

DEFORMATION EFFECTS IN CASE OF A FLOW WITH STRETCHING OF POLYMER SOLUTIONS

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ABSTRACT

The considered experimental data of polarizatin-optical study of wall turbulence of polymer solutions reducing turbulent friction give a convincing confirmation of a strong deformation effect of a hydrodynamic field on macromolecules under wall turbulence. The obtained results support the idea that the mechanism of drag reduction is uniquely related to the process of complete unrolling of macromolecules which cause nonlinear elasticity effects.

Velocity and velocity gradient fields arising at the entrance of a small capillary during the free-converging flow (in conditions of near-the-wall turbulence and of filtration flow) of aqueous solution of polyethyleneoxide, as well as the degree of the coil-stretch transition of the macromolecule were experimentally studied. The hydrodynamic field arising under the converging flow conditions resulted in a considerable (~60%) degree of polymer stretching which, in turn, led to a readjustment of the hydrodynamic field itself.

Is established, that regularities of macromolecular in case behaviour of a current with a longitudinal gradient of speed and the effects of elastic deformations anomalous" phenomena have the greatest value for understanding the nature "anomalous" (from the point of view of classical hydromechanics) phenomena - deviations from the law of Darcy and Toms' effect.

The clarified main regularities of macromolecular in case behaviour of a current with a longitudinal gradient of speed and the effects of elastic deformations manifested in this case was applied for the solution of a lot of technological problems, connected with protection of environment.

INTRODUCTION

In the hydrodynamics of polymer solutions there takes place the transition from accumulating experimental information to understanding the physical essence and establishing main regularities of manifestation of memory and elasticity effects. Toms effect revealed as an experimental fact in the late 40-ies, up to now has been causing great difficulties when interpreting it from the point of view of modern ideas of the hydrodynamics of turbulent flow. Therefore the interest of specialists in hydrodynamics in the flow of solutions of polymers revealing low drag in the mode of turbulence is explained not only due to prospects of practical application of soluble polymers but also due to aspiration to use poly-

mer additions as a tool to provide more complete study of turbulent flows.

It is known that near-the-wall turbulent flows possess quasi-regular space-and-time structure, accompanied by big longitudinal gradients of speed. And this must cause considerable effects of elastic deformation. The same also refers to the problem of non-linear filtration, because filtration flow may also be reduced to the superposition of two kinds of flow - that with stretching and that being out of phase. Strong deformation action of filtration flow on molecular coils is yet to be proven.

It is possible to hope, that the way to understanding and describing phenomena - reduction of turbulent friction by polymer additions and abrupt increase of hydrodynamic drag during the flow of polymer solution through porous media - lies through the study of hydrodynamic effects of big reversible (as well as non-reversible) deformations of molecular coils in flows with stretching.

DISTORSIONS OF THE MOLECULAR SHAPE OF FLEXIBLE POLYMERS UNDER WALL-ADJACENT TURBULENCE CONDITIONS

Among the attempts to explain the nature of effect Toms', lying in drag reduction by the polymeric components, special place is taken by a hypothesis, based on strong deformation effect of a near-the-wall turbulence on macromolecules. For the substantiation of this hypothesis experimental proofs of presence of large degrees of deformation of macromolecules in a wall-adjacent zone of a turbulent flow are necessary. The skepticism concerning strong deformation effect of wall-adjacent turbulence on macromolecules is stipulated yet by the fact that, as a rule, shift effects wall-adjacent a turbulence are analysed, and not the, jet flows ("explosions") with a longitudinal gradient of speed which arise in the wall-adjacent area.

Therefore the experiments proving the stretching of molecules in conditions of wall-adjacent turbulence have a fundamental character not only in point of developing the mechanism of drag reduction by polymer additions but also in point of more profound insight into the nature of turbulence itself.

Polyethylene oxide (PEO) molecules have their own anisotropy and anisotropy of the form. And in case of full deployment macromolecules, which can be realized only in streams with expansion there, happens very significant (by 3-4 orders of magnitude more, than for simple shift) and fast increment of factor of birefringence with the

increase of a gradient of velocity acting on molecular coils, up to extremely possible Δn_{∞} , (D'yakova and et. al., 1989).

PEO having the viscosity-average molecular weight of $\overline{M}_{\eta} = 4.10^6$ was used as a polymeric additive and latent root of a viscosity $1,72 \text{ m}^3/\text{kg}$. The solutions of polymer had concentration 0,01-0,05%. Special hydrodynamic canal a rectangular cross-section 4x4 mm and height of 1m was used. Visualization made in wall-adjacent of area located on a distance 0,25m from its extremity of the channel.

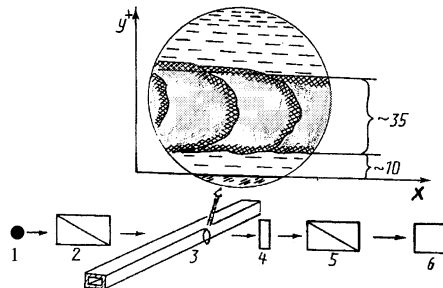


Fig.1. The sketch of a picture of birefringence zone and a diagram of experimental installation (1-mercury lamp; 2-polarizer; 3-hydrodynamic channel; 4-plate a equal to a quarter of a wavelength; 5-analyzer; 6-camera or cine camera).

Fig.1 shows a sketch of a picture birefringence zone of a turbulent boundary layer of a current of a water solution PEO having concentration 0,05% and $Re=2 \cdot 10^4$. Polarization and optical visualization testify, that in the field of $10 \leq y^+ \leq 45$, in which maximum generation of jets of fluid happens, birefringence is localized. In the immediate proximity to the wall ($0 \leq y^+ < 10$) and in the field of the kernel ($y^+ > 45$) birefringence is unvariable ($y^+ = V \cdot y / \nu$, where: y - is coordinate; V - is dynamic velocity; ν - is cinematic viscosity). This fundamental experiment unequivocally shows the presence of strong deformation effect on the molecular coils in certain zones of a turbulent boundary layer, having supercritical longitudinal gradients of speeds. A mean angle of the orientation of polymer molecules with a direction of the main flow is $\sim 35^\circ$. The performed visualization of near-the-wall turbulent flow of water solution PEO has confirmed the conventional ideas about the structure of a turbulent boundary layer.

The adequate experimental confirmation of the unrolling of macromolecules in conditions of the near-the-wall turbulence has made obvious the advantages of using nonturbulence flows with stretching for researching interaction of macromolecules with a hydrodynamic field and allowed to model the main structural singularities of a turbulent boundary layer.

DISTORSIONS OF THE MOLECULAR SHAPE OF POLYMERS UNDER FREE-CONVERGING FLOW CONDITIONS

The research of converging currents has shown that it is possible to generate zones with a mainly longitudinal gradient of velocity with the help of short capillary tube or slot (Pogrebnyak, 1984). On Fig.2 the experimental data describing features of current of water solutions

(PEO) in the underslot camera are indicated (Pogrebnyak and Ivanyta, 1998).

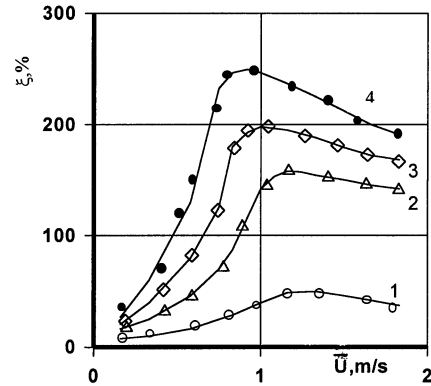


Fig.2. Influence of \overline{U} and angle of entrance into a slot on the relative pressure differential: 1-9°, 2-13°, 3-22°, 4-34°. $C_{PEO}=0.1\%$, $M_{PEO}=4 \cdot 10^6$

It can be seen, that the phenomena, unusual for purely viscous mediums are characteristic of such currents. At certain critical (threshold) values of average exhaust velocity \overline{U} the relative pressure differential begins sharply to increase, and it is the sharper the more is the concentration of polymer in a solution. The marked character of dependence $\xi = f(\overline{U})$ testifies about high dissipation (sometimes, than is on 2 orders of magnitude more) of energy during the course of solutions of polymers through an slot i.e. the increased hydrodynamic resistance on supercritical flow rates is observed. Transition to a mode of current with an increased dissipation of energy is accompanied by formation of the source flooded jet as "cord" or "fillet" enclosed by secondary currents in the shape of a ring-shaped vortex. In case of supercritical mode of current for area of the concentration lying between very diluted and moderately concentrated solutions of polymers, there happens rather strong deformation effect of a hydrodynamic field on molecular chains.

To interpret the data, the structure of the hydrodynamic field and degree of the molecular shape distortions induced by the field should be evaluated. In this study, velocity and velocity gradient fields as well as the degree of the coil-stretch transition at the entrance of the capillary were investigated for various flow regimes.

A flow viscometer with an entrance angle of 180° was used. The instrument contained a cell having a rectangular cross-section 10x17 mm and height of 80 mm and two short removable capillaries having the following diameter and length, respectively: 0.5 and 0.21 mm (capillary I) and 0.37 and 1.1 mm (capillary II). The velocity field at the entrance of the capillaries was measured using a laser Doppler anemometer according to the method (Klochkov and et.al., 1985). The average flow rate \overline{U} was measured volumetrically using a photoelectronic system; the flow downstream the capillary inlet was submerged. PEO having the viscosity-average molecular weight of $\overline{M}_{\eta} = 4 \cdot 10^6$ was used as a polymeric additive. The solutions were prepared in the following manner. A previously (one week before) prepared 0.1% solution of

PEO was diluted with distilled water. Additives of 0.05% potassium iodide were introduced to exclude degradation of the polymer solutions upon storing (Pogrebnyak and et al., 1982).

Distribution of the flow rate along the flow axis for 0.05% PEO solution in dimensionless coordinates is depicted in Fig.3.

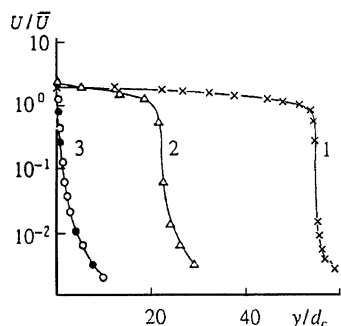


Fig. 3. Velocity distribution for the polymer solution along the flow axis. Flow through the capillary I at the average flow rate $\bar{U} = 2.5 \text{ m}\cdot\text{s}^{-1}$ (1), flow through the capillary II at $\bar{U} = 0.8 \text{ m}\cdot\text{s}^{-1}$ (2) and through the capillary II at $\bar{U} = 0.5 \text{ m}\cdot\text{s}^{-1}$ (3). Filled circles represent the data for water when $\bar{U} = 0.8 \text{ m}\cdot\text{s}^{-1}$

It can be seen that, before the critical flow regime is attained, the anti-thixotropic increase of the effective viscosity is not exhibited and the axial distributions of velocity for the polymeric solution and pure water are almost the same (curve 3) and filled circles on curve 3, respectively. After passing through the critical flow regime, the curves exhibit a considerable deformation and development of the axial velocity profile (curves 1 and 2 in Fig. 3). The latter curves have at least two linear regions. It should be pointed out that after passing through the critical threshold, the flow velocities of the polymeric solutions exhibit considerable fluctuations, exceeding one order of magnitude. The range of fluctuations is dependent on the average flow rate, the diameter of the capillary, the molecular weight of the polymer, its concentration, its temperature, as well as its distance from the capillary inlet.

Step-by-step playback of a video recording of the flow (Ivanuta and et al., 1985) demonstrated that the fluctuations were associated with periodical formation and breakdown of the vortex upstream of the capillary inlet; the breakdown may be partial or complete. The changes with time in the hydrodynamic field correlate with the velocity changes; thus, the maximal rate at the flow axis is attained when the maximal length of the vortex is attained. The moment when the vortex has developed to its final shape seems to be the most interesting, since the largest degree of the coil-stretch transition of polymer can be expected in that state. Hence, when studying the axial distributions of velocity, only the maximal values arising at different average flow rates through the capillary were taken into account. A comparison of the velocity distributions along the flow axis with the corresponding patterns of streamlines allows the conclusion to be drawn that the steep decrease in the velocity occurs at the entrance zone of the vortex.

Using the experimental velocity distributions along the flow axis, the respective rate gradient distributions were calculated (Fig. 4).

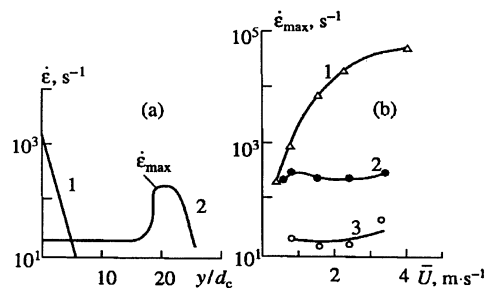


Fig. 4. (a) — Velocity gradient distribution along the flow axis at $\bar{U} = 0.8 \text{ m}\cdot\text{s}^{-1}$ for water (1) and 0.05% PEO solution (2). Measurements were performed with the capillary I; (b) - Dependence of the maximal longitudinal velocity gradient on the average flow rate for water (1) and 0.05% PEO solution (2) and $\dot{\epsilon}$ in the vortex for 0.05% PEO solution (3). Measurements were performed with the capillary I.

It can be seen that the maximal rate gradient $\dot{\epsilon}_{\text{max}}$ occurs not at the entrance of the capillary, but at some distance from that point equal to the length of the vortex (Fig. 4a, curve 2). The $\dot{\epsilon}_{\text{max}}$ at the entrance of the capillary for polymeric solution is considerably lower than that for water. Hence, the hydrodynamic field results in perturbation of the macromolecules, which, in turn, affects the velocity field in such a way that the longitudinal velocity gradients are decreased. Thus, the longitudinal velocity gradient at the vortex axis does not exceed 30 s^{-1} . An increase in molecular weight of the polymer and its concentration also results in decrease of the longitudinal gradient at the vortex axis. Thus, the respective value for 0.2% PEO solution and capillary I at the average flow rate $2 \text{ m}\cdot\text{s}^{-1}$ is equal to 10 s^{-1} . Such low values were also confirmed by the streak photography method. The photographs of the tracks of particles envisage that distances between the particles' positions assumed between the equal time gaps are almost the same, which confirms that the velocity gradient at the vortex axis is close to zero.

Fig. 4b illustrates that the longitudinal rate gradient at the axis of the vortex (curve 3) and maximal value of the rate gradient at the entrance of the capillary (curve 2) are only slightly dependent on the average flow rate through the capillary.

Hence, a novel method of controlling the flow of polymeric solutions has been found. Indeed, the structure of hydrodynamic field of a Newtonian fluid at a given value of the flow rate is strictly determined by the shape of the walls of the flow element and the average flow rate, whereas in our case the polymeric solution itself "regulates" the flow structure, which turns out to be absolutely independent (in classical sense) of the configuration of the walls.

The observed changes in the structure of the hydrodynamic field can be associated with large distortions of the macromolecular coils induced by hydrodynamic field, leading to non-linear elasticity effects. The degree of the coil-stretch transition may be estimated from the value of the deformational factor $\Delta n/\Delta n_{\infty}$, where Δn is the experimental flow birefringence value, while the Δn_{∞} is the limiting value of the flow birefringence calculated at the given concentration of

polymer. The methods of Δn_{∞} calculations and experimental procedure of Δn measurements are given elsewhere (D'yakova and et. al., 1989).

Results of the studies of the influence of hydrodynamic field on the polymeric solution are depicted in Fig.5.

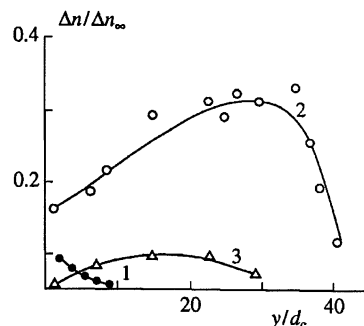


Fig. 5. The distribution of the coil-stretch transition degree over distance from the entrance of the capillary for aqueous PEO solution. $\bar{U} = 1 \text{ m} \cdot \text{s}^{-1}$, $C_{\text{PEO}} = 0.03\%$ (1); $\bar{U} = 2.5 \text{ m} \cdot \text{s}^{-1}$, $C_{\text{PEO}} = 0.03\%$ (2); $\bar{U} = 1 \text{ m} \cdot \text{s}^{-1}$, $C_{\text{PEO}} = 0.1\%$ (3). Measurements were performed with the capillary I.

The value of deformational factor increases when approaching the entrance of the capillary for the average flow rate equal to the critical value (curve 1) and reaches its maximum at rather high \bar{U} values (curve 2). The maximum position of the deformational factor $\Delta n/\Delta n_{\infty}$ at the entrance of the capillary corresponds to the domain with maximal longitudinal velocity gradient (Fig. 4a, curve 2).

As mentioned previously, the flow becomes rather unstable after passing through the critical threshold, which can be seen from the plot of the laser beam intensity vs. time in Fig.6a (the laser beam crossed the flow axis above the capillary entrance at the distance equal to the diameter of the capillary). The fluctuations are accompanied by the flow birefringence at the capillary inlet. Hence, during the flow birefringence measurements, only maximal Δn values at the given average flow rate of polymeric solution have been taken into consideration, as in the case of the velocity measurements.

The obtained distribution of the deformational factor over the flow axis at the entrance of the capillary (Fig. 5) envisages the possibility of a high degree of coil-stretch transition under the free-converging flow conditions. The flow birefringence ratio attains the value of 0.32, which corresponds to ~60% coil-stretch transition degree. Increasing the polymer concentration results in a decrease of the deformational factor (curve 3). Thus, for a 0.1% PEO solution characterized by the $[\eta]_0 C = 1.72$, the $\Delta n/\Delta n_{\infty}$ ratio is equal to 0.1. Hence, in moderately concentrated (semi-dilute) solutions, the coil-stretch transition degree attains 30%.

Fig.6 envisages deformational behavior of macromolecules at the different flow rates. It can be seen that the $(\Delta n/\Delta n_{\infty})_{\text{max}}$, vs. average flow rate dependence

may be divided into three domains. Domains 1 and 3 are characterized by a monotonic increase of the coil size with growth of the flow rate, while in the intermediate domain 2 the transition is rather sharp. From a comparison of Figs. 4 and 6, it can be concluded that an increase of the \bar{U} in the domain I is accompanied by growth of the longitudinal velocity gradient, which results in an increase of the size of the coils.

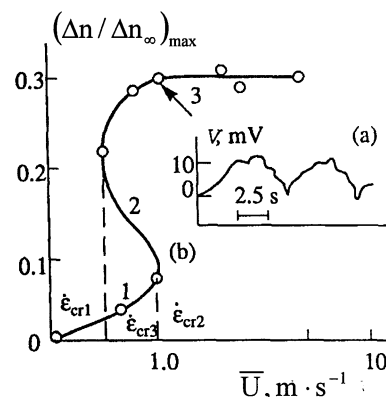


Fig. 6. Fluctuations with time of the laser intensity (a) and dependence of the coil-stretch transition degree on average flow rate (b). Measurements were performed with the capillary I and 0.03% PEO solution. The arrow marks the flow regime corresponding to the (a) plot of the laser intensity fluctuations.

The values of the rate gradients arising at the entrance of the capillary for polymeric solutions are somewhat lower than those for water at the same average flow rate. When attaining some critical velocity gradient $\dot{\epsilon}_{\text{cr}2}$, a sharp transformation of the size of the coils occurs. The sharp jump of the deformational factor with an increase of the average flow rate is an indication that the hydrodynamic field results in conformational instability of the macromolecules and the occurring coil-stretch transition is the first order phase transition. The phase transition results in a considerable readjustment of the velocity field leading to decrease of the longitudinal gradient which takes on the value $\dot{\epsilon}_{\text{cr}3}$; the latter, however, must remain greater than $\dot{\epsilon}_{\text{cr}1}$, which is the rate gradient when the flow birefringence zone is arising at the entrance of the capillary, i.e., the $\dot{\epsilon}_{\text{cr}1} < \dot{\epsilon}_{\text{cr}3} < \dot{\epsilon}_{\text{cr}2}$ condition must

hold. A further increase of \bar{U} only slightly affects the deformational factor and the value of longitudinal gradient, see the domain 3. In that domain, considerable changes in velocity result in only slight variations of the longitudinal gradient (Fig.4b, curve 2); this fact proves the non-linear dependence of the stretching degree on the rate gradient. According to Nikolis and Prigozhin (1977), at least, the cubic non-linearity must occur.

The experimental data presented above clearly demonstrates that the water-polymer system under appropriate conditions of the converging flow exhibits self-organization with the negative feedback coupling. Indeed, increase of the longitudinal rate gradient results in the coil-stretch transition of the polymers, which, in

turn, affects the flow structure in such a way that the longitudinal gradients become smaller. The gradients must remain greater than some critical value sufficient for the coil stretching, which is related to the macromolecule relaxation time θ by the following formula: $\theta \cdot \dot{\epsilon}_{cr} = 0.5$ (Peterlin,1966). Otherwise, the reverse stretch-coil transition occurs (De Gennes,1974) and macromolecules decrease their influence on the velocity field, which, in turn, results in a steep increase of the velocity gradient. This will lead to the coil-stretch transition and all the above processes will happen once again. Hence, the stable state is characterized by the minimal value of the velocity gradient which is sufficient for a sharp coil-stretch transition. Increase in the flow rate results in some additional growth of the deformational factor due to nonlinear effects (Fig. 6, domain 3) sufficient for stability of the rate gradient field of the chosen polymeric system (Fig. 4b, curve 2).

THE MECHANISM OF HYDRODYNAMIC DRAG REDUCTION AND OF NON-LINEAR FILTRATION OF POLYMER SOLUTIONS

The comparison of the data, obtained when modelling eruptions of microjets of a polymeric solution from the near-the-wall area (Pogrebnyak and et.al.,1984) and frequency harmonic effect of solutions PEO on the flow with stretching (Fig.7), with known results on the anisotropy of speed fluctuations and suppression of their high-frequency part, completely agree between themselves (Kutateladze and et.al.,1975), i.e. turbulent (in macroscopic scale) the current is perceived as laminar (in microscale) in case of interaction of a hydrodynamic field with molecules of polymer.

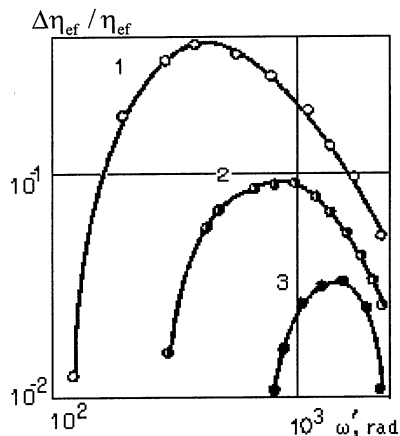


Fig.7. Frequency harmonic effect of solutions PEO on the flow with stretching. $\bar{M}_n = 6 \cdot 10^6$, $C=0,025\%$, \bar{U} : 1-0,3 m·s⁻¹, 2-0,5 m·s⁻¹, 3-0,7 m·s⁻¹. Capillary having the diameter 0.2 mm.

With the help of direct experiments it has been proved, that in halfdiluted and moderately concentrated flooded polymeric jets there is observed the dynamic structure generation under the action of supercritical longitudinal gradients of speed (Pogrebnyak,1992). The research of high-speed converging flows (~250m/s) testify to a certain role

played by the longitudinal gradient of speed realizable in case of the flow in deforming macromolecular coils and minor role of a transverse gradient of speed (Pogrebnyak,1995).

Relying on the data characterising the dynamics of macromolecules in nonturbulent flows with stretching, as well as on the proven strong deformation effect of wall-adjacent turbulence on macromolecules, and also using the data of model researches of singularities of turbulence in a boundary layer (see the above and Pogrebnyak and et.al.,1984), we have offered molecular-and- supermolecular mechanism of the effect of flow resistance drop when introducing of the soluble polymeric components in a turbulent flow. The mechanism of Toms effect consists in the appearance of a self-oscillating mode of reversible processes of unrolling macromolecules under the action of quasiregular longitudinal gradients of speed in a turbulent boundary layer as well as influence teared macromolecules both on molecular (at $C < C_{opt}$), and on supermolecular (at $C > C_{opt}$) levels on the structure of near-the-wall turbulence, i.e. As a result of oscillations of deformations of macromolecules and dissolution of dynamic supermolecular formations, arising under the operation of stretching flows. All this results in the increase of the period of jets of fluid into the external part of a boundary layer and, as a result this causes the thickening of viscous underlayer. As a result of it generation of primary turbulence decreases and general level of turbulent dissipation in the flow gets reduced. In case of too large molecular masses and increase of viscosity above some limit of concentration, stipulated both by the "usual" intermolecular interaction and by the dynamic structures, under formation results in sharp decrease of Toms' effect.

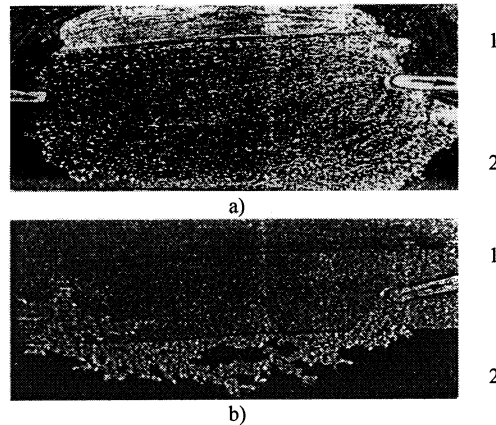


Fig.8. Flowing of a polymeric solution in supercritical modes of current (a) and velocities being subcritical (b) in a porous medium with a stratified heterogeneity. The porosity in layers 1 and 2 is five times as different; $(d_2 / d_1 = 5)$.

The results of the current of polymers solutions in porous mediums testify, that in case current of polymers solutions in subcritical modes characteristic fractal structures, are formed that like in the case of water. If the current in a porous medium occurs in supercritical modes, the polymeric solution will make a broad, equal front of advancement enveloping all the breadth of a cell.

Relatively equal front of advancement of a polymeric solution (Fig. 8a) in supercritical modes of current (at $\dot{\epsilon} > \dot{\epsilon}_{cr}$) in a porous medium with a stratified heterogeneity is observed. In case of flowing of water or solutions of polymers in such mediums (Fig.8b), velocities being subcritical, the advance of front of a flowing liquid occurs mainly in a stratum with greater porosity.

The observable features of current of polymers solutions in porous mediums are explained with the help of molecular-and-supermolecular mechanism. The mechanism of consists in the appearance of a self-oscillating mode of reversible processes of deployment macromolecules under the operation of quasiregularly of arising longitudinal gradients of velocity in a porous medium and influence of deploying macromolecules both on molecular (at $C \cdot [\eta] \leq 0,2$), and on supermolecular (at $C \cdot [\eta] > 0,2$) levels (Pogrebnyak,1992), on the structure of filtration current i.e. as the result of oscillations of a strain of macromolecules and solubility of dynamic supermolecules formations originating under the operation of stretching currents there is an increased dissipation of energy and nonlinearity of filtration current. In case of filtration current of polymers solutions the nonlinearity also ensures alignment of front of a displacing polymeric liquid in stratified nonhomogeneous layers and broad spanning of a layer in case of oil extracting.

The developed approach to explain of non-linear filtration and of turbulent drag reduction mechanisms and agrees well with the general scheme of selfregulated processes, in which negative feed-backs dominate, which is characteristic of systems, capable to change their properties under an operation of external physical effects, in this case under the operation of jet flows locally arising in a porous material and boundary layer with stretching.

CONCLUSION

The work is an original research in the field of an engineering ecology and physics of polymer solutions, directed to the development of a system of views and principles, permitting to explain "anomalous" phenomena - Toms' effect, deviations from the law of Darcy, processes increase of their flocculation properties of macromolecular, that was allow to develop physico-chemical fundamentals: an ecological technology (based on the method of polymeric water-flooding) increase oil recovery of layers; technology of polymeric localization toxicants (including radioactive ones) under ground, and also a device, permitting to increase the flocculation ability of macromolecules at the expense of their unrolling by a hydrodynamic field, by increasing thus a degree of clearing natural and waste waters and regeneration of spent lubricating oils.

The obtained data about the dynamics of macromolecules in conditions of a stretching flow have also determining value for the solution of practically important problems, connected with the increase of effectiveness of fire suppression with water using polymers (for development of the device to feed of polymer into turbulent water current) and destruction of hard materials (mountain rocks, slags etc.) using for this purpose high-speed jets of polymer solutions.

The established regularities of manifestation of elastic deformations, arising in case of the flow of polymer solutions in the porous medium are well as revealed transition of hydrolyzed polyacrylamide in water under the action of radioactive radiation into hydrogel, have made it possible to propose a method of polymer localization of toxicants (radioactive ones being included) under ground and ecologo-technological criteria of its introduction.

The realization of technology of polymer localization of toxicants in the lithosphere will promote protection of the natural environments.

Thus, the work demonstrates a unique approach (use of effects of elastic deformations, exhibited in solutions of polymers) for the solution of a lot of technological problems, connected with protection of environment.

REFERENCES

- D'yakonova, N.E., Brestkin, Y.V., Agranova, S.A. and Pogrebnyak, V.G., 1989, "Birefringence effects when there flow solutions of polymers in conditions of a stretching hydrodynamic field", *Vysokomol. Soedin., Ser. B*, vol. 31, no. 11, pp. 844-846.
- De Gennes, P.G., 1974, *J. Chem. Phys.*, vol. 60, no. 12, pp. 5030-5042.
- Ivanyuta, Y.R., Pogrebnyak, V.G., Naumchuk, N.V. and Frenkel, S.Y., 1985, "Flow structure of polyethylene oxide solutions in the input zone of a short capillary", *Inzh.-Fiz. Zh.*, vol. 49, no. 4, pp. 614-621.
- Kutateladze, S.S., Mirinov, B.P., Nakoraykov, v.E. and Habahpasheva, E.M., 1975, "Experimental research of near-the-wall turbulent flows", Nauka SO AN SSSR, Novosibirsk.
- Klochkov, V.P., Kozlov, L.R., Potykevich, I.V. and Soskin, M.S., 1985, "Reference Book on Laser Anemometry, Long-Distance Spec-troscopy and Interferometry", Ed. Soskin, M.S., Kiev.
- Nikolis, G. and Prigozhin, I., 1977, "Self-Organisation in Non-Equilibrium Systems. From Dissipative Structures to Order Through Fluctuations", Wiley-Interscience, New York.
- Peterlin, A., 1966, *J. Polym. Sci., Polym. Lett.*, vol. 4, no. 4, pp. 287-291.
- Pogrebnyak, V.G., Ivanyuta, Y.F., Naumchuk, N.V., 1982, USSR Inventor's Certificate, no. 983377, *Byulleten'hobretenii*, no. 47, p. 141.
- Pogrebnyak, V.G., Naumchuk, N.V. and Tverdokhle, S.V., 1984, "Experimental investigation of solutions of polymers under near-the-wall turbulence simulated conditions", *Interfacial Layers under Complex Conditions*, Ed. Mironov, B.P., Novosibirsk, pp. 120-127.
- Pogrebnyak, V.G., Naumchuk, N.V., and Tverdokhle, S.V., 1992, "Dynamic structureformation in the solutions of hydrodynamically active polymers", *Inzh.-Fiz. Zh.*, vol.63, no.2. pp.147-150.
- Pogrebnyak, V.G., Naumchuk, N.V., 1995, "Activity hydrodynamic of polymers in high-speed converging flows", *Inzh.-Fiz. Zh.*, vol.68, no.1. pp.146-148.
- Pogrebnyak, V.G., Ivanyuta, Y.F., 1998, "Experimental research of the influence of conditions of polymer admission to the boundary layer on a drop of turbulent friction", *Proceedings of the International Symposium on Seawater Drag Reduction*, Newport, Rhode Island, pp.295-297.