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Computing elements for the architecture of a new type of rotating volumetric pump

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Abstract

The paper presents the computation steps of the main dimensions of the components of a rotating volumetric pump. The rotor radius, the height of the rotating piston, the radius of the volumetric pump case with two profiled rotors is specified. The steps to be taken regarding the rotating volumetric pump dimensions analyzed in this paper are highlighted.
The end of the paper presents the advantages of using rotating volumetric pumps.
Keywords: *Rotating volumetric pump, profiled rotor.*

1. Introduction

The expansion of scientific research in the field of working machines in the energetic field has focused mainly on rotating machines [1] [2] [3]. The advantage of rotating machines is that the entire engine torque is used to drive the fluid to the working machines, and the entire energy of the thermal agent on the force machines is used to drive the machine shaft.
The constructive solution presented in this paper has the advantage of a "reversible" machine in the sense that it can be used as a working machine or as a force machine.
As a working machine it can be used as follows [4] [5] [6] [7] [8]:
- fan for clean or suspended gas;
- low pressure compressor;
- pump for fluid transport;
- vacuum pump;
- fan for pneumatic transport.

As a force machine can be used as follows [9] [10] [11] [12] [13] [14] [15]:
- steam motor;
- combustion motor;
- hydrostatic motor;
- pneumatic motor.

For the proposed constructive solution the operating principle is presented and the main dimensions of the rotating volumetric pump are indicated.

2. The constructive solution and operating principle of the rotating volumetric pump

The volumetric pump (fig.1) has two identical profiled rotors (2, 5) of a special shape which rotate with the same speed within a case (1, 4). The synchronous rotation of the rotors is provided by two gearwheels attached to the shafts 7 and 9, which form a cylindrical gear mounted outside the cases. The pump is driven externally via the driving shaft (9).

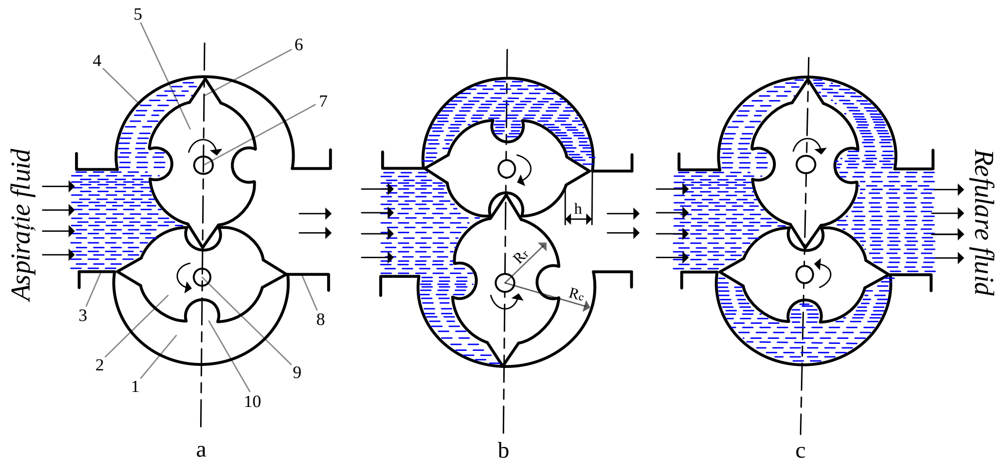

Fig. 1 Proposed beam former The rotors position after a 90° rotation
1- lower case; 2- lower rotor; 3- sucction chamber; 4- upper case; 5- upper rotor; 6- rotating piston; 7- driven shaft; 8- discharge chamber; 9- driving shaft; 10- cavity in which the upper rotor piston enters.

The aspirated fluid (fig. 1. a) is transported to the discharge and after a 90° rotation of both rotors, the situation in Figure 1.b and thereafter in Figure 1.c is reached.

In Figure 1, the two rotors have the same radius (R_r), the cylindrical case has the radius (R_c), and the triangular-shaped rotating piston has the height (z). It can be seen from Figure 1 that:

$$R_c = R_r + z \;[m] \tag{1}$$

The question is how big can *z* be for a specified R_c value.

3. Determination of the maximum value of the ratio $\frac{z}{R_c}$

The value of the ratio can vary within the limits 0 ÷ 1. Practically, the value of the ratio is $\frac{z}{R_c} < 1$ since the rotors are mounted on the shafts 7 and 9; therefore, the height of the piston must be smaller than the case radius. Approximately 7 < 0.9 R_c. So, theoretically $\frac{z}{R_c} = 0 \div 0.9\ R_c$ [16] [17] [18].

To mathematically determine the maximum value of the ratio $\frac{z}{R_c}$, two rotors having the same radius (R_r) and tangent at point K (Figure 2) are considered.

To simplify the calculations, a single piston (4) fixed to the rotor (1) was considered.

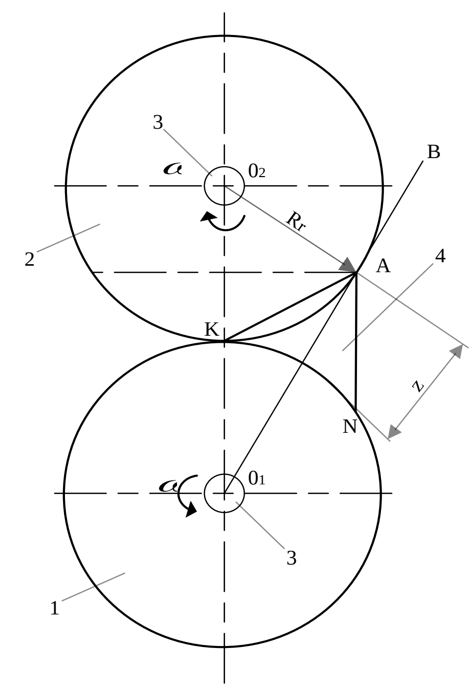

Fig. 2 Computing notations.

The rotor radius (1) is prolonged with a length z, and so the line 0_1B reaches the rotor (2) at point A [19] [20]. Theoretically, when point K reaches point D, point A reaches K, and point N reaches K, because the length of the circular arcs AK, KD and KN is the same. When the piston (4) comes out of the gap created in the rotor (2) points A and N reaches point K; the sealing between the two rotors being ensured by direct contact between the sides surfaces of the rotors.

From the rectangular triangle $0_1 0_2 A$ results:

$$0_1 0_2^2 = A0_2^2 + A0_1^2 \quad (2)$$

$$(2R_r)^2 = R_r^2 + (R_r + z)^2 \quad (3)$$

relation that becomes:

$$z^2 + 2R_r z - 2R_r^2 = 0 \quad (4)$$

$$z_{1,2} = \frac{-2R_r \pm \sqrt{4R_r^2 + 8R_r^2}}{2} \quad (5)$$

The negative solution is inconclusive and the following is obtained:

$$z = -R_r + R_r\sqrt{3} = 0.732 R_r \quad (6)$$

The case radius will be:

$$R_c = R_r + z = R_r + 0.732R_r = 1.732R_r \quad (7)$$

From (6) and (7) results:

$$R_c = \frac{z}{0.732} + z = 2.366 \cdot z \quad (8)$$

From (8) results

$$\frac{z}{R_c} = 0.423 \quad (9)$$

or

$$z = 0.423\ R_c \quad (10)$$

$$\frac{z}{R_r + z} = 0.423 \quad (11)$$

From (11) results:

$$z = 0.733 R_r \quad (12)$$

Relations (10) and (12) determine the maximum height of the piston depending on the case radius or the piston radius.

4. Determining the main dimensions of the rotating volumetric pump

In [21] [22] the theoretical expression for calculating the flow rate circulated by the this type of rotating volumetric pump is deduced:

$$\dot{V} = \pi \cdot l \cdot z(z + 2R_r) \cdot \frac{n}{30}\ \left[m^3/s\right] \quad (13)$$

Where:
l - rotor length [m];
z - piston height [m];
R_r - rotor radius [m];
n - machine speed [rot / min].
Substituting the relation (12) in (13) results:

$$\dot{V} = \pi \cdot l \cdot 0.733 \cdot R_r (0.733 \cdot R_r + 2R_r) \cdot \frac{n}{30}$$

$$\dot{V} = 2 \cdot \pi \cdot l \cdot R_r^2 \cdot \frac{n}{30} \quad (14)$$

Choosing: $l = K R_r^2$ where K ≦ 1 and result:

$$\dot{V} = 2 \cdot \pi \cdot K \cdot R_r^3 \cdot \frac{n}{30} \quad (15)$$

From the relation (15) one can observe that for a chosen speed, the pump's volumetric flow rate is a function:

$$\dot{V} = f(ct \cdot R_r^3) \quad (16)$$

The power to drive the volumetric pump will be [23] [24]:

$$P = \dot{V}\Delta p\ [W] \quad (17)$$

$$P = \pi \cdot l \cdot z \cdot (z + 2R_r) \cdot \frac{n}{30} \cdot \Delta p \quad (18)$$

where Δp is the pressure increase of the fluid between suction and discharge.

The main dimensions of the pump are set according to the geometric and functional parameters as follows:

1. For a given volumetric flow rate $(\dot{V})$ and a selected speed from relation (15), result the size $K \cdot R_r^3$.

2. Depending on the available technology, $K = \frac{l}{R_r}$ ≦1 is chosen.

3. After determining K in relation (15) the value of R_r is obtained.

4. Choosing $z \le 0.733\ R_r$ the case radius results: $R_c = R_r + z$. Thus, the dimensions l, R_r, z, R_c are calculated and the geometric architecture of the rotating volumetric pump results.

5. Conclusions

The use of rotating machine or rotating volumetric pumps has the advantages of:

- The engine torque received at the pump shaft is used almost entirely to increase the potential energy of the flowing fluid. From the above mentioned computational relations, it is noted that $\dot{V} = f(ct \cdot R_r^3)$ what requires special attention to the choice of the rotor radius.
- The studied volumetric pump can transport viscous fluids, suspension fluids and other polyphase fluids.
- The pump's solution is relatively simple and has a higher reliability in operation.

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