Journal of Engineering Physics and Thermophysics, Vol. 74, No. 1, 2001

INJECTION OF QUICKLY PREPARED "SOLUTIONS" OF POLYETHYLENE OXIDE INTO A TURBULENT FLOW IN A TUBE

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UDC 532.526.532.72

Results of an experimental investigation of the effect of reducing the hydrodynamic friction resistance in injection of quickly prepared "solutions" of polyethylene oxide into a turbulent flow in a tube, performed in different temperature regimes of injection of these "solutions" into the turbulent flow, are presented. A description of the design of a device for quick preparation of polymeric "solutions" is given. The time of preparation of the "solutions" was varied from 0.2 to 40 sec. The experiments have been performed for a wide range of concentrations of the polymer in the injected "solutions."

The effect of reducing the hydrodynamic friction resistance (RHDFR) on a surface in turbulent flow of water in the presence of small additions of water-soluble high-molecular-weight polymers (for example, polyethylene oxide) in the flow is well known (see [1]). This is confirmed by numerous experiments on investigation of water flow in tubes with different diameters and of the motion of well-streamlined bodies in water. In some cases, the experiments were organized in such a way that a polymer was injected into the near-wall region of the flow, for example, through a slot, in the form of a polymeric solution prepared in advance (PSPA) with a fairly high concentration. In this case, on the surface in the flow a diffuse boundary layer with a variable concentration of the polymer across its cross section was formed. In other cases, the flow of the polymeric solution about the surface had a lower concentration; however, its value was constant throughout the entire region of the flow.

What all these investigations had in common was that, in the experiments, a polymeric solution prepared in advance, i.e., a true solution, was used. The preparation of such a solution represents a rather complex and prolonged (several hours or even days) technological process that, in addition, requires large geometric volumes that are used in both preparation and storage of the polymeric solution prepared in advance until it is used. These two circumstances present problems when a polymeric solution prepared in advance is used in practice for RHDFR purposes.

Moreover, a serious deterrent to the practical use of polymeric additions for the purpose of reducing hydrodynamic friction resistance is the economic aspect of the problem, since the cost of a polymer can be fairly high. However, if polymeric additions are used sporadically, temporarily, and in extreme situations, expenditures related to their cost become insignificant compared with the benefit derived when the extreme situation is resolved: for example, the need for a sharp increase in the water flow rate in drainage systems in the case of heavy showers and freshets; the need for an increase in the velocity of a ship in the case where it overcomes high-velocity flows; the need for motion of a hydrofoil craft "on the wings" (on the hydrofoils) in the case of heavy waves or in the case of its overload (rescue work and other emergencies); the need for an increase in the range of a water jet in the case of fire fighting, etc.

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For the above-considered cases, especially for cases where polymeric additions are used in the exploitation of various technical means that are characterized by a deficiency of free geometric volumes (small ships, fire-fighting vehicles, and so on), compact systems for preparation of highly efficient polymeric solutions that do not contain large volumes for subsequent complete dissolution of them are of great importance. Such compact systems could be installed on currently available technical objects without any considerable expenditures on reconstructing them. At the same time, in extreme situations these technical objects could possess improved tactical and technical characteristics as compared to their regular variants.

Thus, an alternative variant to the use of polymeric solutions prepared in advance can be quick continuous preparation of a polymeric solution in necessary amounts with simultaneous injection of the entire prepared solution into the turbulent flow. This process implies that a polymeric solution does not accumulate "on board." Quick preparation of the solution can be performed with the help of a compact device for mixing the polymeric material found "on board" (powder, paste, or solid briquette) with the "outboard" water. In this case, it is assumed that the solution should be prepared within a very short time interval: the time between the moment of contact of the initial polymeric material with water in the mixing device and the moment of injection of the produced solution into the turbulent flow can be from fractions of a second to several seconds. In the subsequent discussion we will call this time *t* the time of preparation of the quickly prepared polymeric solution (QPPS).

From the viewpoint of the physicochemical nature of dissolution processes, this quickly prepared polymeric solution can only arbitrarily be called a solution, because it represents an aqueous-polymeric suspension containing a large amount of incompletely dissolved polymer. Evidently, such a suspension also contains dissolved molecules of the polymer that, for the most part, have a relatively low molecular weight and particles of the polymer in different stages of swelling.

It is known that the magnitude of the RHDFR effect in injection of a polymeric solution prepared in advance into a turbulent flow depends on many parameters related to the characteristics of the polymeric material and the polymeric solution, the conditions of injection of this solution into the turbulent flow, and the parameters of the turbulent flow itself (see [1]). Determination of the optimum conditions of injection of a polymeric solution prepared in advance into a turbulent flow for the purpose of producing the necessary RHDFR effect is a complex multiparameter problem that has not been solved satisfactorily so far despite the large number of investigations performed worldwide.

In using a quickly prepared polymeric solution, all other things being equal, the time of preparation *t* is one of the most important parameters determining the magnitude of the RHDFR effect. This parameter characterizing the "speed" of preparation of the quickly prepared polymeric solution has the meaning that while the "solution" traverses the path from the device for mixing the polymer with water to the site of injection of it into the flow, processes of complete dissolution occur in the "solution" that change the proportion between the water, the dissolved polymer, and the polymeric particles in different stages of swelling. The larger the time of preparation *t*, the larger the amount of the dissolved polymer in the "solution," i.e., the higher the effective concentration of the polymer in it.

The process of manifestation of the RHDFR effect in the case where a quickly prepared polymeric solution is used, as compared to that in the case of use of a polymeric solution prepared in advance, is additionally complicated by the fact that the process of complete dissolution of polymeric particles also occurs after injection, in the turbulent flow itself, i.e., in addition to diffusion of the injected polymeric solution, the process of its "generation" occur in the flow.

The first attempts to investigate the possibility of reducing the hydrodynamic friction resistance using a quickly prepared polymeric solution were made by the authors of [2]. More complete generalized data obtained in the case of injection of a quickly prepared polymeric solution into a turbulent flow in a tube, including new data on the influence of the temperature on the RHDFR effect are given below.

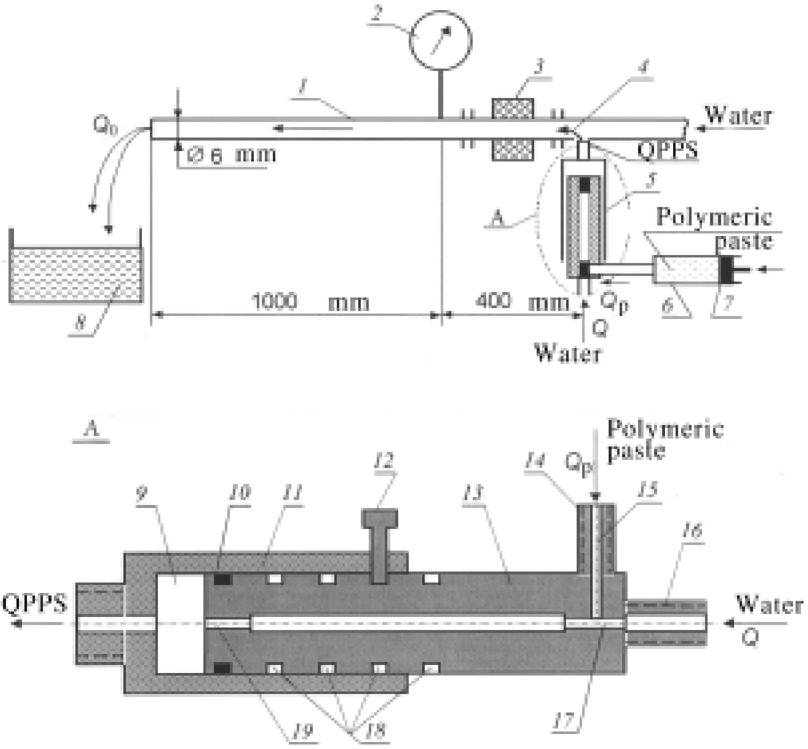

Fig. 1. Schematic of the experimental tube stand and the jet mixer with a chamber for complete dissolution: 1) measuring tube; 2) standard pressure gauge; 3) flow meter; 4) openings for injection of the polymeric solution; 5) jet mixer; 6) cylinder with the polymeric paste; 7) piston for feeding the polymeric paste; 8) catch tank; 9) chamber for complete dissolution; 10) sealing collar; 11) casing of the chamber for complete dissolution; 12) fixing rod; 13) casing of the jet mixer; 14) connection for feeding the polymeric paste; 15) channel for feeding the polymeric paste; 16) connection for supplying water; 17) nozzle; 18) ring channels; 19) nozzle.

The experiments were performed on a tube stand. A schematic of the stand is shown in Fig. 1. The main elements of the stand are a measuring tube 1, a standard pressure gauge 2, and a flow meter 3. A developed turbulent flow into which a polymeric solution was injected was realized in the measuring tube 1. The RHDFR effect R was determined by the method of measuring the pressure differential ΔP in the measuring tube 1:

$$R = \frac{\lambda_\mathrm{s} - \lambda_\mathrm{w}}{\lambda_\mathrm{s}} \cdot 100\% \,. \tag{1}$$

The coefficients λ_s and λ_w should become equal for the same flow rates Q_0 of the liquid flowing through the measuring tube; therefore, formula (1) is transformed to the form

$$R = \frac{\Delta P_\mathrm{s} - \Delta P_\mathrm{w}}{\Delta P_\mathrm{s}} \cdot 100\% \,. \tag{2}$$

The polymeric solution was injected into the flow upstream of the flow meter 3 through the side opening 4 in the main tube, positioned a distance of 400 mm from the beginning of the measuring tube 1. The measuring tube was made of stainless steel, and it was 6 mm in diameter and 1000 m in length.

To prepare a quickly prepared polymeric solution, use was made of a polymeric paste that represented a thoroughly mixed mixture of polyethylene oxide powder (30%) with glycerin (70%). Glycerin is a very suitable substance that disperses polymeric particles effectively and prevents them from sticking together.

Figure 1 also shows the design of a device for preparing a quickly prepared polymeric solution that represents a jet mixer with a chamber for complete dissolution. The water for preparing the quickly prepared solution enters the device through the connection 16. The polymeric paste drawn from the system for feeding and metering is introduced into the water flow through the connection 14, the channel 15, and the side opening in the nozzle 17. Downstream of the nozzle 17, the hydraulic channel sharply expands in a stepwise manner (the cross-sectional area of the channel increases by a factor of four). The polymeric paste is mixed intensely with the water. Then the mixture of the water with the paste goes through the nozzle 19 and enters the chamber for complete dissolution 9, where the intense process of mixing and dissolution continues. After the chamber for complete dissolution 9, the quickly prepared polymeric solution produced is injected into the turbulent flow through the opening 4 in the tube wall. The nozzles 17 and 19, which are placed 100 mm apart in the hydraulic channel 2 mm in diameter, are identical; they represent simple stepped necks 1 mm in diameter and 10 mm in length. With a rate of water flow through the jet mixer $Q = 1.7 \cdot 10^{-5}$ m^3/sec, the velocity of the flow in the nozzles is $U = 21.6$ m/sec.

The chamber for complete dissolution 9 is structurally the space bounded by the casing of this chamber 11 and the casing of the jet mixer 13.

The inside diameter of the casing of the chamber for complete dissolution is 29 mm. The space for complete dissolution can change owing to the displacement of the body of the jet mixer 13 (as a piston) in the body of the chamber for complete dissolution 11, and it can be fixed by the fixing rod 12 that goes into the ring channels 18 in the casing of the mixer. The channels 18 are placed a distance of 15 mm from one another, which makes it possible to change the time of preparation of the quickly prepared polymeric solution in steps of 0.6 sec (with a rate of water flow through the jet mixer $Q = 1.7 \cdot 10^{-5}$ m^3/sec). The quantity t is determined as the ratio of the volume of the chamber for complete dissolution 9 to the rate of water flow Q through the jet mixer. Structurally, it is easy to realize other variants of the time of preparation by changing the distance between the channels 18 and by changing their number.

In the experiments with polymeric solutions prepared in advance, a polymeric solution with the required concentration went through the jet mixer 5 and was injected into the turbulent flow through the opening 4 (see Fig. 1). In this case, a polymeric paste was not supplied to the jet mixer.

All the experiments were performed for four values of the time of preparation of the quickly prepared solution t, sec: 0.17, 0.75, 1.33, and 1.91 with the use of three samples of polymeric paste, which differed only in the mean size d of the particles of the polymeric powder: sample No. 1, $d = (40–60) \cdot 10^{-6}$ m; sample No. 2, $d = (60–100) \cdot 10^{-6}$ m; sample No. 3, $d = (100–140) \cdot 10^{-6}$ m. The molecular weight of the polyethylene oxide was $M \approx 4 \cdot 10^6$.

The experiments were performed in the following order.

At first, we determined the pressure differential ΔP_s in the measuring tube for a rate of water flow through it Q_0 without injection of a polymeric solution. Then, for the chosen value of the parameter t, which was set by the position of the fixing rod 12 (see Fig. 1), we determined the pressure differential ΔP_w in the case of injection of a polymeric solution (a polymeric solution prepared in advance or a quickly prepared polymeric solution) of the required concentration into the turbulent flow in the tube. The quantity ΔP_w was measured for the same rate of water flow through the tube Q_0 as in the case of measurement of ΔP_s. Processing of the experimental results consisted in calculating the set of values of the RHDFR effect R by formula (2) for the corresponding sets of parameters t and C in the case of injection of a quickly prepared polymeric solution or simply for a set of parameters C in injection of a polymeric solution prepared in advance.

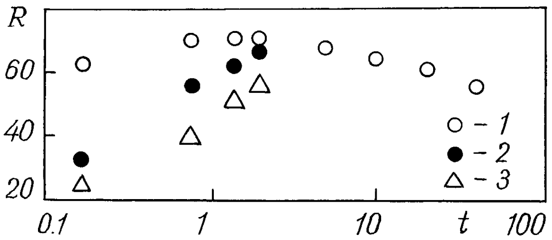

Fig. 2. Influence of the time of preparation of the QPPS and the size of the particles of the polymeric material on the RHDFR effect: 1) $d = (40–60)\cdot10^{-6}$ m; 2) $(60–100)\cdot10^{-6}$; 3) $(100–140)\cdot10^{-6}$. R, %; t, sec.

The experiments were performed under the following conditions.

The mean velocity of the flow in the measuring tube was constant and equal to U_0 = 9.6 m/sec, which corresponded to $Q_0 = 2.7\cdot10^{-4}$ m^3/sec. The flow rate of the polymeric solution (a quickly prepared polymeric solution or a polymeric solution prepared in advance) injected into the flow was equal to $Q = 1.7\cdot10^{-5}$ m^3/sec in all the experiments.

In the experiments on investigating the influence of the size of the particles of the initial polymeric material and the time of preparation of the quickly prepared polymeric solution on the RHDFR effect, the mass concentration of the injected quickly prepared polymeric solution was constant and equal to $C = 1.6\cdot10^{-3}$. This is a conventional quantity that was defined as $C = 0.3\rho_pQ_p/\rho_0Q_0$, where Q_p and Q_0 are, respectively, the volumetric flow rates of the polymeric paste and the water in the jet mixer, and ρ_p and ρ_0 are the densities of the polymer and the water. The coefficient 0.3 corresponds to the content of the polymer in the polymeric paste (30%).

The results of the experiments on the influence of the time of preparation of the quickly prepared polymeric solution and the size of the polymeric-material particles on the value of the RHDFR effect R are presented in Fig. 2.

For a quickly prepared polymeric solution prepared from a polymeric material in which the mean size of the particles is $d = (40–60)\cdot10^{-6}$ m, we performed special experiments on determination of R for increased times of preparation of the quickly prepared polymeric solution ($t >> 2$ sec). To increase t, we placed a hose 12 mm in diameter between the chamber for complete dissolution and the opening for injection of the quickly prepared polymeric solution. The value of the parameter t was determined by the length of this hose and the volume of the chamber for complete dissolution, and it could be increased to 40 sec.

Analysis of the results presented in Fig. 2 allows the following conclusions:

a) it is clearly seen that R depends on the time of preparation of the quickly prepared polymeric solution t. With increase in the parameter t, the effect is enhanced and approaches a certain maximum value, which is obvious for a quickly prepared polymeric solution with a size of the particles of the initial polymeric material $d = (40–60)\cdot10^{-6}$ m;

b) it is clearly seen that R depends on the mean size of the particles of the initial polymeric material. With decrease in the parameter d, the effect is enhanced and the hydrodynamic efficiency of the quickly prepared polymeric solution R depends less and less on the time of preparation t;

c) a large increase in the time of preparation of the quickly prepared polymeric solution leads to an interesting result – a decrease in the magnitude of the RHDFR effect R. For a polymeric paste with a mean size of the particles $d = (40–60)\cdot10^{-6}$ m, the maximum value of R was detected at $t \approx 2$ sec. A further increase in the parameter t from 2 to 40 sec leads to a decrease in R from 70 to 56%.

The decrease in the efficiency of the quickly prepared polymeric solution in the case of a large increase in the time of preparation can be explained based on the hypothesis of formation of supermolecular structures in an aqueous solution of polyethylene oxide (see [3]). The hypothesis lies in the fact that in aque-

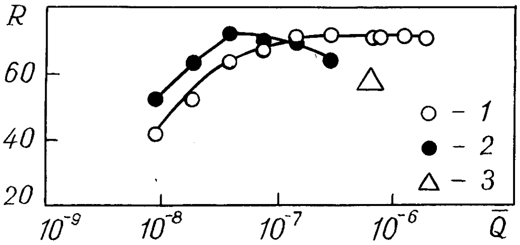

Fig. 3. Dependence of the RHDFR effect on the specific reduced flow rate of the polymer: 1) QPPS, t = 2 sec; 2) PSPA; 3) QPPS, t = 40 sec.

ous solutions of high-molecular-weight polymers supermolecular structures arise. The formation of these structures leads to an increase in the kinematic viscosity of the polymeric solution. In [2], an experiment on comparison of the viscosity of a polymeric solution prepared in advance and the viscosity of the quickly prepared polymeric solution is described. It follows from this experiment that whereas the viscosity of the quickly prepared polymeric solution (at $t \approx 2$ sec) is practically equal to the viscosity of water, the viscosity of the polymeric solution prepared in advance increases rapidly with increase in the concentration of the polymer in the solution. For a concentration of the polymer $C = 1 \cdot 10^{-3}$, the viscosity of the polymeric solution prepared in advance is approximately 4–5 times higher than the viscosity of water.

Thus, in injection of a quickly prepared polymeric solution, the decrease in R with increase in t can be explained by the fact that at $t \approx 2$ sec a detectable number of supermolecular structures did not have time to form in the quickly prepared polymeric solution, and at $t \approx 40$ sec this did happen.

We also performed comparative experiments on the influence of the concentration C of injected quickly prepared polymeric solutions and polymeric solutions prepared in advance on the value of the RHDFR effect. The experiments were performed for the following values of the concentration C: $3.2 \cdot 10^{-3}$, $1.6 \cdot 10^{-3}$, $0.8 \cdot 10^{-3}$, $0.4 \cdot 10^{-3}$, $0.2 \cdot 10^{-3}$, and $0.1 \cdot 10^{-3}$. The required value of the concentration of the quickly prepared polymeric solution was obtained by additional dilution of the initial polymeric paste fed into the device for preparing a quickly prepared polymeric solution with glycerin. To prepare the polymeric solution prepared in advance and the quickly prepared polymeric solution we used a polymeric paste in which the size of the particles was equal to $d = (40–60) \cdot 10^{-6}$ m. The time of preparation of the quickly prepared polymeric solution was equal to $t \approx 2$ sec.

We also performed a series of five experiments with injection of a quickly prepared polymeric solution with an increased concentration C: $6.4 \cdot 10^{-3}$, $8.6 \cdot 10^{-3}$, $12.8 \cdot 10^{-3}$, and $21.4 \cdot 10^{-3}$. These concentrations were attained by increasing the rate of feed of the initial polymeric paste into the jet mixer. The experiments with injection of a quickly prepared polymeric solution with a concentration $C = 6.4 \cdot 10^{-3}$ were performed for two values of the parameter t: 2 and 40 sec.

The results obtained are presented in Fig. 3c in the form of the dependence of R on the reduced specific flow rate of the polymer $\bar{Q}$. Here $\bar{Q} = QC/U_0S$.

Analysis of these results allows the following conclusions:

a) in injection of a polymeric solution prepared in advance, an increase in $\bar{Q}$ (in our case, an increase in C) to a certain value causes the effect R to increase to a maximum value, and then the magnitude of the effect R decreases;

b) in injection of a quickly prepared polymeric solution, the curve of the dependence $R(\bar{Q})$ is shifted toward larger values of $\bar{Q}$ compared to that for the polymeric solution prepared in advance, and no maximum characterizing the polymeric solution prepared in advance is observed. An increase in the parameter $\bar{Q}$ to $\bar{Q} \approx 3 \cdot 10^{-7}$ causes an asymptotic increase in R. A further increase in $\bar{Q}$ has no influence on the RHDFR effect;

TABLE 1. Temperature Regimes of the Experiments

No. of the series and the curve in Fig. 4	1	2	3	4	5
T_0, ^{o}C	15	15	15	2	2
T_w, ^{o}C	15	40	60	2	60

c) the result of the experiment in which injection of a quickly prepared polymeric solution with a time of preparation equal to t = 40 sec was performed (point 3 in Fig. 3) is of interest. The increase in the parameter t from 2 to 40 sec decreased the effect R from 70 to 56%. The point lies on the extension of the curve $R(\overline{Q})$ obtained for a polymeric solution prepared in advance.

d) in injection of a quickly prepared polymeric solution, the maximum value of R is equal to the maximum value of R in injection of a polymeric solution prepared in advance (~70%).

All the differences in the action of a polymeric solution prepared in advance and a quickly prepared polymeric solution on the RHDFR effect are well explained by the above-mentioned hypothesis of formation of supermolecular structures:

a) in injection of a quickly prepared polymeric solution ($t \approx 2$ sec), these structures have no time to form and the magnitude of the effect R increases with increase in the concentration of the polymer in the solution. For a certain value of this concentration, the effect reaches saturation and then it remains constant;

b) in the case of injection of a polymeric solution prepared in advance, in both the injected polymeric solution and in the near-wall region of the turbulent flow supermolecular structures that increase the kinematic viscosity of the flow appear after the injection. The higher the concentration of the polymer in the injected solution, the higher the viscosity appearing due to the presence of the supermolecular structures. Beginning from a certain value of the concentration C, the viscosity suppresses the RHDFR effect. This leads to the appearance of a maximum on the $R(\overline{Q})$ curve;

c) the relative shift of the $R(\overline{Q})$ curves obtained for a polymeric solution prepared in advance and a quickly prepared polymeric solution is explained by the fact that in the quickly prepared polymeric solution the amount of dissolved "working" polymer is always somewhat smaller than that in the polymeric solution prepared in advance for the same values of C. As has already been noted, for a quickly prepared polymeric solution, the concentration C is conventional;

d) the result of the experiment in which the injection of a quickly prepared polymeric solution with a time of preparation equal to t = 40 sec was performed is also well explained by the hypothesis of the existence of supermolecular structures: the time of preparation t = 40 sec was found to be sufficient for supermolecular structures characteristic of a polymeric solution prepared in advance to be formed in the injected quickly prepared polymeric solution, i.e., for the viscosity of the quickly prepared polymeric solution to become equal to the viscosity of a polymeric solution of the corresponding concentration prepared in advance. This caused the magnitude of the effect R to decrease from 70 to 56% (see 3 in Fig. 3).

All the above-described experiments with quickly prepared polymeric solutions were performed under isothermal conditions at temperatures of 15–20^{o}C. In the case of practical use of a quickly prepared polymeric solution, the question of the influence of the temperature on the efficiency of the solution inevitably arises, since the temperatures of both the main and injected flows can change within wide limits: from (2–4)^{o}C to (60–80)^{o}C. Grounds to expect the physicochemical processes of dissolution of the polymer, the processes of heat transfer and diffusion of the polymer into the flow, and the RHDFR effect to be closely related are given by a number of investigations on polymeric solutions prepared in advance (see, for example, [4]). Below, are results of an investigation of the influence of the temperature on the RHDFR effect are given.

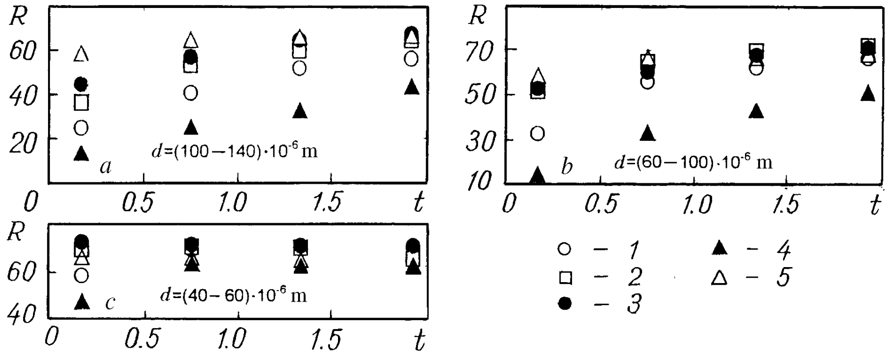

Fig. 4. Influence of the temperature of the main and injected flows on the RHDFR effect (1–5 – see Table 1): a) d = (100–140)$\cdot 10^{-6}$ m; b) (60–100)$\cdot 10^{-6}$ m; c) (40–60)$\cdot 10^{-6}$ m.

We performed five series of experiments that differed in the combination of the temperatures T_0 and T_w. The temperature regimes are given in Table 1.

Each series consisted of 12 experiments, in which 3 samples of polymeric paste were investigated and the time of preparation t had four values (0.17, 0.75, 1.33, and 1.91 sec). The samples differed in the mean size of the polymeric particles d. The concentration of the injected quickly prepared solution was constant and equal to $C = 3.1 \cdot 10^{-3}$.

The results obtained are presented in Fig. 4 in the form of the dependence $R(t)$. Analysis of these results allows the following conclusions:

a) for a polymer containing comparatively large particles (d = (100–140)$\cdot 10^{-6}$ m), an increase in the temperature T_w is a powerful factor for enhancement of the effect R. Thus, for example, as T_w increases from 2 to 60°C and t simultaneously increases from 0.17 to 1.91 sec, the value of R increases by a factor of 5 (from 13 to 66%). It is of interest to note that the colder the flow in the measuring tube, the stronger the effect R;

b) as the size of the polymeric particles decreases, the influence of the parameters t, T_0, and T_w become weaker. For d = (40–60)$\cdot 10^{-6}$ m, the values of R remain constant (65–70)% throughout practically the entire range of variation of t.

Thus, in [2] and in the present work, a method for preparation of quickly prepared polymeric solutions has been proposed and some of their properties that decrease the hydrodynamic friction resistance in turbulent flows have been investigated.

The results obtained in the investigations performed can be formulated as follows:

1) the use of quickly prepared polymeric solutions for the practical solution of problems of RHDFR is possible and is preferable to the use of polymeric solutions prepared in advance, since it makes it possible to produce no weaker an effect;

2) to prepare a quickly prepared polymeric solution, one can use a glycerin-based polymeric paste that contains fairly small particles of the polymeric material. The optimum size of the particles is d = (40–60)$\cdot 10^{-6}$ m. An increase in the size d leads to a decrease in the RHDFR effect;

3) the time of preparation of the quickly prepared polymeric solution should be rather short; the optimum time is $t \approx 2$ sec. For smaller values of t, the RHDFR effect is reduced because of the short time of contact of the polymer with the water. For $t \gg 2$ sec, supermolecular structures are intensely formed in a quickly prepared polymeric solution (just as in a polymeric solution prepared in advance), which also leads to a decrease in the RHDFR effect;

4) an increase in the temperature of the injected quickly prepared polymeric solution (in our experiments, to 60°C) makes it possible to obtain fairly high values of the RHDFR effect even for small values of the preparation time ($t < 2$ sec) and comparatively large polymeric particles ($d >$ (40–60)$\cdot 10^{-6}$ m).

NOTATION

t, time of preparation of the quickly prepared polymeric solution; λ_s and λ_w, coefficients of resistance of the measuring tube without injection (standard regime) and in injection of the polymeric solution (working regime), respectively; ΔP_s and ΔP_w, pressure differentials in the measuring tube in the standard and working regimes, respectively; R, effect of reducing the hydrodynamic friction resistance; C, mass concentration of the polymer in the injected solution; Q, volumetric flow rate of the injected polymeric solution; Q_0, volumetric flow rate of the water in the measuring tube; $\overline{Q}$, specific reduced flow rate of the polymer; U_0, mean velocity of the flow in the measuring tube; S, area of the interior surface of the measuring tube; d, mean size of the particles of the initial polymeric material; T_0, temperature of the flow in the measuring tube; T_w, temperature of the water entering the device for preparing a quickly prepared polymeric solution.

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