Advanced Materials Research Vol. 905 (2014) pp 487-491
Online available since 2014/Apr/28 at www.scientific.net

doi:10.4028/www.scientific.net/AMR.905.487

Influence of the rotor architecture and of the speed on the volumetric efficiency of a new type of rotating volumetric machine

Malik HAWAS[1, a], Nicolae BĂRAN[1,b] and Antonios Detzortzis [1,c]

[1] Independence Splai 313, cod 060042, Bucharest, Romania

[a]maliknhawas@yahoo.com, [b]n_baran_fimm@yahoo.com,[c]tony@elrom.net

Keywords: rotating volumetric machine, rotating piston

Abstract. In this paper the authors establish the calculus expression of the volume flow rate for a new type of working machine that can work as pump, fan or low pressure compressor.The calculation of volumetric efficiency is established for a new type of machine.The results of the experimental research on the influence of the speed on the volumetric flow rate of the machine are exposed.

Introduction

For piston machines, the alternating rectilinear movement of the piston is transformed in a rotation movement by using a slider-crank mechanism; this mechanism generates energy losses because of the frictions that can appear during its work. In their research, authors oriented towards eliminating this mechanism, by constructing some rotating mechines that could work as well as motor machines (rotating thermic motors) or as working machines (pumps, fans, compressors).

The energy provided from outside by the machine shaft is transformed almost entirely in pressure potential energy because the motor movement: $M=F\cdot b=F\cdot b\cdot sin\alpha$ is maximal; the force (F) exerced by the piston is always pependicular (α=90) on the force arm (b).

The force arm is the sum between the rotor radius (fig.1) and half of the height of the rotating piston. Researches made by the authors in the rotating machines field have as a departure point a patent [1].

The term of „rotating machine" from the title of this paper refers to the fact that this machine type can work as a pump, fan or low pressure compressor, namely the machine can transport liquids or gas with or without suspensions. In this paper the authors analyze the work of this machine only as a volumetric pump with profiled rotors.

Proposition for the constructive solution

The machine is composed (fig.1) by two identical rotors (2,5) with a special shape, that rotate with the same speed inside the casings (1,4); the synchronous rotations of the two rotors is provided by a cylindrical gearing composed by two gears with inclined teeth, placed inside or outside the machine. The gear wheels have the same pitch diameters and are placed on the shafts 7 and 9; they provide a rotation motion such that the rotating pistons (6) of the upper rotor can enter in the cavities (10) of the lower rotor.

It can be remarked from fig.1 that for a 360^o rotation of one shaft, two volumes will be transported from the intake to the discharge chambers:

$$V_u = \left(\pi \cdot R_c^2 - \pi \cdot R_r^2\right) \cdot l \ [m^3 / rot] \quad (1)$$

where: R_c- the radius of the casing [m]; R_r-the rotor radius [m]; l- the length of the rotor [m].

By replacing $R_c = R_r + z$, where z is the height of the rotating piston, it results:

$$V_u = \pi \cdot l \cdot z \cdot \left(2R_r + z\right) \ [m^3 / rot] \quad (2)$$

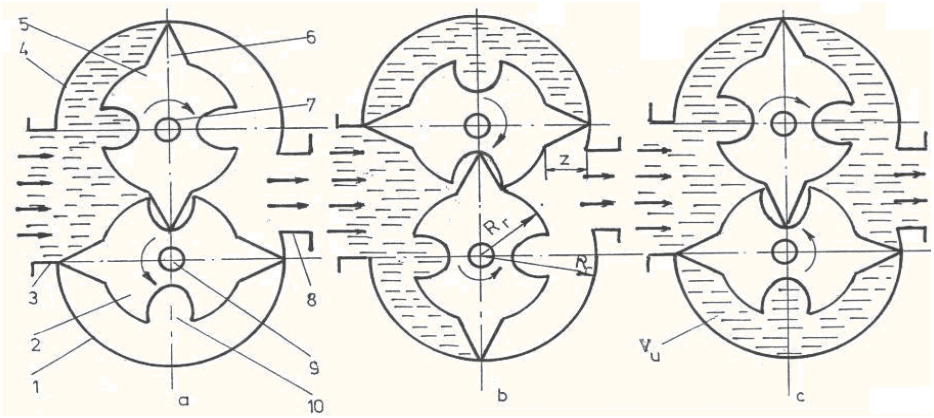

Fig. 1. The working principle of the volumetric rotation machine
a,b,c, the position of the rotors after a 90° rotation
1 – lower casing; 2 – lower rotor; 3 – intake chamber; 4 – upper casing; 5 – upper rotor; 6 – rotating piston ; 7 – driven shaft; 8 – discharge chamber; 9 – driving shaft; 10 – cavity where the upper rotor piston enters

The volumetric flow rate of the fluid transported by a rotor will be of:

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

where: n- rotational speed of the machine [rpm];
For the whole machine, which has two identical rotors, the theoretical flow rate will be of:

$$\dot{V}_t = 2 \cdot \dot{V} = \pi \cdot l \cdot z \cdot (2R_r + z) \cdot \frac{n}{30} \quad [m^3/s] \tag{4}$$

The theoretical power necessary to drive the machine will be of [2]:

$$P_m = \dot{V}_t \cdot \Delta p \quad [W] \tag{5}$$

where: $\Delta p = p_r - p_a \quad [N/m^2]$; p_r-the discharge pressure; p_a-the intake pressure.
It can be remarked from the relation (4) that:
- the volumetric flow rate increases linearly depending on the length and radius of the rotor (l, R_r) and with the speed (n);
- the volumetric flow rate increases depending on the square of the piston height (z).

Establishing the calculating relation for the volumetric efficiency of this new type rotating volumetric machine

The volumetric efficiency (η_v) of the machine is computed as the ratio between the real volumetric flow rate ($\dot{V}_r$) and the theoretical volumetric flow rate($\dot{V}_t$) [2] [3] [4]:

$$\eta_v = \frac{\dot{V}_r}{\dot{V}_t} \tag{6}$$

That characteristic is important because it interferes in the expression of effective machine efficiency (η_e). The internal architecture of the rotating pump is very simple and thus the energy loses on fluid transportation through pump could be neglected, meaning that it is possible to neglect the hydraulic efficiency (η_h). With this assumption the effective efficiency could be defined as a ratio between two powers or as a multiplication of two efficiencies [4]:

$$\eta_e = \eta_v \cdot \eta_m \tag{7}$$

where: η_m is the pump mechanical efficiency. The volumetric efficiency takes in consideration the volumetric loses of fluid($\Delta \dot{V}$) [2].Relation (6) can be written:

$$\eta_v = \frac{\dot{V}_r}{\dot{V}_t} = \frac{\dot{V}_t - \Delta \dot{V}}{\dot{V}_t} = 1 - \frac{\Delta \dot{V}}{\dot{V}_t} \tag{8}$$

where: $\Delta \dot{V}$ is the fluid flow loss due to:

- back-flow from discharge to intake in the following interstices (gaps):
- radial gap between the pistons' edges and inner cylindrical surface of the cases (1) and (4) (fig. 1).
- frontal gap between the lateral surfaces of rotors (2) and (5) and the inner surfaces of lateral walls, which are fixed on case.

By replacing relation (4) in (8), it is obtained that:

$$\eta_v = 1 - \frac{30 \cdot \Delta \dot{V}}{\pi l z \left(z + 2R_r \right) n} \tag{9}$$

Without evaluating, at this time, the influence of $\Delta \dot{V}$ from the relation (8), it is noticed that the volumetric efficiency increases in correspondence with the increase of constructive parameters *l*, *z*, R_r and functional parameter *n*.

Experimental research

Experimental researches on the influence of the piston height (z) and on the rotor radius (R_r) on the flow rate transported by the machine involve large investments that authors cannot afford.

Consequently, it was studied experimentally in the laboratory only the influence of the machine speed on the flow rate transported by the machine.

For the rotating volumetric working machines used for the transport of the fluids, the characteristic curves are experimentally constructed depending on the overflow pressure [6] or depending on the rotational speed [7].

First of all we constructed theoretically the characteristic diagram $\dot{V}_t = f(n)$, for R_r=0.05 m; l=0.05 m; z= 0.03 m.

After examination of the value range of the rotational speed of the machine the following values were chosen: n=300, 320, 340, 360, 380, 400 rpm; the values of the theoretical flow rate $(\dot{V}_t)$ exposed in table 2 were obtained for these rotational speeds, from relation (9).

Table 1.Values of the theoretical flow rate function of n

n [rpm]	300	340	360	380	400
$\dot{V}_t [l/min]$	367.38	416.36	440.85	465.34	489.84

The characteristic curve $\dot{V}_t = f(n)$ (fig.2) was traced using data from table 2.

The function presented in figure 2 is linear; when n increases, the volumetric flow rate of the machine increases proportionally with the rotational speed.

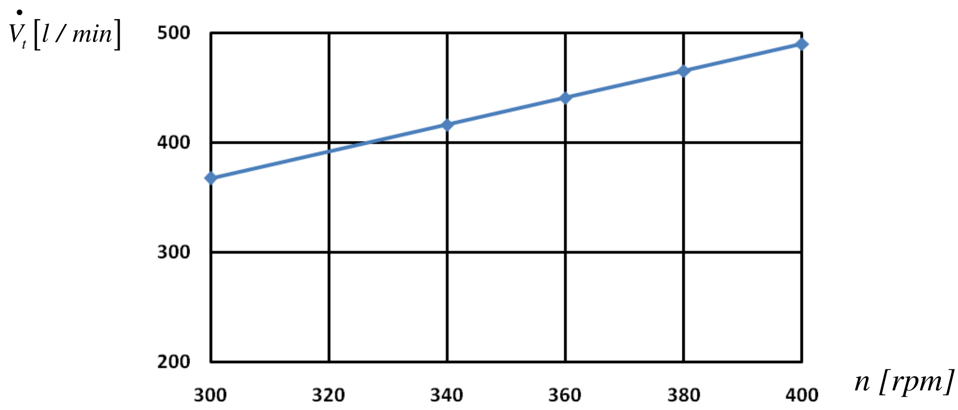

Fig. 2. Characteristic curve $\dot{V}_t = f(n)$

Using the experimental researches made in the frame of the Department of Thermotechnics, Engines, Thermic and Refrigeration Equipment, the rotating machine was tested in the same range of rotational speeds, measuring with an electromagnetic flow meter the real fluid flow rate $(\dot{V}_r)$ transported by the machine.

The results of the measurements are exposed in table 2.

Table 2.Values of the real flow rate function of n

n [rpm]	300	340	360	380	400
$\dot{V}_r\,[l/min]$	349.00	396.37	421.01	444.86	470.24

Figure 3, constructed using the data from table 3, presents the characteristic curve $\dot{V}_r = f(n)$ in both cases: the theoretical and the real one.

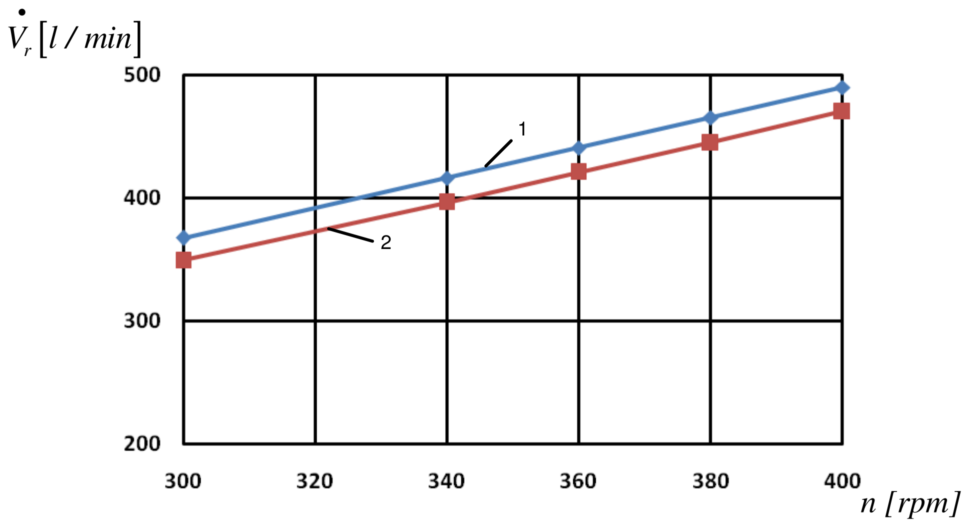

Fig. 3.Characteristic curve $\dot{V} = f(n)$

1-curve constructed using theoretical data; 2 – curve constructed using experimental data

A good coincidence between the two curves can be remarked from figure 3; the difference is:

$$\Delta\dot{V} = 367.38 - 349.00 = 18.38\ \ l/\min \qquad (10)$$

Experimental data lead to a volumetric efficiency of:

$$\eta = \frac{\dot{V}_r}{V_t} = \frac{349}{367.38} = 0.94 = 94\% \qquad (11)$$

This value coincides well with data from the specialty literature [6] [7] for this type of rotating volumetric machine.

Conclusions

1. The fluid flow rate transported by the machine increases when the height of the piston increases and decreases when the radius of the rotor increases; this happens if the radius of the casing is constant;
2. When the rotational speed of the machine increases, the fluid flow rate increases linearly depending on it.
3. Compared to working machines with pistons with rectilinear alternating movement used for the transport of the same fluid flow rate, the energy consumption is lower in the case of rotating working machines with profiled rotors, because the motor torque at the shaft level is almost entirely transmitted to the transported fluid.
4. This new type of working machine can successfully replace any type pf pump and cpompressor with relatively low discharge pressures.
5. The values of volumetric efficiency fit in the data from specialty literature.
6. The machine has an increased reliability, providing the transport of the polyphase fluids, with low and high viscosity.
7. This machine type can be used in the energy, chemical and mineral oil fields.

References

[1] N. Băran, Ghe. Băran a. o. „Steam rotating motor", Patent no.111296 released by the State Office for Inventions and Trademarks OSIM Bucharest. (1996).

[2] N. Băran, P. Răducanu a.o.„ Bases of Technical Thermodynamics" Technical Thermodynamics, (in Romanian), no. 3, POLITEHNICA PRESS Publishing House, Bucharest. (2010)

[3] N. Băran, A.Detzortzis, M. Bărăscu, „Influence of the rotor shape on the flow rate transported by a machine with profiled rotors" Termotehnica, no.1, AGIR Publishing House, Bucharest. (2012)

[4] N. Băran, I. M. Căluşaru, Antonios Detzortzis, Research Regarding the Testing of a New Type of Rotating Machine with Profiled Rotors, Journal of Materials Science and Engineering A 2 (3) (2012), pp. 372-376.

[5] A. Motorga, „Influence of constructive and functional parameters on the performances of rotating machines with profiled rotors" (in Romanian), PhD Thesis, Faculty of Mechanical Engineering and Mechatronics, POLITEHNICA University of Bucharest. (2011)

[6] M.Exarhu, „Hydraulic and pneumatic machines and plants" (in Romanian),Andor Tip S.R.L Publishing House. Bucharest. (2006).

[7] C., Turcanu, N., Ganea, „Volumetric pumps for liquids" (in Romanian), Technical Publishing House. (1987).

Advances in Applied Materials and Electronics Engineering III
10.4028/www.scientific.net/AMR.905

Influence of the Rotor Architecture and of the Speed on the Volumetric Efficiency of a New Type of Rotating Volumetric Machine
10.4028/www.scientific.net/AMR.905.487