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ON THE CORRECTION FACTOR FOR CALIBRATION OF THE FLOWMETERS WITH AXIAL TURBINE

Prof. PhD. Eng. Gavril AXINTI
Lecturer PhD. Eng. Adrian-Sorin AXINTI
“Dunarea de Jos” University of Galati

ABSTRACT

This paper refers to axial turbine flowmeters used for technical measurements of volumetric flows at hydraulic driving systems. This study demonstrates that volumetric flow through the transducer has proportional value with the angular speed of turbine, and the proportionality factor the depends on constructive parameters and on hydraulic agent characteristics. The proportionality parameter was introduced as a calibration factor of the apparatus with respect to the transducer type which was used for measurement. This paper is useful for designing and developing this kind of apparatus, for measurement activities that involve flowmeters, and for those who analyze the basic principles of flow measurements (researchers, designers, students, etc).

KEYWORDS: axial turbine, volumetric flows

1. INTRODUCTION

It is well known from the experimental practices that the axial turbine flowmeters are produced with certain serial types, which cover the usual values of measurements domain. This fact is necessary for maintaining the measures quality for volumetric flow within the accepted technical and scientific limits. Hereby, each apparatus of a certain type requires a set of proportionality correction factors, and these corrections will be made directly on the gauge of the apparatus from the measurement chain.

The correction factors will be introduced by typing into the specialized gauge (0000,0) of the apparatus (see fig.1).

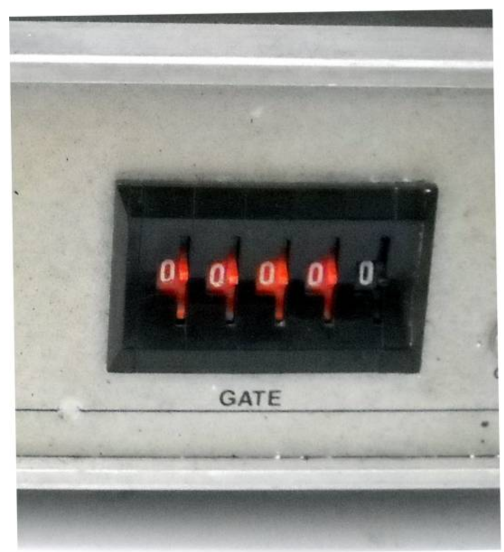


Fig. 1. The flowmeter apparatus

This paper demonstrates that the volumetric flow of hydraulic agent circulated through the turbine flowmeter is proportional with the angular speed of te turbine, and the proportionality factor depends on constructive parameters and on the hydraulic agent characteristics.

The results presented in this paper are useful for designing and developing this kind of apparatus, for measurement activities that involve flowmeters, and for those who analyze the basic principles of flow measurements.

2. THE EXPRESSION OF THE CORRECTION FACTOR

In fig. 2 is depicted the basic structural diagram of a turbine flowmeter. The data in the figure are necessary for basic calculus in obtaining the calibration constant of the flowmeter. The notations in fig. 2 have the next significations: a- rotor width; S- the step of the rotor blades; R_i, R_e- inner, respective outer radius of the rotor; r- the dynamic radius; dr- infinitesimal radius, β - bias angle of the rotor blade with the axial direction; w, w_r - absolute flowing speed through the rotor (theoretical, real); u, u_r- tangential speed of the rotor (theoretical, real); ω_i , ω - rotor angular speed (theoretical, real); Q- volumetric flow of the liquid through the transducer; θ - angular deviation of absolute real speed compared with the theoretical (whit respect to the axial direction).

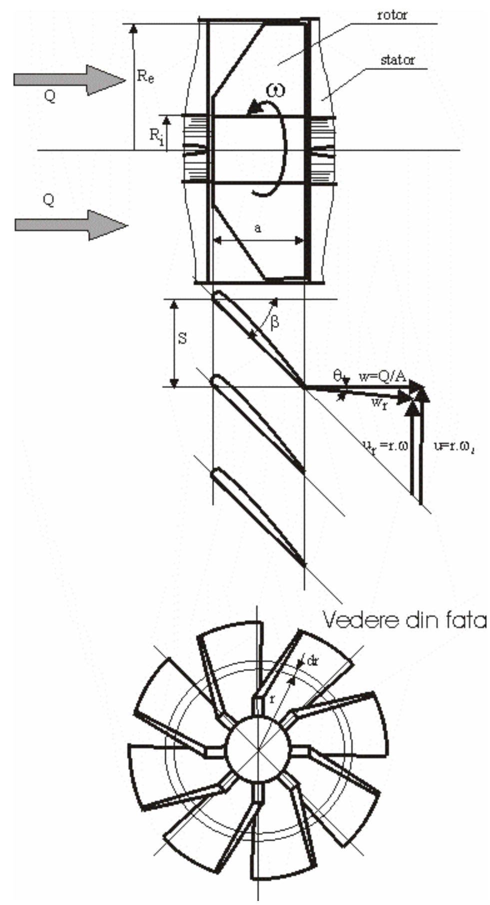


Fig. 2. The characteristics of a flowmeter turbine

The fig. 2 shows that from the velocities triangle, at the output of the turbine blades, can be written the expression

$$u = w.tg\beta \Rightarrow \frac{\omega_i}{w} = \frac{tg\beta}{r_m} \qquad (1)$$

Also, from the velocities triangle, there may results differences between theoretical and real velocities, and these provided by the fact that a part of kinetic energy of flowing liquid is lost through friction with the self components of the flowmeter, and the other part contributes to the rotational movement of the turbine. The flowmeter performances depend on the corrections which will be made for taking into account the energy losses, because the transducer measures the angular real speed. Hereby, it can be deduced the expression of the necessary moment for turbine movement, supposing the friction losses are unessential comparative to those made by dynamic forces applied to the turbine blades.

The expression of the moment applied to the turbine is

$$M = \frac{\int_{R_i}^{R_e} \rho Q.dA.r.\Delta u}{A} \left[N.m\right] \qquad (2)$$

where:

$\rho Q -$ is the mass flow which crosses the flowmeter;

$dA = 2\pi r.dr -$ is the infinitesimal area to apply the inertial force;

r - is the radius of the force;

$\Delta u = r(\omega_i - \omega) -$ is the losses of tangential speed;

$A = \pi(R_e^2 - R_i^2) -$ is the flowing calibrated area of the flowmeter.

After the computations done in expression (2), and supposing the medium radius of the flowmeter as such

$$r_m = \sqrt{(R_e^2 + R_i^2)/2} \, ,$$

it results:

$$M = \rho A w r_m^2 (\omega_i - \omega) \qquad (3)$$

If into the expression (3) will dignify the real angular speed as a function of the theoretical, results

$$\omega = \omega_i - \frac{M}{\rho A w r_m^2} \qquad (4)$$

From expression (4) results that angular speed losses of turbine rotor are a consequence of the moment M.

The expression of moment M, with respect to dynamic forces applied on turbine blades, and supposing that these forces were applied at distance $R = (Re + Ri)/2$ by the axis, is

$$M = n.F_d.R.\sin\beta \qquad (5)$$

The expression of dynamic force at one blade, supposing the step S of blades, is [1]

$$F_d = \frac{c_d.\rho.w^2.S}{2} \approx 0{,}074.\Re e^{-0{,}2}\rho.w^2.S \qquad (6)$$

where c_d is a dynamic coefficient in dependence with Reynolds number $\Re e$.

From equations (5) and (6) results

$$M = 0{,}037.\Re e^{-0{,}2}\rho.w^2.S.n.(R_e + R_i).\sin\beta \qquad (7)$$

Replacing equations (7) and (1) in (4), results

$$\frac{\omega}{w} = \frac{tg\beta}{r_m} - \frac{M}{\rho.A.\omega^2.r_m^2} \qquad (8)$$

From equation (8) results the theoretical absolute speed, and the expression of volumetric flow crossing the flowmeter

$$Q = w.A = \omega.K_{DN} \qquad (9)$$

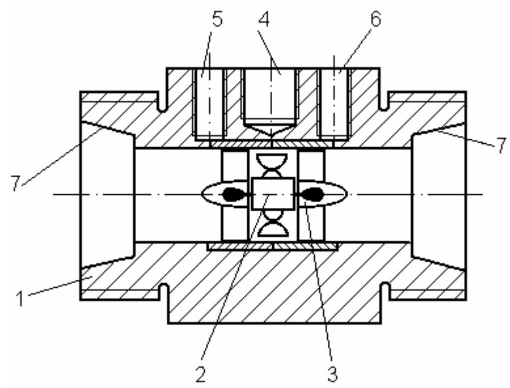
Where

$$K_{DN} = \frac{r_m^2.A^2}{r_m.A.tg\beta - 0{,}037.\Re e^{-0{,}2}.n.S.(R_e + R_i).\sin\beta} \qquad (10)$$

is the flowmeter constant. This parameter is proper of each type of transducer, because each of them is used only for a dedicated flow values domain (see fig. 3).

Such as it can be observed in the schematic section through a flowmeter (see fig.3a), the main parts of this kind of device are:

1- the rigid body of the flowmeter;
2- the axial turbine;
3- the turbine bearings;
4- the special hole for mounting of the inductive transducer used for rotation velocity measure (angular velocity sensor plug in);
5- the special hole for temperature transducer (temperatute sensor plugged);
6- the special hole for pressure transducer (minimmes type pressure sensor plugged);
7- the special plugs for linkage of the flowmeter into the hydraulic fixture.



a)

b)

c)

Fig. 3. Types of flowmeter

3. CONCLUSIONS

It was observed that this constant depends only on the constructive parameters and the value is appropiate for a certain flowmeter structure, or, in other words, for a certain flowmeter type.

Each type allows for measurements on a certain flows domain which have the small Reynolds number, less than 1600.

The flowmeter acquires the angular speed with the help of inductive transducer which counts the pulses due to each turbine blade in a time period.

The apparatus (actually, the indicator gauge component) of the measurement chain allows the calibration through specific constant K_{DN} input for every used transducer. Also, this apparatus performs the mathematics of equation (9).

The characteristics in equation (10) are used with respect to technical units, because the unit of the flow parameter is [l/min].

From the expression (10) results that the value of the calibration constant is proportional with the squared medium radius of the turbine and with the squared flowing area, therefore with the flowing nominal diameter of the transducer.

The constant is dependent on blade attack angle, blades number, blades step, and *Reynolds* number.

If it takes into account the *Reynolds* number expression and wetry to formulate the communication speed through the flowmeter with respect to the fluid flow parameter, results

$$Q = \frac{\pi \upsilon \mathrm{Re}}{4} d \tag{11}$$

$$Q = (4{,}1165...10{,}328)d \tag{12}$$

Considering the previous equation (11) with Re = 1900, ν = 46...100 [cSt] and diameter *d* [mm], the flow with respect to the nominal diameter is with flow parameter *Q* in [l/min] for diameter *d* in [mm].

Technical units were used for all the expressions in this analysis with respect to numerical range of proper variation experimental acquired for these parameters.

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