves. One of the rotors is intermediate between the other two rotors and rotates in a cavity which is smaller than the cavities of the other two. It must be understood that this is only an example of an application of the invention. It moreover shows that two pistons are sufficient, in similar conditions, to constitute a pump or a compressor and that consequently a four-stroke engine could also be constructed from merely two pistons provided valves are added. However, three pistons offer the advantage of affording simultaneously the four chambers of the cycle of the motor.

The outer pistons are symmetrically disposed relative to the axis of the intermediate piston. They have one eccentric portion whereas the intermediate piston, which rotates at a quarter of their speed, has four eccentric portions. This choice seems to be the most appropriate to a four-stroke engine but it is not intended to limit the invention thereto. The condition of compatibility concerning the relative disposition of the cavities is then expressed: $a+b/4 \leqslant 2\pi/4$. This shows that the section of the cavities must correspond to an angle at the centre of the intermediate cavity which is necessarily less than 90°. Consequently, each portion of the intermediate cavity corresponds to an angle at the centre exceeding 90° so that two eccentric portions of the intermediate piston can be simultaneously in contact with one of the portions of this cavity. The chosen disposition more than satisfy the foregoing condition and this allows giving a certain width to the eccentric portions of the intermediate piston. This width can be put to use, as explained hereinbefore, to improve the sealing in the region of the intermediate piston without effective contact. In the presently-described embodiment, it is exploited for equipping the eccentric portions with sealing elements.

The chamber **1** is constituted by a single case in which are provided three cavities S_1, S_2, S_3, respectively having axes X, Y, Z and containing outer pistons R_1, R_2, and an intermediate piston R_3. Each of the outer cavities S_1 and S_2 has two generatrices 2^a, 3^a and 2^b, 3^b which are common to the intermediate cavity S_3. The cavities and the pistons are axially defined by two end walls F_1 and F_2 perpendicular to the axes.

The outer pistons R_1, R_2 are identical and have a cylindrical outer lateral face the eccentric portion of which consists of an edge which is shown in section by the points 4^a, 4^b. These points correspond to the most eccentric generatrices of these pistons. They are in contact, or nearly in contact, with the corresponding cavities in the phases of the movement in which they are not situated in the intermediate cavity. Provided along each of these generatrices, in the presently-described embodiment, is a sealing element 5^a, 5^b.

The intermediate piston R_3 comprises in the presently-described embodiment, four eccentric portions **6** also provided with sealing elements **8**, faces **7** being interposed between said portions **6**. The shapes of the faces **7** are not critical provided they permit the passage of the points 4^a, 4^b. The shape of the eccentric portions **6** and of their sealing elements is not critical provided they are inscribed in the intermediate cavity and have at least one generatrix of contact with the latter in the phases of their movement in which they are not located in the outer cavities. The choice of this shape results from the shape of the outer pistons, defined as an envelope of the eccentric portions **6**.

On the respective end faces, the pistons also have sealing elements 9^a, 9^b, 9^c, which co-act with the walls F_1, F_2 of the enclosure. The pistons are respectively journalled in bearings 10^a, 10^b, 10^c.

Formed in the case is an intake passage **11**, communicating with the inner face of the enclsoure by way of a port 11^a, and an exhaust passage **12** communicating with the enclosure by way of a port 12^a. The element S_2 of the case also comprises an ignition spark-plug **13**. The intermediate piston R_3 is fixed to a shaft **14** carrying a ring gear **15** having internal teeth with which mesh two identical gears 16^a, 16^b which are respectively mounted on shafts 14^a, 14^b fixed to the pistons R_1 and R_2 and have a quarter of the number of teeth of the ring gear.

As shown in FIG. 1, the engine according to the invention comprises a compressor stage I and a motor stage II interconnected by an intermediate part III. Bearing in mind the direction of rotation shown by arrows F, it can be seen that, among the four chambers formed, two increase in volume, namely, the intake chamber facing the corresponding port and the chamber which is symmetrical relative to the centre axis Z and is the expansion chamber in which the explosion occurs, and the other two decrease in volume, namely, the exhaust chamber facing the corresponding port and the symmetrical chamber constituting the compression chamber.

The four strokes of the cycle are thus effected simultaneously.

At the end of the compression, the mixture compressed in stage I is transferred to the compression chamber of stage II by way of the chamber defined by the piston R_3 and the lower part of the cavity S_3. The mixture is then ignited and the expansion or driving phase occurs until the edge 4^b of the piston R_2 uncovers the exhaust port 12^a. The continuity of the operation of the machine avoids intervention of valves.

An important advantage of the machine according to the invention employed as a motor or compressor is the possibility of choosing the compression ratio as desired by suitably determining the ratio between the speeds of the adjacent pistons and the relative dimensions of their cavity. The illustrated arrangement corresponds to a ratio of 7–8.

It seems advisable to choose the shaft fixed to the piston R_2 of the motor stage as the output shaft of the machine.

The disposition and the shape of the pistons facilitate to an internal cooling bearing in mind the large free volume formed within the pistons, especially in the outer pistons R_1 and R_3, and in their shafts **14**, 14^a, 14^b. The fins **17** provided inside the shafts 14^a, 14^b facilitate this cooling. Radially-extending blades **18** are provided on the ring gear **15** for circulating cooling fluid.

The enclosure can be easily cooled by a circulation of fluid (not shown).

Further, in order to improve the conditions under which

the sealing elements 5^a, 5^b of the outer pistons come in contact with the corresponding cavity of the enclosure, a suitable machining can be provided on the junction edges 2^a, 3^a, 2^b, 3^b.

If the shape of the sealing element is such that the contact with their cavity is restricted to a generatrix, the junction between the cavities must necessarily remain pointed. On the other hand, if the relative distribution of the cavities allows a certain width of the zones of contact between the intermediate piston and its cavity, the points of junction between the cavities can be removed or flattened to a corresponding extent without altering the definition of the chambers. This disposition, which favours the transfer between the compressor stage and the motor stage, is, as seen before, particularly recommended if elimination of the sealing elements is contemplated.

It must be moreover noted that although the machining of the four circular cylindrical cavities presents no problem, the machining of the pistons can be carried out easily in providing between the tools and the work-pieces to be machined the kinematic relations which must exist between the various pistons, these relations being expressed by the aforementioned condition of contact between the pistons.

Although a specific embodiment of the invention has been described, many modifications and changes may be made therein without departing from the scope of the invention as defined in the appended claims.

Having now described my invention what I claim as new and desire to secure by Letters Patent is:

1. In a machine affording chambers of variable volume of utility as a pump, compressor or motor and comprising an enclosure having suitable intake and exhaust ports and in which enclosure are movable a plurality of rigid rotary pistons which co-act to create chambers, the pistons rotating in the same direction and with predetermined speeds about parallel axes which are fixed relative to the enclosure, said axes being embodied by shafts interconnected by a suitable connecting mechanism, each piston comprising at least one eccentric portion which moves in a cavity of the enclosure whose shape corresponds, apart from a minimum clearance, to a portion of a surface of revolution generated by the or each eccentric portion of the piston, the axis of each cavity consequently coinciding with the axis of rotation of the corresponding piston, the cavities communicating in pairs, the various couples of adjacent pistons being such that the eccentric portion or portions of each thereof extend successively alternately and at least partially into the adjacent cavity whereas the portions thereof which are less eccentric allow the passage of the eccentric portions of the adjacent piston; the feature that said connecting mechanism is such that the speeds of rotation of two adjacent pistons are different, the ratio between the numbers of different eccentric portions of the two adjacent pistons being the inverse of the ratio between the speeds of rotation of said two adjacent pistons.

2. A machine as claimed in claim **1**, wherein the cavities and the pistons have cylindrical shapes each axially defined by two plane faces perpendicular to the axes, the cavities being constituted by portions of circular cylinders, the relative arrangement of the cavities being such that each of the eccentric portions of the pistons has at least one generatrix location at a distance from the axis which is equal, apart from clearance, to the radius of the corresponding cavity, that is, such that the relation

$$a+\frac{b}{n}\leq 2\frac{\pi}{d}$$

is satisfied, wherein a and b designate the angles at the centre corresponding to the zone of communication between said cavities respectively in the first and second cavity, d the number of eccentric portions of the first piston and n the ratio between said number and the number of eccentric portions of the second piston.

3. A machine as claimed in claim **2**, comprising three pistons one of which is an intermediate piston and rotates in an intermediate cavity having a radius smaller than that of the cavities of the other two outer pistons which rotate at the same speed and are disposed with their cavities symmetrically relative to the axis of the intermediate piston, said connecting mechanism being such that the intermediate piston rotates slower than the outer pistons, the ratio between the respective speeds of said two types of pistons being a rational number, the numbers of eccentric portions of each of said types of pistons being, to within a multiple, respectively equal to the denominator and the numerator of said number, said eccentric portions being inscribed, apart from clearance, in the corresponding cavity, the shape of the outer pistons being defined as the envelope, apart from minimum clearance, of the eccentric portions of said intermediate piston.

4. A machine as claimed in claim **3**, wherein in a phase of the movement, two successive eccentric portions of the intermediate piston are simultaneously in contact, apart from clearance, with the same portion of the corresponding cavity, in zones having a certain width, the points of the enclosure at the junction of the cavities being cut away to an extent corresponding to said width.

5. A machine as claimed in claim **3** operating as a four-stroke motor, wherein each of the outer pistons comprises one eccentric portion whereas the intermediate piston comprises four eccentric portions and consequently rotates at a quarter of the speed of the outer pistons.

6. A machine as claimed in claim **5**, comprising a ring gear carried by the shaft of the intermediate piston, said ring gear having internal teeth, second gears fixed to the shafts of the outer pistons and meshing with the internal teeth of said ring gear, each of said second gears having a quarter of the number of teeth of said ring gear.

7. A machine as claimed in claim **5**, wherein one of the outer pistons and its cavity constitute a motor stage, the shaft fixed to said one of the outer pistons constituting the output shaft of the machine.

8. A machine as claimed in claim **3**, wherein the clearances between the eccentric portion of a piston and the corresponding cavity and between each eccentric portion of the intermediate piston and the outer pistons are such that a correct sealing of the chambers is achieved without sealing means along said eccentric portions.

9. A machine as claimed in claim **1**, wherein the shafts of the pistons are hollow and include fins and are part of an internal cooling circuit for the pistons.

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