SECTION 5. MECHANICAL ENGINEERING

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5.1 The effect of the influence of aqueous metaupon solutions on the friction resistance in the gap between a rotating rotor and a stationary stator

One of the well-known ways of saving energy is the regulation of the braking moment of the hydraulic brake by changing rotor eccentricity in a hydrodynamic active fluid [278]. The design of the hydraulic brake is characterized by small dimensions and energy consumption of the stator drive and allows arbitrary orientation of the rotor shaft in space. The hydraulic resistance of the rotor in a hydrodynamic active fluid is controlled by moving the stator, forming an annular closed confusing-diffuser gap between them. The advantage of this method of regulating the braking torque is described in the works [279, 280].

A Literature review. Data on the influence of hydrodynamic active micelle-forming surfactants (MFS) on turbulent friction resistance when studying the flow of their micellar solutions in pipes are given in the work [281].

The possibility of effective use of MFS to increase the efficiency of some closed hydraulic systems for supplying heat and cold or water pumping systems is shown in paper [282].

Additives of MFS in homogeneous solutions have reverse mechanical destruction. This allows them to be used without loss of efficiency in main pipelines, where the movement of working fluids is provided by pumps.

The results of experimental studies on determining the dependence of the coefficient of the moment of hydrodynamic friction resistance on the Reynolds number during the flow of water-salt solutions of hydrodynamic active industrial metaupon paste in the gap between coaxial cylinders are given in [283]. These conditions make it possible to maintain certain friction stresses on the wall of rotating cylinder for a long time. Sodium chloride, the content of which in metaupon solutions was 8.0%, was used as an electrolyte that helps micelle formation in surfactant solutions.

The structural and mechanical properties of surfactant solutions and their hydrodynamic efficiency depend significantly not only on the concentration of additives, but also on the structure of the hydrocarbon radical of the surfactant molecule [283, 284].

The analysis of literary sources showed that the most of scientific works are devoted to the study of the flow of liquids with surfactants between coaxial cylinders. However, there are works devoted to the study of such flows between not coaxial cylinders. For example, paper [285] showed that during the flow of surfactant between not coaxial cylinders when the outer cylinder was rotating, the rotor resistance decreased by 18% at the values of the Reynolds number $5000 < Re < 15000$, and the stator resistance decreased by an average of 20% at $2000 < Re < 10000$ and up to 30% at $Re = 15000$.

Experimental research. Experimental stand. In the experimental stand (Fig. 1), the rotor is rigidly connected to the shaft of a DC electric motor mounted on a base plate. The stator, filled with the working fluid, relative to the rotor was installed with the possibility of radial reciprocating motion. The stator diameter was D = 142 mm, the rotor diameter was d = 42.1 mm and the rotor height was H=153 mm.

A detailed description of the experimental stand is presented in [286].

The annular gap between the rotor and the stator with a width b_k, corresponding to their initial concentric arrangement, changed into a closed confuser-diffuser gap with a width b_e (Fig. 2) when the rotor position changed.

The experiments were carried out at a relative gap width equal to $b_e/b_к = 0.265…1.0$ (Table 1).

Selection of working fluid. The studies were carried out for water flows and flows of water with metaupon additives with mass concentrations of 0.1%, 0.5% and 1.0%. For thickening, 7% of their weight of sodium chloride (NaCl) was added to metaupon solutions and for stabilization – 0.2% of sodium hydrogen carbonate ($NaHCO_3$).

Table 1

The values of the relative width of the gap between the rotor and the stator were studied

Diameters, mm		d/D	Relative gap width $b_e/b_к$
Rotor diameter d	Stator diameter D		
42.1	142	0.30	0.265; 0.51; 0.755; 1.0

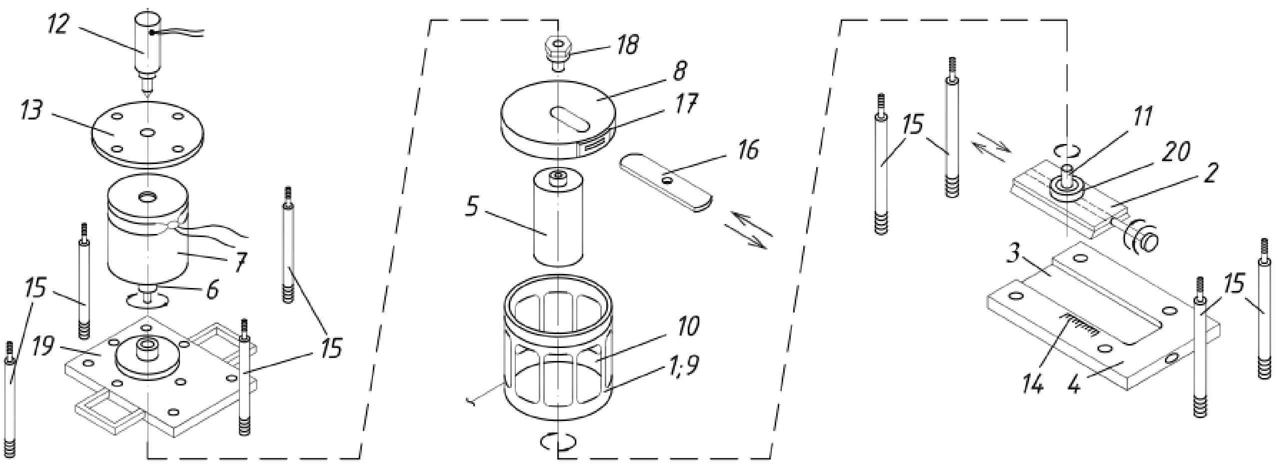

Figure 1. Scheme of the experimental stand: 1 – stator; 2 – movable plate; 3 – groove; 4 – base plate; 5 – rotor; 6 – shaft; 7 – DC electric motor; 8 – cover; 9 – metal frame; 10 – transparent cylinder; 11 – axis; 12 – tachometer; 13 – plate; 14 – scale; 15 – stand; 16 – sealing plate; 17 – seals; 18 – intermediate sleeve; 19 – plate; 20 – clamp [286]

Calculation formulas. The average tangential stresses on the rotor wall are determined by dependence:

$$\tau = \frac{T}{2\pi \cdot r \cdot H}, \qquad (1)$$

where T – the total friction force applied to the side surface of the rotor.

Taylor criterion determined by dependence:

$$Ta = \frac{V \cdot b}{\nu} \cdot \sqrt{\frac{b}{r}}, \qquad (2)$$

where V – linear rotation velocity of the rotor;

ν – kinematic viscosity of the liquid;

r – rotor radius.

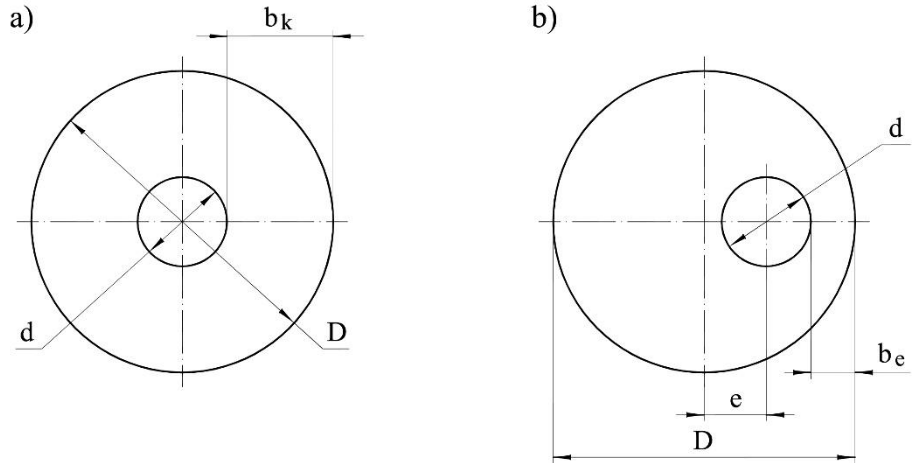

Figure 2. Schemes of coaxial (a) and non-coaxial (b) arrangement of the rotor and stator: e – eccentricity; b_k – the width of the gap with a concentric arrangement of the rotor; b_e – the width of the gap with a eccentric arrangement of the rotor

The friction coefficient in the gap between the rotor and the stator was determined as:

$$C_f = \frac{G}{Re^2}, \tag{3}$$

where G – dimensionless torque on the inner cylinder in the gap between the rotor and the stator,

$$G = \frac{T}{\rho \cdot \nu^2 \cdot H}, \tag{4}$$

where ρ – liquid specific gravity;

ν – kinematic viscosity of the liquid.

Reynolds criterion determined by dependence:

$$Re = \frac{\Omega \cdot r \cdot (r_o - r)}{\nu}, \tag{5}$$

where r_o – stator radius;

Ω – angular rotation velocity of the rotor.

The effect of influence on the rotor frictional resistance was determined by the formula:

$$DR\% = \frac{c_{f,\omega} - c_{f,s}}{c_{f,\omega}} \times 100. \qquad (6)$$

where $c_{f,\omega}$ – coefficient of friction in the gap between the rotor and the stator during water flow; $c_{f,s}$ – coefficient of friction in the gap between the rotor and the stator during water with metaupon additives flow.

Results and discussion. The results of the influence of eccentricity and concentrations of aqueous solutions of metaupon on the hydrodynamic resistance of the rotor are presented. Each of the obtained points is the arithmetic mean of three repeated measurements.

Graphic dependences of $\tau = f(Ta)$ for the flow of aqueous solutions of metaupon in the gap between cylinders for d/D = 0.30 and b_e/b_k = 0.265; 0.51; 0.755; 1.0 is presented in fig. 3.

For the studied range of values of the Taylor criterion Ta = 100000...450000, the average tangential stresses on the wall of the rotor, which rotated in water and in aqueous solutions of metaupon (Fig. 3, a, b, c), decrease with an increase in the criterion Ta and with a decrease in the ratio b_e/b_k, i.e. with increasing eccentricity e (Fig. 2).

During water flow, the tangential stresses on the rotor wall (d/D = 0.30) for all investigated values of b_e/b_k increase. Additions of metaupon increased the tangential stresses on the rotor wall with coaxial arrangement of the cylinders (b_e/b_k = 1) for concentrations 0.1%, and decreased them for concentrations 0.5% and 1.0%. With an eccentric arrangement of the rotor, its hydraulic resistance increased for all values of b_e/b_k (Table 2). Additives of metaupon of all studied concentrations caused a change in the resistance of the rotor.

On fig. 4 presents the results of the change in the friction coefficient for aqueous solutions of metaupon (C = 0.1%, 0.5%, 1.0%) at relative gap widths b_e/b_k = 1.0; 0.755; 0.51; 0.265.

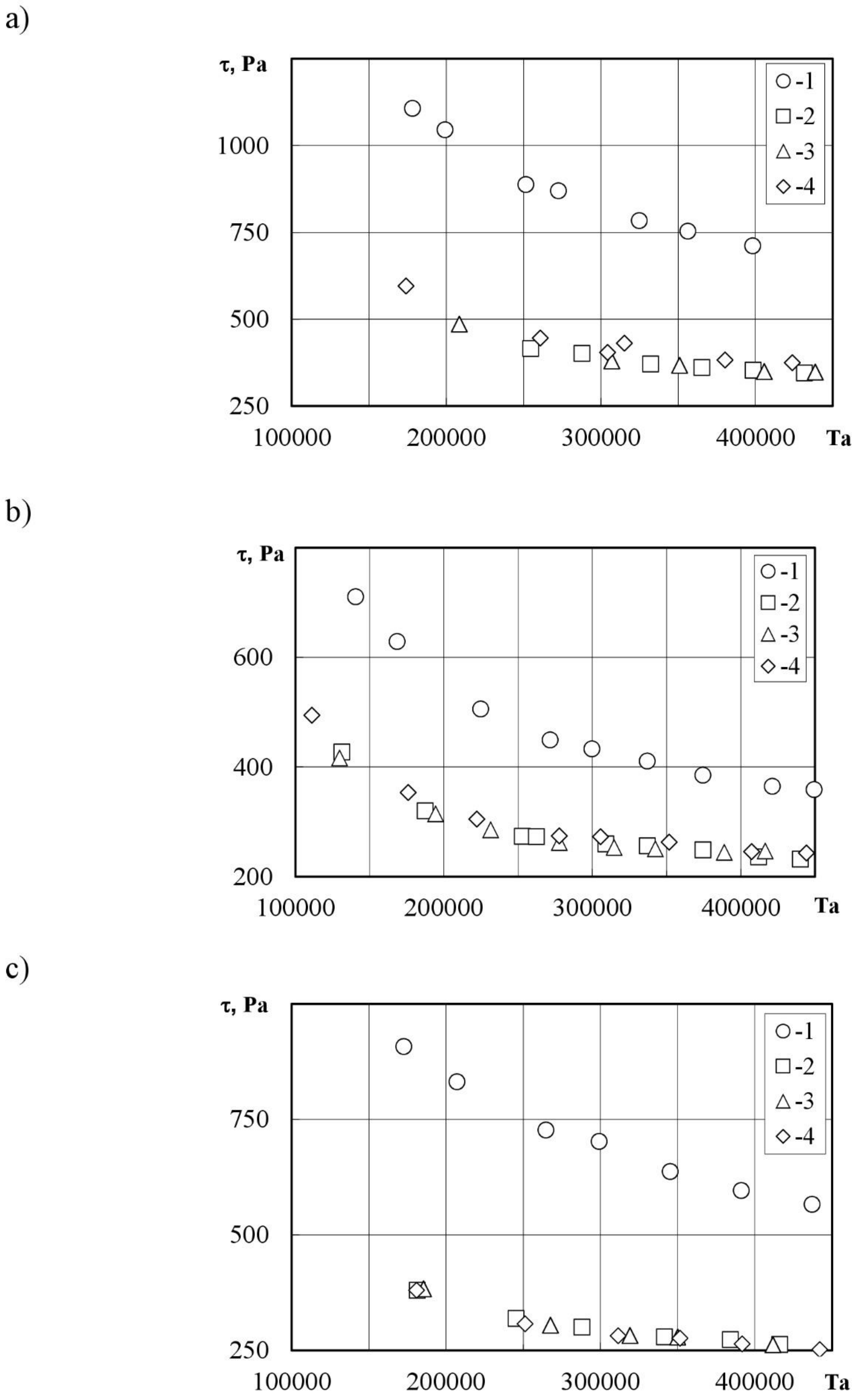

Figure 3. Influence of the eccentricity of the rotor with d = 42.1 mm during rotation in metaupon solutions with mass concentrations, %: 0.1 (a); 0.5 (b); 1.0 (c) for the width of b_e/b_k = 1.0 – (1); 0.755 – (2); 0.51 – (3); 0.265 – (4)

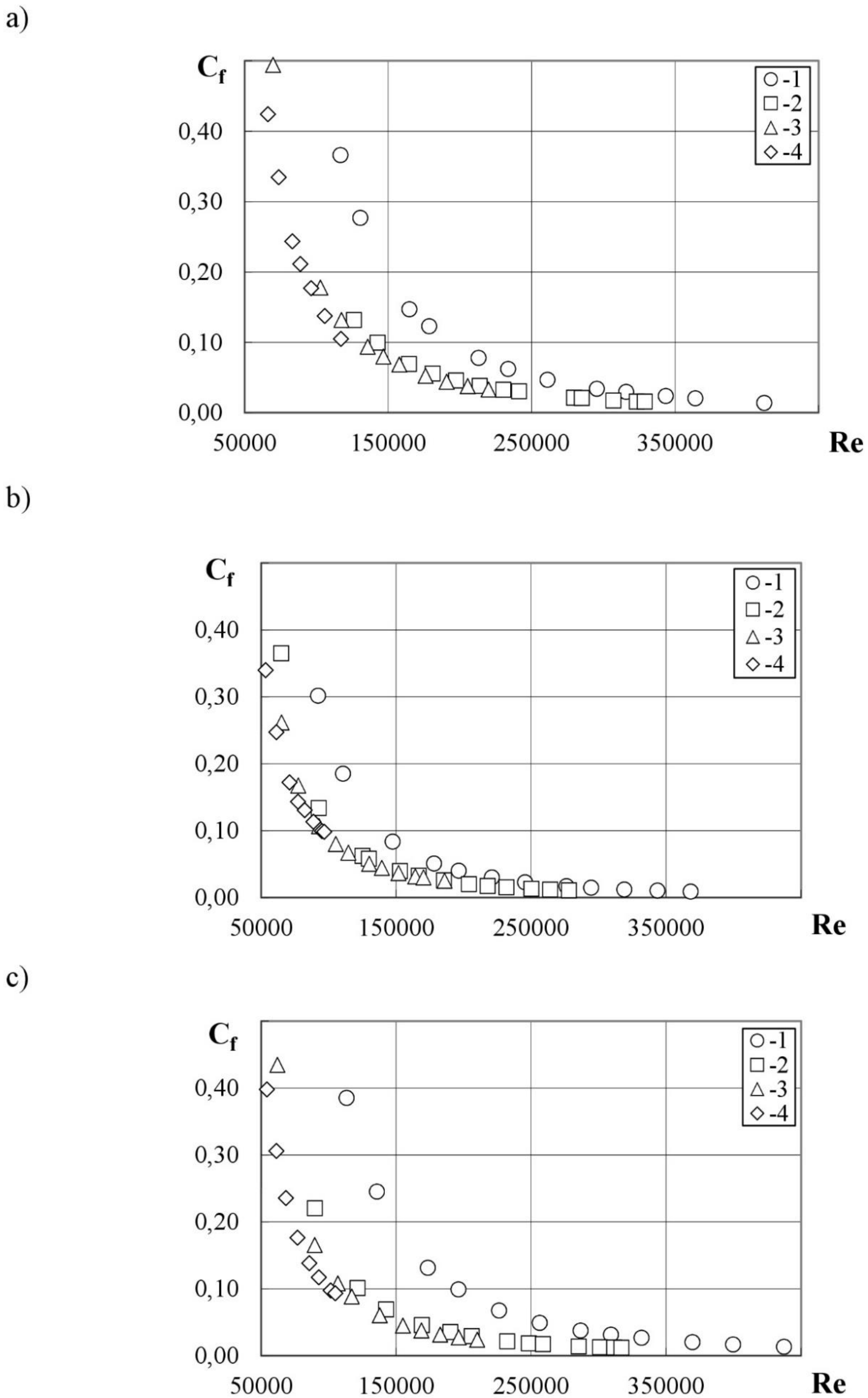

Figure 4. Influence of the eccentricity of the rotor with d = 42.1 mm during rotation in metaupon solutions with mass concentrations, %: 0.1 (a); 0.5 (b); 1.0 (c) for the width of b_e/b_k = 1.0 – (1); 0.755 – (2); 0.51 – (3); 0.265 – (4)

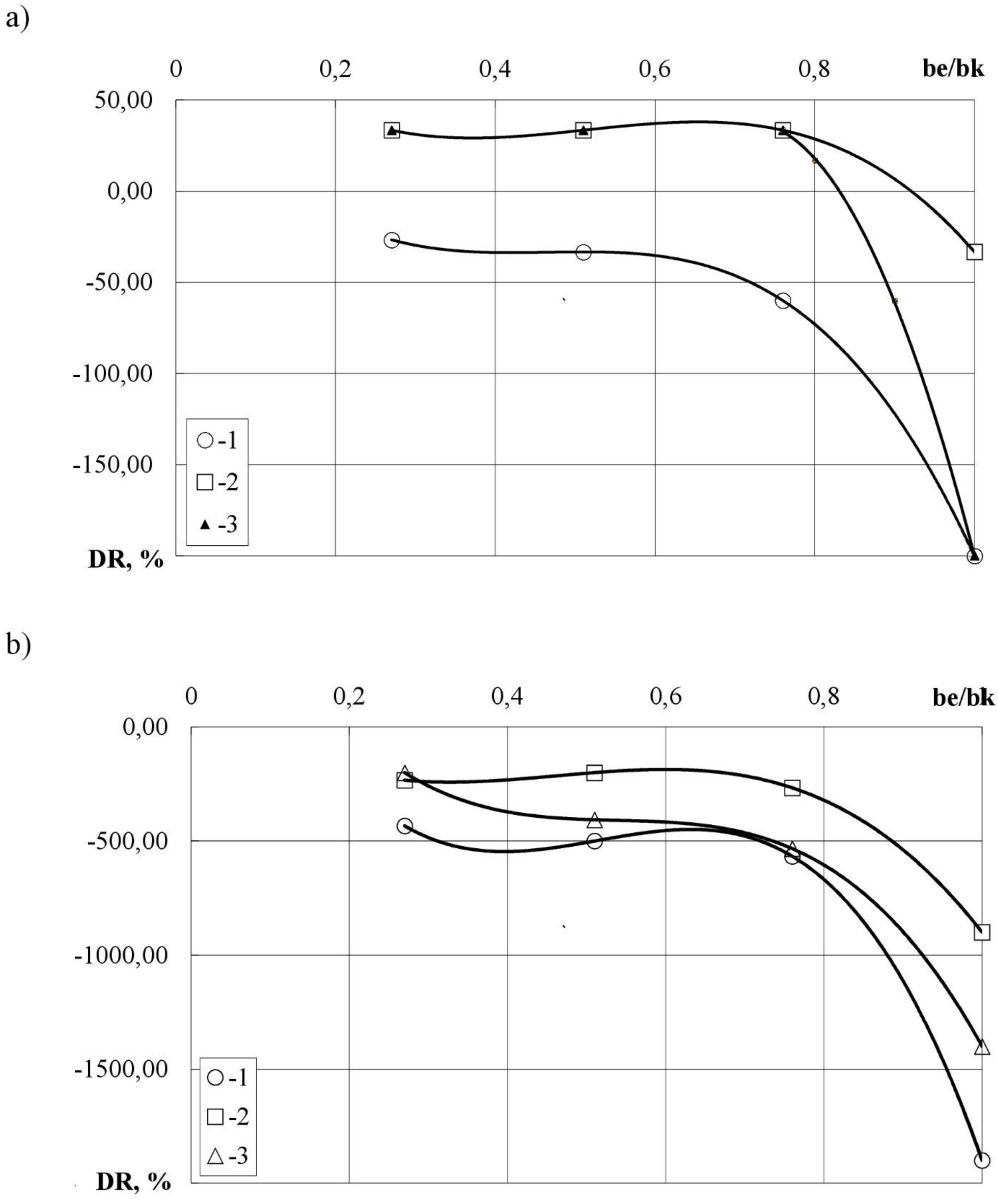

Figure 5. The effect on the friction resistance at a relative gap width b_e/b_k for aqueous solutions of metaupon with mass concentrations of 0.1% (1), 0.5% (2) and 1.0% (3) at Re = 200000(a) and 100000(b)

With an increase in the values of the Reynolds criterion, the friction coefficient decreases for all studied concentrations of aqueous solutions of metaupon. For fixed values of the Reynolds number, a decrease in the friction coefficient of the studied solutions was obtained with a decrease in the width of the gap [287-293].

Table 2

The impact of the inconsistency position of the rotor on its hydraulic resistance at Ta = 400000

Relative gap width $b_e/b_к$	Tangential stresses on the rotor wall τ, Pa, at the concentration of an aqueous solution of metaupon C, %			
	0	0.1	0.5	1.0
1.0	574	711	370	590
0.265	1260	380	260	263

The effect of DR aqueous solutions of metaupon on the frictional resistance of the rotor at Re = 200000 and Re = 100000 decreases with increasing values of b_e/b_k, starting from b_e/b_k = 0.6…0.755 for concentrations C = 0.1% and 0.5%, respectively (Fig. 5). Moreover, increasing the concentration from 0.1 to 0.5% reduces this effect. The concentration C = 1.0% occupies an intermediate value of the DR effect, therefore its use is inefficient.

Therefore, the performed studies revealed the effect of aqueous solutions of metaupon with mass concentrations C = 0.1%, 0.5%, 1.0% on the friction resistance in the gap between the rotating rotor and the stationary stator at d/D = 0.30 for the values of b_e/b_k = 1.0; 0.755; 0.51; 0.265.