KAPITEL 8 / *CHAPTER 8* [8]

THE INFLUENCE OF THE ECCENTRICITY OF THE CYLINDRICAL ROTOR RELATIVE TO THE STATOR ON HYDRAULIC RESISTANCE IN AQUEOUS SOLUTIONS OF DITALAN

DOI: 10.30890/2709-2313.2023-22-01-015

Introduction

In pursuit of design improvement, heightened operational reliability, reduced thermal, mechanical, and electrical losses, and enhanced efficiency, various types of engines are tested. These tests entail applying a load through hydraulic brakes, as detailed in [1]. Hydraulic brakes are also used during operational and resource tests of engines of tractors, agricultural machines, cars and other vehicles.

Hydraulic brakes have been the most widely used type of brakes in bench research due to their relatively simple design and high energy consumption compared to other brake types.

The method of regulating the braking torque of a hydraulic brake by changing the eccentricity of the rotor in the working fluid with hydrodynamically active additives is described in detail in works [2-4].

8.1. The analysis of the literary sources

The circulation of fluid with hydrodynamically active additives in the closed confuser-diffuser gap between the non-coaxial rotor and stator is found in drilling rigs with the eccentricity of drill and casing pipes, in sliding bearings, colloid mills, etc.

Most of the literature sources focus on fluid flows with hydrodynamically active additives between coaxial cylinders [5], with less frequent mentions of flows between spheres or disks.

The influence of hydrodynamically active additives in the flow between eccentric cylinders was reported in [6]. Specifically, these additives reduced rotor resistance by 20%. In two-thirds of these studies, a numerical experiment was conducted, while the remaining one-third involved physical experiments.

The purpose of this study is to experimentally investigate the influence of the eccentricity of a cylindrical rotor relative to the stator on hydrodynamic resistance

[8]**Authors:** *Pitsyshyn Bogdan Stepanovych, Orel Vadym Ihorovych, Popadyuk Igor Yuriyovych, Matlai Ivan Ivanovych*

in aqueous solutions of Ditalan.

8.2. Laboratory investigations

8.2.1. Experimental setup

The experimental setup scheme for studying the influence of the eccentricity of the cylindrical rotor relative to the stator on hydraulic resistance in aqueous solutions of Ditalan is presented on Figure 1 [7].

The Rotor 7 is driven by a direct current electric motor 9 and is rigidly mounted on its shaft 8. The motor is positioned between plates 13 and 14, which are secured to plate 4 on racks 16 and 17. Within the groove 3 of base plate 4, movable plate 2, on which stator 1 is fixed, is moved using handle 6.

The braking moment experienced by the rotor when in contact with the working fluid is calculated by monitoring the power consumption of the electric motor.

The initial position of the rotor is coaxial with the stator. Any eccentricity resulting from the movement of plate 2, along with the stator, is indicated by index arrow 18 relative to scale 15. The rotation speed of the rotor is controlled by adjusting the voltage supplied to the electric motor. A tachometer was utilized to measure the rotor's rotation speed. The installation kit includes an AC rectifier and a transformer for voltage regulation.

The presence of a transparent cylinder allows for the visual examination of changes in the structure of the working fluid flow in the gap between the rotor and the stator. These changes occur as the stator transitions from an annular configuration to a closed confuser-diffuser, with varying geometric parameters including width and angles that converge and diverge.

The annular gap between the surfaces of the rotor and the stator, corresponding to their initial position, transformed into a closed confusor-diffuser configuration (as shown in Fig. 2) as the position of the stator changed. Experiments were conducted with relative gap widths ranging from 0.12 to 1.0 (refer to Table 1). The rotor's rotation speed, regulated by adjusting the motor's voltage, varied from 5 to 500 min^{-1}, and this was measured using a tachometer.

Key technical data of the experimental stand with adjustable braking torque: internal stator diameter – 142 mm; stator height – 153 mm; rotor diameter – 26.3 mm; rotor height – 153 mm; diameter ratio d/D – 0.18; rotor rotation speed – 5-500 min^{-1}; overall dimensions: 200×307×540 mm; weight with rotor – 18 kg.

 ISBN 978-3-949059-99-5

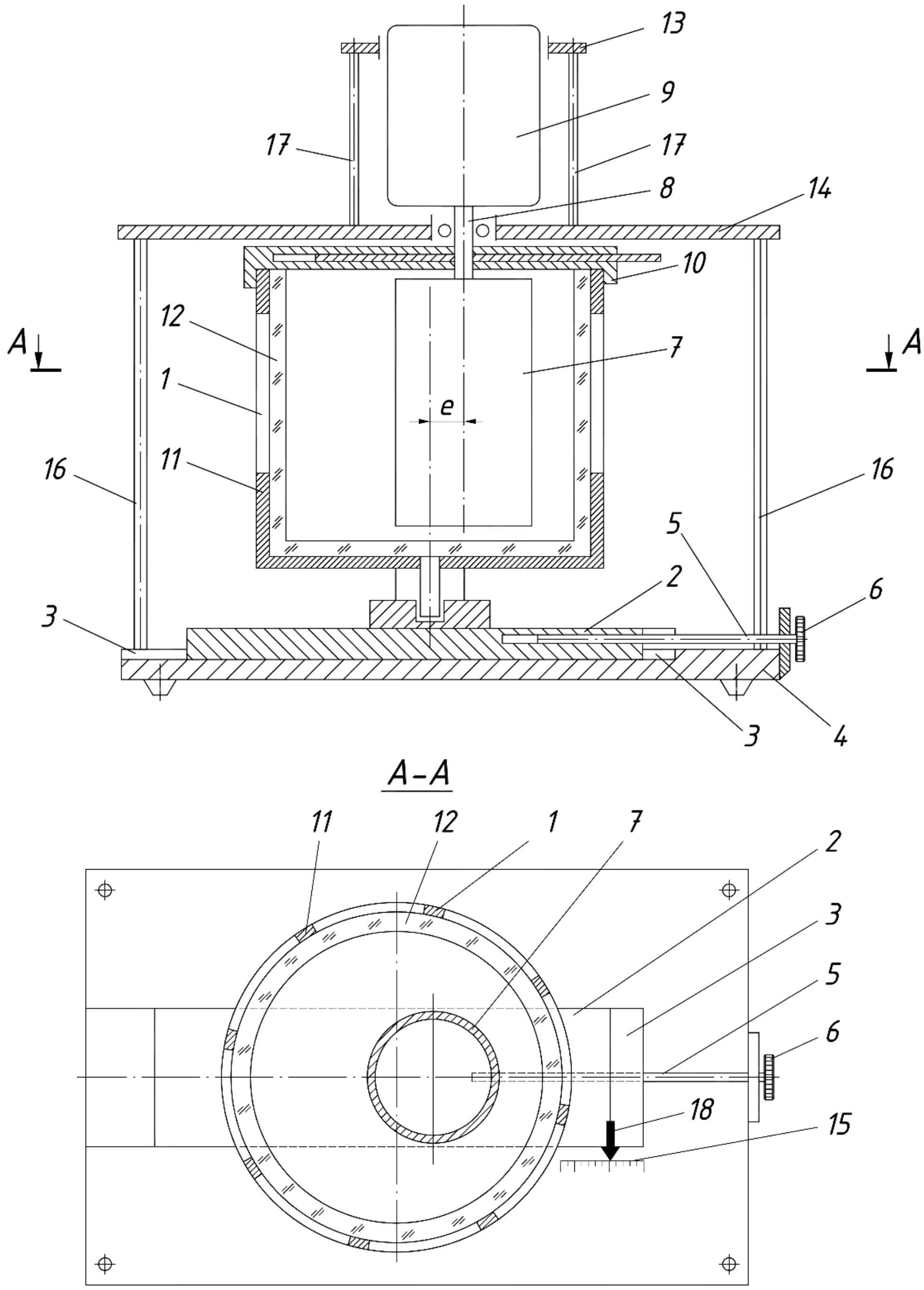


Figure 1 - Scheme of the experimental setup:
1 – stator; 2 – movable plate; 3 – groove; 4 – base plate; 5 – driving screw; 6 – handle; 7 – rotor; 8 – shaft; 9 – current electric motor; 10 – cover; 11 – metal frame; 12 – transparent cylinder; 13, 14 – plates; 15 – scale; 16, 17 – racks; 18 – index arrow

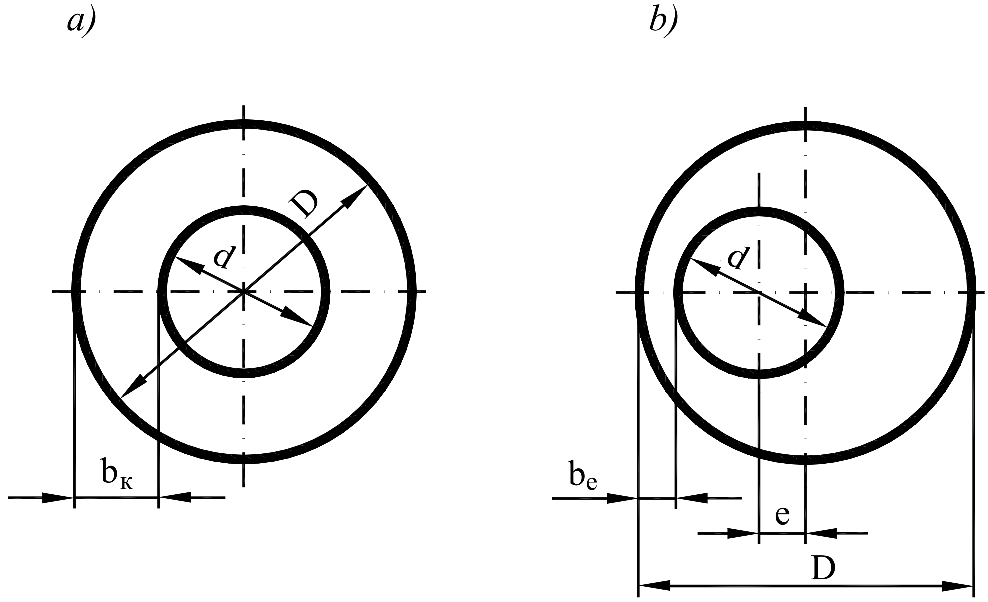


Figure 2 - Schemes of the rotor location relative to the stator:
a) concentric; b) eccentric; b_k – gap width with coaxial arrangement of cylinders; b_e – the same for eccentric; e – eccentricity

Table 1. The values of the relative gap width between the rotor and the stator that were studied

Diameters, mm		d/D	b_e/b_k
Stator diameter D	Rotor diameter d		
142	26,3	0,18	1,0; 0,72; 0,46; 0,29; 0,12

8.2.2. Selection of the working fluid

The flows of water and aqueous solutions of Ditalan (Ditalan OTS-45) with mass concentrations of 1% and 8% were studied. To thicken these solutions, we added 3% of their weight in sodium chloride (NaCl), and for stabilization, we added 0.2% of sodium hydrogen carbonate ($NaHCO_3$). Stabilization was performed to prevent the loss of hydrodynamic activity. The temperature of the investigated solutions ranged from 25.0°C to 30.0°C.

8.2.3. Mathematical equations

Average tangential stresses τ on the rotor's wall:

$$\tau = T/(2\pi \cdot r \cdot H), \qquad (1)$$

where T – the total friction force applied to the side surface of the rotor; r – rotor radius (r = 0.5·d); H – rotor height.

$$T = M/r, \qquad (2)$$

where M – braking torque acting on the rotor.

 ISBN 978-3-949059-99-5

$$M = N \cdot 60/\Omega, \tag{3}$$

where N – power consumption of the electric motor; Ω – rotor angular rotation speed.

$$N = I \cdot U, \tag{4}$$

where I – current strength; U – voltage.

$$\Omega = 2\pi \cdot n, \tag{5}$$

where n – number of rotor revolutions.

The coefficient of friction in the gap between the rotor and the stator:

$$C_f = G/\mathrm{Re}^2, \tag{6}$$

where G – dimensionless torque on the inner cylinder in the gap between the rotor and the stator; Re – Reynolds number:

$$G = T/\rho \cdot \nu^2 \cdot H, \tag{7}$$

where ρ – water specific gravity; ν – kinematic viscosity of the water.

Reynolds number:

$$\mathrm{Re} = \Omega_i \cdot r_i \cdot (r_o - \mathrm{r}_i)/\nu, \tag{8}$$

where r_o – radius of the stator.

Taylor criterion:

$$\mathrm{Ta} = V \cdot b/\nu \cdot \sqrt{b/r}, \tag{9}$$

where V – linear rotor rotation velocity; b – the width of the confuser-diffusor gap between the rotor and the stator:

$$b = (r_o - r) - e, \tag{10}$$

where e – eccentricity (Fig. 2, b).

Effect of influence on frictional resistance:

$$DR\% = C_{f,\omega} - C_{f,s}/V_{f,\omega} \times 100, \tag{11}$$

where $C_{f,\omega}$ – coefficient of friction in the gap between the rotor and the stator for the flow of water; $C_{f,s}$ – the same for the flow of aqueous solutions of Ditalan.

8.2.4. Discussion of the obtained results

The experiments were carried out on the experimental setup (Fig. 2) for the ratio b_e/b_k = 0.12; 0.29; 0.46; 0.72; 1.00 (Table 1).

The paper presents the results of studying the influence of eccentricity and the concentration of Ditalan aqueous solutions, with mass concentrations of 1.0% and 8.0%, on the hydrodynamic resistance of the rotor. Each of the data points obtained through experiments represents the arithmetic mean of three measurements.

Graphs depicting the dependence of τ = f(Ta) for the flow of Ditalan aqueous solutions with mass concentrations of 1.0% and 8.0% in the gap between the

ISBN 978-3-949059-99-5

cylinders, where d/D = 0.18 and b_e/b_k = 1.0, 0.72, 0.46, 0.29, and 0.12, are presented in Figure 3.

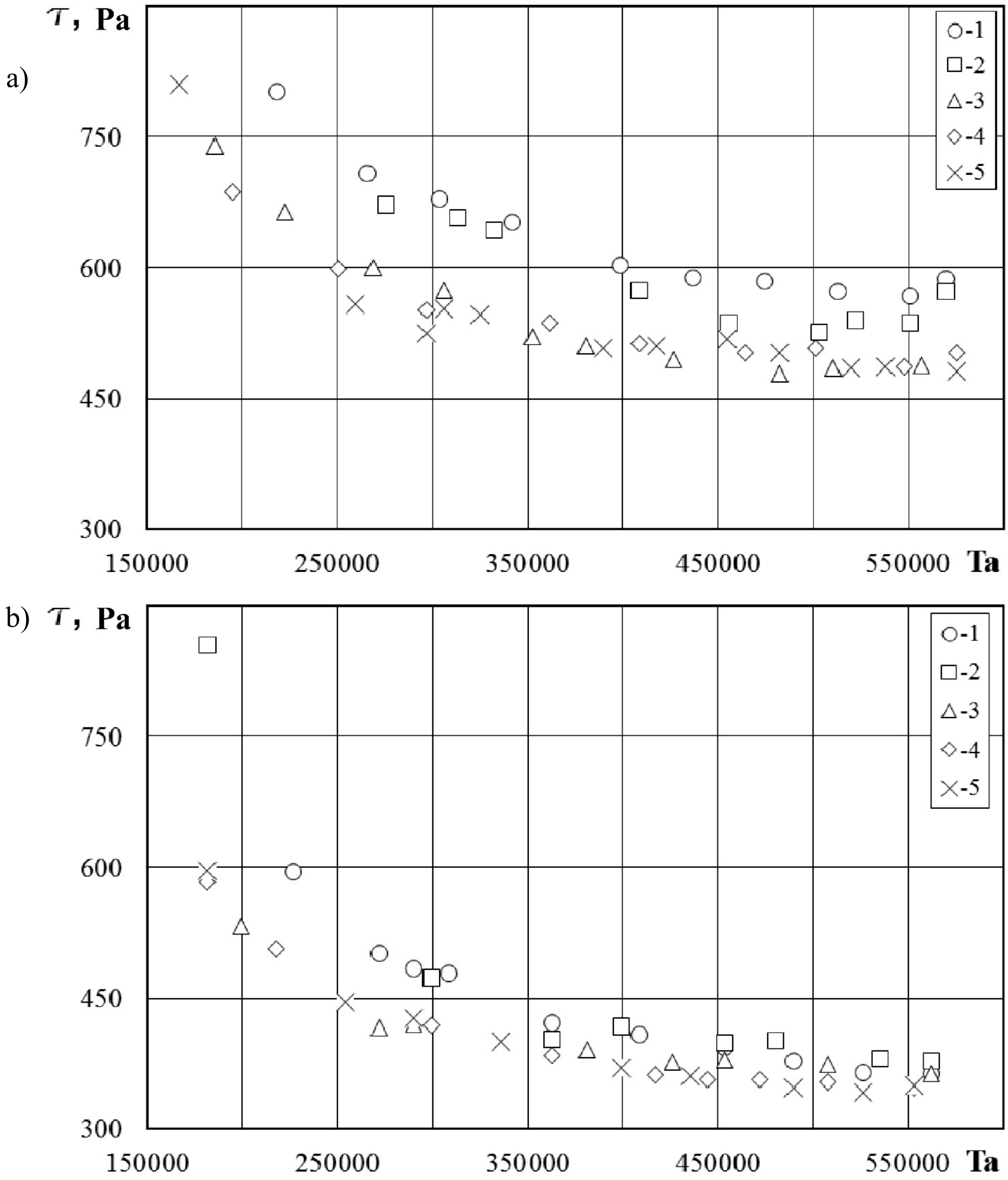


Figure 3 - Influence of the rotor eccentricity (d = 26.3 mm) during rotation in Ditalan solutions at various mass concentrations: 1.0% (a); 8.0% (b) for gap width b_e/b_k = 1.0 – (1); 0.72 – (2); 0.46 – (3); 0.29– (4); 0.12 – (5)

In the studied range of values for the Taylor criterion (Ta = 150,000...600,000), the average tangential stresses on the rotor wall, while rotating in water and aqueous solutions of Ditalan (Fig. 3, a, b), decrease with increasing Ta and decreasing relative gap width (b_e/b_k), which corresponds to increasing eccentricity (Fig. 2).

The tangential stresses on the rotor wall at d/D = 0.18 for all investigated values of the relative width of the gap b_e/b_k increase with flow of water.

Additions of Ditalan reduced the tangential stresses on the rotor wall at the concentric arrangement of the cylinders (b_e/b_k = 1) for the studied concentrations. At the eccentric arrangement of the rotor, its hydraulic resistance increased for all investigated values of the relative width b_e/b_k of the gap (Table 2). Additions of Ditalan in mass concentrations of 1.0% and 8.0% caused a change in rotor resistance.

Additions of Ditalan reduced the tangential stresses on the rotor wall in the case of concentric arrangement of the cylinders (b_e/b_k = 1) for the studied concentrations. For the eccentric arrangement of the rotor, its hydraulic resistance increased for all investigated values of the relative gap width (b_e/b_k) (refer to Table 2). The addition of Ditalan at mass concentrations of 1.0% and 8.0% resulted in a change in rotor resistance.

Table 2. The influence of an eccentric rotor location on its hydraulic resistance at Ta = 550,000

$b_e/b_к$	Tangential stresses on the rotor wall τ, Pa, at the concentration of an aqueous Ditalan solution C, %		
	0	1,0	8,0
1.0	930	580	365
0.12	1250	480	345

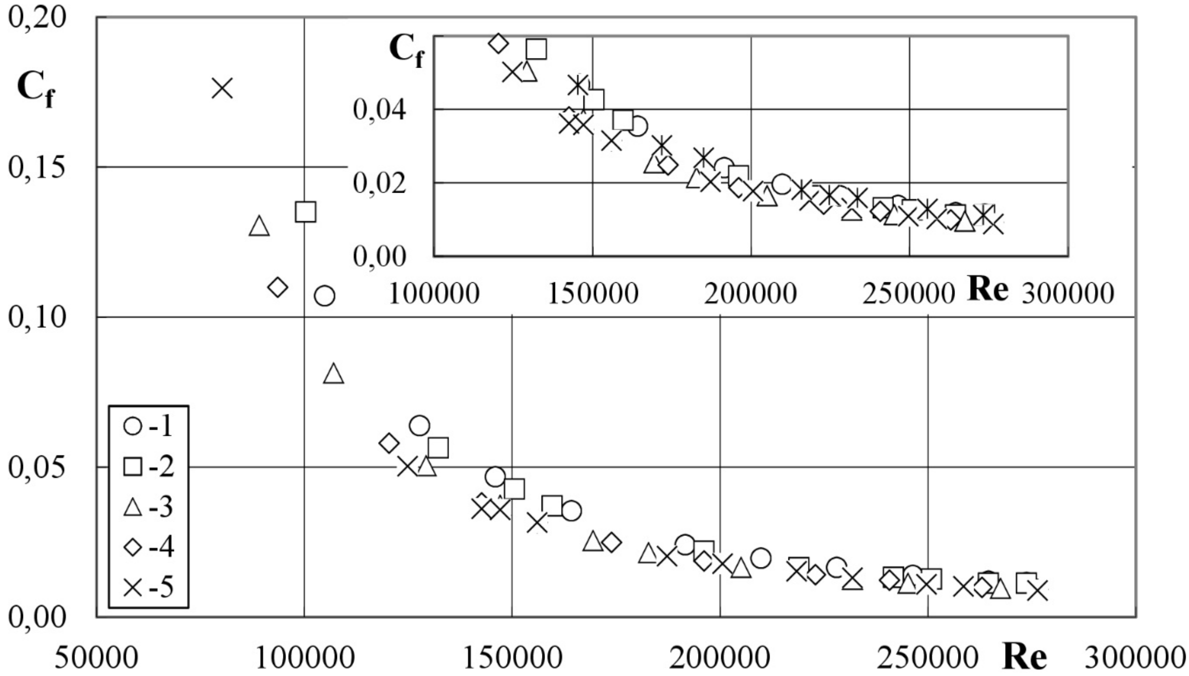
The results of changes in the coefficient of friction for aqueous solutions of Ditalan, with mass concentrations of C = 1.0% and 8.0%, at relative gap widths b_e/b_k = 1.0, 0.72, 0.46, 0.29, and 0.12, are presented in Figure 4.

For the investigated concentrations of Ditalan aqueous solutions, the friction coefficient (C_f) decreases as the values of the Reynolds criterion increase. For fixed values of the Reynolds number, with a decrease in the width of the gap, a decrease in the friction coefficient of the investigated solutions was obtained, which corresponds to the results of [8-11].

The effect of DR aqueous solutions of Ditalan on rotor friction resistance at Re = 150,000 decreases with increasing values of b_e/b_k, within the ranges of 0.12-0.29 and 0.46-0.72 for investigated concentrations (Fig. 5, a) and in the range of 0.72-1.0 increases. In the range b_e/b_k = 0.29-0.46, the effect does not change.

At Re = 200,000, the influence of DR aqueous Ditalan solutions for all investigated concentrations decreases within the range of 0.46-0.72, and then increases as the relative gap width approaches b_e/b_k = 1.0 (Fig. 5, b). The effect of the influence of DR aqueous Ditalan solutions in the range of the relative widths of the interval b_e/b_k = 0.12-0.42 is unchanged for the studied concentrations.

a)



b

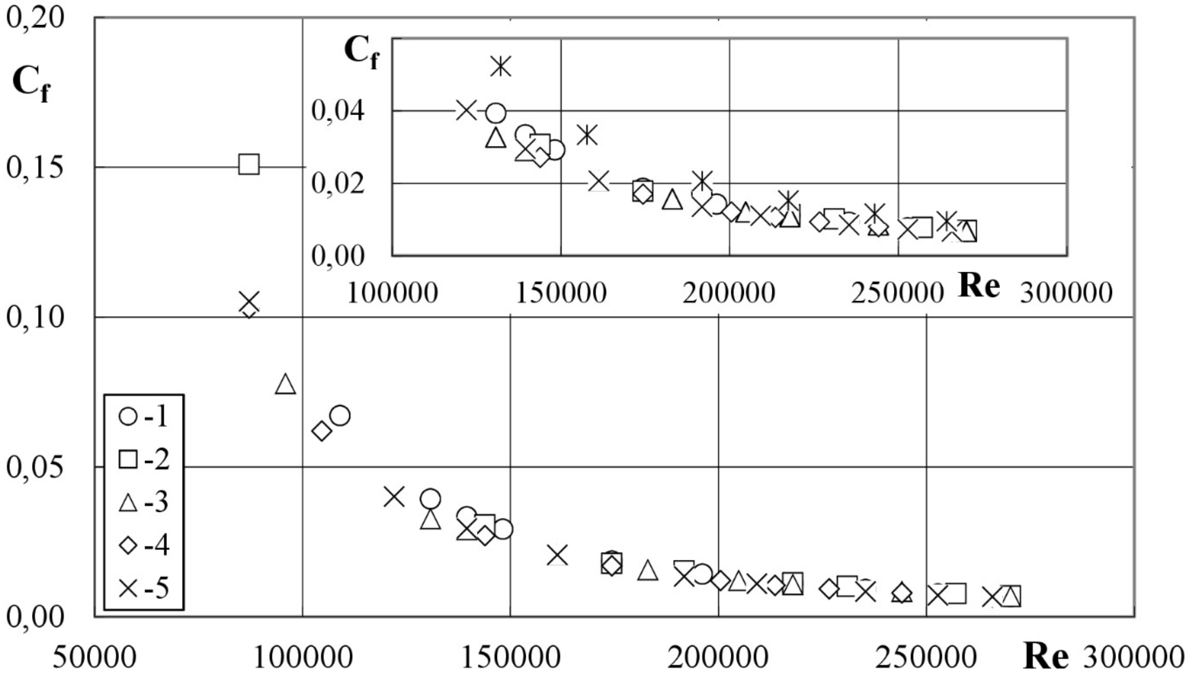


Figure 4 - Influence of the rotor eccentricity (d = 26.3 mm) during rotation in Ditalan solutions at various mass concentrations: 1.0% (a); 8.0% (b) for gap width b_e/b_k = 1.0 – (1); 0.72 – (2); 0.46 – (3); 0.29– (4); 0.12 – (5)

ISBN 978-3-949059-99-5

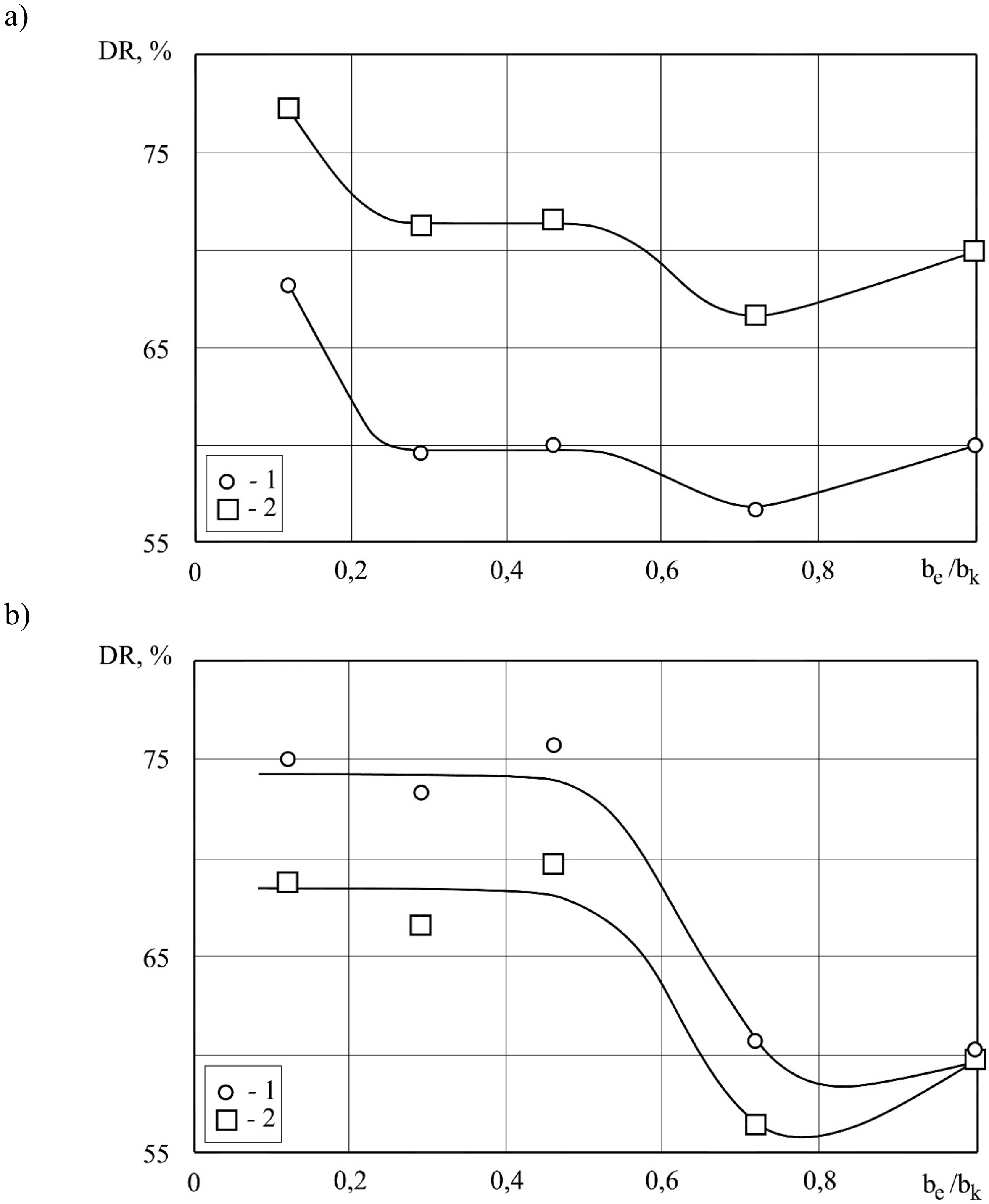


Figure 5. Influence on frictional resistance at the relative gap width (b_e/b_k) for aqueous solutions of Ditalan with mass concentrations of 1.0% (1) and 8.0% (2) at Reynolds numbers of 150,000 (a) and 250,000 (b)

 ISBN 978-3-949059-99-5

Conclusions

1. The dependence of the hydrodynamic efficiency of Ditalan on the concentration of the solution was confirmed.

2. A decrease in the friction coefficient with an increase in the Reynolds criterion was confirmed for all investigated values of eccentricitie.

3. The effect of Ditalan aqueous solutions of mass concentrations C = 1.0% and 8.0% on the friction resistance in the gap between the rotating rotor and the stationary stator at d/D = 0.18 for b_e/b_k = 1.0; 0.72; 0.46; 0.29; 0.12 was revealed.

 ISBN 978-3-949059-99-5