DISTRIBUTION OF VALVE-GEAR SYSTEMS FOR ROTARY MACHINES

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ABSTRACT

The invention concerns a distribution system for a rotary machine of the type having a rotor with an epicyclic profile comprising N lobes and disposed eccentrically inside a stator having N + 1 lobes, each lobe of the stator forming with the rotor a working chamber having a variable volume.

The distributor disc is driven in a circular movement of translation by a combination of two eccentric movements, one of which is that of the rotor and the other is an eccentric movement having its centre displaced with respect to the axis of the machine and is rotated by the rotational movement of its shaft at the same angular speed.

The invention is applicable to rotating compressors, motors and other rotating machines.

10 Claims, 3 Drawing Figures
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DISTRIBUTION OF VALVE-GEAR SYSTEMS FOR ROTARY MACHINES

The present invention relates to a distribution system for a rotary machine of the type having a rotor with an epicycloidal profile comprising N lobes and arranged eccentrically inside a stator having N + 1 lobes, each lobe of the stator forming with the rotor a working chamber having a variable volume.

There are particularly known compressors which work on this principle, in which each working chamber has a set of admission clapper valves and a set of delivery clapper valves. In spite of their well known advantages and their usual use in piston compressors, these clapper valves have numerous drawbacks, especially for their use in rotary machines, to which the Applicant is giving his more particular attention.

In fact, these rotary machines comprise quite naturally by their construction, contrary to piston machines, a number N + 1 of working chambers which is fairly large, which gives them greater uniformity of working, but which necessitates a larger number of clapper valves. These clapper valves, generally arranged in a ring and which must be capable of being dismantled for inspection or replacement, have with their manifolds a relative bulk which is excessive and which substantially reduces the advantage of small overall size of these rotary machines.

In addition, these clapper-valves considerably restrict the surface area of the casing which can be used for cooling — highly desirable for the compressor.

It should also be observed that these rotary machines can rotate more rapidly than piston machines, that the working chambers operate at higher frequencies, and that the free clapper-valves are liable to work badly at these high frequencies.

Finally, the reversibility of these machines to compressed gas motors does not permit the use of clapper-valves and necessitates a positive distribution system synchronized with the speed of the driving shaft.

For all these reasons, it is advantageous to utilize both as a compressor and as a motor, a rotating distribution system which covers and uncovers at appropriate moments the communication ports between the working chambers and the intake and outlet manifolds for the fluid. Systems of this kind exist currently in hydraulic pumps and hydraulic motors.

Unfortunately, these distributors applied to compressors and motors for compressed gas do not possess adequate lubrication and cooling in order to accept the high pressures and speeds which are furthermore permitted by the whole of the device.

The friction of the discs on their slide faces would involve large losses of power and rapid losses of fluid tightness and wear.

The object of the present invention is a distributor which fulfills the same purpose as that described above, which to that end remains synchronized with the shaft, but in which the movement is a circular translation of low linear speed, utilizing the particular kinematics of the rotary machine in question.

In machines of this kind, the drive of the rotor is obtained from a gear having KN teeth where K is a whole number, fixed on this rotor and engaging with a fixed crown-wheel having K (N + 1) teeth, rigidly fixed to the stator.

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According to the invention, the distribution is effected by a distributor disc held against a friction face, mounted freely for rotation on an eccentric crank-pin of the central rotating shaft of the machine and comprising a toothed crown-wheel fixed on the said distributor, centered on the axis of the said eccentric crank-pin and identical with the fixed crown-wheel of the stator, and driven by a pinion identical with the driving pinion of the rotor, also centered on the said rotor and rigidly fixed thereto, the said distributor being displaced by the action of rotation of the central shaft at the same angular speed for all the points of its surface and of its crown-wheel in a single circular movement of translation.

More precisely, on the rotor is fixed a gear of KN teeth (N being the number of lobes of the rotor and K being a whole number), engaging with a crown-wheel fixed on the stator, of K (N + 1) teeth. The rotor is eccentric with respect to the central axis by a value:

\[ E = MK \] (N + 1) − KN/2 = MK/2

in which M is the module of the gears.

In one advantageous form of embodiment of the invention, the gear of KN teeth on the rotor is brought into engagement with a second crown-wheel of the same diameter as the first, having K (N + 1) teeth. If the centre of this second crown-wheel is held on the axis of the machine, it will remain stationary like the first, but if the centre of this second crown-wheel is displaced with respect to this axis, with the condition of maintenance of engagement, it will rotate with the shaft at the angular speed \( \omega \) and all the points of the crown-wheel will describe the same small circles at the angular speed \( \omega \), and at a linear speed which becomes lower as the displacement of the centre becomes less.

The movement of the second crown-wheel will be a circular translation.

The distributor is the holding plate of this second crown-wheel. It is itself maintained on its centre by an eccentric mounted on the main shaft and having as its eccentricity the above-mentioned displacement, it will have the same movement of circular translation as the crown-wheel. This distributor has N + 1 pairs of orifices, one for the intake of the gas and the other for its outlet, each pair being located in front of the outlet opening of the channel which communicates with each working chamber.

A second characteristic feature of the invention is the sliding swivel mounting of the working part of the distributor plate on the crown-wheel holding plate in order to permit the free application of the distributor plate against its slide-face.

A key prevents any relative angular movement of the two concentric plates.

According to a third characteristic feature of the invention, the admission and exhaust manifolds are arranged in a circular manner in order that the distributor may be automatically applied against its slide-face by a chosen value of pressure of the gas compressed by the machine or of the driving gas. This construction could be compared with the operation of a slide-valve of a steam engine, which valve has an alternating rectilinear movement which could be considered as a projection of the circular movement of the present distributor, this movement permitting a single member to ensure the distribution for the N + 1 working chambers of the machine.
A fourth characteristic feature of the invention is the coating of the slide-face with a non-metallic material having a very low coefficient of friction, for example a combination of Teflon and graphite. This eliminates the necessity of lubrication for the distributor. It should be noted that the use of such materials is permissible, since the temperature of the gases is always lower than 200°C.

An example of construction of the distribution device forming the object of the invention will be described below with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic representation in exploded perspective view of the kinematics of the operation of the distributor;

FIG. 2 shows a view in longitudinal section of the whole of a compressor comprising a rotor with three lobes, namely N = 3, following a preferred example of embodiment of the invention;

FIG. 3 shows a front view in the direction of the arrow F of FIG. 2, of the corresponding distributor wheel, showing the profile of the distribution orifices.

In FIG. 1 there is shown the general axis \( a_4 - a_6 \) of the machine, which is at the same time the axis of the driving shaft (compressor) or driven shaft (motor) and the axis of the stator. There has been chosen in this case by way of example, a machine in which \( N = 3 \), that is to say the stator having the centre \( a \) has four lobes \( C \) and the rotor having its centre at \( O \) has three lobes \( d \) with an eccentricity \( O_\alpha = E \).

On the axis \( O_2 \) of the rotor is keyed the pinion \( f \) having a pitch-circle radius equal to \( 3E \). This pinion engages with the crown-wheel \( g \) having a pitch-circle radius of \( 4E \), fixed on the stator. It is known that the rotation of the shaft \( a_4 - a_6 \) at the speed \( \omega \) causes rotation of the rotor about the axis \( O_2 \) at the speed \( -\omega/3 \), thus defining the variation of volume of the working chambers.

According to the invention, the axis \( O_2 \) is extended to \( O_3 \) and the pinion \( f \) is extended up to \( f_1 \), the pitch circle of the pinion \( f_1 \) having thus the same radius \( 3E \) as the pitch circle of the pinion \( f \) and the same setting; it is a parallel section of the same pinion.

There is engaged with \( f_1 \) a second crown-wheel \( g_1 \) having the same pitch circle radius \( g \), that is to say \( 4E \) without first defining the position of its centre \( I_1 \). Its eccentricity \( O_1 I_1 \) is equal to \( E \), like \( O_4 a_4 \) and \( O_6 \), namely:

\[
O_1 I_1 = E = O_4 a_4 = O_6.
\]

In the plane perpendicular to the axis \( a_4 - a_6 \), \( O_1 I_1 \) may be oriented through \( 360^\circ \) around \( O_4 \), the angle \( \alpha = I_1 O_4 a_4 \) may be chosen at any value comprised between 0 and \( 360^\circ \). Also, in the isosceles triangle \( I_1 O_4 a_4 \), there will be the relation:

\[
\rho = I_1 a_4 = 2E \sin \alpha/2.
\]

In addition, \( I_1 a_4 \) rotates about the axis \( a_4 \) at the speed \( \omega \), like the triangle \( I_1 O_4 a_4 \) as a whole, while remaining in a plane \( j \) perpendicular to \( a_4 - a_6 \).

However, the radius \( l_1 h \) or any other radius of the circle \( g \), always remains equipollent to itself during this displacement, so that all the points of the plane \( j \) (integral with the crown-wheel \( g_1 \)) describe equal circles of the same radius \( \rho \) with the same speed \( \omega \). The plane \( j \) has a circular movement of translation.

In the case where \( \alpha = O \), then \( \rho = O \), the circle \( g_1 \) is fixed as is also the circle \( g \) and its extension. The plane \( j \) is stationary when \( \alpha = 180^\circ \) and \( \pi = 2E \) and the amplitude of the circular translation is a maximum, as is also its linear speed.

\( \alpha \) may be chosen in such manner that the linear speed of the plane is a minimum, while retaining however sufficient amplitude of movement to ensure correctly the action of distribution which is referred to below.

Since \( N = 3 \) and there are four working chambers, the plane \( j \) will be divided into four equal sectors, each of which will possess two orifices \( k \) and \( m \) communicating respectively and continuously with the inlet and outlet of the fluid at the front of the plane and successively covering and uncovering the orifice \( q \) of the conduit \( n \) of the working chamber corresponding to the sector of the plane considered.

It will be observed that there could be two separate conduits \( n \) and \( n' \), the orifices \( q \) and \( q' \) of which would be respectively controlled by the orifices \( k \) and \( m \) of the distributor plane. The amplitude could then be smaller, as could also the speed and the friction, but at the cost of an increase in dead space.

In FIG. 2, the compressor is constituted by its stator (1) which carries the profile having the reference \( C \) on FIG. 1, by its rotor 2 which carries the profile reference \( D \) in FIG. 1, and by the side plates 3 and 4.

The central shaft 5 having its axis \( a_1 - a_6 \) is mounted on roller bearings 6 and 7 housed in the side-plate 3 and the casing 22. It carries the eccentric crank-pin 40 having its axis at \( O_1 O_2 \), about which pivots the rotor 2 by its sleeve bearing 10. At its two extremities, the shaft 5 carries counterweights to balance the eccentric mass of the rotor. One of these weights is carried by the driving pulley 8 while the other has the reference 9.

The pinion 11 (referenced at \( f \) in FIG. 1) having a radius \( 3E \) is mounted fixed on the rotor 2 on the bearing 9. The pinion 11 engages on one side with the toothed crown-wheel 12 having a radius \( 4E \) (referenced \( g \) in FIG. 1) rigid with the side plate 4, and accordingly fixed, and on the other side with the crown-wheel 13 having a radius \( 4E \) (referenced \( g_1 \) in FIG. 1) fixed on the hub 14 of the distributor end-plate, which rotates on its sleeve-bearing 17 on the eccentric crank-pin 18 (having the axis in FIG. 1) of the shaft 5.

The movement of the hub 14 is a circular translation movement; all the points of 14 describe circles having a radius \( l_1 \), \( a_4 \).

On the hub 14 is slidable keyed the external crown-wheel 15 with a key \( 19 \) which also permits a slight swivel movement of this crown-wheel on the outer spherical face 20 of the hub 14. This outer crown-wheel 15 constitutes the distributor proper. Its mounting on the hub 14, as has been described above, has the purpose of enabling it to be freely applied against the friction slide face 16 forming part of the side-plate 4.

Of course, apart from this very slight axial displacement, the movement of the distributor 15 in the radial plane \( j \) of the distributor 15 is the same as that of its hub 14, namely a circular translation.

A casing 21 covers the outlet of the shaft 5 and the counterweight 9.

On the opposite side-plate 4 is mounted a distributor casing 22 comprising an annular admission or suction chamber or manifold 23 and its inlet 24, a concentric annular delivery or evacuation chamber or manifold 25 covering the periphery of the disc and part of its rear
face in order to facilitate its cooling and holding in position by the effect of the clapper-valve.

Bolts 26 clamp together in a single block the stack of parts 21, 3, 1, 4 and 22 ensuring an easy and rapid dismantling of the assembly and good accessibility to all the parts.

When working as a compressor, the pulley 8 drives in rotation the shaft 5, the eccentric and the gear of which 11–12 drive the rotor 2 in its conjoint bearing in the stator 1. The air or fluid to be compressed is successively drawn-in, compressed and evacuated from each chamber 27 of the stator through a single opening 28 formed in the side-plate 4 and the plate or friction slide-face 16.

FIG. 2 shows the chamber 27 at its maximum volume, the crown-wheel 15 having just closed the communication of the opening 28 with an admission port 29 (FIG. 3) previously in the compression-delivery phase. The diametrically-opposite chamber, the lobe of which is completely filled by that of the piston, has just completed its delivery phase, and the delivery port 30 moves away and is replaced by the adjacent admission port 29. The other two chambers set perpendicularly and not being shown in FIG. 2, are set symmetrically, one in the compression-delivery phase and the other in the admission-suction phase. The communication of the suction port 29 with the circular manifold 23 is effected through a circular channel 31 and grooves 32 formed in the interface of the crown-wheel 15 and the hub 14. The communication of the exhaust port 30 with the circular delivery manifold 25 is effected by a circular peripheral groove 33 in the crown-wheel 15.

The opening and closure of the ports 29 and 30 is regulated by the amplitude and relative orientation of the eccentric 18 and the eccentric 10–11 of the rotor 2 with respect to the axis of rotation of the shaft 5.

The existence of a movement of two dimensions and the production of the optimum amplitude by the choice of the angle α gives great freedom in designing ports which ensure the best conditions of distribution and especially the reduction of wire-drawing or throttling effects to a minimum.

The low relative speed of the faces in frictional contact permits, in certain applications, the slide-face 16 to be made of synthetic material with good friction properties, such as Teflon, and also the various lateral joints 34 of the rotor and the circular joints 35 of the crown-wheel 15, making it possible to eliminate any lubrication of these zones and any contamination of the compressed fluid.

The circular translation movement, similar to a surface-finishing operation, tends to wipe-out any accidental scratches in the slide-face 16 due to solid impurities, and thus to maintain good fluid-tightness.

This fluid-tightness is also ensured by the maintenance of the crown-wheel 15 under pressure against the slide-face 16, by a clapper-valve effect. When starting-up, the simple pressure on the crown-wheel 15 of the joint 35 opposite to the slide-face 16 is sufficient to ensure its forcible application, subsequently effected by the delivery pressure. The balancing of this pressure in order to reduce the friction losses can be regulated by the dimensioning of the pressure surface areas.

When a pressure regulator is employed, the positive clapper effect of the distribution by slide-valves and slide-face according to the invention does not permit automatic regulation in free air on no-load working, as in clapper-valve compressors. In this case, it is provided to put the rear zones of the joints-strap or sealing straps (not shown) of the stator to free air by a channel 36, which enables these joint-strap or sealing straps to be pushed to the bottoms of their housings and, during these periods, effects a sweeping of air cleaning away the impurities and dust which have accumulated in the chambers and the zones of the joints.

In this case of operation as a compressor with a ceiling pressure, a non-return valve 42 is provided on the outlet circuit and a calibrated valve 40 is placed on the outlet 36 of the connection to free air of the rotor-stator joints.

The shape of the delivery port 30 is chosen in such manner that its opening only begins when a pressure in the vicinity of the delivery pressure is obtained in the working chamber 27, so as to obtain maximum efficiency. Similarly, when the machine operates as a motor, this same orifice 30 is defined in such manner as to ensure the chosen rate of expansion.

Finally, as has previously been stated, the single conduit 28 may be replaced by two conduits, one for the entry of fluid and the other for its outlet, and these conduits may each be located at the most favorable point so as to render the choice of the position and shape of the ports 29 and 30 still more flexible.

What I claim is:

1. A rotary machine comprising:
a rotor with N lobes,
a pinion with KN teeth rigidly fixed on said rotor (K being a whole number),
a stator having N + 1 chambers,
a crown wheel with K (N + 1) teeth fixed on said stator, a centrally disposed rotatable shaft coupled to said rotor by a first eccentric crank pin on which said rotor is rotatable,
said rotor being driven in rotation by said pinion,
said pinion being concentric with an eccentric bearing and engaging said crown wheel,
said stator having the same axis as the rotatable shaft,
a distributor disc supported against a friction face of a side plate, said disc being rotatably mounted on a second eccentric crank pin on said rotatable shaft,
a toothed crown wheel rigidly fixed on said distributor disc and centered on the axis of said second pin, and said disc crown wheel being driven by said pinion.

2. The rotary machine of claim 1 in which said disc crown wheel has the same diameter and module as said stator crown wheel.

3. The rotary machine of claim 1 in which admission and evacuation ports communicate with at least one chamber of said stator through at least one opening in said side plate.

4. The rotary machine as claimed in claim 1, in which said distributor disc is formed by a central hub and by a distribution crown-wheel swivel-mounted externally on said hub and rigidly fixed for rotation with said hub, and orifices of admission and evacuation circuits of a distributor casing on the side plate, said circuits being adapted to open into an orifice of said friction face.

5. The rotary machine as claimed in claim 4, in which said admission circuit is constituted by an annular manifold which is closed on said distributor disc at the level
of the hub to crown crown-wheel interface, said interface being provided with a plurality of grooves for communication with the opposite face of said disc.

6. The rotary machine as claimed in claim 4, in which a calibrated valve is mounted on the outlet of a circuit connecting rear cavities of rotor-stator sealing straps to free air, and a non-return valve mounted on said evacuation circuit, to ensure the operation of said machine, working as a compressor on no-load and at the ceiling pressure.

7. The rotary machine as claimed in claim 4, in which said evacuation circuit is constituted by a circular evacuation manifold closed on the periphery and the rear face, and a non-return valve mounted on said evacuation circuit, to ensure the operation of said machine, working as a compressor on no-load and at the ceiling pressure.

8. The rotary machine as claimed in claim 7, in which the friction face is made of a synthetic material having a base of Teflon and graphite.

9. The rotary machine as claimed in claim 7, in which a casing contains the evacuation manifold concentric with an annular admission manifold which is in turn concentric with a roller bearing of said central shaft, the separation of said manifolds being ensured by circular fluid-tight joints.

10. The rotary machine as claimed in claim 9, in which the pressure of said joint separating said admission and evacuation manifolds is applied against said distributor crown-wheel so as to ensure a forced application of said crown-wheel against said friction face.