A Volumetric Working Machine with Profiled Rotors for Fluids Circulation

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Abstract: *The paper presents a constructive solution of a new type of volumetric rotating machine, with two profiled rotors, which can transport clean fluids or polyphasic fluids. The operation principle of the machine is set out and the computation relations are established for:*
- the rotating machine flow rate;
- the power required to drive the rotating machine.
At the end of the paper, the advantages of this machine are highlighted compared to other machines for fluids circulation.

Keywords: *Rotating machine, Profiled rotors, Polyphase fluids*

1. Introduction

The paper presents a type of rotating working machine with profiled rotors that can operate [1], [2]:
- As a fan, for the circulation of different gas mixtures with or without suspensions.
- As a low-pressure compressor.
- As a rotating volumetric pump for the transport of any type of fluid, liquid, or gas, namely:
- general fluids: water, air, steam, etc.
- polyphasic fluids: water and air, water and sand, water, and ash, etc.
- viscous fluids: oil, diesel, oil, etc.

Table 1 presents a general classification of rotating machines.

Table 1: A general classification of rotating machines

According to the pursued purpose	**Depending on the constructive solution**	**According to the working parameters**
Working machines	With profiled rotors	a) Fans, blowers, pumps
	With pallets	b) Fans, blowers
Force machines	With profiled rotors	c) Internal combustion engines, steam or gas engines, pneumatic engines
	With pallets	d) Steam turbines, gas turbines

The construction of rotating working machines (pumps, fans, blowers) with high performance is topical.
The research aims to build machines that ensure the transformation of the engine torque received from the shaft into useful effects, but with energy losses as small as possible.

Table 2 presents the classification of rotating machines with profiled rotors according to the intended purpose and the constructive solution adopted [1].

Table 2: Classification of rotating machines with profiled rotors

According to the pursued purpose	Depending on the constructive solution
Working machines **Force machines**	Fans for the circulation of gases or vapors
	Blowers for gas and vapor compression
According to the pursued purpose	Hydraulic motors
	Pneumatic motors
	Steam or flue gas engines

2. Presentation of the constructive solution and the operating principle of the rotating machine with two profiled rotors

The machine consists of (figure 1) two identical rotors (2, 5) of special shape, which rotate at the same speed inside some housings (1, 4). The synchronous rotation of the rotors is ensured by two gears fixed on the shafts 7 and 9 which form a cylindrical gear mounted on the outside of the rotating machine [2] [3].
The determination of the contour shape of the two rotors is performed based on a calculation program [3] [4], and the construction of the rotors takes place on a numerically controlled centre [5] [6].

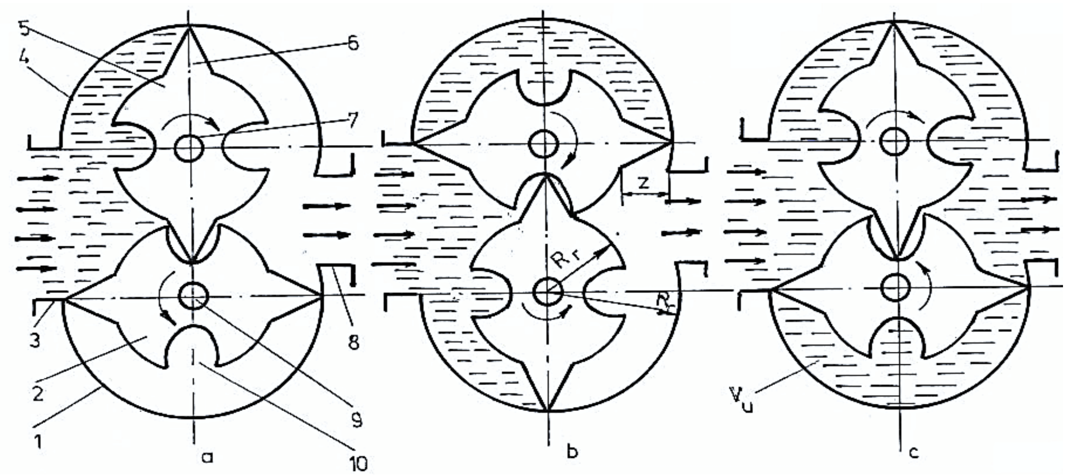

Fig. 1. Rotor position after a 90°rotation
1-lower case; 2-lower rotor, 3-suction chamber; 4-upper case; 5-rotor top; 6-rotating piston; 7-driven shaft; 8-discharge chamber; 9- driving shaft; 10-cavity into which the upper rotor piston enters

The aspirated fluid (figure 1.a) is transported for discharge and after a 90° rotation of both rotors, it reaches the situation in figure 1.b and later in figure 1.c.

3. Establishing the calculation relation of the flow rate transported by the machine

After a 180 ° rotation, the fluid in the useful volume V_u (figure 1.c), i.e., in the space between the pistons, the lower case (1) and the lower rotor (2), will be sent to the discharge chamber. At a complete rotation of the shaft (9) two such volumes will be transported from suction to discharge [1] [2] [3]:

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

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

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

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 the fluid discharged by a single rotor of length l [m] and speed n_r [rot/min] 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 fluid flow rate transported 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 relation (5) one can observe that the flow rate transported by the rotating machine will increase exponentially when the parameters change: l - rotor length [m];z - rotating piston height [m];R_r - rotor radius [m]; n_r - machine speed [rpm].
Obviously, a certain ratio must be established between the rotor radius (R_r) and the piston height (z).

4. Establishing the calculation relation of the driving power of the rotating machine

The presented rotating machine is a volumetric pump, which must achieve a pressure increase equal to Δp [N / m^2]. In this case, the relation (7) will give the theoretical driving power of the machine [8]:

$$P = \dot{V}_m \cdot \Delta p \quad [W] \tag{6}$$

Substituting from relation (5), one can obtain:

$$P = \pi \cdot l \cdot z \cdot \left(z + 2R_r\right) \cdot \frac{n_r}{30} \cdot \Delta p \quad [W] \tag{7}$$

From relation (7) one can observe that the machine power varies according to the following parameters:
* Constructive parameters: l - rotor length [m]; R_r - rotor radius [m]; z - rotating piston height [m].
* Functional parameters: n_r - machine speed [rpm]; Δp- the increase in pressure achieved by the pump between suction and discharge.
The actual driving power of the rotating volumetric pump will be higher [9] [10]:

$$P_r = \frac{P}{\eta_e} \quad [W] \tag{8}$$

where η_e is the effective efficiency of the pump:

$$\eta_e = \eta_v \cdot \eta_m \cdot \eta_h \tag{9}$$

where:
η_v is the volumetric efficiency of the pump.
η_m is the mechanical efficiency of the pump.
η_h is the hydraulic efficiency of the pump.

5. Advantages of the rotating machine compared to other machines used to transport fluids

The evaluation of a technical solution must consider the following aspects:
a) Increased installation efficiency.
b) Increased reliability.
c) A wide field of operation.

d) The value of the investment should be as small as possible.
- The aspirated fluid is conveyed to the discharge with minimal energy losses; thus, the engine torque is $\vec{M} = \vec{F} \times \vec{b} \rightarrow M = Fb\sin\alpha$, where F is the force pressing on the rotating piston; b is the arm force: $b = R_r + \frac{z}{2}[m]$.
The force F is always perpendicular to the arm, so the angle α between the force and the arm will be 90°; as a result, sin90° = 1. This leads to an advantage over piston machines where α is variable over 360°. As a result, neglecting the friction between the rotors and the case, the entire engine torque received from the drive motor is used to convey the fluid.
- The constructive solution presented in the paper has only rotating moving parts; it has a safe operation and easy maintenance.
- This type of rotating volumetric pump can carry any fluid:
* In the field of constructions: different solutions, diesel, etc.
* In the field of hydrotransport: water + sand, water + ash.
* In the food field: oil, syrups, etc.
* Rheological fluids.
* Other pure or polyphase fluids with low or high viscosity; once they reach the pump suction, they are conveyed to the pump discharge.
- The investment for the construction of a pumping installation [9] is not large; this is because a calculation program is available for the construction of the rotors [4] and their construction can be performed on a numerically controlled computer centre [5].

6. Conclusions

- The constructive solution presented in the paper was designed and built in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment within the Faculty of Mechanical and Mechatronics Engineering; after its construction, the pump was tested.
- The results of experimental researches are presented in the paper [11]; it is important that for this type of rotating volumetric pump an effective efficiency $\eta_e = 0.77$ was experimentally determined, a value that exceeds the results obtained for piston pumps, centrifugal pumps, etc. [9] [10] [11].
- This type of pump can be used in the following fields: in agriculture for irrigation, in energy for hydrotransport, in civil or industrial constructions for the circulation of high viscosity fluids; this type of machine can also be used as a fan or low-pressure compressor.

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