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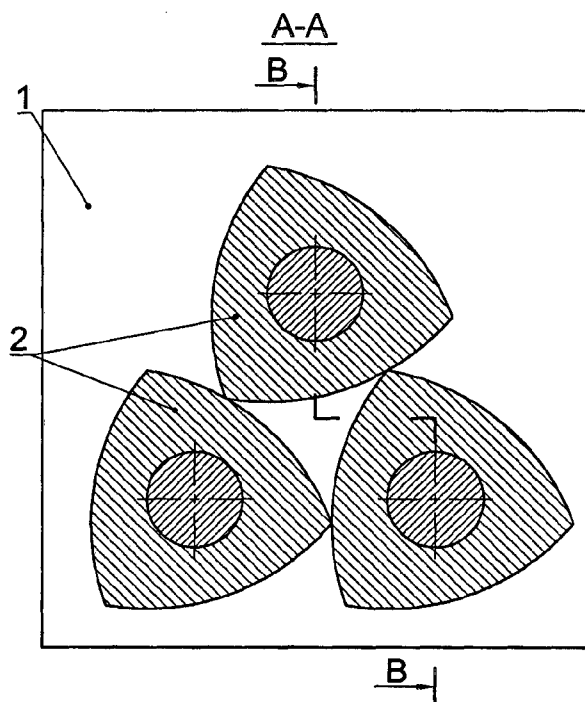


Fig.22

(57) Abstract: (57) Volumetric rotary machine, which may be used as an internal combustion engine, compressor, pump, hydraulic and pneumatic engines. The machine has similar two-rib or three- rib rotors set between the casing's (1) working surfaces. The minimum numbers of three-rib rotors (2) is three, and two-rib rotors (3) are respectively three and four, excepting five. Every three three-rib or four two-rib adjacent rotors with their cylindrical surfaces form closed working chambers. The working chambers are restricted by the casing's working surfaces, from the sides of the rotors' face surfaces. Due to the kinematic relation, the rotors synchronously revolve in the same direction. During the revolving of the rotors working chamber volume periodically changes from zero to its maximum value and vice versa. The symmetry axis, perpendicular to the face surfaces of the rotor, is the rotation axis of each rotor. The rotors' rotation axes are parallel to each other and perpendicular to the casing's working surfaces. The distance of the adjacent rotors' rotation axes is equal to the radius of their cylindrical surfaces. The square of the distance of the rotation axes of the opposite two-rib rotors is the double square of the cylindrical surfaces' radius.

Volumetric rotary machine (variants)

Technical Field

The invention relates to the field of mechanical engineering, particularly, to the rotary-piston machines, and may be used as an internal combustion engine, as well as
5 compressor, pump, hydraulic and pneumatic engines.

Technical level

Conventional internal combustion engine with a crank connecting rod mechanism [2,3] is widely known and used in engineering. Due to the reciprocating motion of pistons, high inertial forces influence on the pistons and connecting rods, causing
10 vibrations and large mechanical loss. Thus, the thermodynamic cycle is imperfect. The useful component of the pressure forces of the gases burning in the chamber is small, due to the characteristics of a crank connecting rod mechanism, especially at the beginning of the combustion stroke when the piston begins to move from the upper dead point, and the pressure and temperature of the burning gases have the maximum
15 value. For this reason, the heat losses are considerably high.

By technical essence, the rotary-piston engine [4] is selected as the closest analogue of the claimed device, which is presently known as Wankel engine. Currently this engine is in limited used in the sphere of motor transport and aircraft. With the same working capacity the engine substantially is more powerful than the conventional
20 reciprocating internal combustion engine. Respectively, the fuel consumption is also considerably higher. The engine has a rotor, the ribs of which slide along the inner surface of the casing, which is a non-circular epitrochoidal cylindrical surface. The rotor performs complex planetary motion. The engine is four-stroke, and all four cycles are performed consistently during one revolution of the rotor with each cycle performs in a
25 certain sector of the casing. The part of the casing, where the burning cycle is performed, heats a lot, and the casing distorts due to the thermal overload, which leads to the decrease in the leak-tightness of the working chambers. In connection with the design of the engine, the compression ratio of working chambers is limited (less than in the piston internal combustion engine). The working chamber at the beginning of the
30 combustion stroke has a form of an elongated and narrow sickle, and therefore the conditions of gas-air mixture ignition and flame propagation are extremely unfavorable. In connection with its extended shape, the working chamber has a large area, causing great loss of heat. Large area and small compression degree of the working chamber prevent the application of the device as a diesel internal combustion engine. When the
35 rotor revolves, the centrifugal forces influencing on radial sealing pieces, sliding along

cylindrical epitrochoidal surface of the casing, have a variable value. In the certain sectors of the epitrochoidal surface of the casing the centrifugal forces take negative values (directed toward the rotation center), which reduces the leak-tightness of working chambers in these sectors. In the technological sense, the production of wear resistant epitrochoidal surface of the casing is quite difficult [1].

Disclosure of the invention

The objective of the claimed invention is to create an internal combustion engine, which has an efficiency, torque, specific power higher than that of existing engines, as well as an adequate working life. The invention can also be used as a compressor, pump, hydraulic and pneumatic engines.

The invention is based on a new technical idea, which lies in the fact that there may be such identical and regular geometric bodies, by which their surfaces and two parallel planes form a closed zone in the space when set between two parallel planes in a certain way and uniformly rotate in the same direction around perpendicular to the planes symmetry axis of the bodies. The volume of this space zone will periodically vary from zero to a certain maximum value and vice versa during the rotation of the bodies. The presence of this space zone with a variable volume is the essence of the claimed invention.

Fig. 1 illustrates two equilateral triangles with side length r , located on the same plane. Each of the one vertexes of the triangles is at one point, and the sides are accordingly parallel to each other. It is obvious that the distance between the perpendicular planes of the triangles and the symmetry axes of the triangles, passing through the points O_1 and O_2 , is also equal to r , and the figure O_1O_2BA is a parallelogram.

If two triangles are rotated in the same direction around their symmetry axes at an arbitrary angle α (fig. 2), the figure O_1O_2BA will also be a parallelogram, where $AB=r$. Hence, during uniform rotating of triangles in the same direction from 0° to 60° , the vertex A of the left triangle will pass through the arc of a circle of radius r , which connects two vertices of the right triangle, the center of which is located at the third vertex of the right triangle (fig. 3).

Fig. 4 illustrates three equilateral triangles with side length r , located on the same plane. Each of one vertexes of the triangles coincides. The arcs of the circle of radius r , connecting two vertices, are drawn from the vertices of each triangle so that the centers of the arcs are located at the third apex of the triangle. The arcs form three identical convex regular figures, the symmetry axes of which (perpendicular to the planes of the

figures) coincide with the symmetry axes of the corresponding triangles.

According to the stated above, during uniform rotation of all three figures in the same direction around their symmetry axes, the figures by their one vertex will slide along the contour of the adjacent figures (fig. 5 – fig. 9), and the area of restricted zone (in the figure is obscured) will tend from the maximum value to zero, when the rotation angle is 60°. During uniform rotation of the figures at the next 60°, the area of restricted zone will tend from 0° to its maximum value (fig. 9 – fig. 12).

Fig. 13 illustrates three bodies, which were obtained by giving the above described regular figures some height h in a direction perpendicular to the plane of the figures. In other words, the bodies are obtained by geometric intersection of three straight circular cylinders with the same radius, which have a common intersection. In this case, the axes of the cylinders are parallel to each other and pass through the vertices of an equilateral triangle with the sides equal to the radius of the cylinders. The axes of the cylinders are perpendicular to the plane of the triangle.

During uniform rotation of the bodies in the same direction around perpendicular to the face surfaces symmetry axes from of 0° to 60°, the volume of a restricted zone will tend from its maximum value to zero (fig. 13 - 17). In case of uniform rotation of the bodies up to at another 60°, the volume of restricted zone will tend from zero to its maximum value (fig. 17 - 20). During uniform rotation of the bodies at the next 60°, the cycle repeats, and the volume of restricted zone will tend from its maximum value to zero (fig. 13 - 17) and so on.

Thus, if the bodies rotate at the same speed and direction, the value of restricted by them zone will periodically change from zero to maximum and vice versa.

The bodies, described above, conventionally will be called "three-rib rotor" or "rotor" in the further text. The inclosing of the group of three three-rib rotors from two face sides between smooth plates (between one pair of flat and parallel to each other working surfaces), will create a closed chamber with a variable volume, which is restricted by two plates and three rotors. This chamber will be the working chamber of the claimed device (an internal combustion engine, compressors, pumps, hydraulic and pneumatic engines). The plates will be the casing of the device (fig. 21 - 23). The group of three three-rib rotors (2), enclosed in a casing (1) is an analogue of the pair of piston-cylinder conventional internal combustion engine or a compressor with slider-crank mechanism. The intake and exhaust ports, as well as gas distribution mechanism are not illustrated in the drawings (fig. 21 - 23). It is obvious that the device, as an internal combustion engine, can run in four-stroke operating cycle (intake, compression, combustion,

release), and as a compressor, pump, hydraulic and pneumatic engines – in two-stroke operating cycle (intake, release). Each combustion stroke is performed during the rotation of the rotors at an angle of 60° . Six combustion strokes are performed in turn during complete revolution of the rotor.

5 The device can be made by using various kinematic schemes and different number of rotors. The number of three-rib rotors, set between a pair of flat and parallel to each other working surfaces of the body, can be three or more. It is necessary to create a kinematic relation between the rotors in order to allow the rotation of the rotors with the same speed and direction (synchronously). The link can be achieved through a variety
10 of mechanical gears and mechanisms. The rotor has three cylindrical and two parallel to each other flat (face) surfaces, which are the surfaces of the body, obtained by geometric intersection of three straight circular cylinders with the same radius, common intersection and parallel axes. The axes of the cylinders pass through the vertices of an equilateral triangle with the sides equal to the radius of the cylinders, and are
15 perpendicular to the plane of the triangle. The axis of rotation of each rotor is the symmetry axis of rotation, which is perpendicular to the face parallel working surfaces of the rotor. The axes of rotation of the rotors are parallel to each other and perpendicular to the flat and parallel to each other working surfaces of the casing. The distance of the rotation axis of any two contiguous three-rib rotors is equal to the radius of cylindrical
20 surfaces of the rotors. All three-rib rotors have the same angular position relative to their rotation axes. The each triplet of adjacent rotors with their cylindrical surfaces and flat and parallel to each other working surfaces of the casing form a closed working chamber with a variable volume. The device can also be multi-section having at least two pairs of flat and parallel to each other working surfaces of the casing. The group of
25 rotors, set between each pair of flat and parallel to each other working surfaces, is a separate working section. The sections are parallel to each other. The number of three-rib rotors in each section may be three or more. The angular positions relative to their axes of rotation, set in one section of rotors, can differ from the angular positions set in the other sections of rotors (this insures the overlap of combustion strokes). Each three-
30 rib rotor can consist of one unit (one-piece design), or more than one unit (modular design). The rotors can have technological holes, grooves and cavities of various forms (for installation of the pieces, etc., ensuring the leak-tightness of the working chambers). The parts of the casing, forming flat and parallel to each other working surfaces, may also have technological holes, grooves and cavities of various forms (for installations of
35 the pieces, ensuring the leak-tightness of the working chambers from the face parts of

the rotors, etc.).

Fig.24 illustrates two squares with side length r , located on the same plane. The squares coincide on one side. It is obvious that the distance between the perpendicular planes of the squares and the symmetry axes of the squares, passing through the points O_1 and O_2 , is also equal to r ; and the figure O_1O_2BA is a parallelogram.

When both squares are rotated in the same direction around their symmetry axes at an arbitrary angle α (fig. 25), the figure O_1O_2BA also will be a parallelogram, where $AB=r$. Thus, during uniform rotation of the squares in the same direction from 0° to 90° , the vertex A of the left square will pass through the arc of a circle with radius r , connecting the two opposite vertices of the right square. The center of the arc is on the third top B of the right square (fig. 26).

Fig. 27 illustrates four squares with side length r , located on the same plane and having one common vertex. The sides are respectively parallel to each other. The diagonals, drawn from the two opposite vertices of each square, form a square. The arcs of a circle with radius r are drawn from the two opposite vertices of each square so that the centers of the arcs locate on the other two opposite vertices of the same square. The drawn arcs form four identical convex regular figures, the symmetry axes of which (perpendicular to the plane of the figures) coincide with the symmetry axes of the corresponding squares.

According to the stated above, in case of uniform rotating of all four figures in the same direction around their symmetry axes, the figures by one vertex will slide along the contours of the adjacent figures (fig. 28 - 32); and the area of the restricted zone (is obscured in the figures) will tend from its maximum value to zero, when the rotation angle is 90° . During uniform rotation of the figures at the next 90° , the area of the restricted zone will tend to its maximum value (fig. 32 - 35).

Fig. 36 illustrates four bodies, which were obtained by giving the above described regular figures some height h in a direction perpendicular to the plane of the figures. In other words, the bodies are obtained by geometric intersection of two straight circular cylinders with the same radius, which have a common intersection. Herewith, the axes of the cylinders are parallel to each other and pass through the ends of one of the diagonals of the square with the sides equal to the radius of the cylinders. The axes of the cylinders are perpendicular to the plane of the square.

During uniform rotation of the bodies in the same direction around the symmetry axes, perpendicular of the face surfaces, from 0° to 90° , the volume of a restricted zone will tend from its maximum value to zero (fig. 36 - 40). During uniform rotation of the

bodies at another 90° , the volume of restricted zone will tend from 0° to its maximum value (fig. 40 - 43). In case of uniform rotation of bodies at the next 90° , the cycle repeats and the value of the restricted zone will tend from its maximum value to zero (fig. 36 - 40) and so on.

Thus, during the rotation of bodies at the same speed and direction, the volume of the restricted zone periodically changes from zero to its maximum and vice versa.

The bodies, described above, conditionally will be called "two-rib rotor" or "rotor" in further text. The inclosing of the group of four two-rib rotors from two face sides between smooth plates (between one pair of flat and parallel to each other working surfaces), will create a closed chamber with a variable volume, which is restricted by two plates and four rotors. This chamber will be the working chamber of the claimed device (an internal combustion engine, compressors, pumps, hydraulic and pneumatic engines. The plates will be the casing of the device (fig. 44 - 46). The group of four two-rib rotors (3), enclosed in a casing (1) is an analogue of the pair of piston-cylinder conventional internal combustion engine or a compressor with a slider-crank mechanism. The intake and exhaust ports as well as gas distribution mechanism are not illustrated in the drawings (fig. 44 - 46). It is obvious that the device, as an internal combustion engine, can run in four-stroke operating cycle (intake, compression, combustion, release), and as a compressor, pump, hydraulic and pneumatic engines – in two-stroke operating cycle (intake, release). Each combustion stroke is performed during the rotation of the rotors at an angle of 60° . Four combustion strokes are sequentially performed during complete revolution of the rotor.

The device can be made by using various kinematic schemes and different number of rotors. The number of two-rib rotors, set between the pair of flat and parallel to each other working surfaces of the casing, can be four or more, except for five. It is necessary to create a kinematic relation between the rotors in order to allow rotation of the rotors with the same speed and direction (synchronously). The kinematic relation can be achieved through a variety of mechanical gears and mechanisms. The rotor has two cylindrical and two parallel to each other flat (face) surfaces, which are the surfaces of the body, obtained by geometric intersection of two straight circular cylinders with the same radius, common intersection and parallel axis. Herewith the axes of the cylinders pass through the ends of one of the diagonals of the square with the sides equal to the radius of the cylinder. The axes of cylinders are perpendicular to the plane of the square. The rotation axis of each rotor is the axis symmetry of rotation, which is perpendicular to the face parallel working surfaces of the rotor. The axes of rotation of

the rotors are parallel to each other and perpendicular to the flat and parallel to each other working surfaces of the casing. The distance of the rotation axes of any two contiguous two-rib rotors is equal to the radius of cylindrical surfaces of the rotors. The square of the distance of the rotation axes of any two opposite two-rib rotors is equal to the double square of the radius of the cylindrical surfaces of the rotors. The angular position of any two adjacent two-rib rotors relative to their rotation axes is fixed the way that the rotors are rotated in the ratio of each other at an angle of 90° . The each quadruple of adjacent rotors with their cylindrical surfaces and flat and parallel to each other working surfaces of the casing form a closed working chamber with a variable volume. The device can also be multi-section, having at least two pairs of flat and parallel to each other working surfaces of the casing. A group of rotors, placed between each pair of flat and parallel to each other working surfaces, is a separate working section. Sections are parallel to each other. The number two-rib rotors in each section can be four or more, except for five. The angular positions relative to their rotation axes, set in one section of the rotors, can differ from the angular positions, set in the other section of the rotors (this insures the overlap of the combustion strokes). Each two-rib rotor may consist of one unit (one-piece design), or more than one units (modular design). The rotors can have technological holes, grooves and cavities of various forms (for installation of the pieces ensuring the leak-tightness of the working chambers from the face parts of the rotors, etc.).

Brief description of the graphic materials

The invention is illustrated by the drawings, where:

Fig. 1 - two equilateral triangles in the initial position;

Fig. 2 - two equilateral triangles rotated through an angle α ;

Fig. 3 – sliding of the top of a triangle along the arc of a circle;

Fig. 4 – obtaining of three convex regular figures;

Fig. 5 - three convex regular figures in the initial position;

Fig. 6 - three convex regular figures in the second position;

Fig. 7 - three convex regular figures in the third position;

Fig. 8 - three convex regular figures in the fourth position;

Fig. 9 - three convex regular figures in the fifth position;

Fig. 10 - three convex regular figures in the sixth position;

Fig. 11 - three convex regular figures in the seventh position;

Fig. 12 - three convex regular figures in the eighth position;

Fig. 13 - three three-rib rotors in the initial position;

Fig. 14 - three three-rib rotors in the second position;

Fig. 15 - three three-rib rotors in the third position;

Fig. 16 - three three-rib rotors in the fourth position;

Fig. 17 - three three-rib rotors in the fifth position;

5 Fig. 18 - three three-rib rotors in the sixth position;

Fig. 19 - three three-rib rotors in the seventh position;

Fig. 20 - three three-rib rotors in the eighth position;

Fig. 21 - working chamber restricted by the surfaces of three three-rib rotors and the casing;

10 Fig. 22 - working chamber restricted by the surfaces of three three-rib rotors and the casing (section A-A);

Fig. 23 - working chamber restricted by the surfaces of three three-rib rotors and the casing (section B-B);

Fig. 24 - two squares in the initial position;

15 Fig. 25 - two squares rotated through an angle α ;

Fig. 26 - sliding of the vertex of the square along the arc of the circle;

Fig. 27 - obtaining of four convex regular figures;

Fig. 28 - four convex regular figures in the initial position;

Fig. 29 - four convex regular figures in the second position;

20 Fig. 30 - four convex regular figures in the third position;

Fig. 31 - four convex regular figures in the fourth position;

Fig. 32 - four convex regular figures in the fifth position;

Fig. 33 - four convex regular figures in the sixth position;

Fig. 34 - four convex regular figures in the seventh position;

25 Fig. 35 - four convex regular figures in the eighth position;

Fig. 36 - four two-rib rotors in the initial position;

Fig. 37 - four two-rib rotors in the second position;

Fig. 38 - four two-rib rotors in the third position;

Fig. 39 - four two-rib rotors in the fourth position;

30 Fig. 40 - four two-rib rotors in the fifth position;

Fig. 41 - four two-rib rotors in the sixth position;

Fig. 42 - four two-rib rotors in the seventh position;

Fig. 43 - four two-rib rotors in the eighth position;

35 Fig. 44 - working chamber restricted by the surfaces of four two-rib rotors and the casing;

Fig. 45 - working chamber restricted by the surfaces of four two-rib rotors and the casing (section C-C);

Fig. 46 - working chamber restricted by the surfaces of four two-rib rotors and the casing (section D-D);

5 Fig. 47 – the graphs of piston engine torque with that of two-rib and three-rib rotors with the same displacement volume during the combustion stroke;

Fig. 48 – the graphs of working chamber volume extension of the piston engine with that of the engines of two-rib and three-rib rotors with the same of working chamber volume during the combustion stroke;

10 Fig. 49 – the graphs of the expansion velocity of the working chamber volume of the piston engine with that of the engines of two-rib and three-rib rotors with the same working chamber volume during the combustion stroke;

Fig. 50 – the scheme of the engine with six three-rib rotors and kinematically coupled chain drives;

15 Fig. 51 - the scheme of the engine with six three-rib rotors and kinematically coupled chain drives (type E);

Fig. 52 - the scheme of the engine with six three-rib rotors and kinematically coupled lever motion;

20 Fig. 53 - the scheme of the engine with seven three-rib rotors and kinematically coupled lever motion;

Fig. 54 - the scheme of the engine with seven three-rib rotors and kinematically coupled cylindrical gear train;

Fig. 55 - the scheme of the engine with seven three-rib rotors and kinematically coupled combined mechanism;

25 Fig. 56 – the scheme of the engine with nine two-rib rotors and kinematically coupled chain drives;

Fig. 57 – the longitudinal section of two-section engine with fourteen three-rib rotors;

Fig. 58 – the cross-section (F-F) of the cylindrical gear train of two-section engine with fourteen three-rib rotors;

30 Fig. 59 - the cross-section (G-G) of the cylindrical gear train of two-section engine with fourteen three-rib rotors;

Fig. 60 - the cross-section (H-H) of working section of two-section engine with fourteen three-rib rotors;

35 Fig. 61 - the cross-section (I-I) of working section of two-section engine with fourteen three-rib rotors;

Fig. 62 - the cross-section (J-J) of valve gear of two-section engine with fourteen three-rib rotors;

Fig. 63 – the longitudinal section (K-K) of combustion chamber of two-section with fourteen three-rib rotors;

5 Fig. 64 – the scheme illustrating the overall dimensions of two-section engine with fourteen three-rib rotors;

Fig. 65 – the longitudinal section of multi-section engine with thirty-two two-rib rotors;

Fig. 66 - the cross-section (L-L) of the cylindrical gear train of multi-section engine with thirty-two two-rib rotors;

10 Fig. 67 - the cross-section (M-M) of working section of multi-section engine with thirty-two two-rib rotors;

Fig. 68 - the cross-section (N-N) of working section of multi-section engine with thirty-two two-rib rotors;

15 Fig. 69 - the cross-section (O-O) of valve gear of multi-section engine with thirty-two two-rib rotors;

Fig. 70 – the view of the combustion chamber port of the engine with three-rib rotors from the side of the working chamber;

Fig. 71 – the view of the combustion chamber port of the engine with two-rib rotors from the side of the working chamber.

20 The Implementation of the Invention

The most important parameter, characterizing the power of the internal combustion engine, is the engine torque transmitted to the output shaft of the engine during the combustion of air-gas mixture. To be more specific, it is the ratio of the engine torque, transmitted to the output shaft, to the engine displacement volume (specific engine torque on the displacement volume). As greater is the following ratio, such greater is the efficiency of the engine, resulting in the reduction of fuel consumption and increase of power.

30 The dependence of the working chamber volume change from the rotation angle of the output link (crank, rotors) has a significant influence on in the processes of intake, combustion and expansion of gas-air mixture.

Mathematical calculations for the engine torques and working chamber volumes for the conventional internal combustion piston engine, internal combustion engine with two-rib rotors and internal combustion engine with three-rib rotors have been done. The dependence of the engine torque from the displacement volume during the combustion stroke, the dependence of pressure from rotation angle of the output link (turning angle

of crank and rotors), the average engine torque and change laws of the working chamber have been revealed. The pressure of burning gases in the working chamber has a variable value. To simplify the calculations, the average value for pressure has been used.

5 Fig. 47 represents the graphs of the piston engine torque with the engine torques of two-rib and three-rib rotors with the same displacement volume during the combustion stroke, where: M - total torque on the output shaft of the piston engine, M_2 - total torque on the output shaft of the engine with two-rib rotors, M_3 -total torque on the output shaft of the engine with three-rib rotors.

10 Fig. 48 represents the graphs of working chamber volume variation of the of piston engine with that of the engines of two-rib and three-rib rotors with the same working chamber volume during the combustion stroke, where: v - variation of working chamber volume of the piston engine, v_2 - variation of working chamber volume of the engine with two-rib rotors, v_3 - variation of working chamber volume of the engine with three-rib
15 rotors.

Fig. 49 represents the graphs of changing of the velocity of the working chamber volumes of piston engine with the velocities of the working chamber volumes of the engines of two-rib and three-rib rotors with the same working chamber volumes, where:

$\frac{dv}{dT}$ - changing of the velocity of the working chamber volume of the piston engine, $\frac{dv_2}{dT}$

20 - changing of the velocity of the working chamber volume of the engine with two-rib rotors, $\frac{dv_3}{dT}$ - changing of the velocity of the working chamber volume of the engine with three-rib rotors.

In modern internal combustion piston engines the ratio of the length of the connecting rod to the radius of the crank is within the 3.2 - 4.2 range [2,3]; while small
25 values are used in high-speed engines, and larger values - in low-speed engines. The graphs, related to the piston engines, are made for the case when the ratio of the length of the connecting rod to the radius of the crank equals to 3.7, which is an average value of the 3.2 - 4.2 interval.

For the full, the graphs from rotation angle α are reduced to the combustion stroke T ,
30 and the horizontal axis is chosen as the axis of T of the combustion strokes, because during the combustion stroke the crank of the piston engine rotates through an angle of 180° , the rotors of the engine with two-rib rotors rotate through an angle of 90° , and the rotors of the engine with three-rib rotors rotate through an angle of 60° . In other words,

the equivalent operation of engines requires that the crank piston engine rotates twice as faster than the rotors of the engine with two-rib rotors, and trice as faster than the rotors of the engine with three-rib rotors.

According to the calculations, during the same displacement volume and pressure the average torque of the engine with two-rib rotors is about 2.2 times greater than that of the piston engine, the average torque of the engine with three-rib rotors is about 3.2 times greater than that of the piston engine, and the average torque of the engine with three-rib rotors is about 1.5 times greater than that of the engine with two-rib rotors.

The torque acting up to the rotors of the engines with two-rib and three-rib rotors depends on the working chamber volume and does not depend on the radius of the cylindrical surfaces and the height of the rotors (the volume can be kept up at the same value by decreasing the radius and increasing the height or vice versa). It allows creating engines with the same working chamber volume by rotors of different geometric dimensions.

Working chamber volume change laws for the engines with two-rib and three-rib rotors are very close to each other, so in the figures the graphs are aligned (fig.48) or nearly aligned (fig.49). The combustion stroke is conditionally divided into two parts (the first half and the second half). The graphs show that the volume expansion of the piston engine at about the first half of the combustion stroke takes faster than those of the engines with two-rib and three-rib rotors. At the same time the expansion process in the engines with two-rib and three-rib rotors is almost the same.

During the first half of the intake stroke, due to working chamber volume rapid increase, the flow rate of in-taking gases increases, thus the resistance forces to gas flows of intake ports and valves increase (the resistance forces are proportional to the square of the flow rate), which leads to an increase in mechanical losses [3]. In the first half of the intake stroke the flow rate of the in-taking gasses in the engines with two-rib and three-rib rotors will be lower due to the slower increase of the working chamber volume, and the mechanical losses of the flow will be also lower than those in the piston engine. In the second half of the working stroke the working chamber volume expansion velocity decreases. Besides, the gas flow has a certain kinetic energy, and due to the inertia the intake keeps on under more favorable conditions, despite the fact that in the second half of the intake stroke the volume expansion velocity in the engines with two-rib and three-rib rotors decreases slower than that in the piston engine.

If we consider the average value of the torque in the first and second halves of the combustion stroke, in the first half of the stroke the average torque value is several

times greater than in the second half. This is because during the combustion of the air-gas mixture at first, the pressure sharply increases, then with increasing of the working chamber volume it starts to decrease [3]. Since the working chamber volume expansion in the engines with two-rib and three-rib rotors in the first half of the stroke increases slower than that in the piston engine, the average pressure value of burning gases will be greater. So, the average torque value in the engines with two-rib and three-rib rotors will be slightly greater than the results of the calculations.

The results indicate that theoretically it is possible to create such engines with two-rib and three-rib rotors, the displacement volumes of which will be respectively 2.2 and 3.2 times less than that of the piston engine of the same capacity. The fuel consumption decrease and the efficiency increase are directly related to the decrease of the displacement volume (with retaining the power).

Since the working scheme of the compressor, pump, hydraulic and pneumatic engines is a simplified version of the internal combustion engine working scheme, only the internal combustion engine variants are presented in the further text.

Kinematic relation, insuring the possibility of simultaneous rotation of the rotors, can be put into effect by means of gear trains, chain drives, gear belt transmission, lever motions.

Since the minimum value of the working chamber volume equals to zero, a separate combustion chamber is needed. The position of the combustion chamber may be at an equal distance from the rotation axes of the adjacent three three-rib or four two-rib rotors, adjoining one of the working surfaces of the casing. In the case of a compressor, pump, hydraulic and pneumatic engines, intake and exhaust ports are set instead of the combustion chamber only.

During the operation the ribs of the rotors slide along the cylindrical surfaces of the adjacent rotors. Because of it the leak-tightness of working chambers should be provided. The leak-tightness of working chambers can be carried into the effect by contact or non-contact methods. The leak-tightness by the contact method is presently quite successfully applied in the closest analogue. There have been used face sealing pieces in face parts of the rotor and the radial sealing pieces in the edge parts of the rotor. As the rotors of the engines with two-rib and three-rib rotors perform only a simple rotational motion, in case of sealing in a similar way the sealing pieces function in more favorable conditions than in the closest analogue. Besides, during revolving of the rotor at a constant velocity, the centrifugal forces, acting up on the radial sealing pieces, are also constant (in contradistinction to the closest analogue). Since the rotation axes of

the rotors are fixed, the lubrication of the sealing pieces can be done through the rotor shafts, using hollow shafts. Lubrication by this method can insure an accurate dosage of the lubricant.

In manufacturing of rotors with high accuracy and appropriate thermal conditions, it is possible to allow very small clearances of the same size between rotor ribs and adjacent rotors. The leak-tightness may be ensured by the forces of the surface tension of the lubricant and compressed wave of the lubricant, pushed by the ribs of the rotor. In case of this sealing method the frictional forces and the wear of the pieces will be minimal. It will allow using higher rotor speeds in difference to the contact sealing.

Nonflammable lubricants with a high boiling point, reducing the emission of harmful gases, may be used. The emission of some amount of lubricant with deflating gases from the working chamber is possible. By applying special separation devices it is possible to separate lubricant drops from the deflating gases and return them to the engine.

The figures (fig. 50 - 56) represent a simplified scheme of engines with three-rib rotors (2) or two-rib rotors (3) set in the casing (1) by means of shafts (4). The invisible parts are shown in dashed lines.

Fig. 50 and fig. 51 represent the scheme of an engine with six three-rib rotors. The kinematic relation is achieved by means of two chain drives (5,6). The engine has four working chambers and is an analogue of the conventional four-cylinder piston engine.

Fig. 52 represents the scheme of an engine with six three-rib rotors, where the kinematic relation is achieved by means of a lever motion. One crank (7) is set in every shaft (4) of the rotors (2). The cranks have the same length and are pivotally connected to each other by the same lever (8). The mechanism is a multi-crank hinged parallelogram.

Fig. 53 represents the scheme of the engine with seven three-rib rotors, where the kinematic relation is achieved by means of a lever motion (similar to the mechanism in fig. 52). The engine has six working chambers and is an analogue of the conventional six-cylinder piston engine.

Fig. 54 represents the scheme of the engine with seven three-rib rotors, where the kinematic relation is achieved by means of a cylindrical gear train. One gear (9) is set in every shaft (4) of the rotors (2). The gears are similar and engage with the help of three additional gears (10). The additional gears insure the possibility of synchronous rotation of the rotors in the same direction.

Fig. 55 represents the scheme of the engine with seven three-rib rotors, where the

kinematic relation is achieved by means of a combined mechanism. One gear (9) is set in every shaft (4) of the external rotors (2). The gears are similar and go into engagement with the internal gear (11) with the internal teeth, coaxial to the shaft of the central rotors. The kinematic relation of the central rotor is achieved by means of a chain drive (12) with one of the outer rotors. The output shaft of the engine is the shaft of the large gear (11) (not shown in the figure).

Fig. 56 represents the scheme of the engine with nine two-rib rotors, where the kinematic relation is achieved by means of four chain drives (13,14,15,16). The engine has four working chambers and is an analogue of the conventional four-cylinder piston engine.

Fig. 57 represents the longitudinal section of the engine with fourteen three-rib rotors. The engine has a casing (1) and seven working shafts (4). Two rotors (2) are set in each shaft the way that the engine is divided into two working sections with seven rotors in each section. The engine has twelve working chambers (six chambers in each section) and is analogue of the conventional twelve-cylinder piston engine.

The kinematic relation of the rotors is achieved by means of a cylindrical gear train. Five gears (9) and one gear (17) with the same diameter and number of teeth are set on the six shafts of the external rotors. The gears mesh with the large gear (18), coaxial to the shaft of the central rotors (fig. 57 - 58). The output shaft of the engine is the shaft (21) of the large gear. The kinematic relation of the central rotors is achieved by the gear train between the gear (19), set on the central shaft (4) and the gear (17), set on one of the shafts of the outer rotor, by application of an intermediate gear (20) (fig. 57, 59).

The rotors (2) of the first working section of the engine (fig. 60) are rotated relative to the rotors (2) of the second working section (fig. 61) through an angle of 30° . Since the combustion stroke in the engine with three-rib rotors runs during the rotation of the rotors through an angle of 60° , the symmetrical overlap of the combustion strokes occurs in the first and second sections (when the beginning of the combustion stroke occurs in the first section, the middle of the combustion stroke – in the second section or vice versa). The overlap of the combustion strokes insures smooth and stable operation of the engine.

Combustion chambers (26) and gas distribution mechanism (fig. 57, 60, 62, 63) are set between the two sections of the engine. The cams (24) set on the shafts (4) of the external rotors, can freely rotate around the shaft. They put the intake and exhaust valves (25) in motion. All the valves are conventionally shown in the figures in a closed

position. The intake and exhaust ports are not shown in the figures. The cams are kinematically coupled with a chain drive (23). They receive the possibility of rotation from the shaft of the central rotor also by means of the chain drive (22), which has a gear ratio $i = 4/3$.

5 If the radius of the cylindrical surface of the rotor is 100 mm and the height of the rotors is 50 mm, the total displacement volume of the engine will be 0.97 liters. The diameter of the circle, described by the rotor, will be $D = 315.5$ mm (fig. 64). Since the average torque of the engine with three-rib rotors is 3.2 times greater than that of the piston engine, the engine with three-rib rotors with 0.97 liters displacement volume will
10 be equivalent to the piston engine with 3.1 liters displacement volume. This indicates that the dimensions of the engine with three-rib rotors are less than that of the piston engine of an equal power.

The group of three three-rib rotors (2) (fig. 22) and the group of four two-rib rotors (3) (fig. 45) with the same radius of the cylindrical surfaces have similar dimensions (cross-
15 sectional dimensions). When cylindrical surfaces have the same displacement volume and radius, the height of the three-rib rotors is 5.32 times greater than that of the two-rib rotors. This indicates that manufacturing multi-section configuration engines with two-rib rotors are advisable.

Fig. 65 represents longitudinal section of multi-section engine with thirty-two two-rib
20 rotors. The engine has a casing (1) and four working shafts (4). Eight rotors (3) are set on each shaft the way that the engine is divided into eight working sections, each having four rotors. The engine has eight working chambers (one chamber in each section) and is an analogue of the conventional eight-cylinder piston engine.

The kinematic relation of the rotors is achieved by means of a cylindrical gear train.
25 Four gears (9) with the same diameter and number of teeth, set on four shafts (4) of the rotors, mesh with the large gear (18) (fig. 65 - 66). The output shaft of the engine is the shaft (21) of a large gear.

In each pair of the working sections the rotors (3) of one working section of the engine (fig. 67) are rotated relative to the rotors (3) of the other working section (fig. 68)
30 through an angle of 45° . Since the combustion stroke of the engine with two-rib rotors runs during turning the rotors at an angle of 90° , the symmetrical overlap of the combustion strokes occurs in each pair of the sections (when the beginning of the combustion stroke occurs in the first section, the middle of the combustion stroke – in the second section or vice versa). The overlap of the combustion strokes insures
35 smooth and stable operation of the engine.

Combustion chambers (26) and gas distribution mechanism (fig. 65, 67, 69) are set between each pair of sections of the engine. The cams (24), set on the shafts (4) of the rotors, put the intake and exhaust valves (25) in motion. All the valves are conventionally shown in the figures in a closed position. The intake and exhaust ports are not shown in the figures.

When the apexes of the rotors pass the section of the port, connecting the combustion chamber with the working chamber, the leakage of gases from the combustion and working chambers through the gaps between the cylindrical surfaces of adjacent rotors is possible. To prevent the leakage of gases, it is advisable that the port, connecting the combustion and working chambers, has a droplet shape (instead of a round hole) at the junction with the working chamber. Fig. 70 represents the view of the combustion chamber (26) port of the engine with three-rib rotors (2) from the side of the working chamber (on the surface of the casing (1)), which is a regular figure, consisting of three drop-shaped holes, where $\alpha \leq 60^\circ$. The symmetry axes of the drop-shaped holes intersect with the rotation axes of the rotors. Fig. 71 represents the view of the combustion chamber (26) port of the engine with two-rib rotors (3) from the side of the working chamber (on the surface of the casing (1)), which is a regular figure, consisting of four drop-shaped holes, where $\beta \leq 45^\circ$. The symmetry axes of the drop-shaped holes are rotated through an angle of 22.5° relative to the perpendicular lines drawn from symmetry center of the figure to the rotation axes of the rotors. The direction of the rotation of symmetry axes of the drop-shaped holes is opposite to the direction of the rotation of the rotors. The direction of rotation of the rotors is indicated with arrows. The invisible parts of the ports are shown in dashed lines.

The engine has a high specific torque of the combustion volume. It is possible to create an engine with a lesser combustion volume and dimensions, and greater power. The reduction of fuel consumption and increase of the efficiency are directly dependent on the decrease of the combustion volume.

The rotors perform only a simple rotational movement, so the machine is completely balanced (the inertial forces of some pieces of gas distribution mechanism are negligible and they can be disregarded). The torque, formed from the gas pressures, is directly transmitted to the rotor shafts without the use of intermediates. As a result, there is no vibration and the mechanical losses from the friction are small. Due to the rotational movement, the rotors have a large total moment of inertia. Large moment of inertia may exclude the use of the flywheels, which insure uniform rotation. The design features of the engine only allow the application of a gas distribution mechanism with

rotating pieces. The absence of the pieces with reciprocating motion insures a stable and smooth operation of the engine.

At the beginning of the combustion stroke the working chamber (the combustion chamber) has a small surface area, so heat losses are small. Due to the shape of the combustion chamber, the conditions for gas-air mixture ignition and flame propagation are favorable.

The machine has a high compression degree. Due to the small surface area of the combustion chamber and a high compression degree, the machine may be used as a diesel internal combustion engine.

All combustion strokes are consistently performed in each working chamber. The engine heats up evenly, so the thermal loading is low.

Despite the large number of pieces, they have simple construction and high manufacturability in terms of production. Since the working surfaces are flat cylindrical outer surfaces, the tooling may be done with high precision and purity by using wear-resistant, solid and durable materials. The use of solid and wear-resistant materials increases the working life of the engine.

Due to the simple rotational motion of the rotors, the centrifugal forces, acting up on the radial sealing pieces, are constant, which results in high sealing level of the working chambers. Low thermal loading, high accuracy and the cleanliness of the working surfaces of the rotors also increase the leak-tightness.

The favorable conditions for gas-air mixture ignition and flame propagation, a high sealing degree of the working chambers and small displacement volume, combined with high power, reduce the emission of toxic gases.

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4. W. Froede, BRD 1144052, F02b (Patent FRG). Application Date – 9 June, 1959 (the closest analogue).

Claims

1. Volumetric rotary machine comprising a casing with a pair of flat and parallel to each other working surfaces, a rotor set between the working surfaces of the casing, a working chamber with a variable volume, intake and exhaust ports; **differs in following**,
5 that the machine has at least three rotors with possibility of synchronous rotation with the same speed and direction by the way of kinematic relation; each rotor has three cylindrical and parallel to each other two flat face working surfaces, which are the surfaces of the body obtained by geometric intersection of three straight circular cylinders with the same radius, common intersection and parallel axes; the axes of the
10 cylinders pass through the vertices of an equilateral triangle with the sides equal to the radius length the cylinders, and are perpendicular to the plane of the triangle; the symmetry axis, perpendicular to the parallel face working surfaces of the rotor, is the rotation axis of each rotor; the rotation axes of the rotors are parallel to each other and perpendicular to the flat and parallel to each other working surfaces of the body; the
15 distance of the rotation axes of any two adjacent rotors is equal to the radius of the cylindrical working surfaces of the rotors; all rotors have the same angular position relative to their rotation axes; the working chamber with a variable volume is formed by the cylindrical working surfaces of each triple of adjacent rotors and is restricted by the working surfaces of the casing from the side of the face working surfaces of the rotors.

20 2. The machine according to claim 1; **differs in following**, that the casing has two or more pairs of flat and parallel to each other working surfaces; each pair of the working surfaces form a separate working section; the sections are parallel to each other; the angular positions relative to their rotation axes, set in the same section of rotors, may differ from the angular positions of the rotors of the another section.

25 3. The machine according to claim 1 or 2; **differs in following**, that each rotor is composed of at least one part.

4. The machine according to claim 1 or 2; **differs in following**, that the rotors have holes, grooves and cavities of other forms of technological significance.

30 5. The machine according to claim 1 or 2; **differs in following**, that the parts that form the working surfaces of the casing, have holes, grooves and cavities of other forms of technological significance.

6. Volumetric rotary machine comprising a casing with a pair of flat and parallel to each other working surfaces, a rotor set between the working surfaces of the casing, a working chamber with a variable volume, intake and exhaust ports; **differs in following**,
35 that the machine has four or more than five rotors with possibility of synchronous

rotation with the same speed and direction by the way of kinematic relation; each rotor has two cylindrical and parallel to each other two flat face working surfaces, which are surfaces of the body, obtained by geometric intersection of two straight circular cylinders with the same radius, common intersection and parallel axes; the cylinder
5 axes pass through the ends of one of the diagonals of the square with sides equal to the radius length of the cylinders, and are perpendicular to the plane of the square; the symmetry axis, perpendicular to the parallel face working surfaces of the rotor, is the rotation axis of each rotor; the rotation axes of the rotors are parallel to each other and perpendicular to the flat and parallel to each other working surfaces of the casing; the
10 distance of the rotation axes of any two adjacent rotors is equal to the radius of the cylindrical working surfaces of the rotors; the square of the distance of the rotation axes of any two opposite rotors is equal to the double square of the radius of the cylindrical working surfaces of the rotors; the angular positions of any two adjacent rotors, relative to their rotation axes, differ from each other by 90° ; the working chamber with a variable
15 volume is formed by cylindrical working surfaces of each four adjacent rotors and is restricted by the working surfaces of the casing from the side of the face working surfaces of the rotors.

7. The machine according to claim 6; **differs in following**, that the casing has two or more pairs of flat and parallel to each other working surfaces; each pair of the
20 working surfaces forms a separate working section; the sections are parallel to each other; the angular positions relative to their rotation axes, set in the same section of rotors, may differ from the angular positions of the rotors of the another section.

8. The machine according to claim 6 or 7; **differs in following**, that each rotor is composed of at least one part.

25 9. The machine according to claim 6 or 7; **differs in following**, that the rotors have holes, grooves and cavities of other forms of technological significance.

10. The machine according to claim 6 or 7; **differs in following**, that the parts that form the working surfaces of the casing, have holes, grooves and cavities of other forms of technological significance.

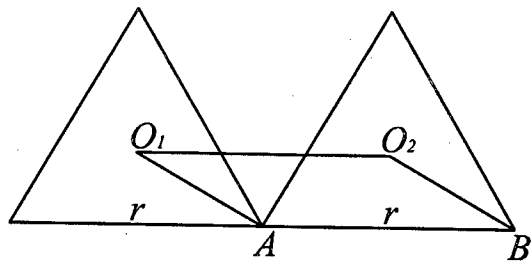


Fig.1

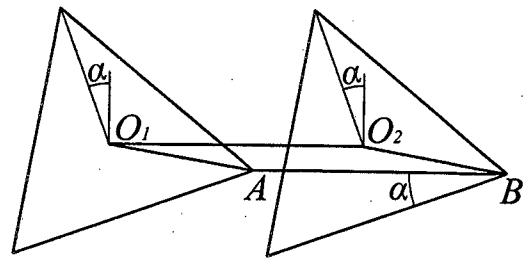


Fig.2

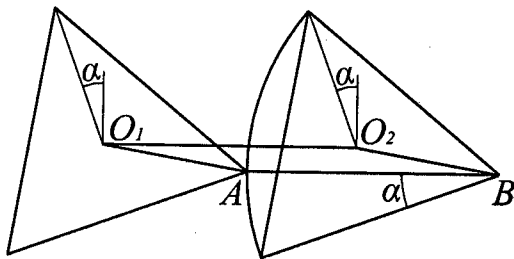


Fig.3

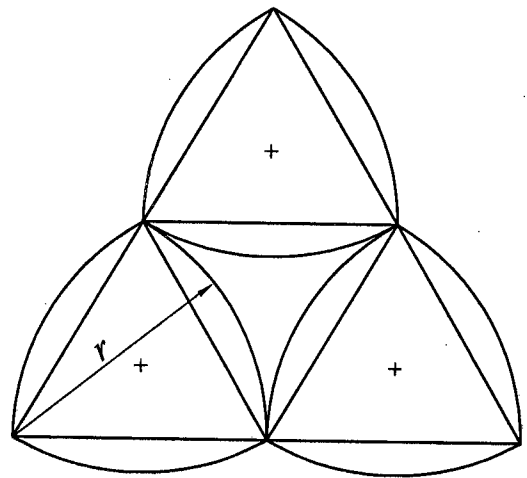


Fig.4

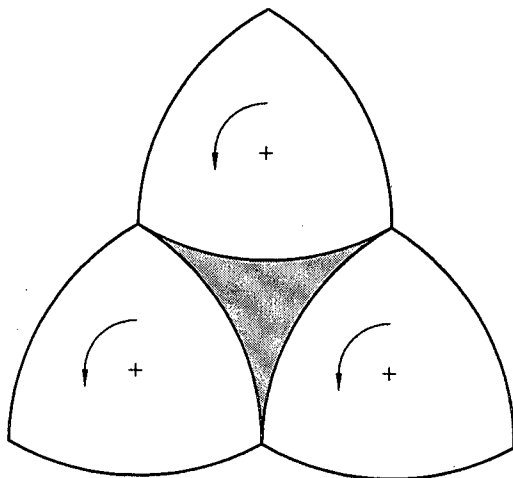


Fig.5

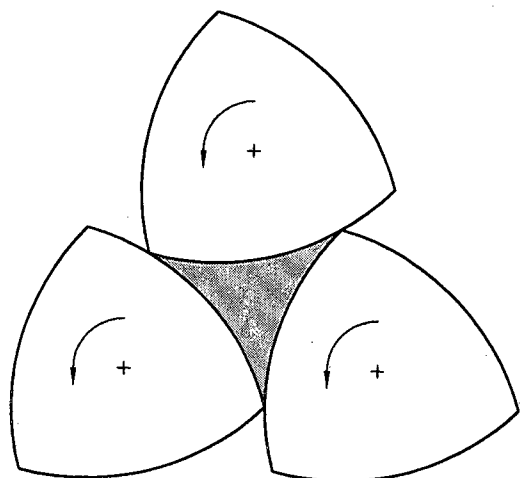


Fig.6

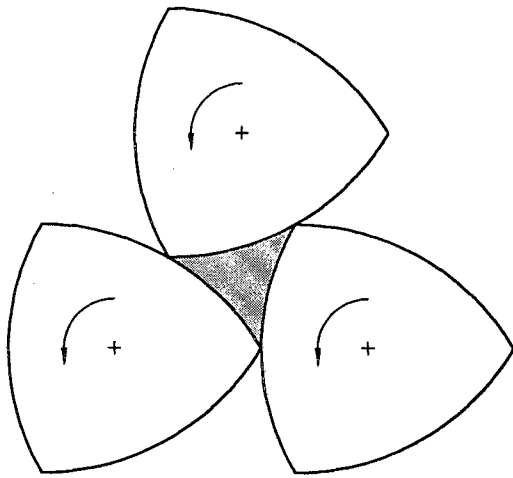


Fig.7

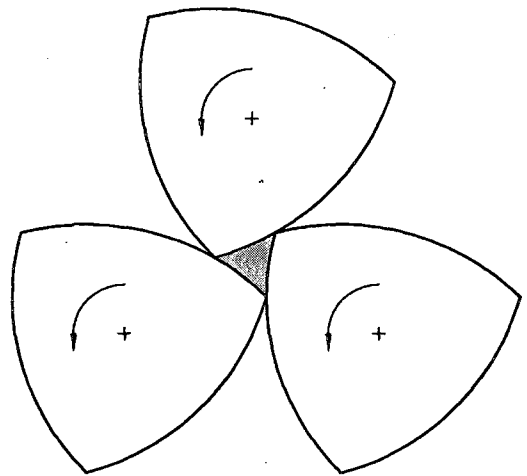


Fig.8

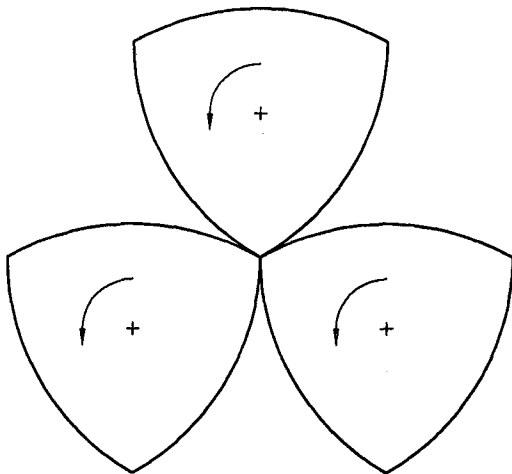


Fig.9

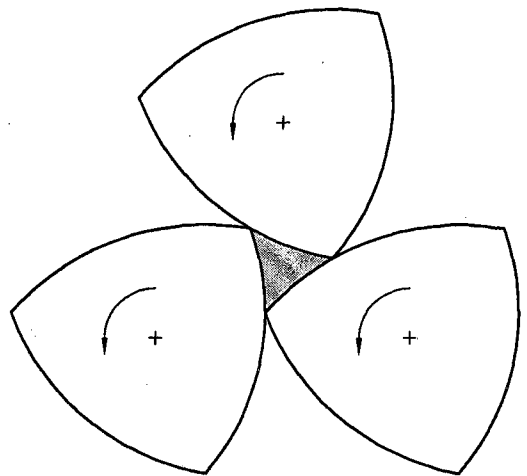


Fig.10

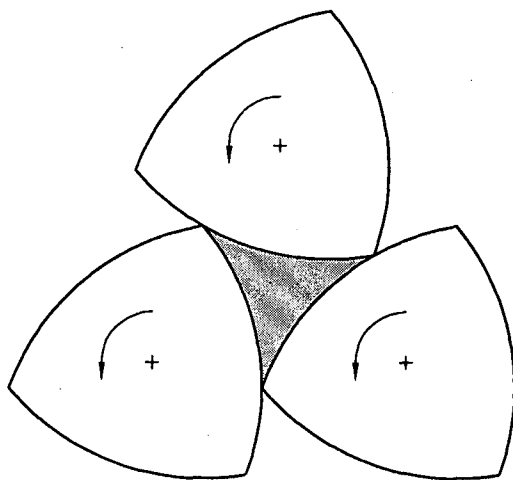


Fig.11

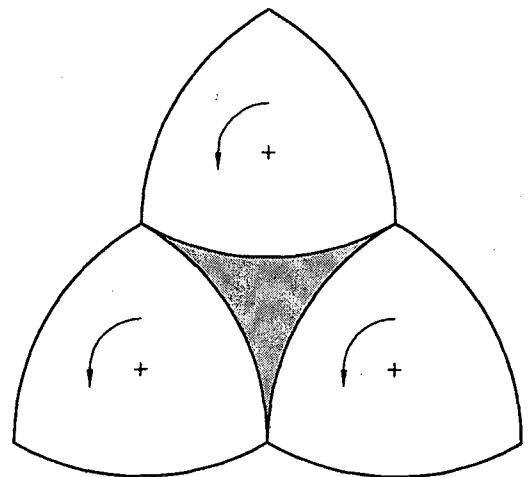


Fig.12

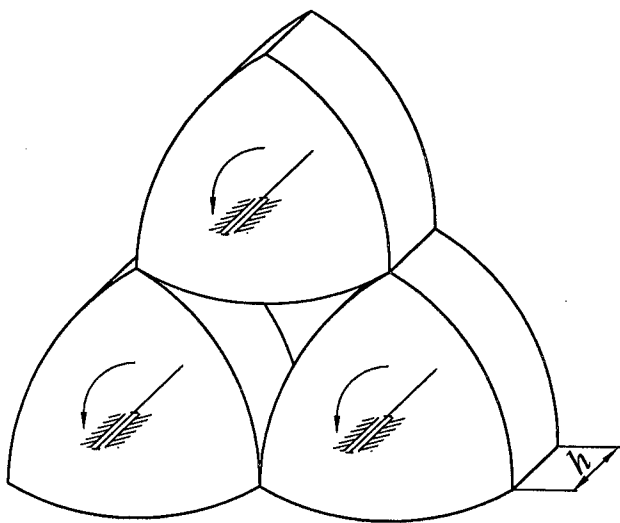


Fig. 13

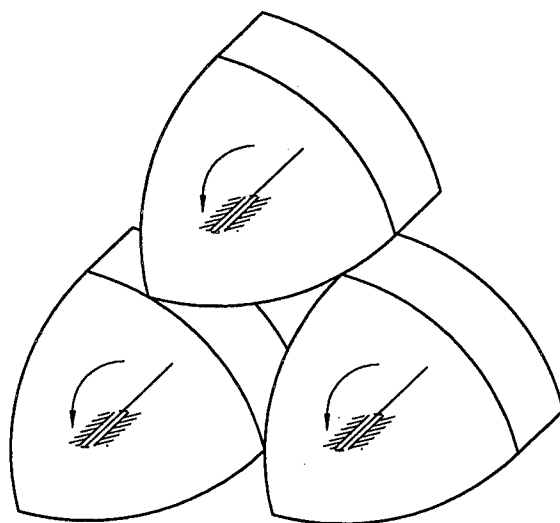


Fig. 14

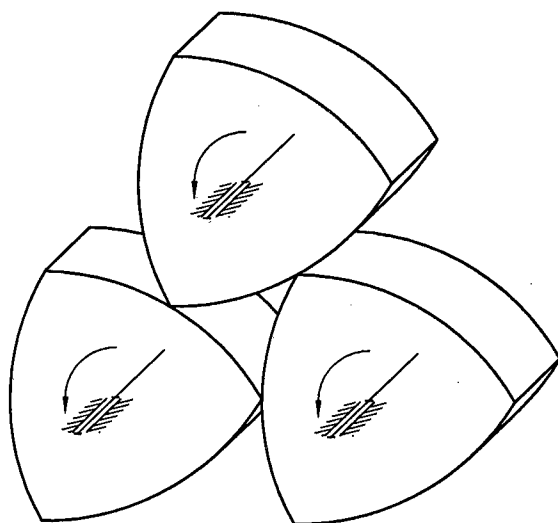


Fig. 15

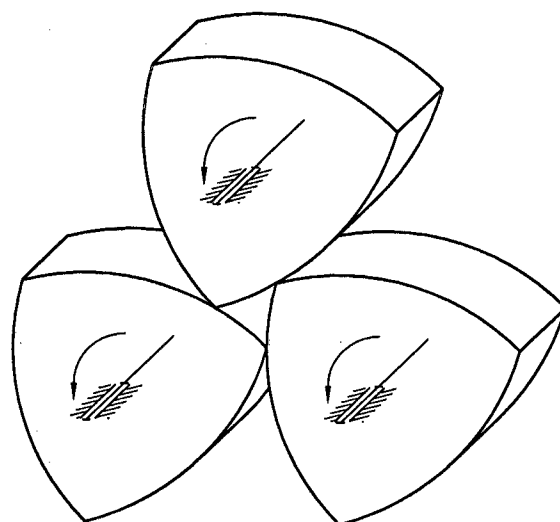


Fig. 16

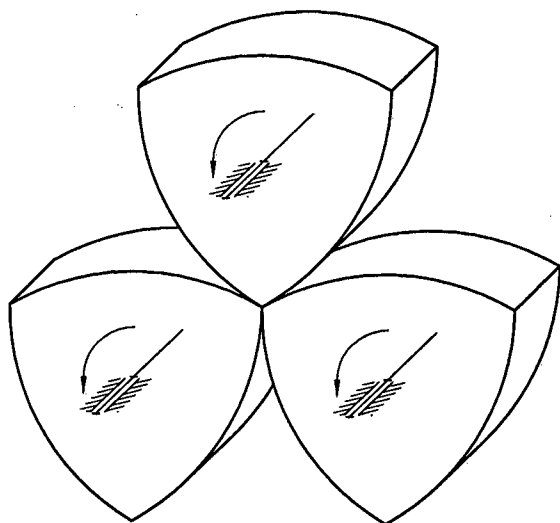


Fig. 17

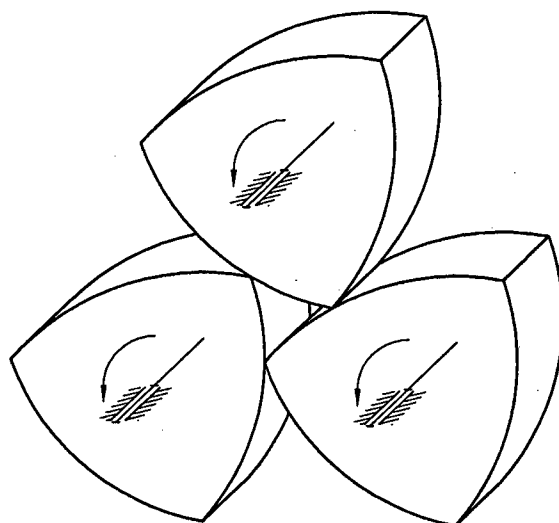


Fig. 18

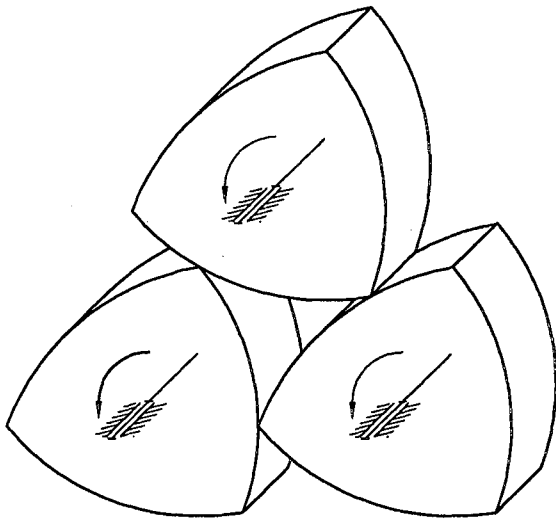


Fig.19

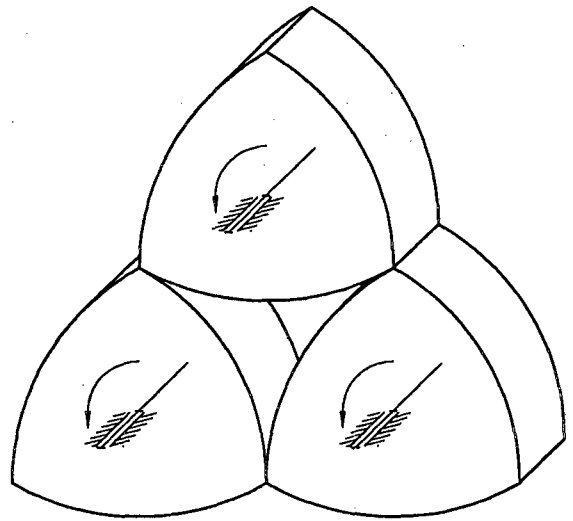


Fig.20

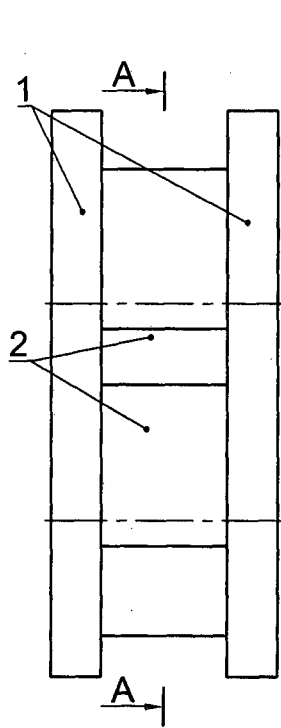


Fig.21

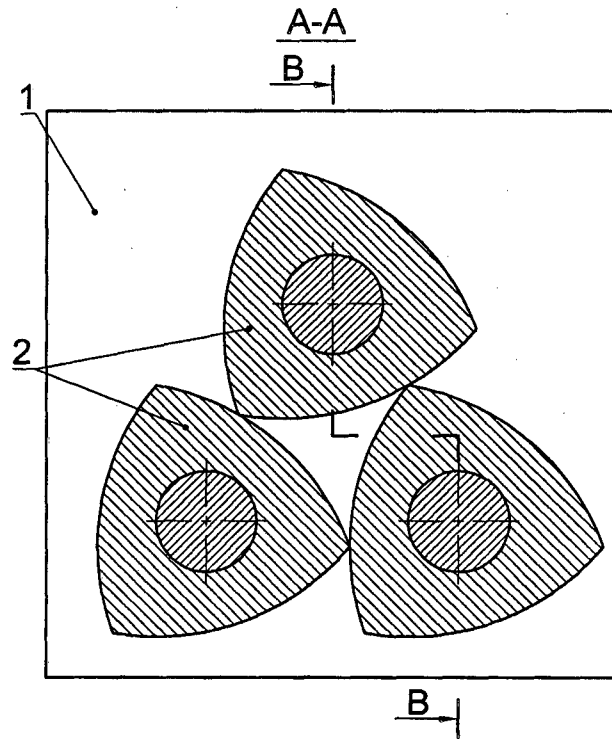


Fig.22

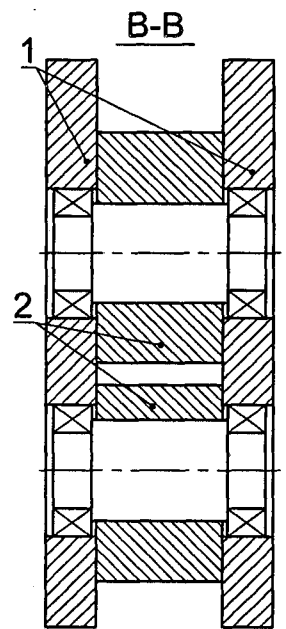


Fig.23

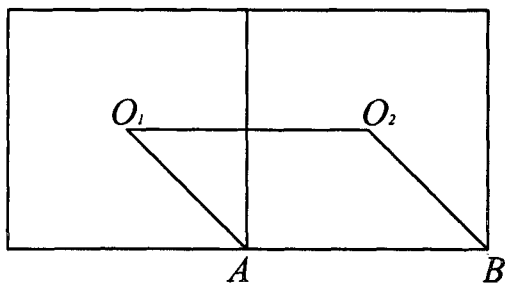


Fig.24

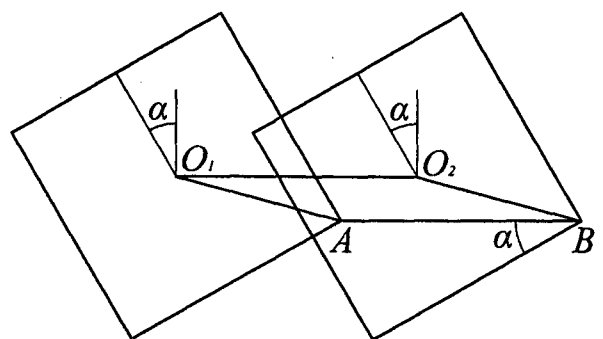


Fig.25

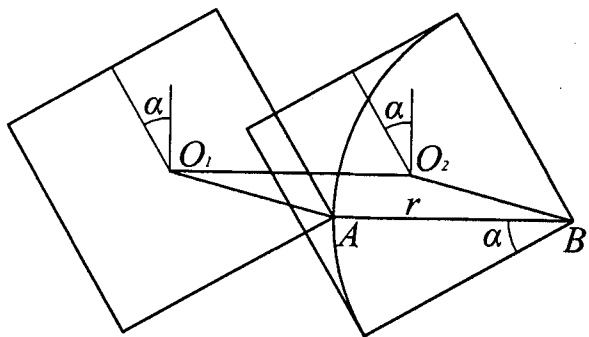


Fig.26

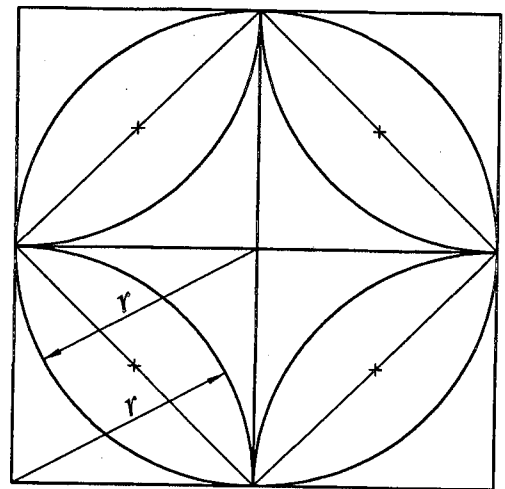


Fig.27

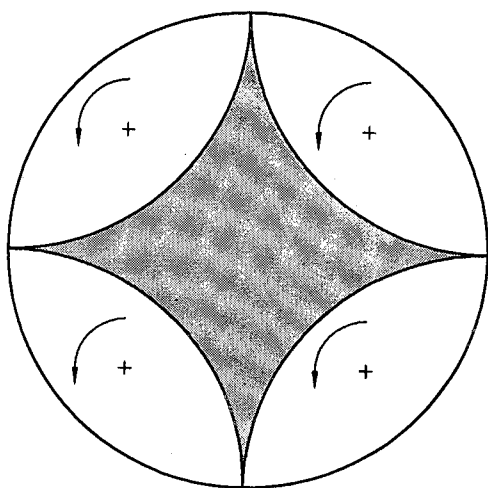


Fig.28

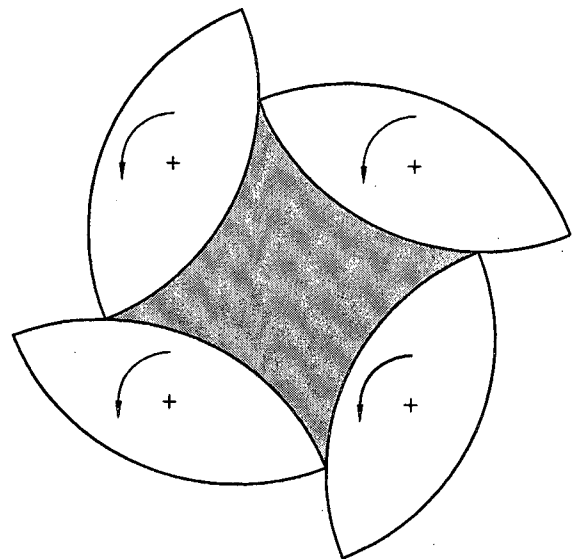


Fig.29

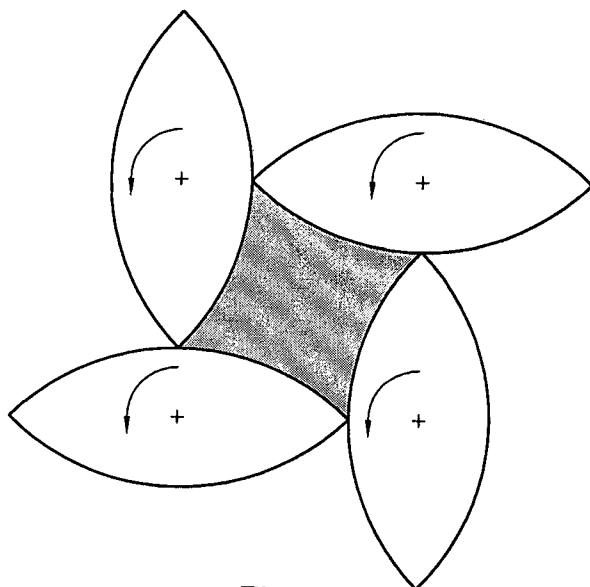


Fig.30

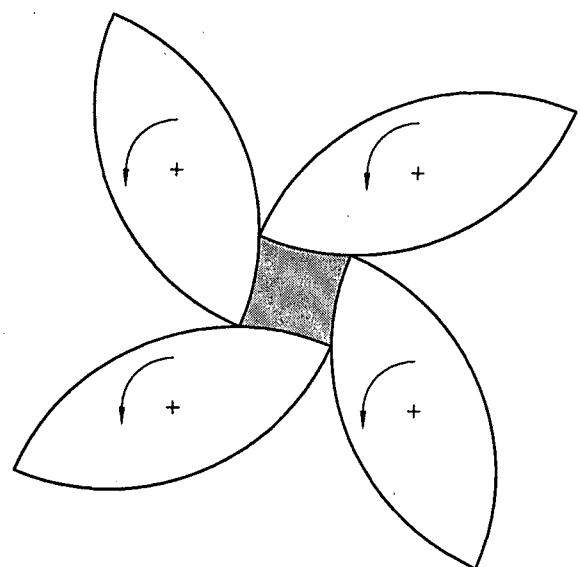


Fig.31

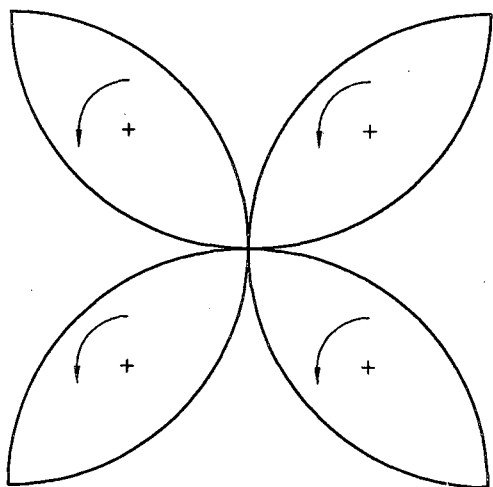


Fig.32

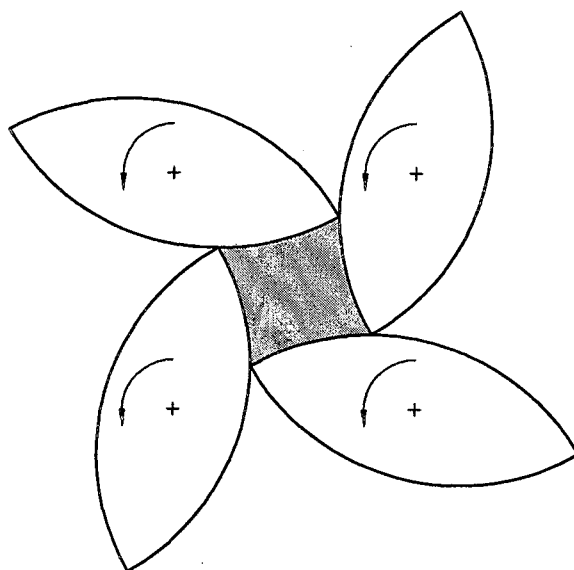


Fig.33

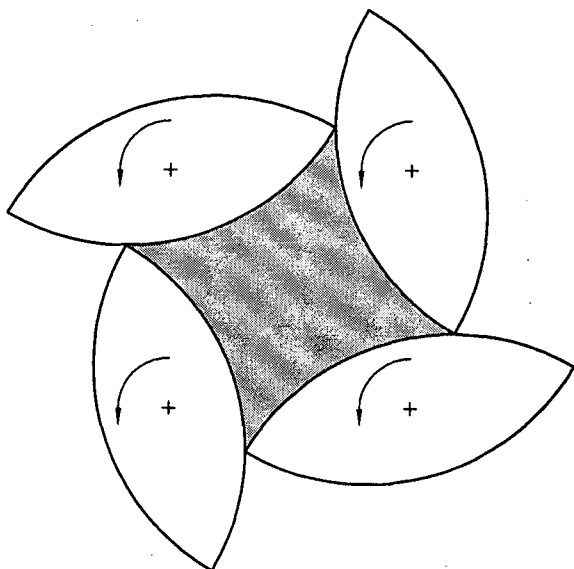


Fig.34

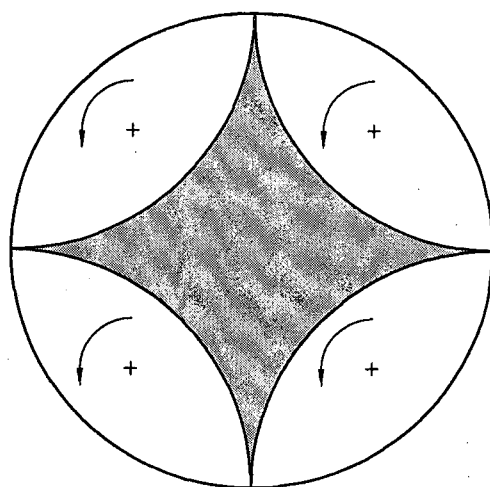


Fig.35

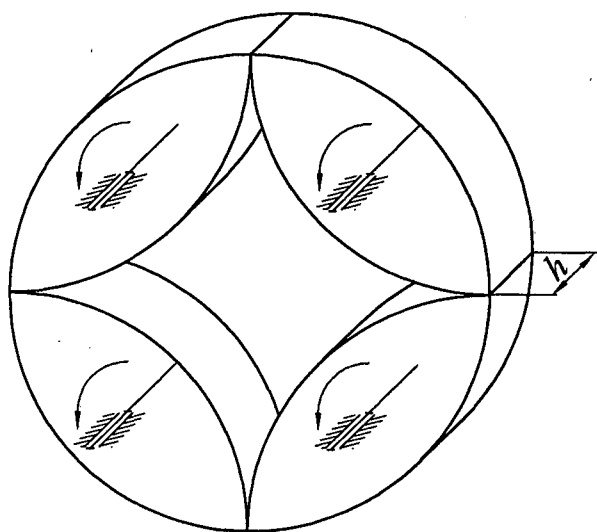


Fig.36

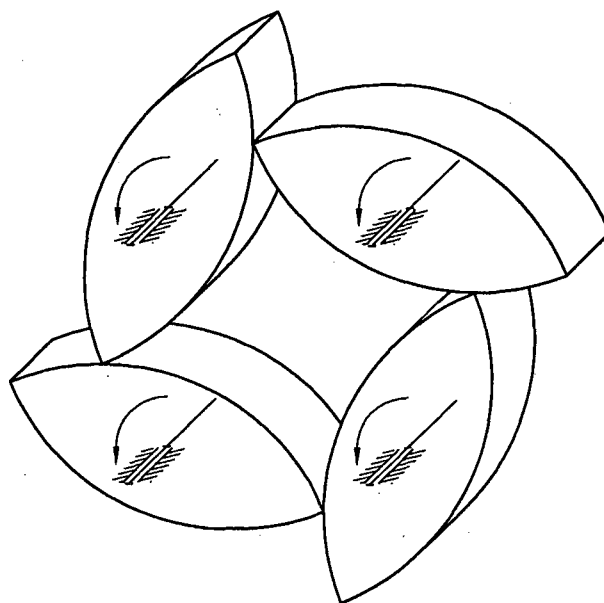


Fig.37

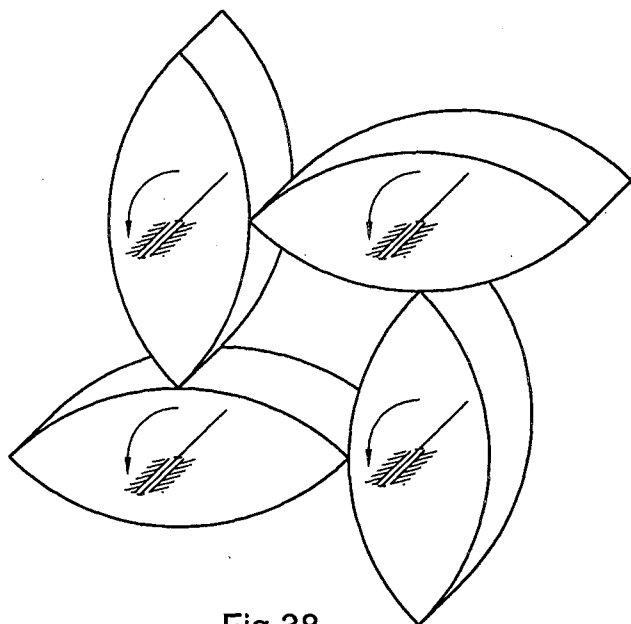


Fig.38

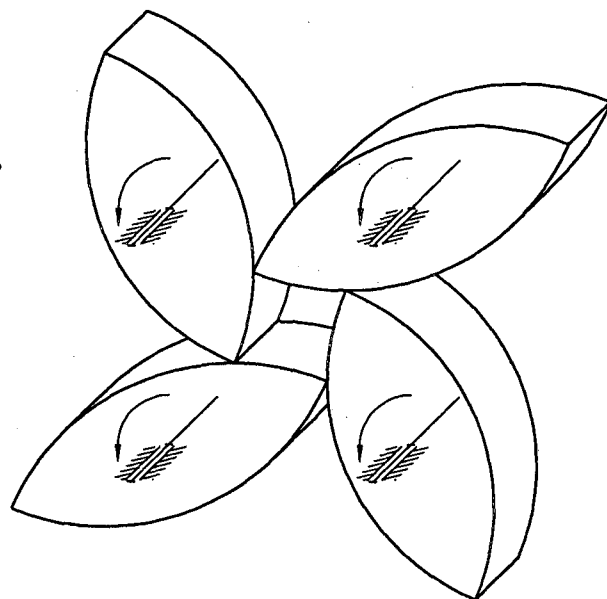


Fig.39

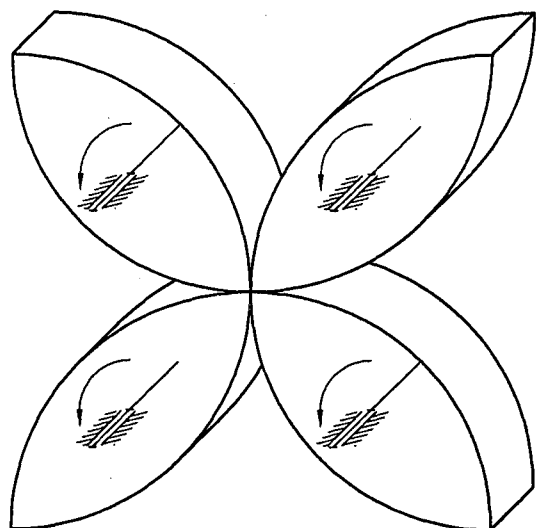


Fig.40

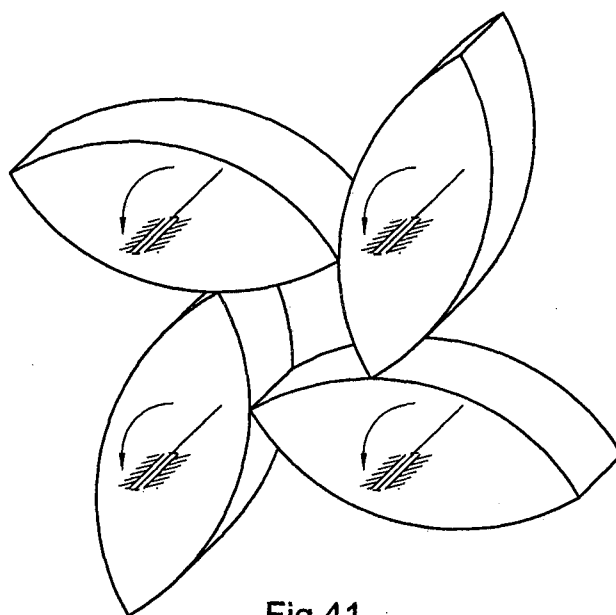


Fig.41

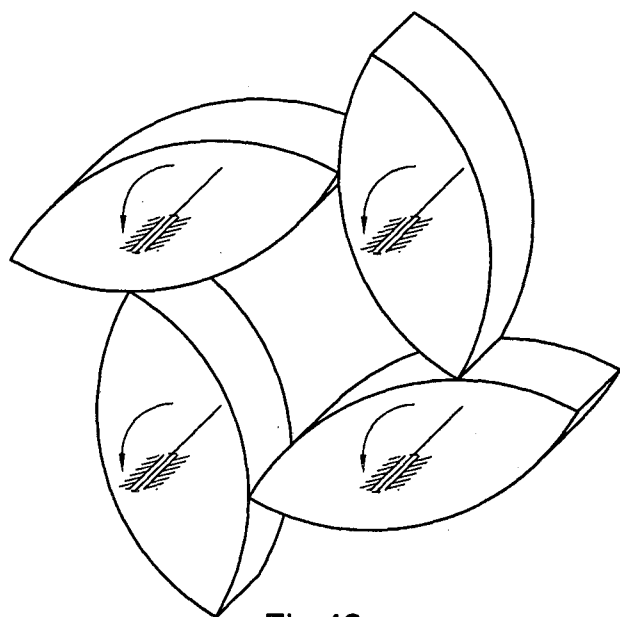


Fig.42

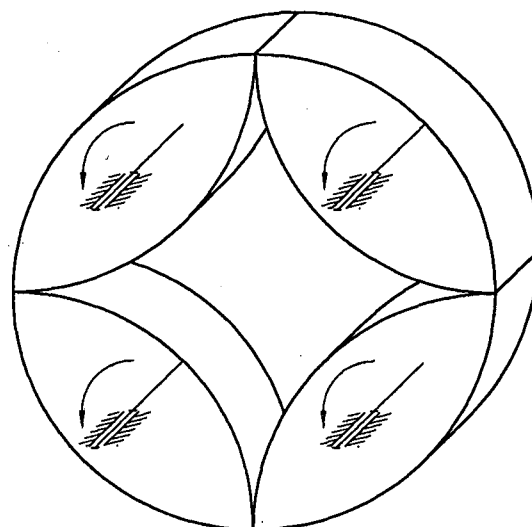


Fig.43

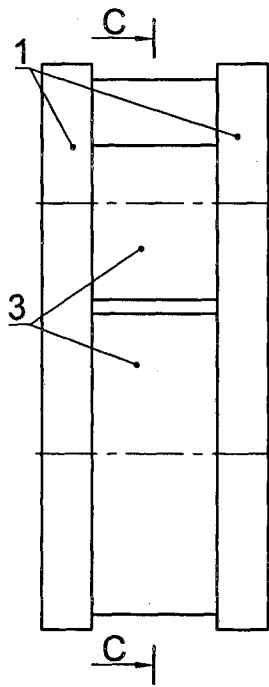


Fig. 44

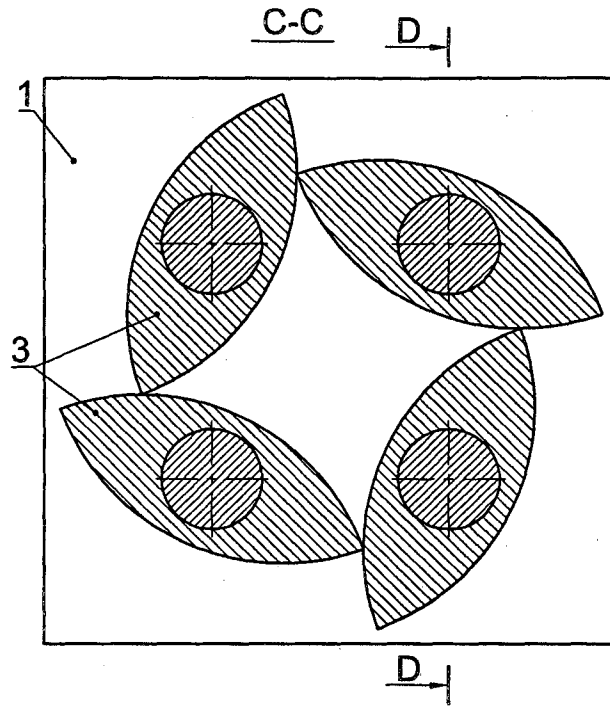


Fig. 45

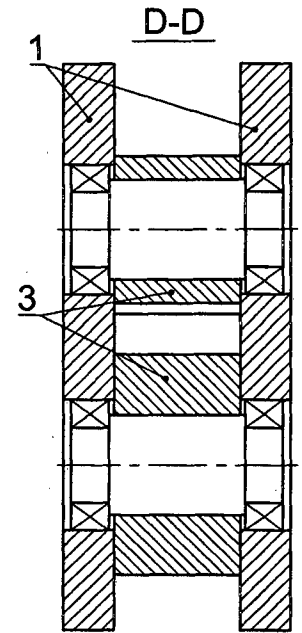


Fig. 46

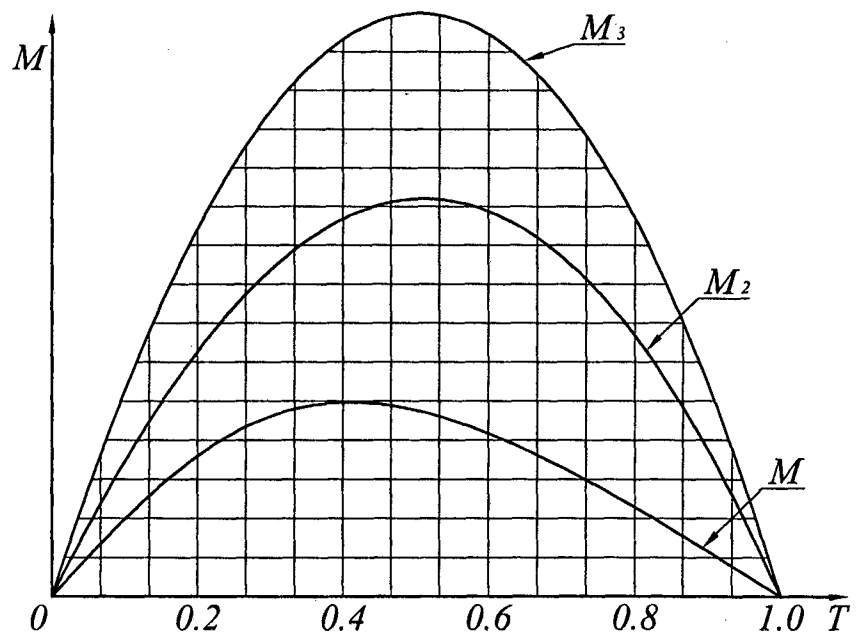


Fig. 47

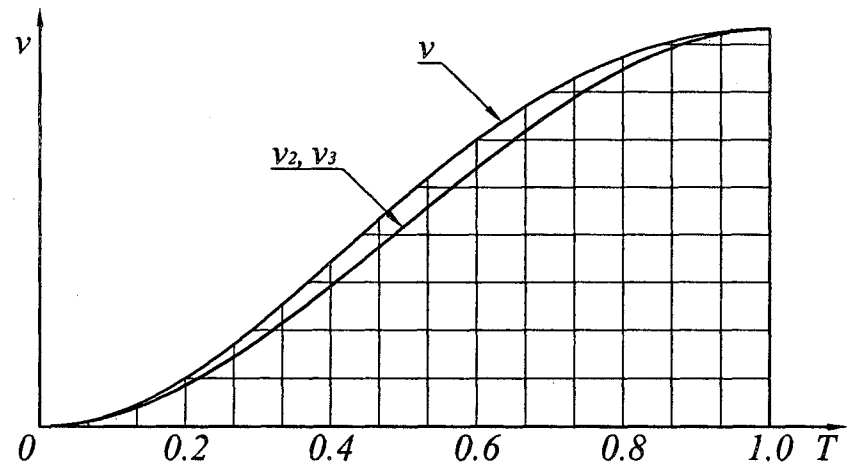


Fig.48

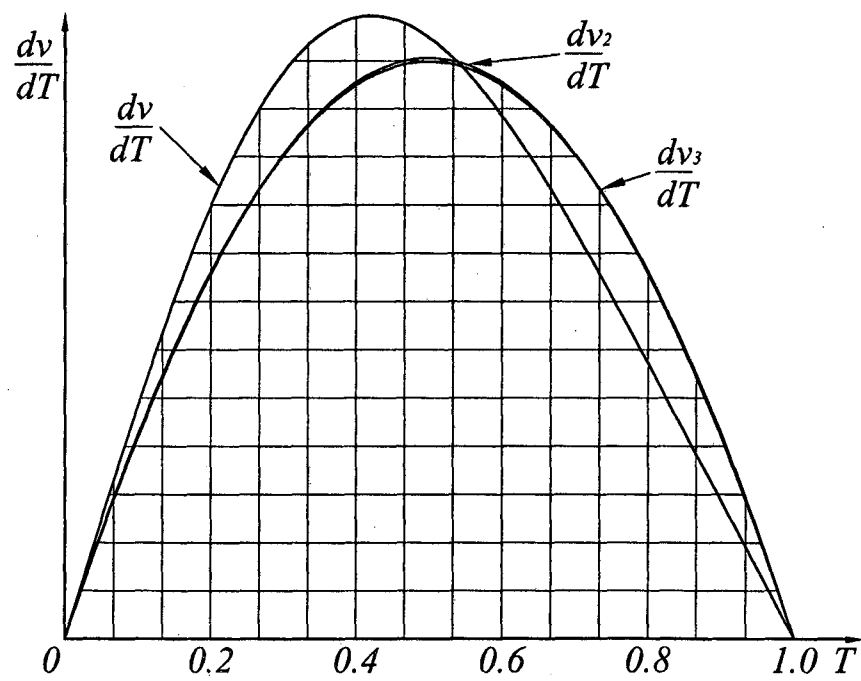


Fig.49

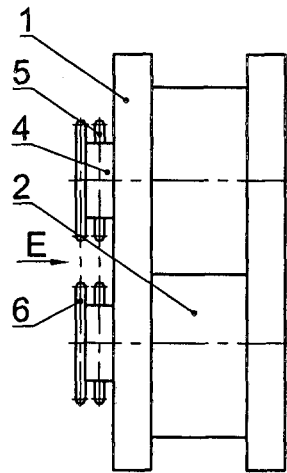


Fig.50

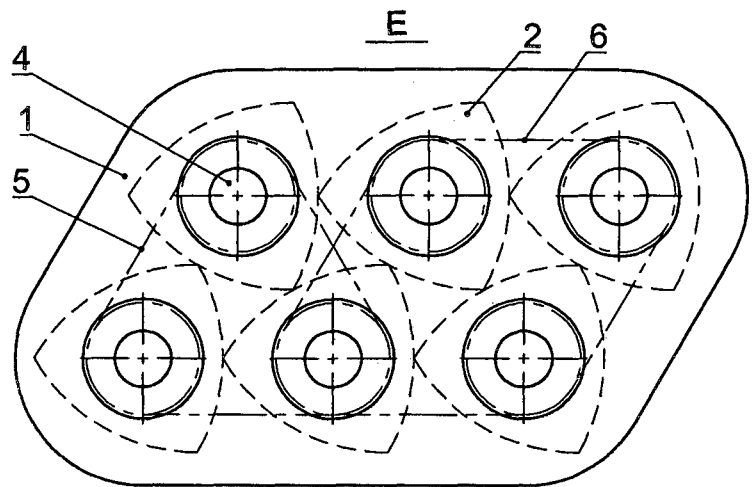


Fig.51

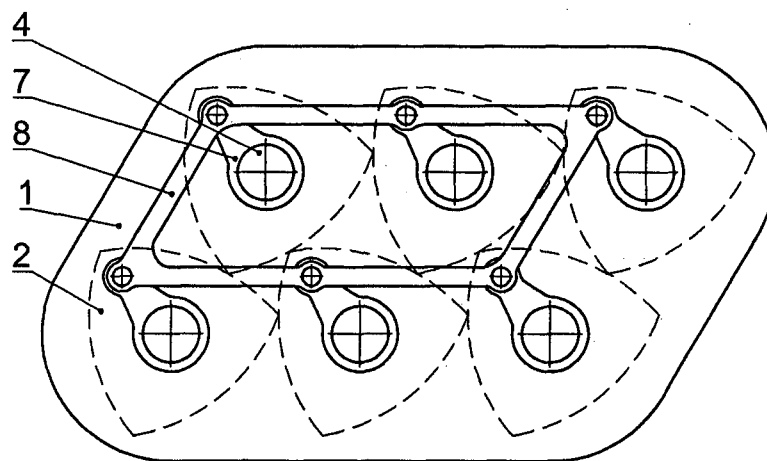


Fig.52

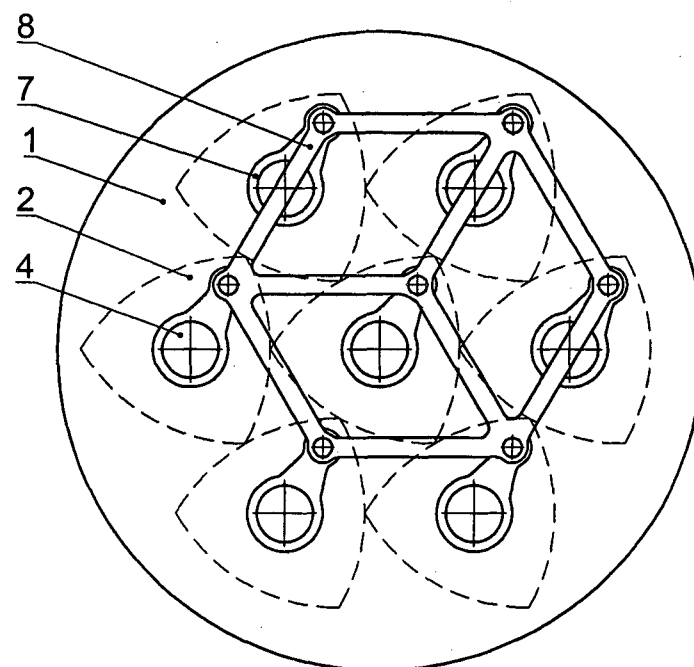


Fig.53

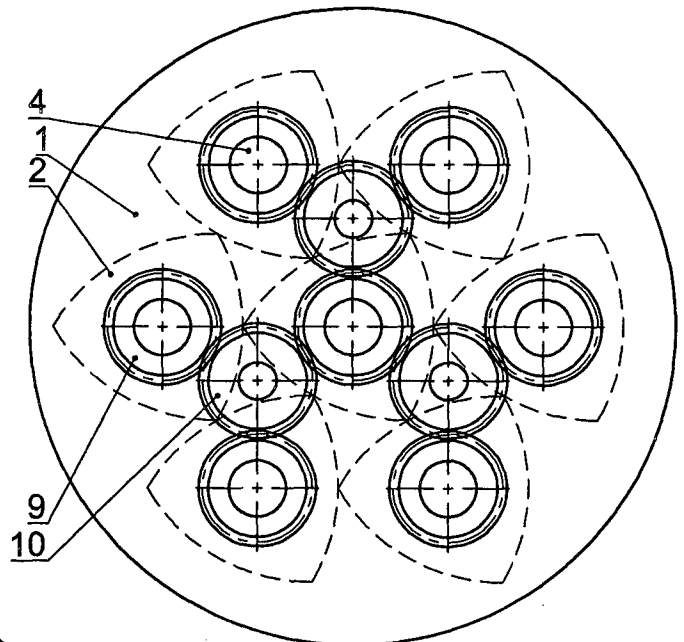


Fig.54

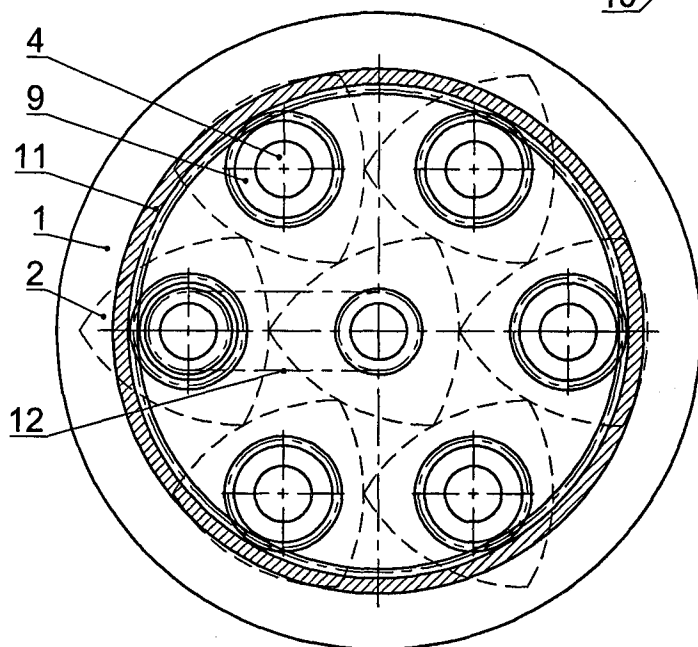


Fig.55

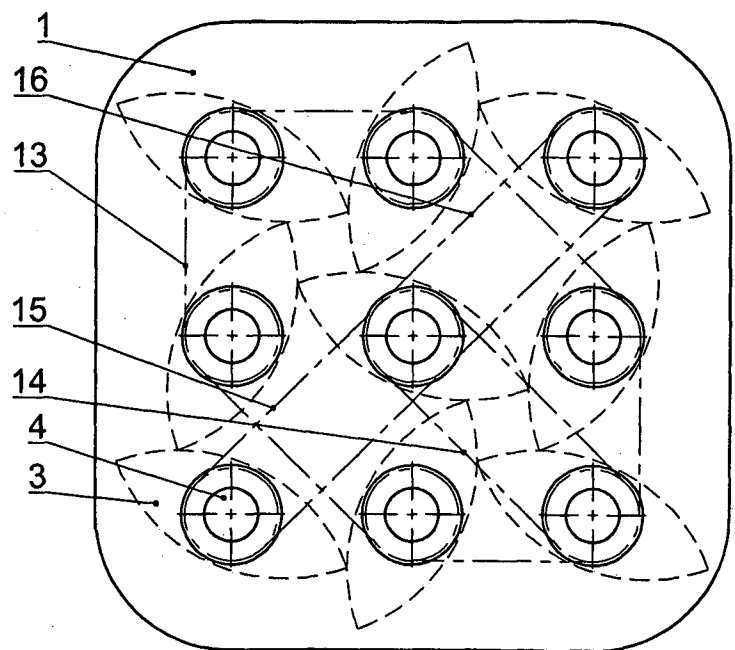


Fig.56

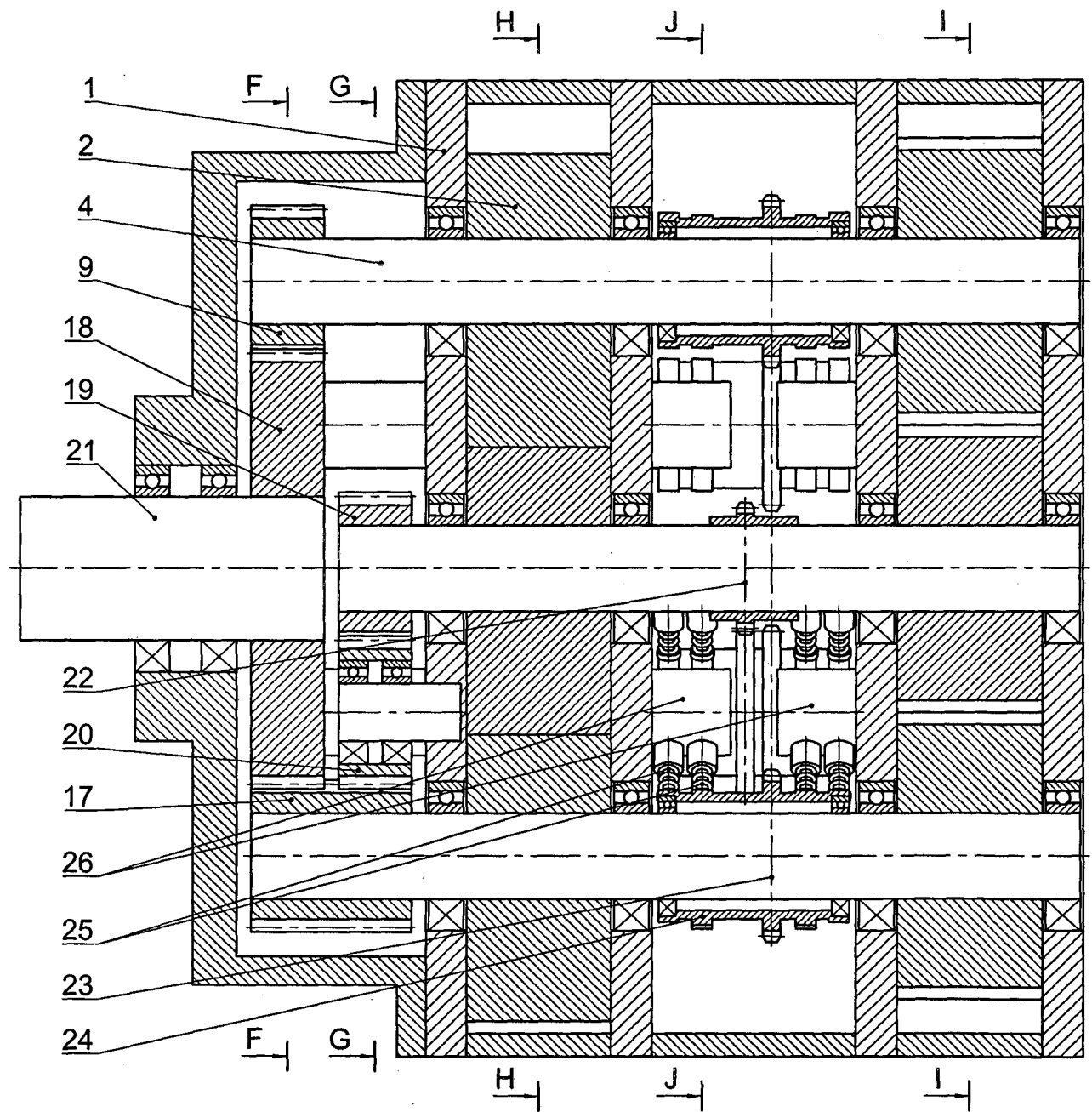


Fig.57

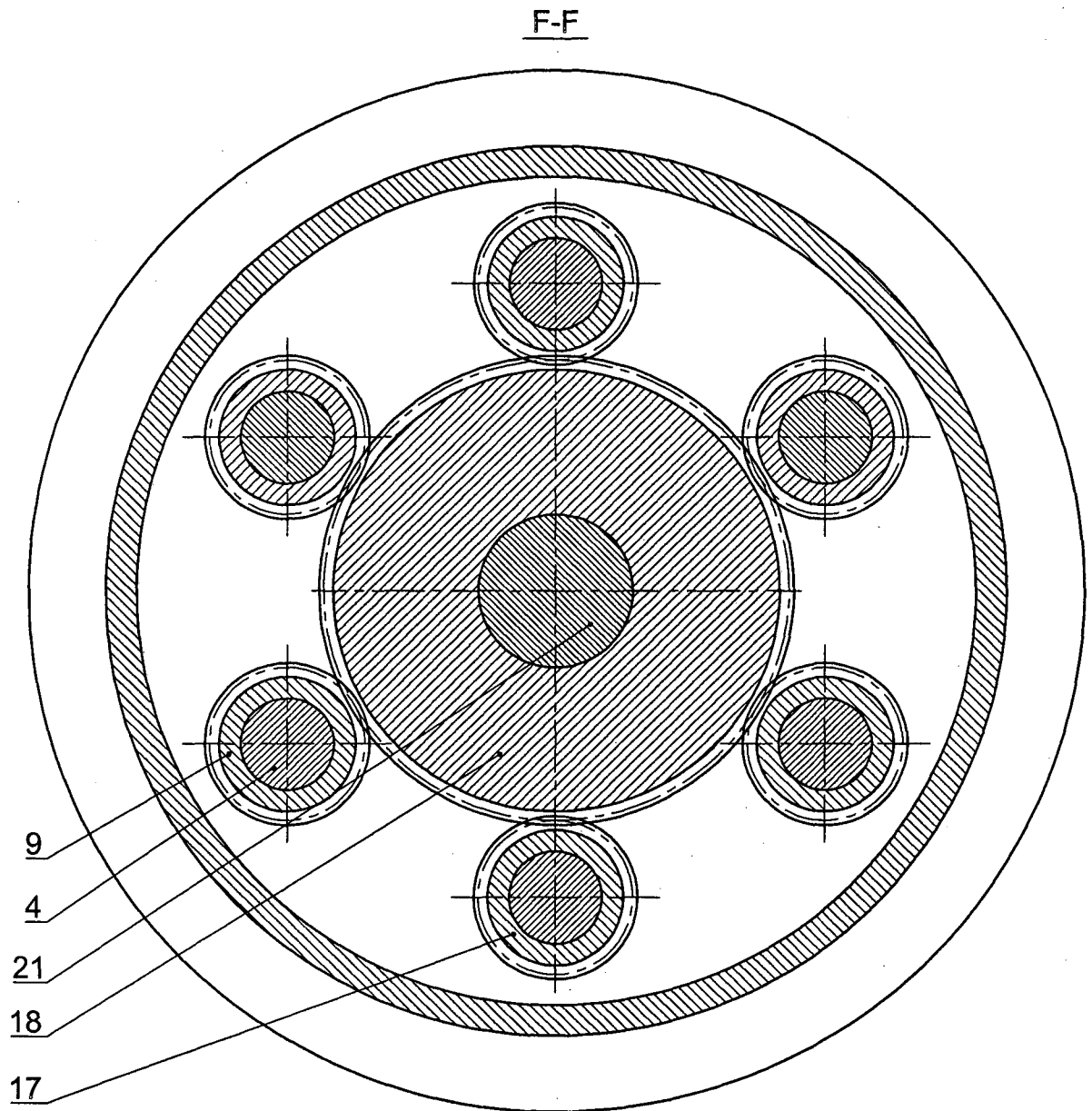


Fig.58

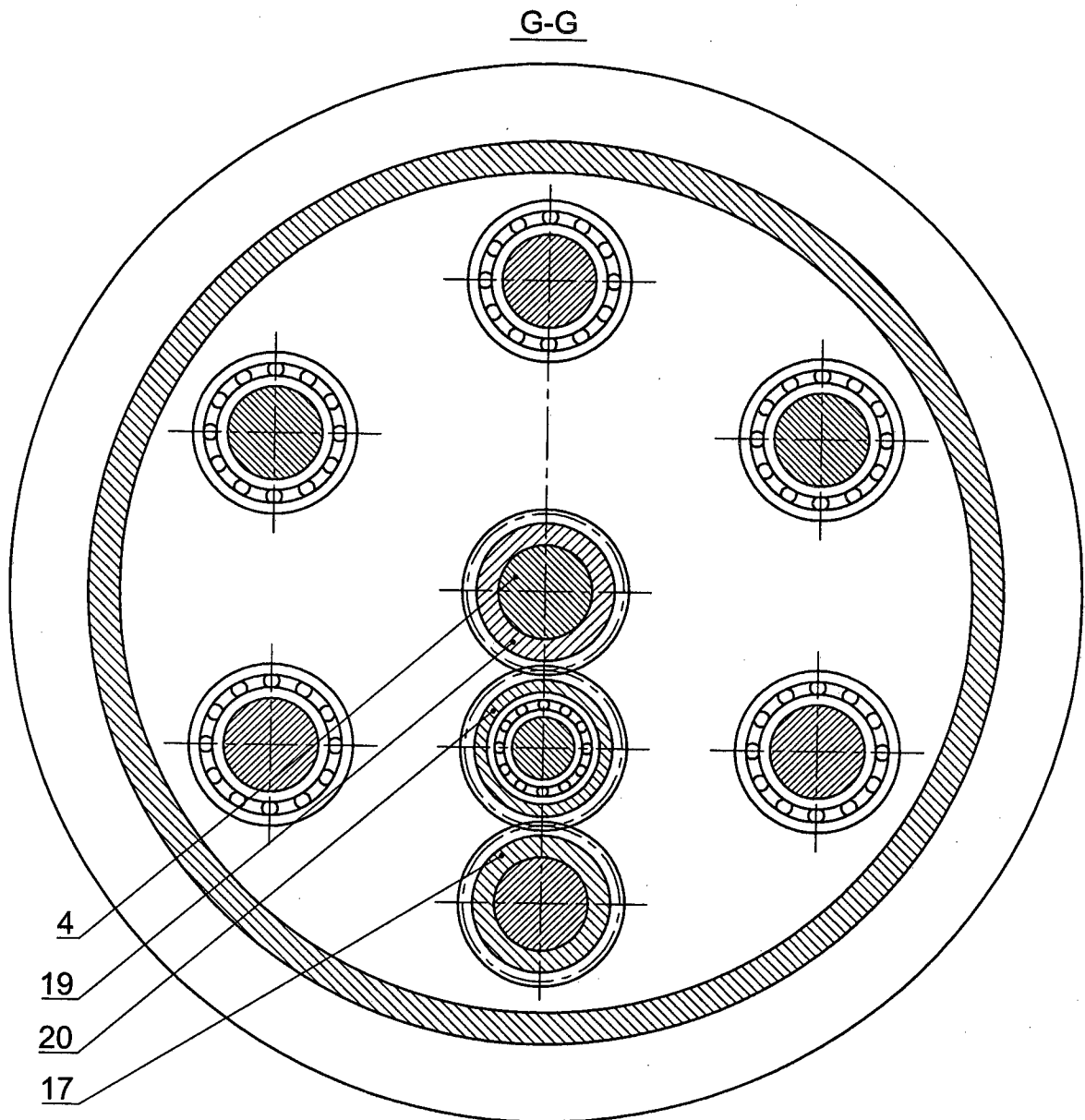


Fig.59

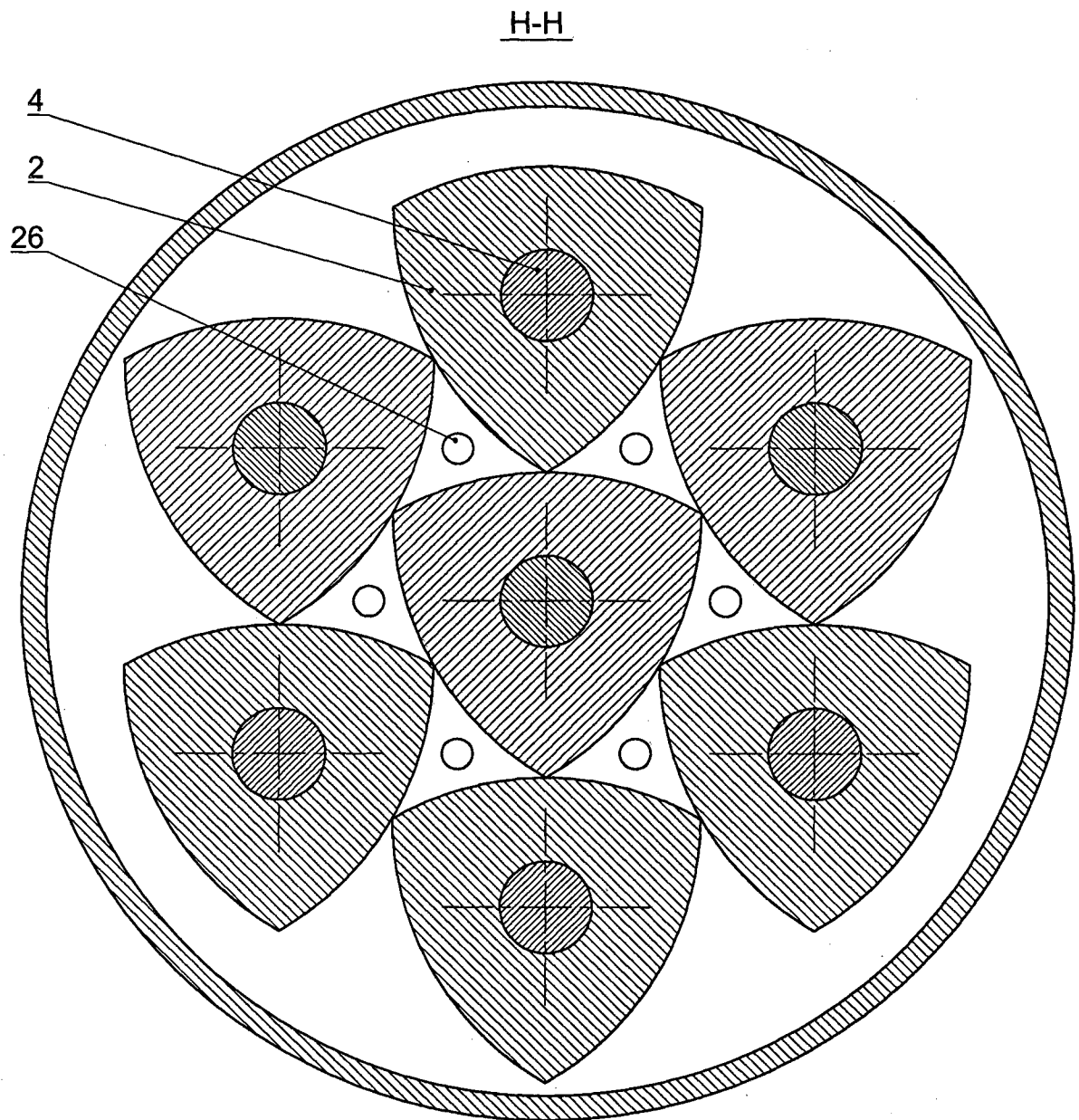


Fig.60

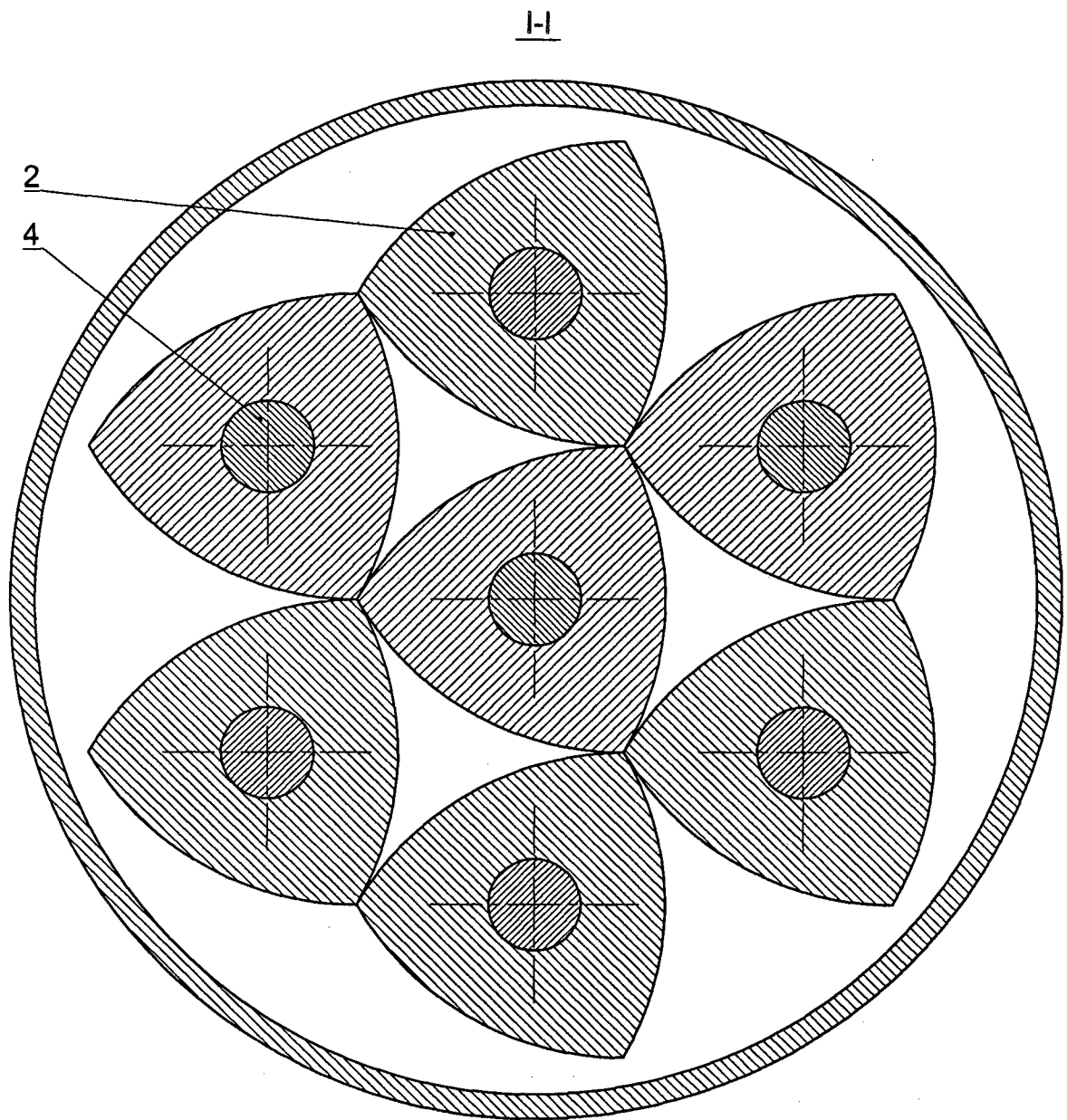


Fig.61

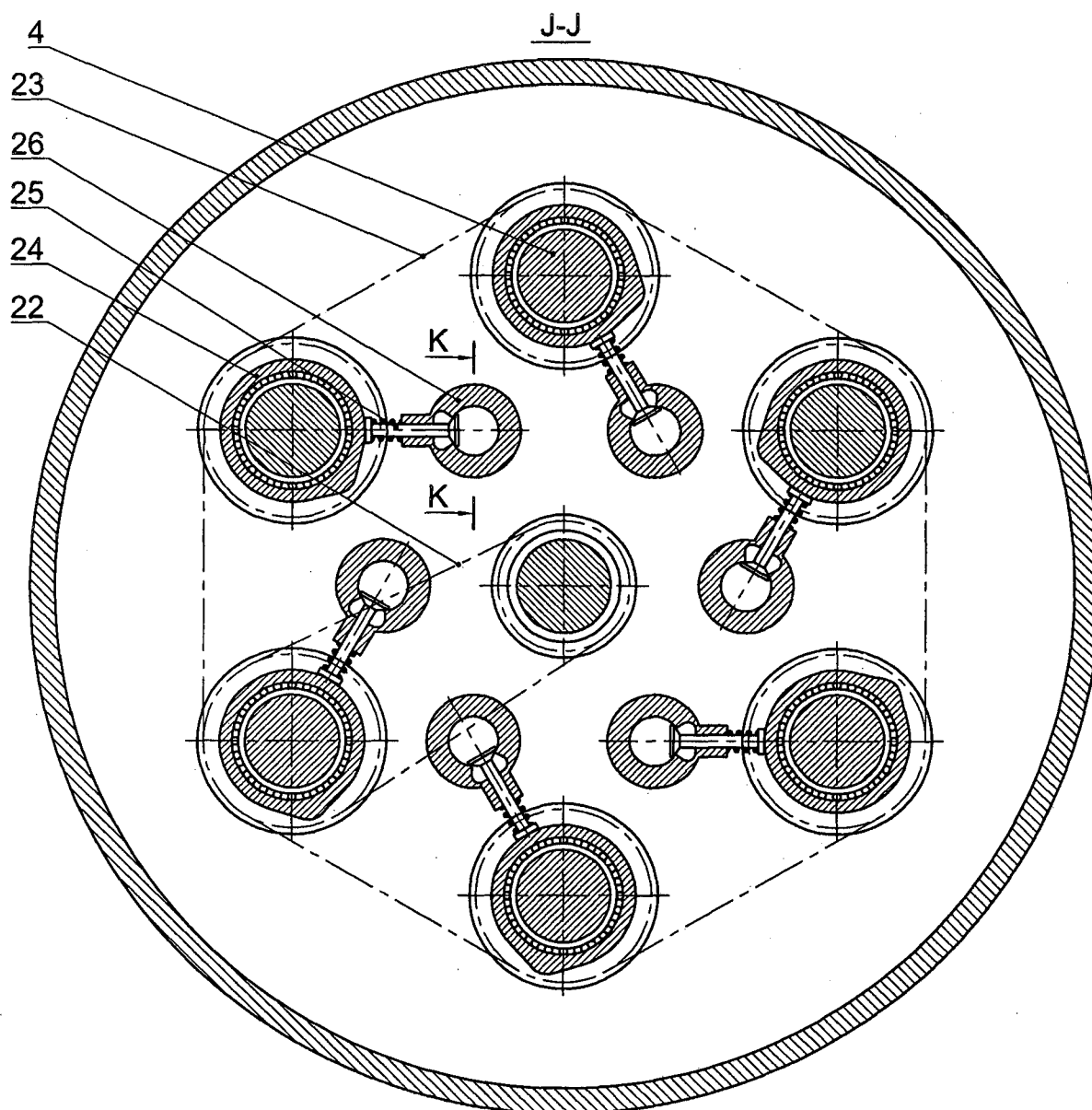


Fig. 62

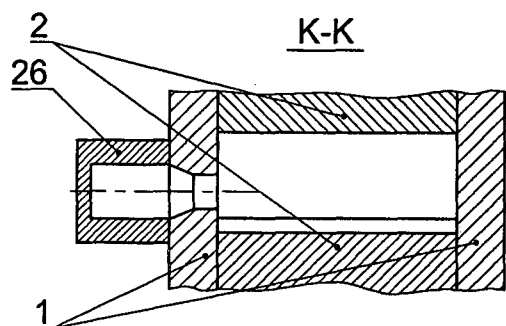


Fig. 63

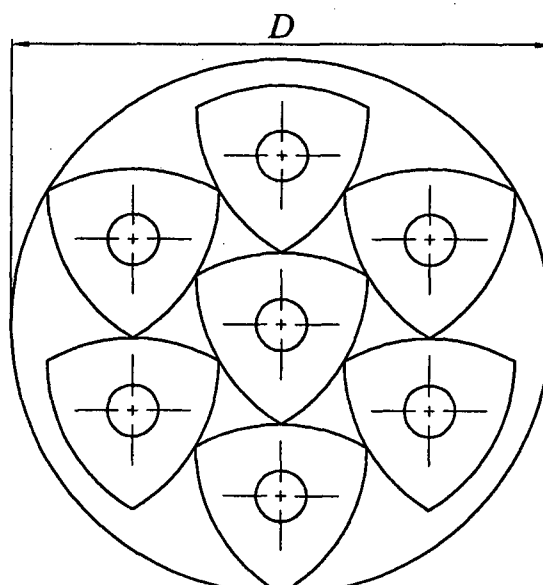


Fig. 64

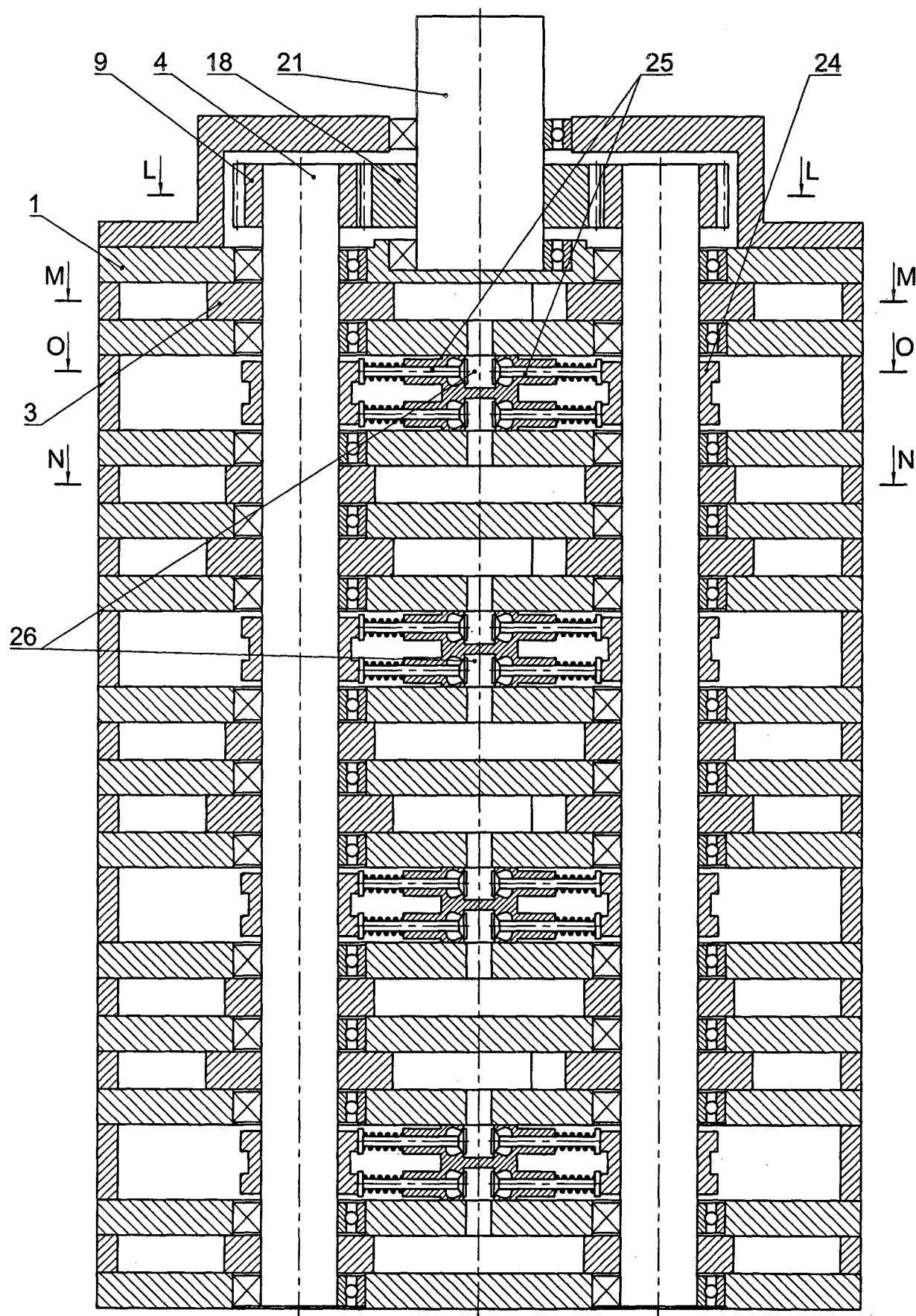


Fig.65

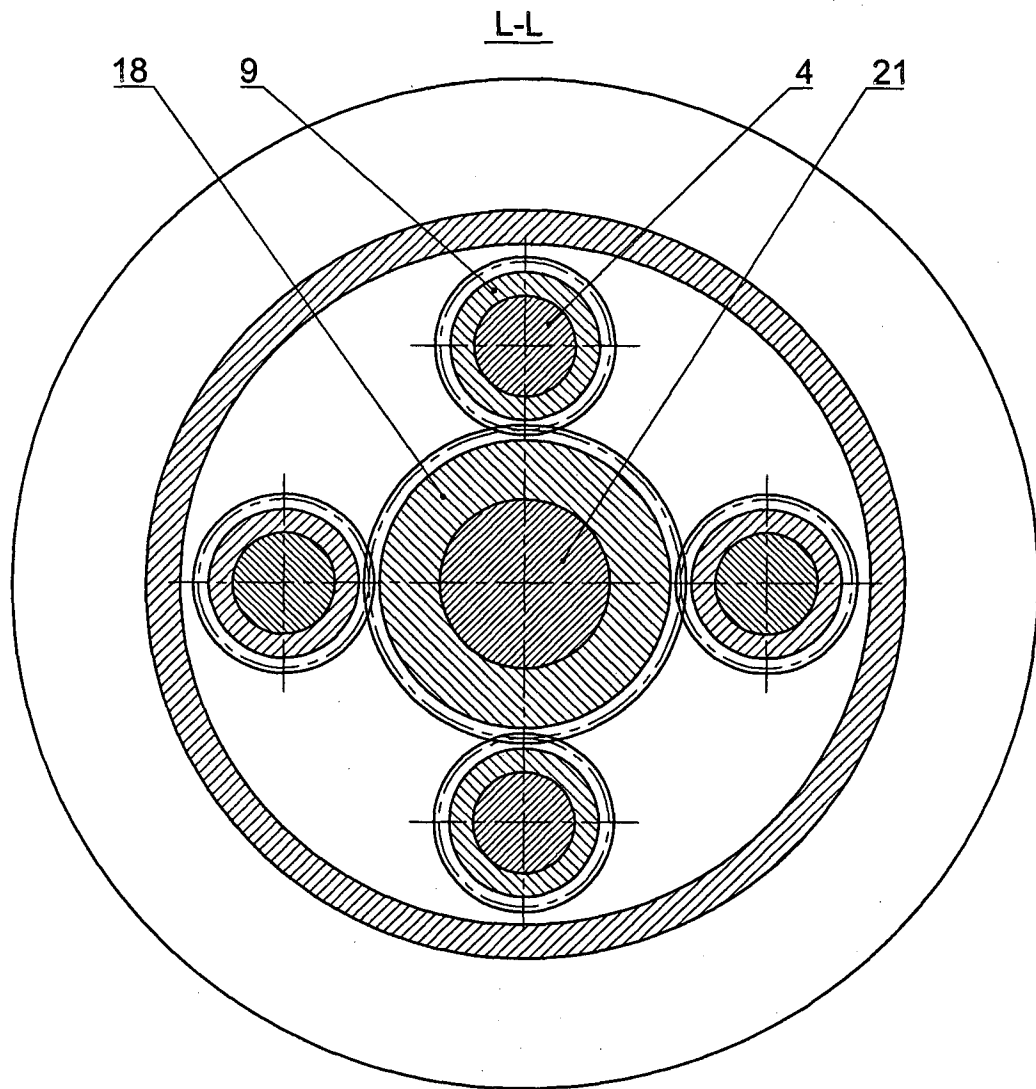


Fig.66

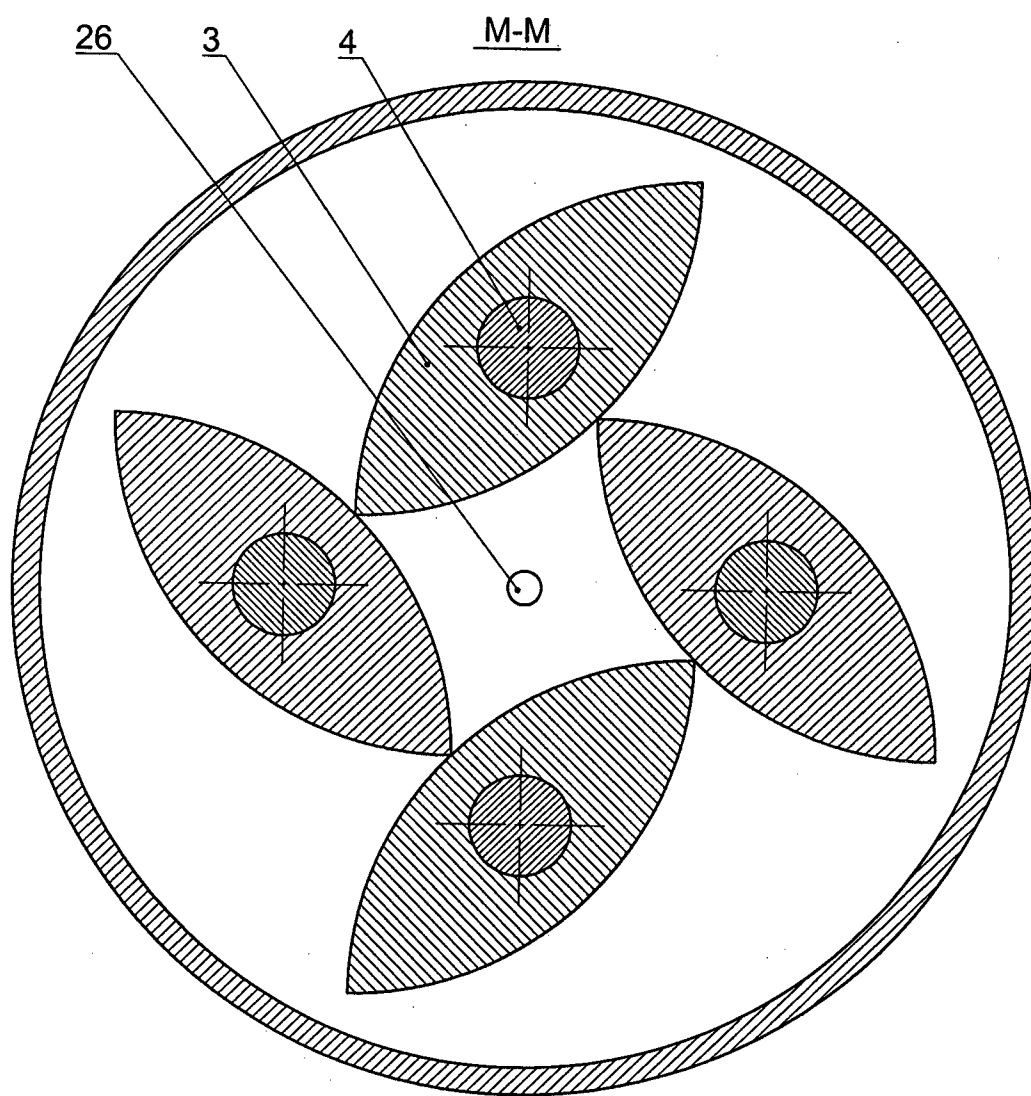


Fig.67

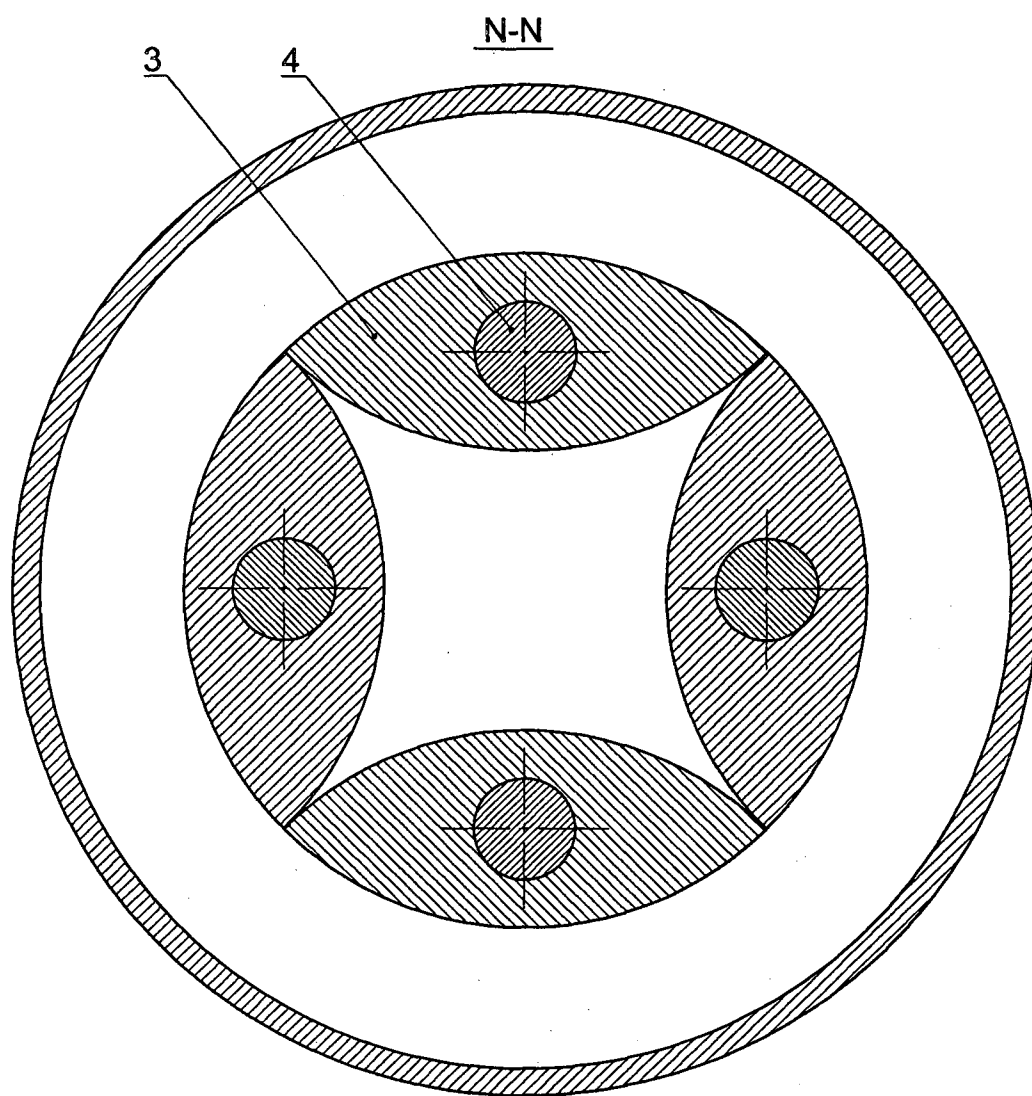


Fig.68

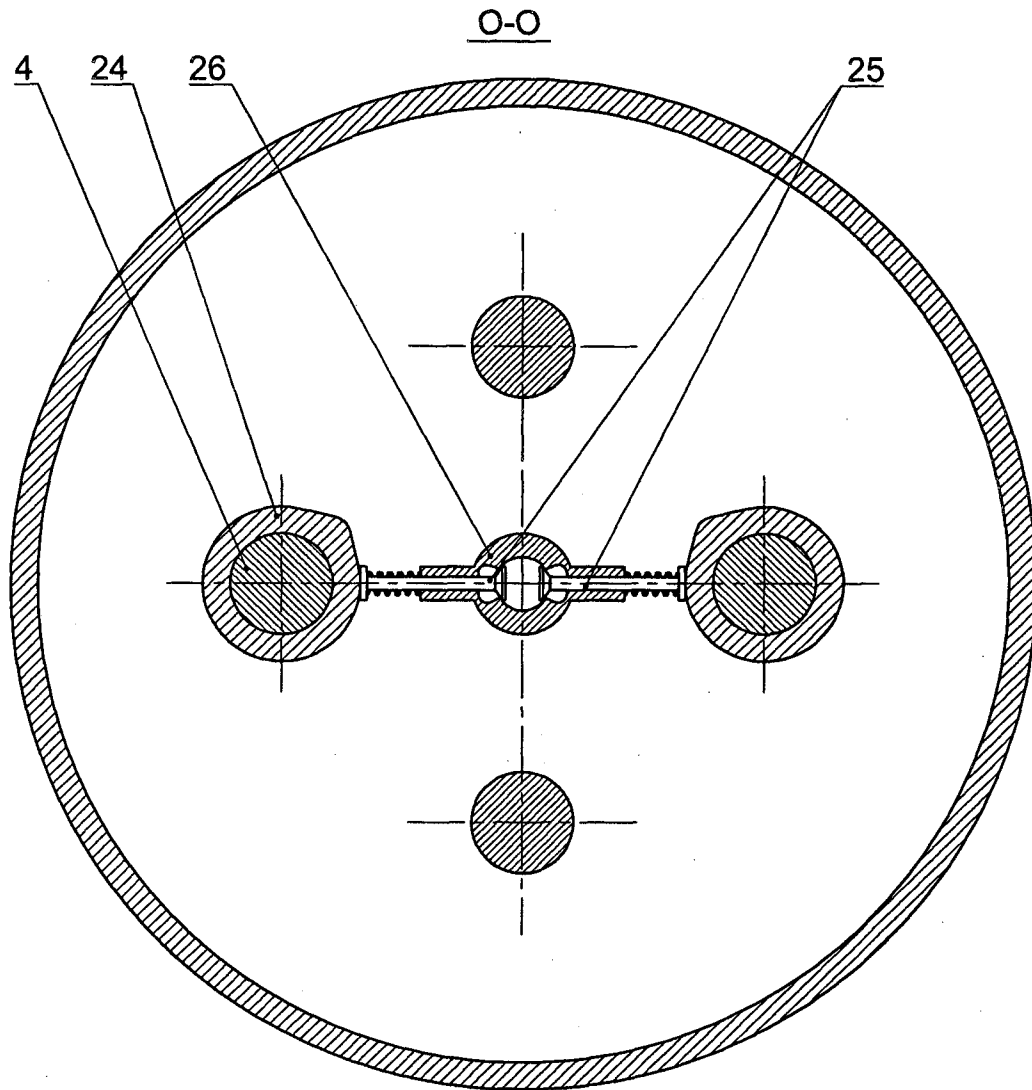


Fig.69

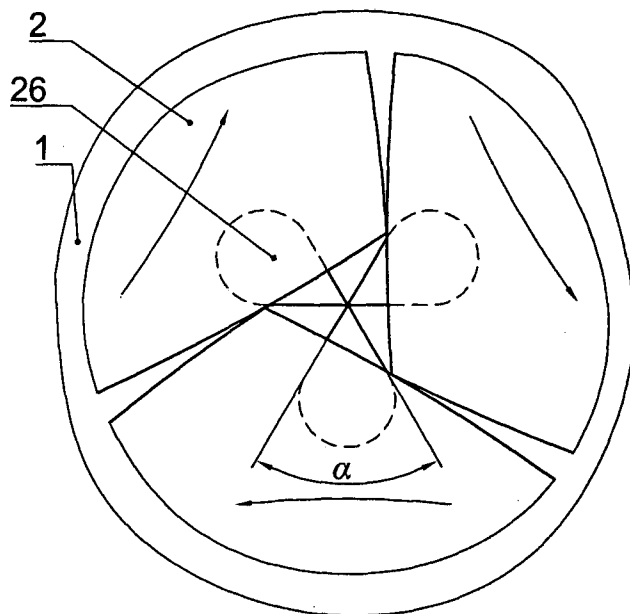


Fig.70

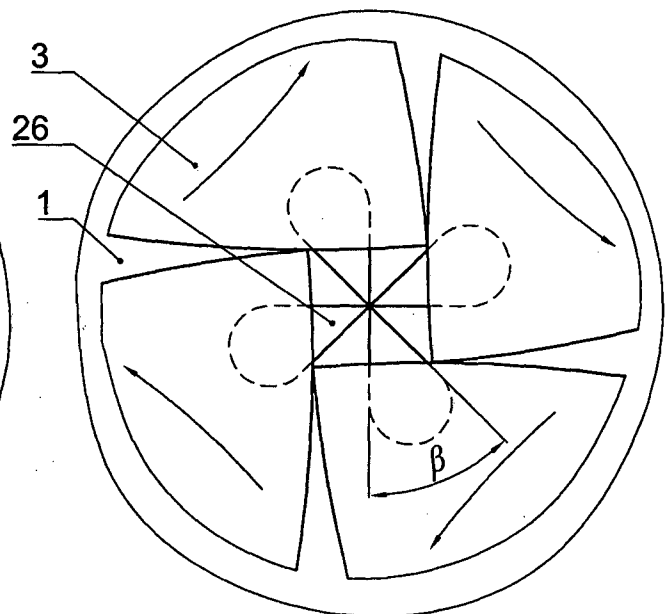


Fig.71