

Researches on the Influence of Geometric and Functional Parameters on the Flow Rate of a Rotating Machine with Profiled Rotors

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ABSTRACT

The purpose of the paper is to find a solution to increase the fluid flow rate in a designed and built rotating machine.

The increase of the flow rate can take place by modifying the following parameters:

- ❖ The geometrical parameters of the profiled rotors,
- ❖ The functional parameters of the machine, namely its speed.

Constructive solutions of the machine that lead to the increase of the flow rate carried by it are presented; the influence of the speed of the machine on the flow rate is exposed, in the case of the analyzed constructive solutions.

Keywords: Rotating Machine, Profiled Rotors, Rotating Piston.

1. INTRODUCTION

Rotating machines with profiled rotors are meeting in the technique both as force machines and as working machines. A classification of rotating machines with profiled rotors is presented in table 1 [1].

Table 1: Classification of Rotating Machines with Profiled Rotors

Classification according to the pursued purpose	Classification from a constructive point of view
<i>Working machines</i>	Pumps for driving fluids or suspensions
	Fans for transporting gases or vapors
	Blowers for gas and vapor compression
<i>Power machines</i>	Hydraulic motors
	Pneumatic motors
	Steam engines or combustion gases

A more difficult problem is to make a rotating machine that can be used as a working machine or a power machine that is theoretically a "reversible" machine.

Such a machine must provide:

- transforming the useful moment with minimal losses when it works as a working machine.
- maximum use of energy of the working agent for the shaft actuation when it works as a force machine.

Pumps are used for the transport of some incompressible fluids, which in the case of the present paper takes the form of a rotating volumetric pump with two profiled rotors.

This constructive solution has the advantages [2]:

a) Can carry any type of nano or polyphase fluid as:

- water, oil, gas;
- water + ash, water + sand;
- food liquids, rheological fluids.

b) At this type of machine there are no moving parts, no valves, etc.

c) The machine has a high reliability and no special materials or technologies are required for its construction.

d) Essential is the construction of the rotors, for which there is a calculation program [3] that can be adopted at a computer center with numerical control (C.N.C.).

For the analyzed constructive solution, depending on the required flow rate, the length of the rotor, its radius and the height of the piston are chosen, resulting in the rotor architecture.

2. OPERATION AND CONSTRUCTION SOLUTION OF THE ROTATING MACHINE WITH PROFILED ROTORS

The fluid sucked into chamber 1 (figure 1) is transported to the discharge chamber (7) by the rotating pistons. The machine has two profiled rotors that rotate counterclockwise inside the case (Figure 1). Each rotor has two rotating pistons that penetrate into the adjacent rotor cavities. The synchronous rotation of the two rotors (3, 8) is ensured by means of two gear wheels which form a cylindrical gear with straight teeth.

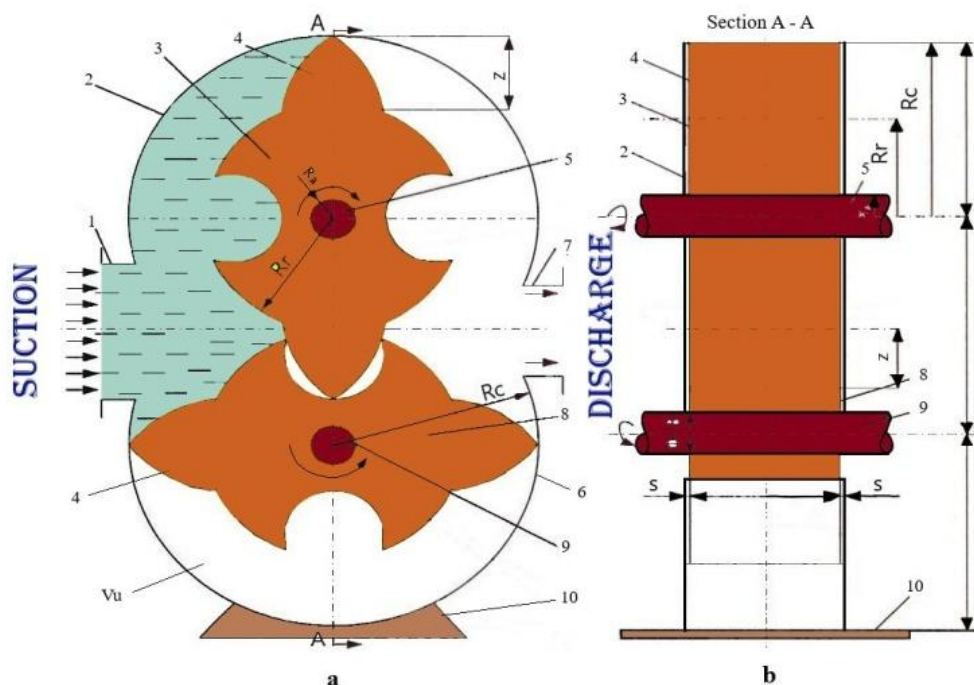


Fig 1: Cross (A) and Longitudinal (B) Section of the Rotating Machine

1 - suction chamber; 2 - upper case; 3 - driven rotor; 4 - rotating piston; 5 - driven shaft; 6 - lower case; 7 - the fluid discharge chamber; 8 - driving rotor; 9 - driving shaft; 10 - machine support.

The shape of the rotor contour was established in [4], and the manufacturing technology in [5].

Such a rotating machine, as a working model, was designed and built in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's of the University Politehnica of Bucharest. With the notations in Figure 1, the relations of calculation of the flow rate driven by the machine and the driving power of the machine are [6], [7]:

$$\dot{V} = \pi l z (2 \cdot R_r + z) \cdot \frac{n}{30} [m^3 / s] \quad (1)$$

$$P_m = \dot{V}_m \cdot \Delta p = \pi l z (2 \cdot R_r + z) \cdot \frac{n}{30} \cdot \Delta p [W] \quad (2)$$

Where, n - machine speed in [rot / min]; Δp - increase in pressure between suction and discharge in N / m^2 .

The pressure increase can also be expressed by the water column meter (H) [8].

$$\Delta p = \rho_{H_2O} \cdot g \cdot H [N / m^2] \quad (3)$$

$$P_m = \pi l z (2 \cdot R_r + z) \cdot \frac{n}{30} \cdot \rho_{H_2O} \cdot g \cdot H [W] \quad (4)$$

3. ESTABLISHING THE MATHEMATICAL RELATION BETWEEN THE ROTOR RADIUS, THE ROTATING PISTON HEIGHT AND THE ROTATING MACHINE CASE RADIUS

Consider a single piston (4) fixed to the lower rotor (Figure 2).

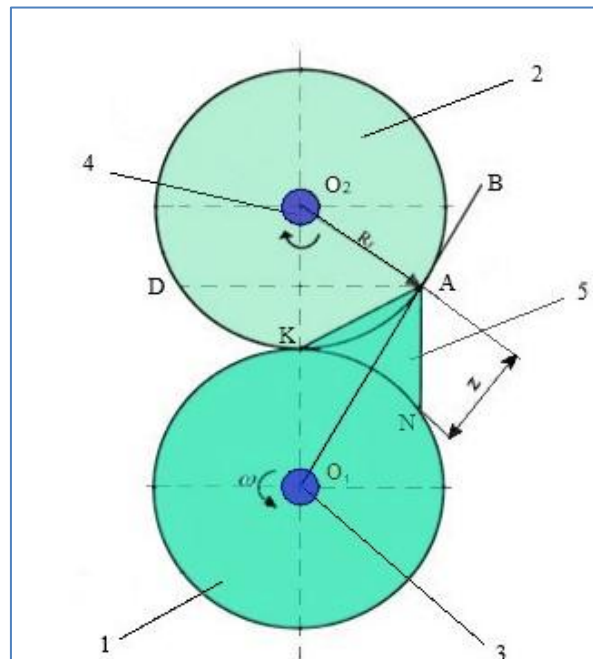


Fig 2: Calculation Notations

1 - lower rotor; 2 - upper rotor; 3 - driving shaft;

4 - driven shaft; 5 - rotating piston of triangular shape.

The radius of the rotor (1) is extended by a length (z) and thus the line O_1B reaches the rotor (2) at point A. Theoretically, when point K reaches point D, point A reaches K, respectively point N reaches K, because the length of the arcs circle AK, KD and KN is the same. When the piston (5) exits the gap created in the rotor (2), points A and N reach point K; the sealing between the two rotors being ensured by the direct contact between the lateral surfaces of the rotors.

From the rectangular triangle O_1O_2A results [9]:

$$O_1O_2^2 = AO_2^2 + AO_1^2 \quad (5)$$

$$(2R_r)^2 = R_r^2 + (R_r + z)^2 \quad (6)$$

relation that becomes:

$$z^2 + 2R_r z - 2R_r^2 = 0 \quad (7)$$

If in the relation (7) the derivative is performed according to z , $z = R_r$ is obtained; this means that the flow rate of the machine is maximum when the height of the piston is equal to the rotor radius.

The same result is obtained if the relation (7) is replaced:

$$R_r = R_c - z \quad (8)$$

$$z^2 + 2z(R_c - z) - 2(R_c - z)^2 = 0 \quad (9)$$

$$3z^2 + 6zR_c - 2R_c^2 = 0 \quad (10)$$

Performing the derivative according to z , from the relation (6) one can obtaine:

$$z = R_c \quad (11)$$

This result is theoretically correct, but difficult to achieve in practice.

4. THE INFLUENCE OF THE ROTATING PISTON HEIGHT AND THE MACHINE SPEED ON THE FLOW RATE TRANSPORTED BY THE ROTATING MACHINE

The relation (1) is repeated, which specifies the value of the flow rate transported by the rotating machine with two profiled rotors:

$$\dot{V} = \pi l z (2 \cdot R_r + z) \cdot \frac{n}{30} [m^3 / s] \quad (12)$$

There are specified:

- case radius: $R_c = 0.08$ [m];
- rotor length of: $l = 0.05$ [m];
- rotating piston height: z [m];
- machine speed $n = 100$ [rot / min].

In addition, two conditions appear:

- The rotors must always be tangent;
- The condition must be respected $R_r \geq z$.

In the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's, a rotating machine with the above data was built, for which the calculations with these data will be performed.

$$\dot{V}_I = \frac{\pi \cdot 0.05}{30} \cdot 0.01(0.01 + 2 \cdot 0.07) \cdot 100 = 0.0007850 [m^3 / s] \quad (13)$$

$$\dot{V}_I = 0.7850 \cdot 10^{-3} [m^3 / s] \quad (14)$$

Similarly, successively modifying the value of z (0.02; 0.03; 0.04 m) the values from table 2 are obtained, taking into account that the two conditions must be respected:

$$\begin{cases} R_c = R_r + z \\ R_r \geq z \end{cases} \quad (13)$$

Table 2: Values of $\dot{V} = f(z)$ for $n_r = 100$ [rot/min]

Version no.	I	II	III	IV
z [m]	0.01	0.02	0.03	0.04
R_r [m]	0.07	0.06	0.05	0.04
R_c [m]	0.08	0.08	0.08	0.08
n_r [rot/min]	100	100	100	100
$\dot{V}_1 \cdot 10^{-3}$ [m ³ /s]	0.7850	1.4653	2.0410	2.5120

Based on the data in table 2, in figure 3 graph 1 was plotted. From figure 3 one can observe that the flow rate is maximum when $z = R_r = 0.04$ [m] which confirms the conclusion resulting from equation (7).

If now the machine speed is changed, the versions are obtained:

$$\dot{V}_2 \cdot 10^{-3} \text{ [m}^3\text{/s] for } n_r = 200 \text{ [rot/min]}$$

$$\dot{V}_3 \cdot 10^{-3} \text{ [m}^3\text{/s] for } n_r = 300 \text{ [rot/min]}$$

$$\dot{V}_4 \cdot 10^{-3} \text{ [m}^3\text{/s] for } n_r = 400 \text{ [rot/min]}$$

Rezultatele de calcul sunt prezentate în tabelul 3.

Table 3: Values of $\dot{V} = f(z)$ for varying n_r

Version no.	I	II	III	IV
z [m]	0.01	0.02	0.03	0.04
$\dot{V}_2 \cdot 10^{-3}$ [m ³ /s]	1.5700	2.9307	4.0820	5.0240
$\dot{V}_3 \cdot 10^{-3}$ [m ³ /s]	2.3550	4.3960	6.1230	7.5360
$\dot{V}_4 \cdot 10^{-3}$ [m ³ /s]	3.1400	5.8613	8.1640	10.0480

Based on the data in table 3, the graphs 2, 3, 4 have been drawn in figure 3.

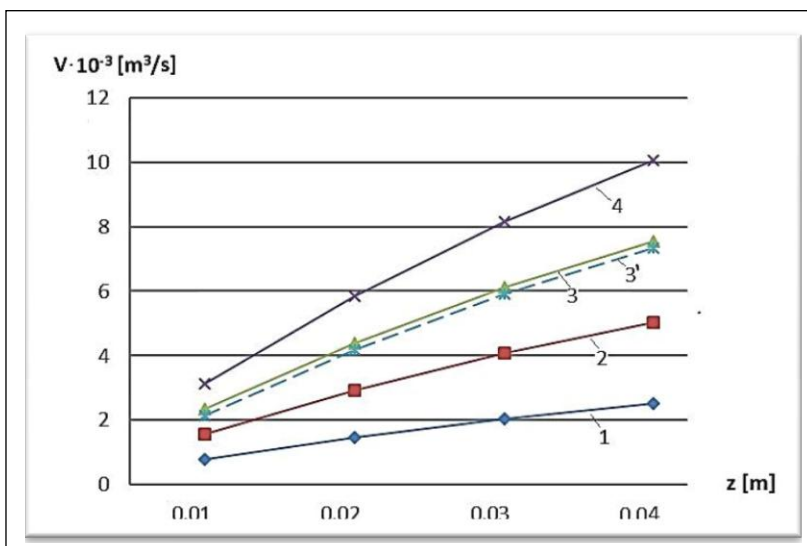


Fig 3: Graphical Representation of the Function $\dot{V} = f(z)$ for Different Machine Speeds

1 - $n_r = 100$ [rot/min]; 2 - $n_r = 200$ [rot/min]; 3 - $n_r = 300$ [rot/min]; 4 - $n_r = 400$ [rot/min]; 3' – experimental data.

Previous experimental researches [10] confirms the accuracy of the performed calculations; thus graph 3' (figure 3) is very close to graph 3.

5. CONCLUSIONS

(1) From the paper it appears that for good functioning, two conditions must be respected:

$$R_c = R_r + z \text{ and } R_r \geq z$$

(2) From equation (7) results that the flow rate is maximum when $z = R_r$.

(3) From figure 3 results that the volumetric flow of fluid rate conveyed by the machine increases with:

- increasing the height of the rotating piston;
- increasing the speed of the machine.

(4) The calculation results were obtained starting from an experimental prototype built in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's of University Politehnica of Bucharest.

(5) For version III these data were experimentally verified, obtaining a good coincidence with the data resulting from the calculation.

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