RESEARCH REGARDING THE PROFILE OF A ROTATING PISTON USED IN THE DESIGN OF VOLUMETRIC PUMP

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În lucrare se prezintă schiţa şi principiul de funcţionare al unui nou tip de pompă volumică rotativă cu două rotoare profilate, identice, care se rotesc cu aceeaşi viteză unghiulară. Se stabilesc relaţiile de calcul pentru determinarea coordonatelor conturului profilului pistonului rotativ şi ulterior se prezintă un exemplu de calcul

The paper presents the sketch and the functioning principle of a new type of rotating volumetric pump with two identical profiled rotors, which rotate with the same angular speed. The computing relations for deducing the outline coordinates of the rotating piston profile are established. A computing example is subsequently presented.

Keywords: rotating piston, profiled rotor, polyphasic fluid transportation

Introduction

Achieving high performance rotating working machines (pumps, fans, compressors) constitutes a today's problem. Efforts are made for obtaining working machines that ensure the transformation of the motor torque at the shaft level in a useful effect with minimum losses.

The existing constructive solutions, [1], [2], are relatively complicated and have significant friction losses. It is also difficult to provide for a proper tightening between the rotor and the stator. The proposed constructive solution is based on a patent, [3], and ensures polyphase fluid transport; the paper intends to establish the shape of the rotating piston in order to guarantee a better tightening between the two profiled rotors.

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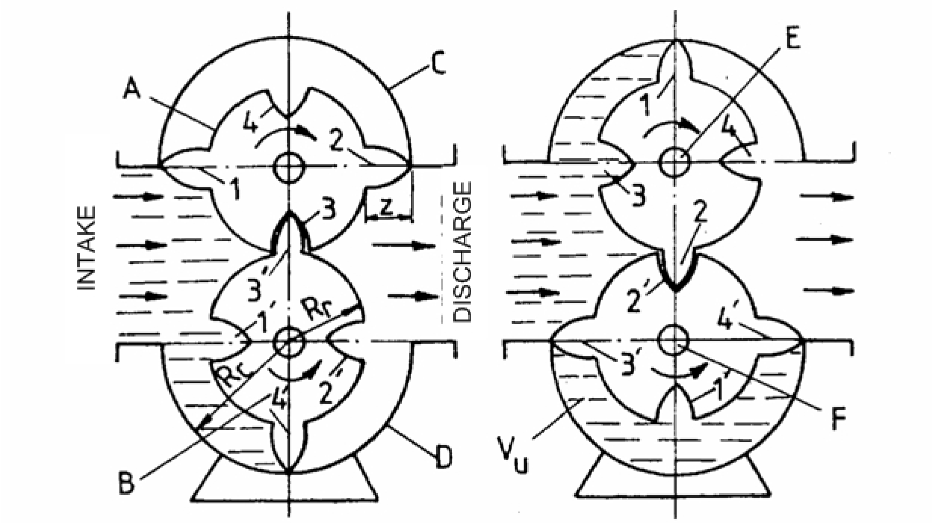
1. Presentation of the constructive solution

The constructive solution and the functioning principle of the pump result from Figure 1.

The two rotors *A* and *B* are tangent and rotate synchronously. There are two ways of guaranteeing the synchronous rotation:



a) b)

Fig. 1. Sketch of the rotating volumetric pump.
A,B – rotors; C, D – half-cylinders; E, F – shafts; 1, 2, 3', 4' – rotating pistons;
1', 2', 3, 4 – cavities in which the pistons penetrate.

- manufacturing of a number of teeth on the lateral surface of the rotors;
- using two gears placed outside the pump and fixed on the shafts *E* and *F* (Fig. 1 b).

The rotating pistons (1, 2, 3', 4' – Fig. 1) enter the cavities of the adjacent rotor.

The suctioned fluid (Fig. 1, a) is transported to the discharge and, after a 90º rotation of both rotors, the system arrives in the position shown in Figure 1 b.

The fluid contained in the available volume V_u (Fig. 1, b), that is the space between the pistons 3' and 4', will be transported to the discharge after a 180º rotation.

Two such volumes will be transported from intake to discharge during a complete rotation.

Computing relations for the flow rate and for the pump driving power are established in [1] and [2]. The computation method for the cavity outline is presented in [4] and [5].

The shape of the rotating piston can be:

a) triangular; in this case there is only one tightening zone between the intake (the low pressure zone) and the discharge (the high pressure zone); this zone appears as a result of the mobile contact between the top of the piston and the inside surface of the casing, respectively of the cavity of the adjacent rotor;

b) a parabole symmetric to the piston axis;

c) a curve with a relatively complex equation; the paper establishes the equations from which the coordinates of the curve points can be deduced; the coordinates are obtained using computation software and are presented in the following paragraph.

2. Establishing computing relations in order to deduce the outline coordinates of the rotating piston profile

The previously presented constructed solution is considered. The rotor radius was chosen $R_r = 50$ mm and the casing radius $R_c = 80$ mm.

If the upper rotor (O_2) is fixed, the point E, placed on the mobile lower rotor (O_1) will arrive to the point A (Fig. 2). Which will be the trajectory of the point E on the annular surface ($R_r \div R_c$) if the two rotors are mobile ?

A rotating coordinate system xO_2y is chosen in order to solve the problem. The coordinates of the point A (x_A, y_A) are established relatively to this system.

The coordinates of point A will be

- I) $x_A = -O_2B = -CD = -AC\cos\alpha.$ (1)

It is obtained from $\Delta\, O_1EC$ that

$$\cos\theta = \frac{O_1E}{O_1C} = \frac{R_r}{R_r + AC} \quad . \tag{2}$$

It results that

$$AC = \frac{R_r(1-\cos\theta)}{\cos\theta} \, . \tag{3}$$

Because in $\Delta\, O_1EC$

$$\theta + 90° + \theta + \alpha = 180° \tag{4}$$

it results

$$\alpha = 90° - 2\theta \, . \tag{5}$$

If (3) and (5) are introduced in (1), it is obtained that

$$x_A = -\frac{R_r(1-\cos\theta)}{\cos\theta} \cdot \cos(90° - 2\theta), \tag{6}$$

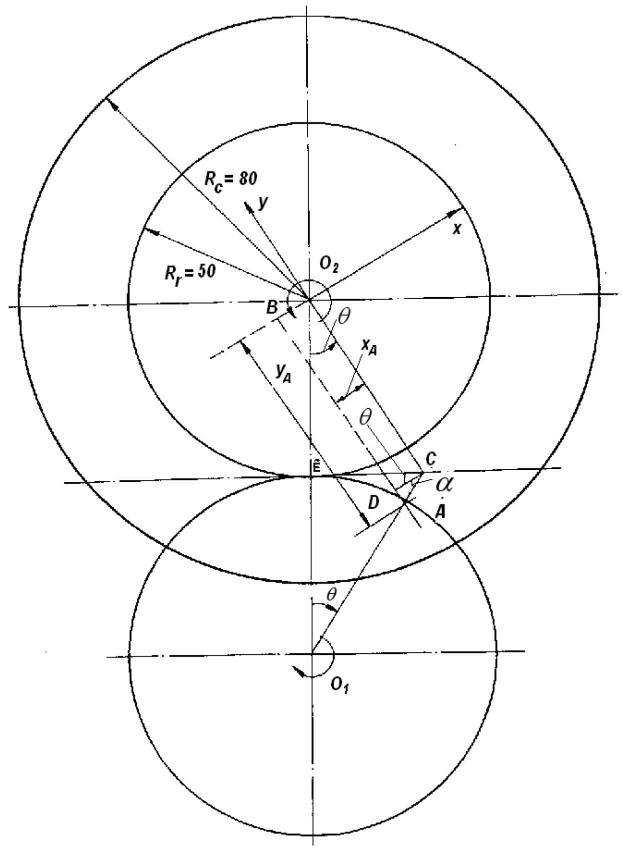


Fig. 2. Notations for computing

or

$$x_A = -\frac{R_r(1-\cos\theta)}{\cos\theta}\cdot\sin 2\theta$$

II) $y_A = -AB = -(BD+DA) = -(O_2C+DA)$ (7)

It is obtained from $\Delta\, O_2EC$ that:

$$\cos\theta = \frac{O_2E}{O_2C} = \frac{R_r}{O_2C};\ O_2C = \frac{R_r}{\cos\theta} \tag{8}$$

$$y_A = -\left(\frac{R_r}{\cos\theta} + AC\sin\alpha\right) = -\left[\frac{R_r}{\cos\theta} + \frac{R_r(1-\cos\theta)}{\cos\theta}\cdot\sin(90° - 2\theta)\right] \tag{9}$$

or $y_A = -\left[\frac{R_r}{\cos\theta} + \frac{R_r(1-\cos\theta)}{\cos\theta}\cdot\cos 2\theta\right]$.

The coordinates of the point *A* will be

$$\begin{cases} x_A = -\dfrac{R_r(1-\cos\theta)}{\cos\theta}\cdot\sin 2\theta; \\ y_A = -\left[\dfrac{R_r}{\cos\theta} + \dfrac{R_r(1-\cos\theta)}{\cos\theta}\cdot\cos 2\theta\right] \end{cases} \quad (10)$$

If the angle θ is eliminated from the system of equations (10), the equation of the curve that establishes the outline of the rotating piston is obtained. This equation is difficult to solve.

3. Computing example

The values in Table 1 are obtained if values R_r=50 mm, R_c=80 mm and θ = 0°, 1°, 2°,…52° are introduced in Equation (10).

Table 1.

Values for x_i, y_i

θ	x_i [m]	y_i [m]	θ	x_i [m]	y_i [m]
0	0	-0,05	27	-0,0049482	-0,0597114
1	-0,2658909	-0,0500152	28	-0,0054953	-0,0603351
2	-0,2125980	-0,0500609	29	-0,0060786	-0,0609660
3	-0,7172460	-0,0501369	30	-0,0066987	-0,0616025
4	-0,0000170	-0,0502430	31	-0,0073564	-0,0622432
5	-0,0000332	-0,0503791	32	-0,0080522	-0,0628863
6	-0,0000573	-0,0505448	33	-0,0087866	-0,0635302
7	-0,0000908	-0,0507398	34	-0,0095601	-0,0641734
8	-0,0001354	-0,0509637	35	-0,0103730	-0,0648142
9	-0,0001926	-0,0512160	36	-0,0112257	-0,0654509
10	-0,0002638	-0,0514961	37	-0,0121184	-0,0660817
11	-0,0003506	-0,0518035	38	-0,0130514	-0,0667050
12	-0,0004543	-0,0521375	39	-0,0140247	-0,0673190
13	-0,0005765	-0,0524973	40	-0,0150384	-0,0679220
14	-0,0007186	-0,0528822	41	-0,0160925	-0,0685123

θ	x_i [m]	y_i [m]	θ	x_i [m]	y_i [m]
15	-0,0008819	-0,0532913	42	-0,0171870	-0,0690881
16	-0,0010678	-0,0537238	43	-0,0183216	-0,0696475
17	-0,0012775	-0,0541786	44	-0,0194963	-0,0701890
18	-0,0015124	-0,0546548	45	-0,0207107	-0,0707107
19	-0,0017737	-0,0551513	46	-0,0219644	-0,0712108
20	-0,0020626	-0,0556670	47	-0,0232572	-0,0716877
21	-0,0023803	-0,0562008	48	-0,0245884	-0,0721395
22	-0,0027277	-0,0567514	49	-0,0259576	-0,0725646
23	-0,0031061	-0,0573176	50	-0,0273641	-0,0729612
24	-0,0033072	-0,0576061	51	-0,0288072	-0,0733276
25	-0,0039596	-0,0584914	52	-0,0302863	-0,0736622
26	-0,0044366	-0,0590963			

Data from Table 1 allow constructing the curve *AC*, which establishes the shape of the profile of the rotating piston (Fig. 3).

The curve *BC* is constructed symmetrical to *AC*, as shown in Figure 3.

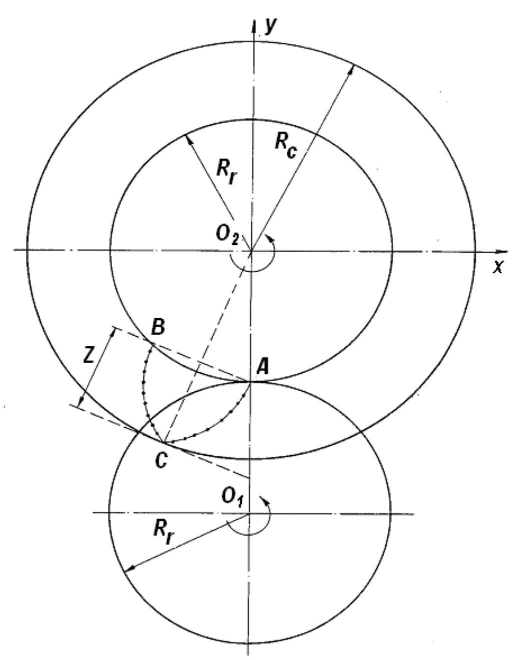


Fig. 3. The outline of the rotating piston, obtained using numerical data (x_i,y_i) from Table 1

The shape of the rotating piston (curve *ACB*) is thus established. A better tightening between intake and discharge is obtained, because of the existence of two contact zones:

- between the piston top and the inside surface of the casing, respectively the cavity of the adjacent rotor (O_1);
- between the cavity edge (point A placed on the rotor O_1) and the lateral surface of the rotating piston (*ACB*) placed on the rotor (O_2).

Conclusions

a. The constructive solution of the pump presented in Fig. 1 belongs to the category of "transport pumps" and not to the pumps which create high pressures; it can be used as fan, compressor or volumetric flow meter.

b. The constructive solution eliminates the disadvantages of other types of rotating pumps (with gear wheels or paddles), where the transported fluid has to be free of solid contaminants; this type of volumetric rotating pump, without valves, can be used for the transport of contaminated, viscous or polyphase fluids.

c. The pump can be easily achieved because the manufacturing technology of the rotors and casing is based on a *CNC* program; the parts are manufactured on a *CNC* center.

d. This type of rotating volumetric pump has real advantages compared to other types of profiled rotor machines [6], [7].

e. The potential users of this type of pump, able to transport any kind of liquid, viscous or polyphase substance, are the specialists in the fields of chemistry, energetics and metallurgy.

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