A NEW TYPE OF VOLUMETRIC COUNTER FOR FLUIDS

Evelina DONISAN, Nicolae BĂRAN, Mihaela CONSTANTIN, Beatrice TĂNASE

POLITEHNICA UNIVERSITY OF BUCHAREST, FACULTY OF MECHANICAL AND
MECHATRONICS ENGINEERING, Bucharest, Romania

Abstract. The paper presents a new type of volumetric counter that has as moving parts two profiled
gears that rotate in a case. The constructive solution of the counter is presented and the computing relation
for the circulated fluid flow rate is deducted. Subsequently, theoretically, the flow rate characteristics it is
constructed $V = f(n_r)$ and the fluid flow rate computing method is indicated.

Keywords: volumetric counter, profiled rotors, rotating piston

1. INTRODUCTION

The fluid flow rate measurement can be made
by direct or indirect methods [1][2].
The direct methods consist in measuring the
volume of fluid that flows per unit of time, and
the indirect ones, in measuring related fluid flow
effects, such as speed, pressure drop, etc.

On the fluid flow, the following principles applies and the following devices used:

a) Variation of the fluid pressure by
conducting some fluid flow constriction; the used
devices are: diaphragm, Venturi nozzles and
Venturi tubes.

b) Variation of the fluids dynamic pressure at
their flow through pipes; device example:
rotameter.

c) Variation of the average fluid flow speed
through pipes; in this case, to flow rate
determination, Pitot-Prandtl tube is used.

d) The flow rate measurement principle by
using electromagnetic induction phenomenon; as
a device, an electromagnetic flowmeter is used.

e) Flow rate measurement using ultrasound;
here, an ultrasonic flowmeter is used.

f) Flow measurement based on the fluids
temperature variation under flowing.

The constructive solution proposed in this
paper is based on previous experiments
performed by authors with rotating machines
with profiled rotors; thus, this constructive
solution has been tested in the department of
Thermotechnics, Engines, Thermal and
Refrigeration Equipment laboratory from Faculty
of Mechanical Engineering and Mechatronics as
a rotating volumetric pump and as a low pressure
compressor [3][4]. If the suction fluid pressure
($p_s$) is larger than the discharge one ($p_d$), the
machine can be operated as a motor, i.e., the
machine is "reversible".

The measuring accuracy of the circulated
fluid flow rate by the counter depends on the gap
between: the pistons top and the case (radial
gap); the lateral surface of the pistons and the
case walls (frontal gap).

The rotors and the case are performed on a
CNC where the execution accuracy is 0.01 mm
[5], which provides a negligible "reverse flow",
therefore, an increased measurement accuracy.

2. THE COUNTER CONSTRUCTIVE
SOLUTIONS AND THE TRANSITED
FLUID FLOW RATE CALCULATION

The fluid volume transported to a rotation of
a rotor will be equal to $2 \cdot V_a$ (fig. 1); $V_a$ is the
volume between the case, rotor and the two
pistons.

![Fig.1. Cross-section through the volumetric machine](image)

1- lower case; 2- lower rotor; 3-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 upper rotor piston enters
It does not take into account the gas volume from the cavity because it is returned to suction when there is contact between the pistons and the rotors.

The profiled rotors (2, 5) rotate with the same speed within the case (1, 4); the synchronous rotation of the rotors is provided by two gearwheels attached to the shafts 7 and 9, which form a cylindrical gear mounted outside the machine.

The aspirated fluid (fig. 1. a) is transported to the discharge and after a 90° rotation of both rotors, the situation in Figure 1.b and thereafter in Figure 1.c is reached.

After a 180° rotation the fluid contained in the useful volume $V_u$ (Fig. 1. c.), i.e in the space between the pistons, the lower case (1) and lower rotor (2), will be sent to the discharge chamber. On a full rotation of the shaft (9) two such volumes will be transported from the suction to the discharge [6] [7]:

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

The case radius ($R_c$) is the sum of the rotor radius ($R_r$) and the piston height ($z$):

$$R_c = R_r + z \quad [m] \quad (2)$$

it results:

$$V_u = \pi \alpha (z + 2 R_r) \quad [m^3/rot] \quad (3)$$

The fluid volumetric flow rate discharged by a single rotor of length $l \quad [m]$ and speed $n_r \quad [rot/min]$ is:

$$V_u = \pi l z (z + 2 R_r) \cdot \frac{n_r}{60} \quad [m^3/s] \quad (4)$$

Because the machine has two identical rotors the fluid flow rate circulated by machine will be:

$$V_m = 2 V_u = \pi l z (z + 2 R_r) \cdot \frac{n_r}{30} \quad [m^3/s] \quad (5)$$

In figure 2 one observes a detail of the both rotors gearing and the related notations.

Fig. 2. Cross-section through the volumetric counter
1- fluid suction connector, 2- upper case, 3- upper rotor, 4- rotating piston, 5- driven shaft, 6- cavity, 7- fluid discharge connector, 8- lower rotor, 9- driving shaft, 10- holder
A new type of volumetric counter for fluids

Notations:
- \( R_a \) - shaft; \( R_a = 9 \) mm;
- \( R_r \) - rotor radius; \( R_r = 50 \) mm;
- \( R_i \) - the inner radius of the manufactured rotor;
- \( R_c \) - case radius; \( R_c = 80 \) mm;
- \( z \) - piston height; \( z = 30 \) mm.

For the rotors construction was necessary to elaborate a computer program of which resulted the coordinates \( x_i, y_i \) of the profile rotor contour [8] [9]; subsequently the rotors manufacturing technology was developed on a computerized numerical control system [10] [11] [12].

The rotating piston contour (4) (fig. 2) can be rectangular, triangular, curvilinear; the rotating piston shape influences the performance of the machine [13] [14] [15].

3. THE FLOW RATE CHARACTERISTICS

The relations that determines the performance of a machine in different working regime, different from the computing ones (nominal) are called the machine characteristics [16] [17]. The relations can be analytical, graphical and are theoretically and experimentally determined.

In the following, the flow rate characteristics \( V = f(n_r) \), will be theoretically established.

In order to determine the flow rate characteristics, the volumetric flow rate formula established in paragraph 2, is resumed:

\[
V = \pi \cdot l \cdot z \cdot (z + 2R_r) \cdot \frac{n_r}{30} \left[ \frac{m^3}{s} \right]
\]

where:
- \( l \) - rotor length [m];
- \( z \) - rotating piston height [m];
- \( R_r \) - rotor radius [m];
- \( n_r \) - rotating speed [rot/min];

The constructive dimensions are chosen:
- \( l = 0.05 \) m; \( z = 0.03 \) m; \( R_r = 0.05 \) m.

The counter speed can be varied using a special device type ALTIVAR [6] [18].

Performing computations, the relation follows:

\[
V = 0.02041 \cdot 10^{-3} \cdot (0.03 + 2 \cdot 0.05) \cdot \frac{n_r}{30} \left[ \frac{m^3}{s} \right] \quad (6)
\]

Because the electric motor that drives the counter has a speed of \( n_r = 940 \) rot/min, this speed should not be exceeded and the theoretical calculations will be performed in the field of: \( n_r = 100, 200, 300, 400, 500, 600, 700, 800, 900 \) rot/min; with these values, the equation (7) gives the data presented in Table 1.

<table>
<thead>
<tr>
<th>( n_r ) [rot/min]</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V \cdot 10^{-3} \left[ \frac{m^3}{s} \right] )</td>
<td>2.041</td>
<td>4.082</td>
<td>6.123</td>
<td>8.164</td>
<td>10.205</td>
<td>12.246</td>
<td>14.287</td>
<td>16.328</td>
<td>18.369</td>
</tr>
</tbody>
</table>

Based on data from Table 1 the curve \( V = f(n_r) \) in Fig. 3 was plotted.

![Graph](image_url)

**Fig. 3. Graphical representation of the function \( V = f(n_r) \)**
From equation (5) one observes that \( V = f(n_r) \) is a linear function, a fact confirmed by the graph in Figure 3.

The volumetric flow rate is influenced by two types of parameters [19] [20]
- Constructive parameters: \( z, l, R_r \)
- Functional parameters: \( n_r \)

This characteristic curve will be compared with the one that will be experimentally determined.

Following the experimental measurements the real flow rate and the flow rate coefficient will be determined.

### 4. THE EVALUATION OF THE VOLUMETRIC COUNTER SPEED AND THE CIRCULATED FLOW RATE

During the research, which is to be experimental conducted in the department laboratory, the speed will be measured by a digital speed counter which has two possibilities for measuring the speed (Fig. 4):

a) With mechanical contact, the device is driven by the electric motor shaft that acts the volumetric counter;
b) Optically.

Based on of counter speed measurements and knowing the flow rate circulated expressed in two ways: \( \text{m}^3/\text{s} \) or \( \text{m}^3/\text{rot} \), a software that will instantaneous indicate the flow rate from a certain period of time since the counter start, was performed.

### 5. CONCLUSIONS

a. This type of volumetric counter has the advantages of:
- Indicates the flow rate instantaneous;
- Indicates the amount of fluid which has transited the counter from the start of the measurements;

b. After experimentally plotting the characteristic \( V = f(n_r) \), the working speed of the machine can be selected.
- If a low flow rate must be monitored, a constant low speed is elected;
- If a high flow rate must be monitored, a constant high speed, is elected.

c. The counter can measure fluids flow rates pure or with impurities fluids flow rates, viscous fluids, polyphasic fluids.

d) These theoretical researches will be experimentally verified in the achievement of a PhD thesis, by Ing. Evelina Donisan.

### REFERENCES

1. M. Marinescu, ş.a, „Mărimi fundamentale în termodinamică”, Editura POLITEHNICA PRESS, București, 2003;
2. N. Băran, ş.a, „Măsurarea parametrilor fluidelor”, Editura SCRISUL ROMÂNESC, Craiova, 1986;
5. V. Tcacenco, Centre de prelucrare cu ax vertical „Alzmetall” Rev. Tehnică și Tehnologie nr. 4, 2005, pag. 16-17;
8. N. Băran, D. Besnea, A. Motorga, „Elements of computing the architecture and manufacturing technology for a new type of profiled rotor”,

Fig. 4. Digital speed counter
A new type of volumetric counter for fluids

PROCEEDINGS International Conference, 6th Workshop on European Scientific and Industrial Collaboration on promoting Advanced Technologies in Manufacturing, WESIC’08 Bucharest 25-26, 2008, pp.233-241;


