KAPITEL 8 / *CHAPTER 8* [8]
INFLUENCE OF CYLINDRICAL ROTOR ECCENTRICITY RELATING TO STATOR ON HYDRAULIC LOSSES IN AQUEOUS DITALAN SOLUTIONS

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Introduction

Proposed mixer (Fig. 1) [1] for the preparation of emulsions, etc. has the following advantages: increasing mixing intensity in the volume of liquid and smooth regulation of flow velocities in its wide range.

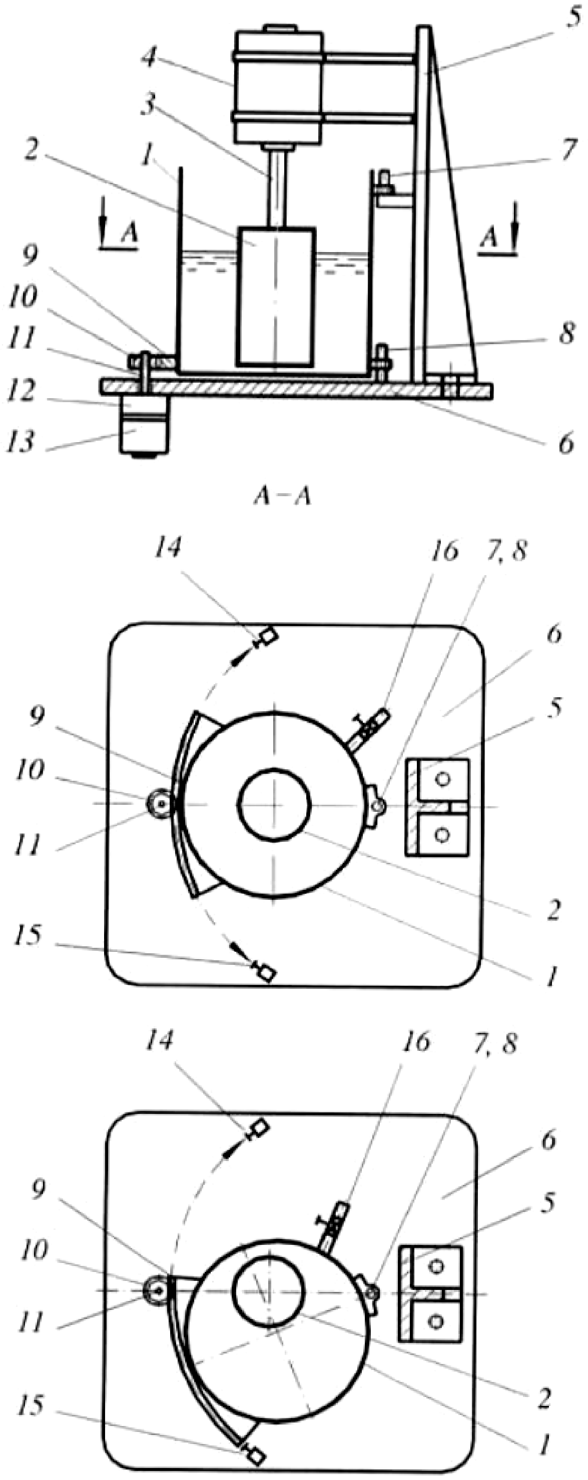

Figure 1. Scheme of the mixer with coaxial and non-coaxial arrangement of the inner cylinder and cylindrical container: 1 – cylindrical container-stator; 2 – inner cylinder-rotor; 3 – drive shaft; 4 – electric motor; 5 – riser; 6 – plate 7, 8 – suspension; 9 – part of the gear sector; 10 – gear wheel; 11 – shaft; 12 – reducer; 13 – reverse electric motor; 14, 15 – winding pole limit switches; 16 – outlet pipeline.

8.1. Literature review.

Based on the analysis of literature sources, a scheme of preparation and introduction of solutions of hydrodynamically active polymers (HAP) into the pipeline to change the pressure in it is proposed (Fig. 2). Such substances, in particular, include micelle-forming of surface-active agents (surfactants).

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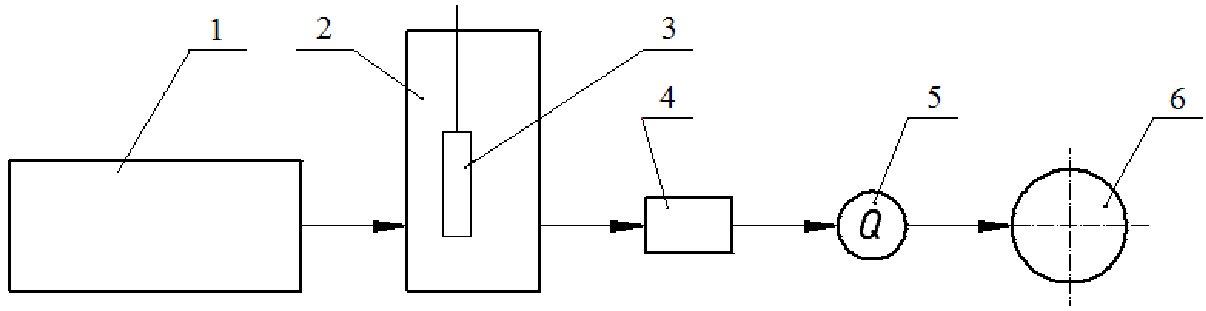

Figure 2. Scheme of preparation and introduction of HAP solutions into the pipeline: 1 – tank for preparation of HAP; 2 – cylindrical container-stator; 3 – inner cylinder-rotor; 4 – pump; 5 – flow meter; 6 – pipeline

The effectiveness of the use of micellar surfactants in pressure pipelines and in closed hydraulic systems is associated with its reverse mechanical destruction. Thus, the optimal concentrations of the composition "Ditalan OTS + NaCl" to reduce the hydraulic resistance of turbulent friction are (0.6…2.4)% + 3% by weight [4, p. 106; 9]. Here, sodium chloride NaCl is a substance that promotes micelle formation (micellar agent). However, aqueous solutions of ditalan OTS can degrade, which can be stopped by adding hydroquinone to the solution [4, p. 39]. Ditalan OTS is ineffective at temperatures above 80 °C, however, at low temperatures retains high hydrodynamic efficiency [4, p. 114].

The advantage of studying the micelle-forming surfactants (MFS) flow between the cylinders is its much smaller geometry compared to the geometry of test facilities such as wind tunnels, water and oil channels, or the flow in the pipes [2].

The hydrodynamic efficiency of MFS significantly depends on its concentration and the structure of the hydrocarbon radical of the surfactant molecule [4, p. 97].

Thus, when the outer cylinder rotates in a gap with a relative width $b_k/r_o = 0.028$ between coaxial cylinders, a decrease of the moment of resistance for an aqueous solution of ditalan OTS with a concentration of 1.2% in a 3% aqueous solution of NaCl begins to appear at the values of the Reynolds number Re = 6000 [4, p. 96]. According to the research results [3], the relative decrease in the hydraulic resistance of the stator in ditalan OTS solutions at the values of the Reynolds number Re = 29000 can reach 59% (Fig. 3).

At the ratio d/D = 0.52 (Table 1) for the investigated range of the Taylor criterion Ta = 15000…150000, the average shear stresses τ on the wall of the rotor, which rotated in water and aqueous solutions of ditalan OTS with mass concentrations of 1% and 8% in 3 % aqueous solution of NaCl, with increasing value of Ta first decrease, then pass a minimum, and then increase. An increase in the eccentricity e (Fig. 4) and the concentration of an aqueous solution of ditalan shift the minimum point of the dependence $\tau = f(Ta)$ toward lower and higher values of Ta, respectively. Large values of τ correspond to lower values of concentrations and higher values of eccentricity. For the studied range of the Reynolds number Re = 60000…260000, the friction coefficient C_f decreases with increasing Re both for water and ditalan solutions. At fixed identical values of Re, an increase in the eccentricity and concentration of the ditalan solution leads to an increase and decrease in the values of C_f, respectively [5].

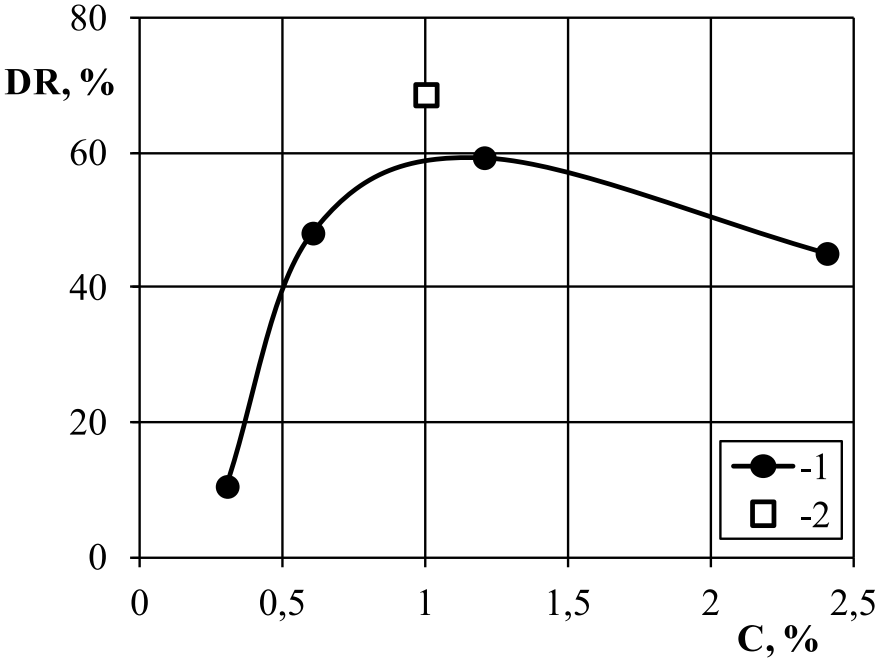

Figure 3. The relative decrease in the hydraulic resistance of the stator (1) and rotor (2) at its concentric arrangement in aqueous solutions of dithalan OTS at Re = 29000: $b_c/r_o = 0.028$ (1); $b_c/r_o = 0.634$ (2)

Table 1. The studied parameters of the mixer and ditalan

	Diameters, mm		The ratio d/D	Ditalan concentration, %	Source
	Stator D	Rotor d			
1.	142	112.9	0.80	1.0; 8.0	[5]
2.		73.5	0.52		[6]

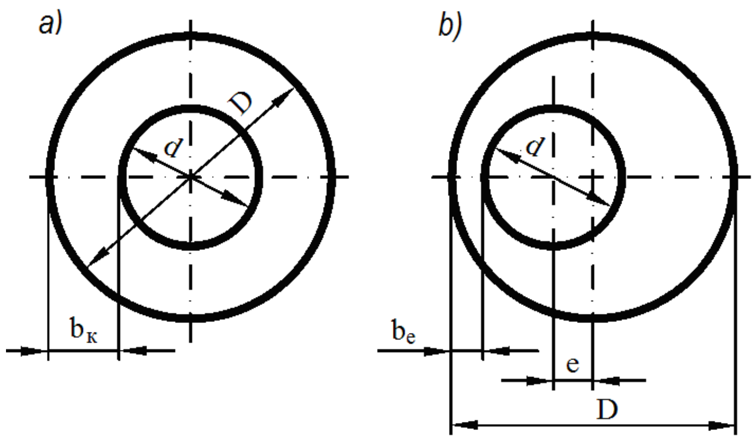

Figure 4. Concentric (a) and eccentric (b) arrangement of the rotor and stator

Instead, at the ratio d/D = 0.52 (Table 1), the value of the relative change of the friction coefficient DR increases to the values of the relative width of the confuser-diffuser gap $b_e/b_k = 0.7$, forming a maximum, then decreases to the values of the relative width $b_e/b_k = 0.03$. In this case, an increase in hydrodynamic resistance occurs [6].

8.2. Experimental research

8.2.1. Experimental stand

A detailed description of the experimental stand is given in the paper [7]. The stator placed relative to the rotor with the possibility of radial reciprocating motion (Fig. 4). In this case, the initial annular gap between the rotor and the stator b_k changed into a closed confusing-diffuser gap b_e with the formation of eccentricity e by changing the position of the stator. The surfaces of the rotor and stator were smooth.

In this study, the diameters of the stator and rotor were D = 142 mm and d = 52 mm, respectively (Table 2) and the height of the rotor was equal to H = 153 mm.

Table 2. The value of the relative width of the gap between the rotor and stator

Diameters, mm		The ratio d/D	Eccentricity e, mm	Relative width of the gap	
Stator D	Rotor d			b_e/b_k	b/r_o
142	52	0.37	0	1.000	0.634
			10	0.778	0.493
			20	0.556	0.352
			30	0.333	0.211

8.2.2. Working fluid selection

The studies were carried out for the flow of water and aqueous solutions of ditalan (Ditalan OTS-45) with mass concentrations of 1 and 8%. To thicken ditalan solutions, NaCl was added to its in an amount of 3% by weight of the solution. Also, to stabilize ditalan solutions, 0.2% by weight of sodium bicarbonate solution $NaHCO_3$ was added to its. Stabilization is necessary to prevent loss of hydrodynamic activity. The temperature of the studied solutions was in the range of 25.5...30.0 °C.

8.2.3. Calculation formulas

The coefficient of friction in the gap between the rotor and the stator was determined by the formula [10]:

$$C_f = \frac{G}{Re^2}, \qquad (1)$$

where G – dimensionless torque on the inner cylinder in the gap between the rotor and the stator [10]:

$$G = \frac{M}{H \cdot \rho \cdot \nu^2}, \qquad (2)$$

where M – torque acting on the rotor:

$$M = \frac{N \cdot 60}{\Omega}, \qquad (3)$$

where N – power consumption of the electric motor:

$$N = I \cdot U, \qquad (4)$$

where I – current strength; U – voltage; Ω – angular speed of rotation of the rotor:

$$\Omega = 2\pi \cdot n, \qquad (5)$$

where n – number of rotor revolutions; ρ – specific mass of water; ν – kinematic viscosity of water; Re – Reynolds number [10]:

$$Re = \frac{\Omega \cdot r \cdot b}{\nu}, \tag{6}$$

where r – radius of the rotor, r = d/2; b – width of the confuser-diffuser gap between the rotor and the stator:

$$b = (r_o - r) - e, \tag{7}$$

where r_o – radius of the stator, r_o = D/2; e – eccentricity. And $b = b_k$ at e = 0 (Fig. 4, a), and $b = b_e$ at $e \neq 0$ (Fig. 4, b).

Taylor criterion was determined by the formula [4]:

$$Ta = \frac{V \cdot b}{\nu} \cdot \sqrt{\frac{b}{r}}. \tag{8}$$

Relative change of the friction coefficient (resistance moment coefficient) was determined as:

$$DR = 1 - \frac{C_{f,s}}{C_{f,w}}, \tag{9}$$

where $C_{f,w}$ – 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. Results and discussion

For the flow of water in the gap between the rotor and the stator (Fig. 5), the experimental points asymptotically approach the values described by the formula for a hydraulically smooth rotor [8]:

$$\frac{1}{\sqrt{C_f}} = 1{,}10 \log_{10}\left(Re_i \sqrt{(C_f)}\right) + 0{,}81. \tag{10}$$

The friction coefficient C_f decreases with increasing value of Re and the concentration of ditalan aqueous solutions and increases with increasing eccentricity. This behavior is qualitatively the same as the experiments at the ratio d/D = 0.52.

At concentric rotation of the rotor with the ratio b_k/r_o = 0.634 in a solution of ditalan with a concentration of 1%, the value of the relative reduction of the friction coefficient is greater than in experiments [3] (Fig. 3), apparently due to the greater width of the gap.

The friction coefficient C_f decreases with increasing criterion Ta and increases with increasing eccentricity (Fig. 6 and Fig. 7) for water and ditalan solutions. This coincides with previous studies with larger rotor diameters.

The value of the relative friction coefficient $C_{f,s}/C_{f,w}$ at the value of the Taylor criterion Ta = 164000 decreases with an increase in the ratio b_e/b_k for both studied ditalan concentrations (Fig. 8).

The decrease in hydraulic resistance is observed only in the concentric arrangement of the rotor, when the ratio b_e/b_k = 1.0, which corresponds to the value of $C_{f,s}/C_{f,w}$ < 1.0; for other values of b_e/b_k an increase in resistance was observed.

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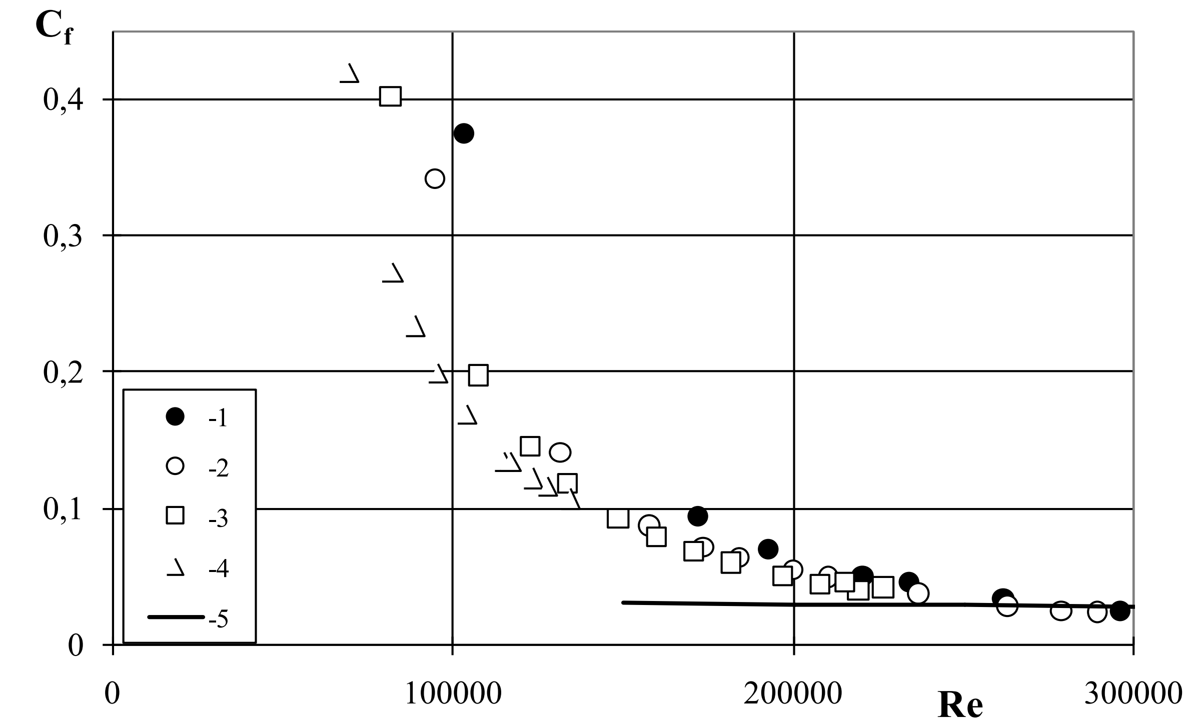

Figure 5. Dependence of the friction coefficient on the Reynolds number on the wall of the rotor for water at eccentricity e, mm: 0 (1); 10 (2); 20 (3); 30 (4); formula (10) – (5)

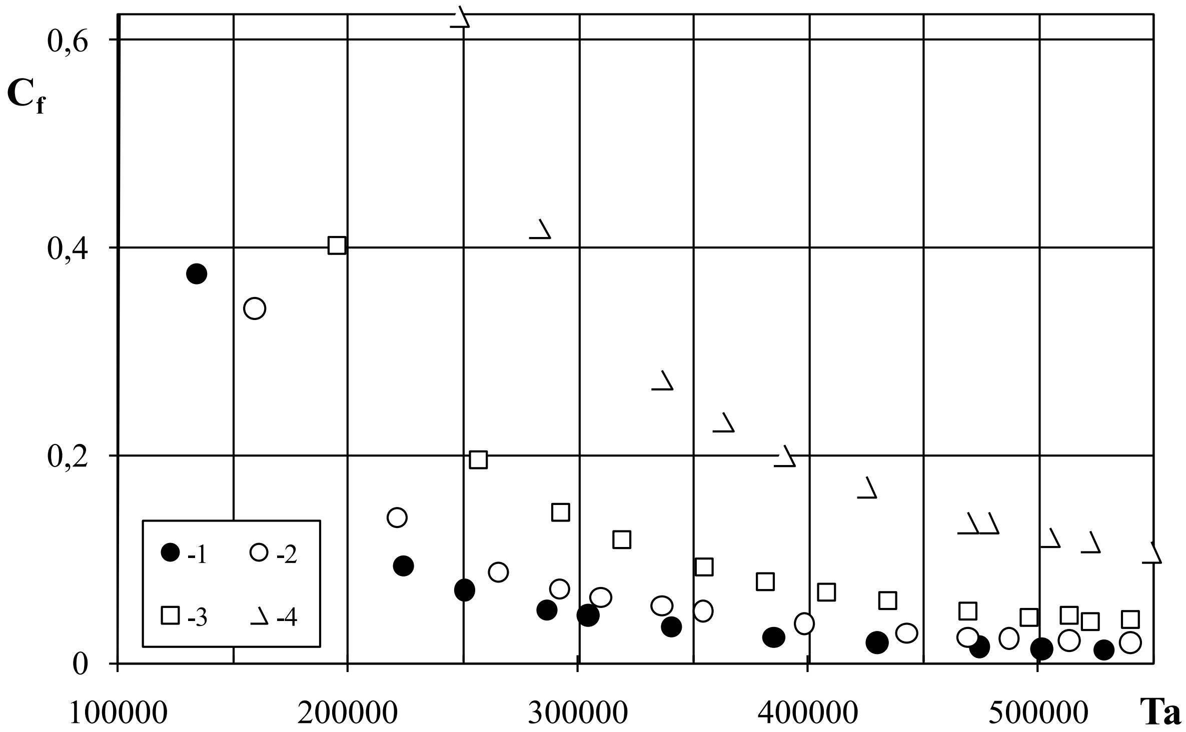

Figure 6. Dependence of the friction coefficient on the Taylor criterion on the wall of the rotor for water at eccentricity e, mm: 0 (1); 10 (2); 20 (3); 30 (4)

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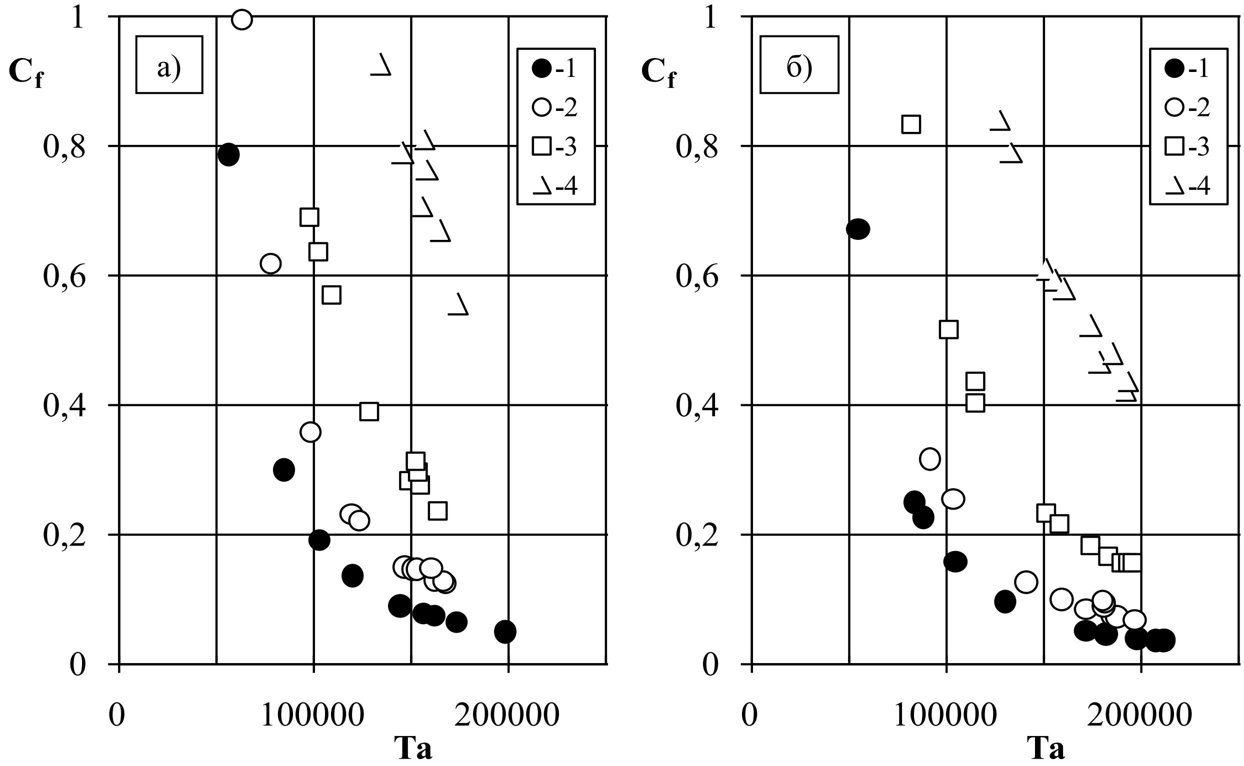

Figure 7. Dependence of the friction coefficient on the Taylor criterion on the wall of the rotor for aqueous solutions of ditalan with concentrations of 1% (a) and 8% (b) at eccentricity e, mm: 0 (1); 10 (2); 20 (3); 30 (4)

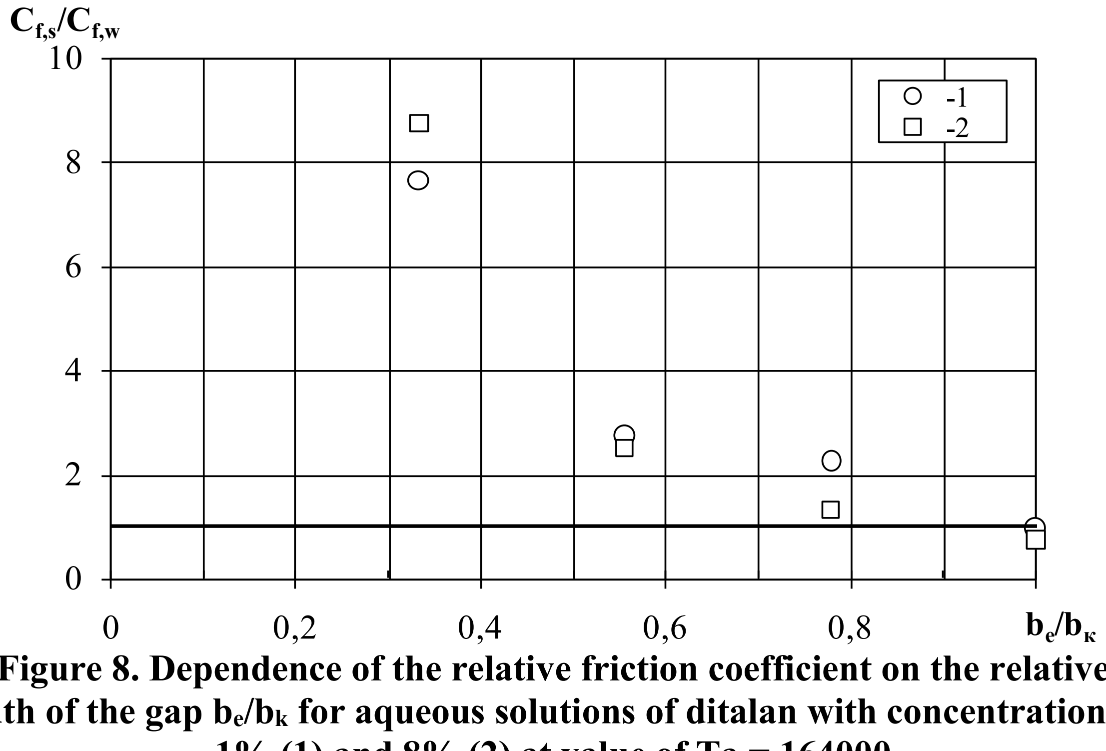

Figure 8. Dependence of the relative friction coefficient on the relative width of the gap b_e/b_k for aqueous solutions of ditalan with concentrations of 1% (1) and 8% (2) at value of Ta = 164000

Conclusions

1. The dependence of the hydrodynamic efficiency of ditalan aqueous solutions on its concentration is confirmed.

2. A decrease in the friction coefficient with an increase in the values of the

Reynolds number and Taylor criteria for the studied eccentricities for both water and dithalan solutions was confirmed.

3. An increase in the friction coefficient for the studied concentrations of dithalan aqueous solution compared to water at a nonzero eccentricity was obtained at fixed values of the Taylor criterion.