FRICTION COEFFICIENT OF PERFORATED AND POROUS DISCS

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This work [1] represents simple approximate relation, necessary for calculating characteristics of disc rotor machines, which includes the friction coefficient C_t of the disk. It is shown, that one can apply a simple method to recalculate C_t of a smooth disc for C_t of perforated one or done from honeycomb-porous material. The admissibility of recalculation is shown experimentally for single discs and packages from several discs basing on testing them as the rotors of centrifugal blower.

The prospect of using the machines with porous rotors requires detailed and fundamental description of hydraulic characteristics of rotating penetrable discs, which became a reason for this research.

It should be noted that even the friction of rotating discs (free and in the cover) is not described precisely enough, since there are some contradictions in experimental data of different authors and, accordingly, they have various degree of correlation with theoretical with theoretical constructs [2].

Following the monograph [2] for examination we are going to use as friction coefficient measure the value

$$C_M = \frac{2M}{\rho\omega^2 r^5} \tag{1}$$

where M is frictional resisting moment; ρ is density; ω – angular velocity; r – disc radius.

Reynolds number in these nominations (ν is kinematic viscosity).

$$\mathrm{Re} = \frac{\omega r^2}{\nu} \tag{2}$$

Thereby, to find the relation of C_M (Re) it is necessary to measure the resisting moment and the velocity of disc rotation (angular velocity), if the geometry and the ambience parameters are stable.

To measure the resisting coefficient (friction) of rotating discs a laboratory installation was designed (Fig. 1) in the form of relatively heavy well balanced disc ∅ 100 mm, weight ~ 350gr, placed on the vertical axis resting upon ball-bearing. The axis is connected to the electrical direct current engine and can work as electrical generator.

The electrical engine spins the rotor and after the power supply is stopped can be tachometer and (or) can be connected to resistive load to create additional resisting moment.

A possibility to accelerate the rotor by the air stream is provided as well. In such a case the registration of rotation velocity by measuring generator voltage is done at all rotation stages.

The disc to be tested is placed on the rotor surface or above it at certain distance for double-sided flow.

Momentum equation for the rotor

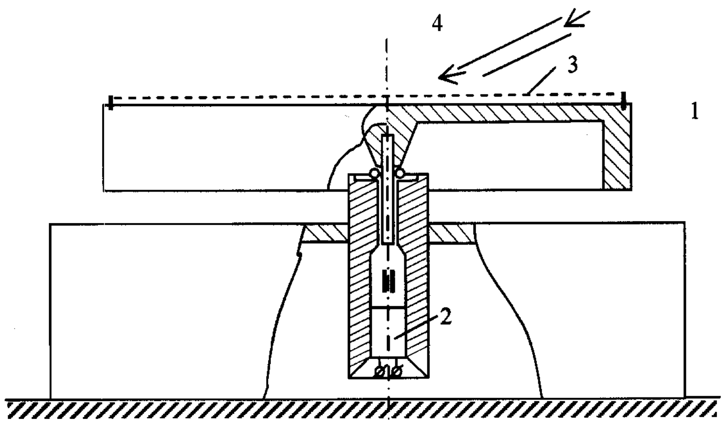

Fig. 1. Installation
1 – massive rotor (base); *2* – electrical engine of direct current, tachometer; *3* – disc to be tested; *4* – nozzle

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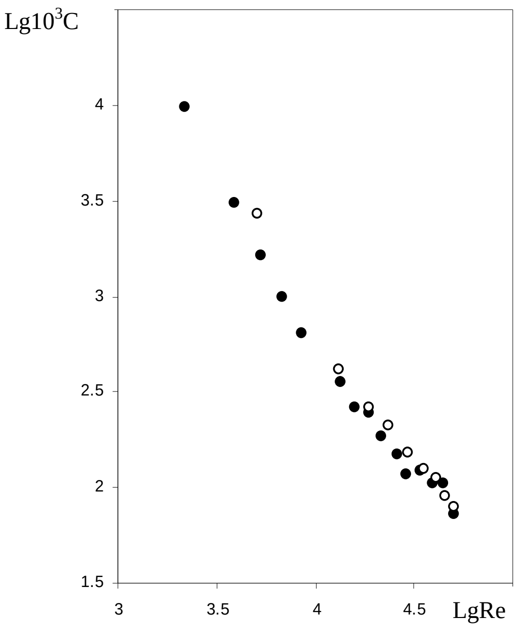

Fig. 2. Comparison of measurements by two ways

$$M_{+} = M_{-} + I\frac{d\omega}{d\tau} \qquad (3)$$

where M_{+} – accelerating moment; M_{-} – breaking moment; I – moment of rotor inertia; τ – time.

Breaking moment

$$M_{-} = M_o + M_d + M_m \qquad (4)$$

where M_o – rotor resisting moment without the disc to be tested; M_d – additional resisting moment from the disc to be tested; M_m – friction resisting moment of mechanical system in the bearings.

Respectively,

$$I = I_o + I_d \qquad (5)$$

where I_o – moment of resistance of the base-rotor without disc to be tested, I_d – inertia moment of the disc to be tested.

Two possibilities to determine the moment follow from (3)

1) in stationary case $\frac{d\omega}{d\tau} = 0$ and $M_{+} = M_{-}$.

Since the power applied for rotating

$$N = M_{+} \cdot \omega \qquad (6)$$

it is necessary to determine N as electrical power of the electrical engine without resistance losses.

2) in case of non stationary motion a good variant is $M_{+} = 0$, i.e. after acceleration up to certain value ω the deceleration happens by inertia; in such a case

$$M_{-} = -I\frac{d\omega}{d\tau} \qquad (7)$$

In any case the initial one is definition $(M_{-})_o$ when $M_o = 0$ and, accordingly, $I = I_o$.

Apparently, that in (1) while determining the disc $C_н$ one should consider that $M = M_{-} - (M_{-})_o$

To determine the excess resisting moment from the disc to be tested two of this ways were used:

Figure 2 shows the results of measuring the base of C_M by two ways. It is obvious that the agreement is satisfactory, but not ideal; scattering of points characterizes the accuracy of measurements.

Typical time dependant curve EMF E is represented in Fig. 3 registering E in~2 s. The electrical generator used had linear characteristic E~ω. One can see, that differentiation dω/dτ at each

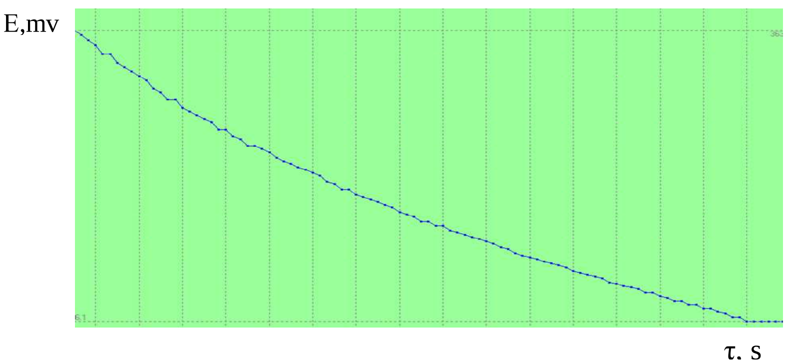

Fig. 3. An example of generator voltage registration

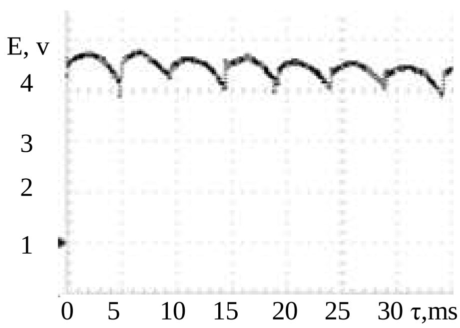

Fig. 4. Oscillogram EM

time gap can cause a large variance, what is obviously connected to the characteristic generated by the EMF E collector motor-generator. (Oscillogram is represented in Fig. 4.)

Thus smoothing for all experimental data represented below was done at time gap 6÷10 s with full time till the stop 100÷200 s.

The photograph of the discs tested is represented in Fig. 5; the disk characteristics are represented in the table.

No.	Disc characteristics	Designation of the points in the figure	$C_M \cdot Re$ in diapason $Re = (7{,}5 \div 25) \cdot 10^3$
0	Smooth surface (base)	o ●	3630
1	Steel 500 hole ∅3 mm	◊	960
2	Aluminum 180 hole ∅ 4 mm	+	2330
3	Brass with large volume spraying and holes	□	4390
4	Copper (highly permeable honeycomb porous materials HPHPM) small-sized pores porosity ~85%	■	4460
5	Bronze 1000 hole ∅1,5 mm with curly turnings crown	Δ	5990
6	Nickel HPHPM large pores porosity 95%	*	8010
7	Aluminum with double-sided spraying h = 2 mm through the perforated matrix	♦	7730
8	Stainless steal HPHPM porosity 95%	▲	10380

The results of experimental definition of C_M by the method from (1)–(7) a represented in Figs. 6 and 7. Figure 6 shows the data for perforated disks with constant thickness. Figure 7 shows the data for "voluminous" discs, i.e. produced from highly permeable honeycomb-porous materials, as well as for the perforated one 5 with double sided crown from conical shavings, as well as the disk 3 with large perforation and high spraying accordingly.

The difference in absolute values C_M at the same Re between "plate" and "voluminous" discs for Re ~< 10^4 is considerable, even though the character of dependence is kept. At high Re for "voluminous" discs the tendency to transition with $C_M \approx$ const is obvious; and for the discs with bigger C_M this transition happens at smaller Re.

In Fig. 6 the data concerning the disc 7 with two-sided spraying are considerably higher. It would seem that it is caused by air passage through the central hole between the base and the disc; and, practically it was two side flow.

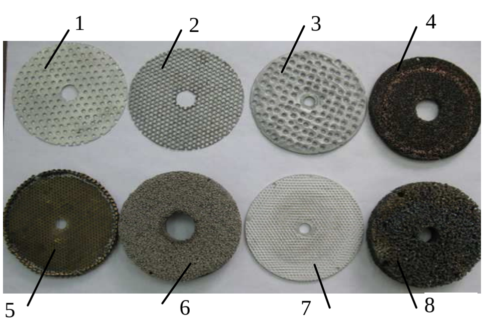

Fig. 5 The photo of the discs

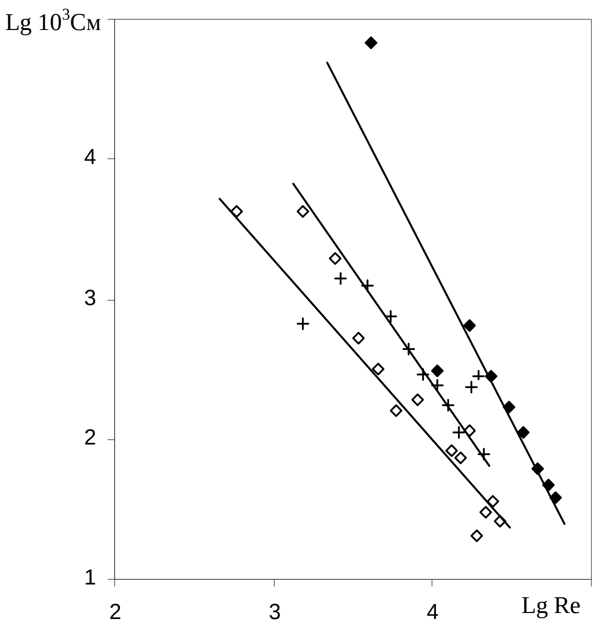

Fig. 6. Perforated discs («plate» ones)

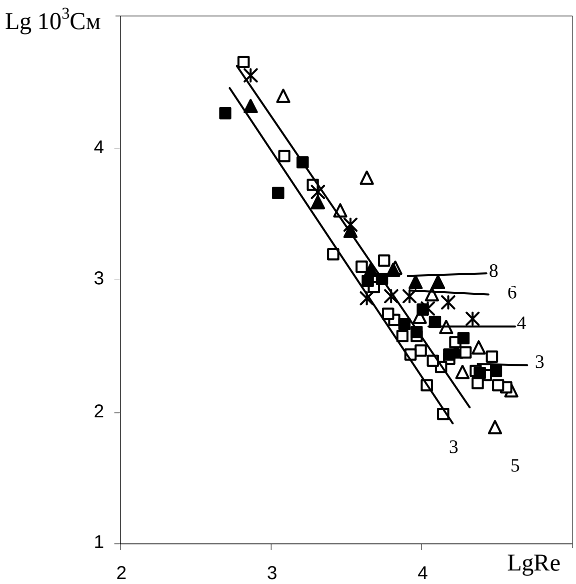

Fig. 7. Discs from porous materials («voluminous» ones)

The smoothness of the curves of the stop (see Fig. 3) allowed making analytical description ω(τ) as ω ≈ 200÷60, that corresponds to Re ≈(7,5÷25)·10^3. The differentiation of analytical dependence allowed making an analytical description for each disc as

$$C_м \cdot Re = const \quad (8)$$

The values of the constants (8) are shown in the table.

The short odd in C_M for the discs with considerably different geometry of permeable material calls attention. This corresponds to the ventilator discharge characteristics (shown in [1]) with porous rotors from various materials; and it demonstrates the necessity to precise the model of recalculation of hydraulic characteristics of permeable materials for effective value C_M needed to calculate the discharge characteristics of machines with permeable rotors.

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