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Rotating Volumetric Pump for Wastewater Conveyance

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ABSTRACT

This paper describes the operating principle and the constructive solution for a rotating volumetric pump with two profiled rotors. Calculation relations are established for the flow rate and the driving power of the rotating pump. An example of a calculation for determining the pump driving power according to the conveyed flow rate is presented; the flow rates were chosen for the case when the pump would be used in an irrigation pumping station. The pump can carry different categories of fluids such as: (1) Fluids with suspended particles (water + ash, water + sand), (2) Viscous fluids (oil, diesel, oil), (3) Multi-phase fluids (water + air, water + steam).

Keywords: Rotating Volumetric Pump, Profiled Rotors, Multiphase Fluids.

1. INTRODUCTION

The machines are aggregates used for the transformation of energies from one form to another with the help of a movable organ which can be: profiled rotor, piston, and blade. *Depending on their required purpose, the machines can be classified into two categories [1],[2]:*

1. Power machines (motor machines) that convert a certain form of energy into mechanical energy; for example: internal combustion engines, steam turbines, gas turbines, etc.

2. Working machines that convert mechanical energy into another form of energy, for example: pumps, fans, compressors.

Both power and working machines are traversed by fluids; according to the flow variation parameters, it is classified as follows:

1. Hydraulic machines that drive or are driven by fluids, neglecting thermal phenomena.

2. Thermal machines that carry gases or vapors (or are driven by them) in which the thermal processes that occur cannot be neglected.

From the class of hydraulic working machines, the present paper deals with a rotating volumetric pump. According to the operating principle, the pumps can be classified into two categories:

1. Volumetric pumps (with piston, with blades, with profiled rotors).
2. Non-volumetric pumps (centrifugal pumps, axial pumps).

From the volumetric pump class, a volumetric pump with profiled rotors will be analyzed; the rotor has a special shape contour mathematically established.

The main advantages of this volumetric pump with profiled rotors consist of the following [3]:

- There are no alternate rectilinear moving parts;
- The mechanical rubbing is reduced;
- The torque received at the pump shaft is used almost entirely to increase the potential position energy of the fluid.

2. OPERATING PRINCIPLE AND CONSTRUCTIVE SOLUTION OF A ROTATING PUMP WITH PROFILED ROTORS

A rotating volumetric pump with profiled rotors is composed *(figure 1)* of two profiled rotors (2), (5), which rotate at same speed inside a case (1), (4); the profiled rotors are engaged by two gear wheels (7) *(figure 2)*, thus ensuring their synchronization. The gear wheels are mounted on the outside of the pump, on the shafts (3), (4) of the two rotors *(figure 2)* [4] [5].

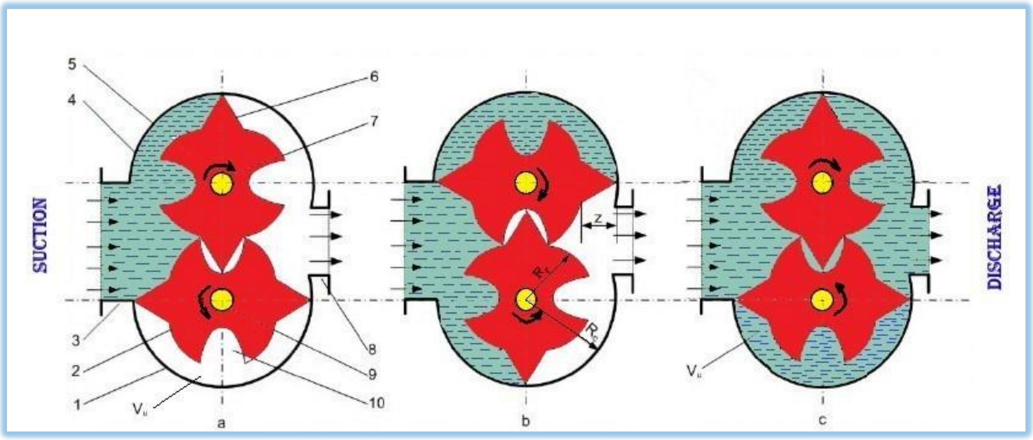

FIG. 1: Position of The Rotors After a 90° Rotation

1 - lower case; 2 - lower rotor; 3 - the suction chamber; 4 - upper case; 5 - upper rotor; 6 - rotating piston; 7- driven shaft; 8 - discharge chamber; 9 - driving shaft; 10 - cavity in which the piston of the upper rotor enters

The fluid entering in the suction chamber (3) is transported to the discharge chamber (8) (figure 1) by the rotating pistons (6); this occurs even if the fluid contains solid particles or is viscous. Figure 1 (a, b, c) shows the fluid flow after a 90° rotation of the two rotors. Figure 2 shows the operating mode of the rotating volumetric pump with profiled rotors. One can observe that the useful volume of the transported fluid (V_u), is the space between two rotating pistons (10) and the upper case.

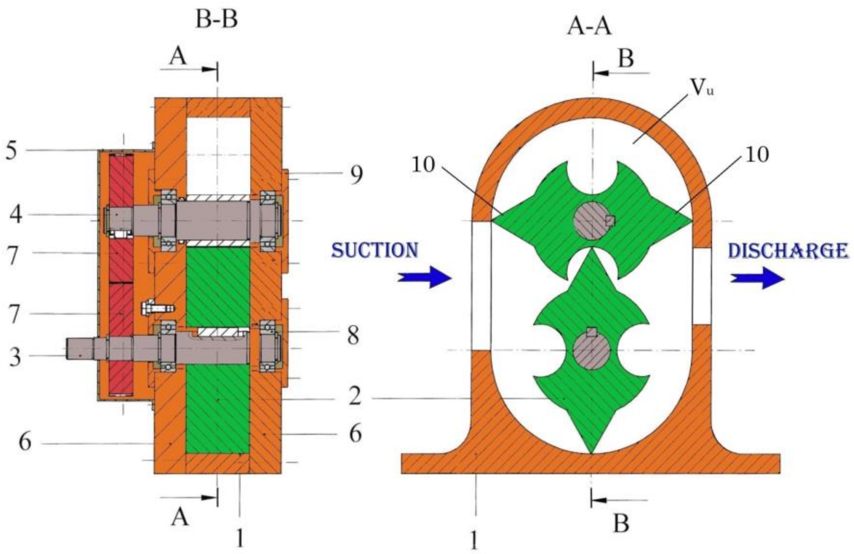

FIG. 2: Rotating Volumetric Pump With Profiled Rotors

1 - oval case; 2 - profiled rotor; 3 - driving shaft; 4 - driven shaft; 5 - oil box; 6 - side wall; 7 - gear wheel; 8 - bearing; 9 - bearing cover; 10 - rotating piston

From figure 2 one can observe that an axonometric sketch of the rotating pump model made of transparent plexiglass; if the rotors rotate in the direction indicated by the arrows drawn on the rotors, then the fluid is driven from the suction to the discharge.

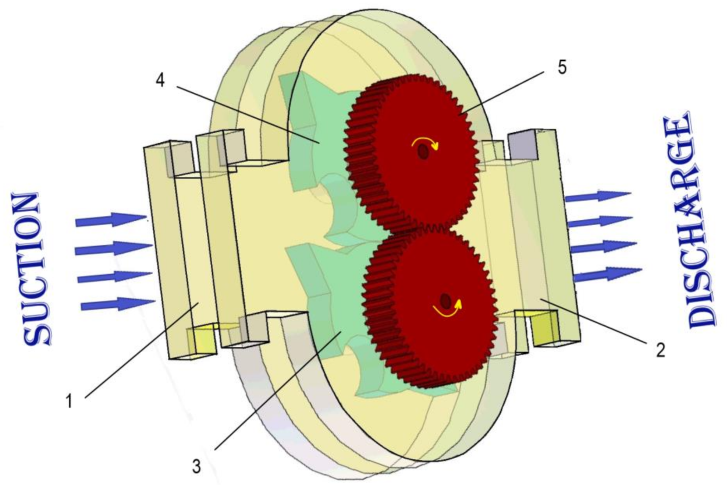

FIG. 3: Axonometric View of A Volumetric Pump Model With Two Profiled Rotors

1 – suction chamber; 2 – discharge chamber; 3 – lower rotor; 4 – upper rotor; 5 – cylindrical gears

This type of pump has the advantage that it can convey towards the discharge chamber (2) any viscous or suspended fluid that enters the suction chamber (1).

3. CALCULATION RELATIONS REQUIRED FOR THE DETERMINATION OF VOLUMETRIC FLOW RATE AND THE DRIVING POWER OF THE PUMP

When operating as a rotating volumetric pump with profiled rotors, at a complete rotation of the shaft (9) two volumes will be transported from suction to discharge [6][7]:

$$V_u = (\pi R_c^2 + \pi R_r^2)\, l \quad [m^3/rot] \tag{1}$$

Where, l - the length of the rotor [m].

Case radius (R_c) is the sum of rotor radius (R_r) and piston height (z):

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

The flow rate conveyed by a rotor is obtained:

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

One can observe that the volumetric flow rate increases linearly with the length (l), with the rotor radius (R_r) and with the speed (n). For the volumetric pump with profiled rotors the theoretical driving power is obtained with the relation [6][7]:

$$P = \dot{V} \cdot \Delta p \ [W] \quad (4)$$

$$\Delta p = \rho_l \cdot g \cdot \Delta H \ [N/m^2] \quad (5)$$

* $\dot{V}$ – volumetric flow rate [m^3 / s]; * Δp – pressure increase [N / m^2]; * ΔH – pumping height [m]; * ρ_l – the density of the conveyed fluid [kg / m^3].

Replacing the flow rate in relation (3) one can obtain:

$$P_m = \pi l z(z + 2R_r) \cdot \frac{n}{30} \cdot \rho_l \cdot g \cdot \Delta H \ [W] \quad (6)$$

It is observed that P_m = f (l, z, R_r, n, ρ_l, ΔH). (7)

Relation (6) is rewritten in the form:

$$P = \dot{V} \cdot \rho_l \cdot g \cdot \Delta H \ [W] \quad (8)$$

It is specified: $\rho_l = 10^3$ [kg/m^3]; g= 9.81 [m^3/s]; ΔH= 10 [m].

$$P = \dot{V} \cdot 10^3 \cdot 9{,}81 \cdot 10 = \dot{V} \cdot 9{,}81 \cdot 10^4 = \dot{V} \cdot 9{,}81 \ [kW] \quad (9)$$

For a waste water flow rate of 10,000 [m^3/h] = 2.77 [m^3/s] results:

$$P = 2{,}77 \cdot 9{,}81 \cdot 10^4 \ [W] = 271{,}33 \ [kW] \quad (10)$$

Performing calculations in similar manner but for other flow rate, ΔH= 10 [m] =ct., the data in table 1 are obtained.

Table 1. The values of the P = f($\dot{V}$)

Flow rate	$\dot{V}$[m^3/h]	10.000	20.000	30.000	40.000	50.000
Flow rate	$\dot{V}$[m^3/s]	2.77	5.55	8.33	11.11	13.88
Driving power	P [kW]	271.33	544.45	817.17	1089.99	1361.62

Based on the data in the table 1, the function P = f($\dot{V}$) was plotted in figure 4.

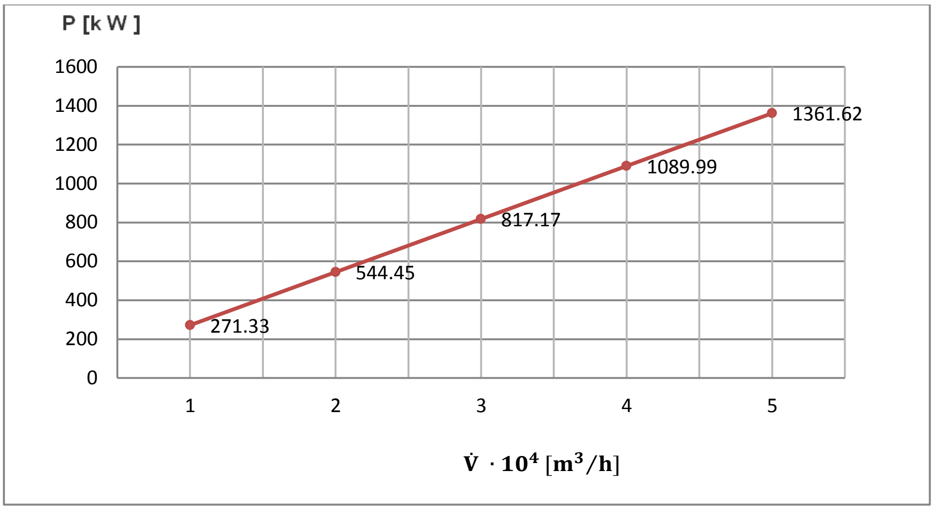

FIG. 4: The Function P=f($\dot{V}$) for H=10 mH_2O

From figure 4 a linear dependence between P and ($\dot{V}$) is observed [8][9]; from the experimental researches [8][9] it was found that the pump has an effective efficiency of 0.77 which is higher than in piston pumps [10] [11] [12].

4. CONCLUSIONS

1. The presented constructive solution can transport clean or suspended liquids, as well as rheological fluids.

2. The driving power of the machine is influenced by the nature of the conveyed fluid, by the fluid density and by the value of the pumping height ΔH.

3. Volumetric pumps with profiled rotors can be used in the field of land improvements, in wastewater treatment plants, in the: mining industry, energy industry, petrochemical industry.

4. Because the pump can convey fluids with coarse particles (sand, sludge, etc.) it is recommended in agriculture for irrigation.

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