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INFLUENCE OF A ROTATING MACHINE ARCHITECTURE ON THE DRIVING POWER

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Abstract—The paper presents the computation method of a pump flow rate and the power required to drive a new type of rotating volumetric pump. The influence of the geometric and functional parameters of the rotating volumetric pump on the theoretical flow rate and on the power required by the machine is revealed.

Keywords—Rotating volumetric pump; rotating profiled piston;

I. INTRODUCTION

Nowadays, researchers seek to create machines to ensure the transformation of the torque received by the shaft into a useful effect with minimal losses. These machines are rotating machines with profiled rotors at which the torque $M = f \cdot b \cdot \sin \alpha$, is maximum during a complete rotation, because the angle α between the force (F) and the force arm (b) is 90^o. The new machine type is "reversible" in the sense that it can act as a working machine or as a force machine. When used as a working machine, the torque transmitted to the shaft is almost entirely used to increase the suction fluid pressure (p_1) at the discharge pressure (p_2).

The machine can be used in the following fields: energy, petro chemistry, agriculture, etc. This type of machine can be used as follows:

I. As a working machine:
- a. pump for the transport of pure fluids or with suspensions;
- b. fan for gas or vapour delivery;
- c. blower;
- d. compressor;
- e. vacuum pump.

II. As a force machine:
- a. hydrostatic motor;
- b. hydraulic motor;
- c. pneumatic motor;
- d. steam motor;
- e. combustion motor.

The advantage of this machine is that the entire torque is used for the fluid transport (for working machines) or the entire thermal energy of the heat exchanger is used to drive the shaft (for force machines).

II. THE CONSTRUCTIVE SOLUTION AND OPERATING PRINCIPLE OF THE ROTATING MACHINE WITH PROFILED ROTORS

The machine consists of two identical profiled rotors (2, 7); they rotate in two cylindrical cases (1, 5), figure 1. The synchronous rotation of the rotors is provided by two gears mounted on the shafts (8, 10), wheels forming a cylindrical gear located outside the machine. The rotors have a rotating movement in reverse direction so that the pistons of a rotor penetrate into the adjacent rotor cavities. In Figure 1.a, after a 180° rotation, the rotating piston (3) reaches the position in Figure 1.b. In this rotation movement, the volume of fluid between the pistons 3 ', 3 of the case 1 and the lateral surface of the rotor (2), denoted by V_u (figure 1), after a rotation of 180 ° of the rotor (2) will be evacuated to the discharge chamber, then outside of the machine. In the following, the machine is considered to operate as a rotating volumetric pump, the fluid pressure increasing from p_1 to p_2.

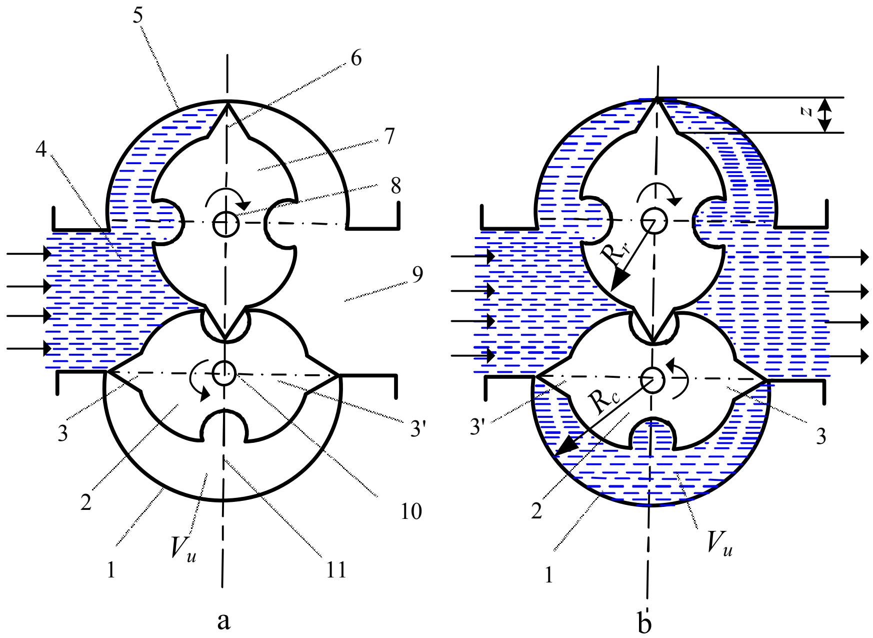

Fig. 1 The rotors position after a 180° rotation
1- lower case; 2- lower rotor; 3,3' – rotating profiled pistons; 4-sucction chamber; 5- upper case; 6-rotating piston of the upper rotor; 7- upper rotor; 8-driven shaft; 9- discharge chamber; 10-driving shaft; 11-cavity in which the upper rotor piston enters

The shape of the rotors is a result of relatively complicated calculations is specified and their construction is performed by a processing C.N.C. centre [1] [2] [3].

III. ESTABLISHING THE FLOW RATE OF THE ROTATING VOLUMETRIC PUMP

After complete rotation of the shaft (10) two volumes (V_u) will be transported from suction to discharge:

$$\dot{V}_u = 2\cdot\left(\frac{\pi R_c^2}{2}-\frac{\pi R_r^2}{2}\right)\cdot l \quad \left[m^3/rot\right] \tag{1}$$

The case radius (R_c) is the sum of the rotor radius (R_r) and the piston height (z), (figure 1).

$$R_c = R_r + z \quad [m] \tag{2}$$

it results:

$$\dot{V}_u = \pi\cdot l\cdot z\left(z+2R_r\right) \quad \left[m^3/rot\right] \tag{3}$$

The volumetric flow rate of a single rotor of length l [m] and speed n_r [rpm] will be:

$$\dot{V}_u = \pi\cdot l\cdot z\left(z+2R_r\right)\cdot\frac{n_r}{60} \quad \left[m^3/s\right] \tag{4}$$

Since the machine has two identical rotors, the flow rate of the fluid delivered by the machine will be:

$$\dot{V}_u = 2\cdot\dot{V}_u = \pi\cdot l\cdot z\left(z+2R_r\right)\cdot\frac{n_r}{30} \quad \left[m^3/s\right] \tag{5}$$

From the relation (5) one can observe that the machine flow rate varies according to the following parameters:
* Geometric Parameters:

l - rotor length [m];
R_r - rotor radius [m];
z - the height of the rotating piston [m].
* Functional parameters:
n_r - machine speed [rpm];

IV. THE COMPUTATION OF THE ROTATING MACHINE DRIVING POWER

The machine is considered to operate as a rotating volumetric pump. In Figure 2 a section through a rotor mounted in a case was drawn. The rotor (1) is attached to the shaft (2) which receives a certain driving power from the outside.

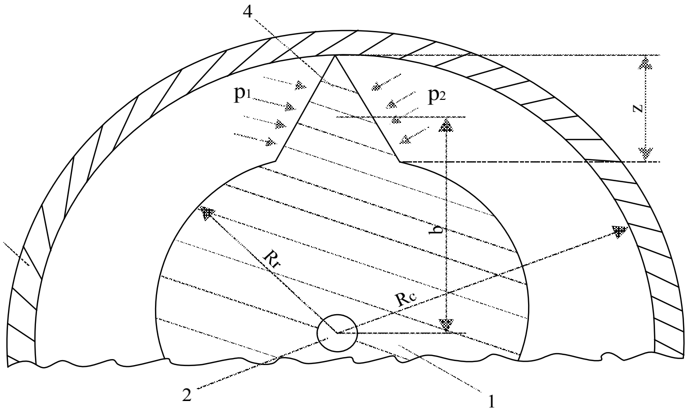

Fig. 2 Computing notations
1 - profiled rotor; 2 - shaft; 3 - case; 4 - rotating piston of triangular shape

As it can be seen in Figure 1, the suction pressure (p_1) is exerted on one piston face and the discharge pressure (p_2) on the other ($p_2 > p_1$); a force acts on the piston:

$$F = A \cdot (p_2 - p_1) \ [N] \tag{6}$$

Where:
A - the area of the transverse section of the piston A = z · l [m²]
z - piston height [m];
l - piston length [m].
So:

$$F = z \cdot l \cdot (p_2 - p_1) \ [N] \tag{7}$$

The torque that is given by a machine shaft is [4] [5]:

$$M = F \cdot b \ [N \cdot m] \tag{8}$$

It is assumed that the force exerted on the piston is applied at its gravity center, that is, at a distance:

$$b = R_r + \frac{z}{2} \tag{9}$$

Equation (8) becomes:

$$M = z \cdot l \cdot (p_2 - p_1) \cdot \left(R_r + \frac{z}{2} \right) \tag{10}$$

The theoretical power transmitted externally by the force machine shaft will be given by:

$$P = M \cdot \omega = 2 \cdot \pi \cdot l \cdot z \cdot \Delta p \cdot \left(R_r + \frac{z}{2} \right) \cdot v \tag{11}$$

So:

$$P = \pi \cdot l \cdot z \cdot (2R_r + z) \cdot (p_2 - p_1) \cdot v \ [W] \tag{12}$$

For the entire machine (or two rotors) the power delivered to the outside will be:

$$P = 2 \cdot P = 2 \cdot \pi \cdot l \cdot z \cdot (2R_r + z) \cdot \Delta p \cdot v \ [W] \tag{13}$$

or:

$$P_m = \pi \cdot l \cdot z \cdot (2R_r + z) \cdot \Delta p \cdot \frac{n}{30} \ [W] \tag{14}$$

The same machine calculating power relation is reached if the formula [7] is considered:

$$P = \dot{V}_m \cdot \Delta p \quad [W] \tag{15}$$

The value of the machine flow rate is given by the equation (10), and results:

$$P = \pi \cdot l \cdot z \cdot (z + 2R_r) \cdot \frac{n}{30} \cdot \Delta p \; [W] \tag{16}$$

Equation (16) is identical to (14) and the following is noted: from equation (14) it is noted that P = f (1, R_r, z^2, n, Δp) relation where the first three parameters are geometric and the next two are functional parameters. It is noted that between P and l, R_r, n, Δp there is a linear dependence, the power of the machine varying proportionally with these parameters. Between P and z there is a second degree function; if in relation (14) $R_r = R_c - z$, is replaced, one can obtain:

$$P = \frac{\pi \cdot l}{30} \cdot n \cdot \Delta p \cdot (2R_c \cdot z - z^2) \tag{17}$$

Replacing $R_c = kz$, unde $k \gtrless 1$

$$P = \frac{\pi \cdot l}{30} \cdot n \cdot \Delta p \cdot (2k \cdot z^2 - z^2) \tag{18}$$

If the derivative is performed and equaled to zero, one can obtain: 2kz - 2z = 0, result k = 1. The result obtained in this equation is that the machine's power is maximum if $z = R_c$. This result is technically real [8] [9] [10].

V. CONCLUSIONS

1. The construction solution is simple and reliable.
2. Two categories of parameters influence the power of the machine built as a pump:
   - geometric parameters: l, R_r, z;
   - functional parameters: n_r, Δp.
3. The most powerful influence on the driving power of the pump is the height of the rotating piston, because P = f (z^2).
4. It is noted that the driving power of the pump varies linearly with l, n_r, Δp, R_c.
5. This type of machine has the advantage of being able to transport fluids with suspensions, polyphase fluids and viscous fluids.

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