Polymer Additives in Hydro Pressure Instalations and Hydraulic Machines

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The article presents the importance of using polymer additives in the hydraulic fluid flow, to reduce the friction, to reduce the linear pressure losses, to increase the flowing velocity, to reduce the pumping energy, to increase the efficiency of the hydraulic machines. The article highlights the Toms effect in hydraulic industrial applications. Its also shows experimental results on single stage centrifugal pump operating with additives in water in different poly acryl amide concentration, highlighting the significant increase of the pump efficiency when the concentration does not affect the fluid viscosity. The pump efficiency increased with 8-10% when the polymer additives concentration was 0,04%. Experiments were performed in Hydraulic Laboratory of University Politehnica of Bucharest. Enhancing theoretical and experimental research in this area, based on the viscosity and elasticity anisotropic properties of the polymer additives solutions, can be created new premises for hydrodynamics and hydro power applications.

Keywords: polymer additives, hydraulic performances, centrifugal pumps

A primary concern in theoretical and applied research studies is to use, in operating process, fluids with increasingly energetic performances. Starting from Toms effect, discovered more than half a century ago and consisting in additive of fluids to flow through pipes and channels with very small amounts of polymer (ppm), a significant reduction of energy losses results. The physical mechanism of this phenomenon is much analysed by researchers who studied the dynamics of turbulent motion and rheology. Practically, the additives reduce the power consumption, that makes industrial application of Toms effect to be very different. The main industrial applications are in the following fields: hydraulic transport of fluids, oil wells, channels, pipelines of hydraulic plants, hydraulic machines, transport of pulverized slurry solutions, propulsion problems, heating systems, biomedicine, fire extinguishing systems, jets separation, and irrigation.

In this paper we gave a large space to experimental researches on channels and on a pump, working with water with polycrylamide additives at different concentration.

Polymer additives in Hydraulic transport

Most experimental researches refer to fluids flow in channels and pipes [1-3]. So, it was experimentally proved that this phenomenon is influenced by many parameters: polymers concentration, solvents type, polymers type and pipe diameter. Experimentally it was demonstrated that there is a limit to which maxim pressure losses tend to decline asymptotically, Virk's asymptote. The empirical relation of this asymptote is known as Virk's relation:

$$\frac{2}{\sqrt{f}} - 19\log\left(\frac{1}{2}\mathrm{Re}\sqrt{f}\right) - 32.4 \qquad (1)$$

f is the coefficient for linear losses.

In figure 1 Virk proposed a diagram that highlight asymptotic limit which seems similar to the phenomenon of saturation [5].

An important technical field in polymer additives have been applied to reduce friction in pipeline of oil transport. Previous experiments denoted the effect of poly isobutylene in turbulent oil flowing in a pipe with 20.3cm diameter and 45 km length. Using concentration of 300 ppm, 600 ppm, 1000 ppm, reductions for oil pressure losses of 16, 21 respectively 25% were obtained.

Global studies over the behaviour of dilutes polymer solutions have been achieved by Sellin [9]. He obtained experimental and theoretical results showing that the polymeric additives have a great contribution to reduce friction in pipe flowing under pressure. In an optimal concentration of polymer in solution with 20-50 ppm, the friction was reduced to maxim 75% from the pressure gradient, comparing with no additives solvents.

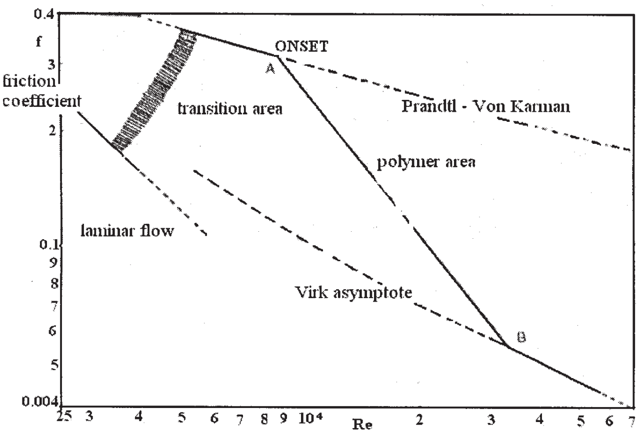

Fig.1. Virk asymptote

Some of these research results have been verified in our Hydraulic laboratory. In our experimental research made with Romanian polymer additives - polyacrilamide type SOLACRIL RPC, MEDASOL and COLAGEN [1] were demonstrated the same characteristics mentioned by Sellin [9], resulting a decreasing of friction coefficient up to 70%.

To determine linear pressure losses in water flow with polymer additives we use the linear friction coefficient f, Altsul' s relation in bellow form:

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$$f(\mathrm{Re},g,c) = 0.11(\varepsilon + \frac{68}{\mathrm{Re}})^{0.25} g(c) \qquad (2)$$

Re is the Reynolds number for pipe flowing, depending of the velocity flow, viscosity and inner pipe diameter.

$\varepsilon = \frac{k}{d}$ is relative roughness,

d is inner diameter and

g(c) is a function depending on the polymer type and its rheological features.

During experiments with polymer additives it was noticed that a great contribution to reducing the pumping energy in plants is given by the horizontal pipes prevailing linear losses.

Relation for pressure losses are:

$$\Delta P = \Delta P_{man} + \Delta P_{geod} + \Delta P_{lin} + \Delta P_{loc} \qquad (3)$$

The effect of polymer additives is on a single term from relation (3), respectively on ΔP_{lin} linear pressure losses.

The major problems in using polymer additives in a network with pumps and pipes are: changing the pump operating parameters, changing the pipes characteristics, the inserting mode of the polymer additives and also economical reasons for open or closed circuit for water and additives.

One of the earliest applications of Toms effect is to increase the efficiency in oil extraction and also in chemical industry.

Polymer additives in sewage systems

There are two types of sewage systems: gravitational and pumping systems. In sewage with pumping system, by injection of polymer additives in short time periods is increased the discharge pressure in channel. The quantity of polymer injected is important, because the discharge system with pump depends on the pump and plant characteristics, as is illustrated in figure 2.

Experimental researches demonstrated that polymer additives effect was to reduce the friction coefficient between 40-70%, mentioning that for pipes with small diameters, was required a higher concentration of polymers.

Experiments from figure 3 demonstrated the increase of flowing velocity between 60-70%, corresponding to the friction coefficient decrease between 60-65%. Polymer PolyoxWSR301 had concentration of 40 ppm.

These values from the figure 3, represent two series of measurements of the velocity in flowing channel, which increase with the polymer concentration [9].

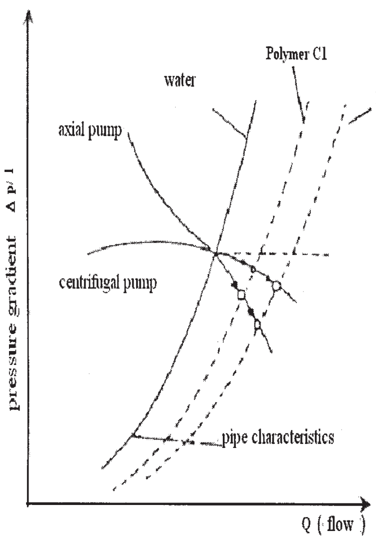

Fig.2. Pumps and plant characteristics at different polymer concentration

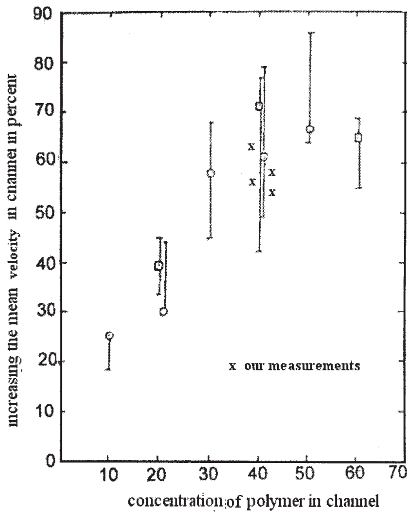

Fig.3. Experimental research - increasing of the mean velocity in channel function of additives concentrations

In channels with permanent flowing are used Chezy and Manning relations and pipe slope is:

$$I = \frac{V^2}{C^2 R} = \frac{Q^2 n^2}{A^2 R^{\frac{4}{3}}} = \frac{Q^2 n^2}{K^2} \qquad (4)$$

With $K = AR^{\frac{2}{3}}$ and $C = \frac{1}{n} R^{\frac{1}{6}}$ -

Equation (4) is Manning's relation and *C* is Chezy coefficient, *A* is the area and *R*, the hydraulic radius.

Using solutions of additives polymer, the rate flow Q increases proportional with the reduction of the asperity *n*, in hypothesis of a constant slope and with constant level flowing.

For rate flow *Q* = constant, head losses are,

$$\Delta h = \frac{Q \cdot n \cdot L}{A^2 R^{\frac{4}{3}}} = cn^2 \qquad (5)$$

$$\Delta h = cn_0^2 (1 - \frac{\Delta n}{n_0})^2 \qquad (6)$$

Where cn_0 represents head losses for liquids without additives.

$$\Delta\Delta h = cn_0^{\ 2} - cn_0^{\ 2}(1 - \frac{\Delta n}{n_0})^2 \qquad (7)$$

Also, the roughness coefficient decreases and the new value is $n = (n_0 - \Delta_n)$.

Pressure losses are between 51 - 75% from the head (pressure) of the liquids without additives:

$$\Delta\Delta h = c(0.51 - 0.75) \qquad (8)$$

When the decrease of the roughness coefficient is between 30%-50%, the head losses are reduced with 51-75%. In pressure flowing with constant rate flow, using polymer additives diluted solutions, the friction is significantly reduced.

Our experiments in a small channel (0.2 m wide and 8 m long), COLAGEN 40 ppm in water confirmed the increase of the mean velocity between 60-65%, compared with mean velocities in clean water. Flow velocities in channel were measured with a hydrometric flow meter.

Polymer additives in hydro-pressure plants and irrigations systems

In short pipes were observed energy losses smaller with 80%, by injecting polymer along the pipe.

Maksimovich studied the influence of polymer flow through galleries free level with diameter between 2-10m and length of 10-100 diameters and observed a significant reduction of energy losses in the uses of polymers, [6].

It can be seen that the using of additives in hydraulic systems lead to significant saving of energy consumption, the experimental results are largely determined by the polymer concentration and type used. Knowing that the polymer additives with big molecular weight can reduce the friction coefficient in turbulent flow, were tested the additives methods in irrigation systems.

Our own experiences realised in researches contracts in University Polytehnica of Bucharest, using Romanian polymers SOLACRIL RPC type, demonstrated the reducing of the pumping pressure losses with 22.5% that can increase the irrigated surface with about 20% . The polymer has also a good effect on the ground (fixing the nitrogen and damming the water vaporization in the ground). These reasons recommend the polymeric additives use in irrigation systems.

Pressure losses are:

$$\Delta h = I \,.\, L \qquad (9)$$

Where I is the slope of the pipe, L is the length of the pipe.

Using polymer additives in agriculture is saved pumping energy and simultaneously is increased the agricultural production.

Influence of the polymer additives on the characteristics of a centrifugal pump single stage

In Hydraulic laboratory of University Politehnica of Bucharest we used polymer additives in experimental researches of a centrifugal single stage pump, in a closed hydraulic plant. We used polymer SOLACRIL RPC type [4], introduced in the collector tank of the pump. The experimental stand consist in a pump with a radial impeller with specific speed n_q = 26, inlet diameter 90 mm, discharge diameter 180 mm, width of the slot b_2 = 12 mm, with 5 blades. This pump was rotated by an electric drive of 7.5 kW with two rotation speed, 1420 rpm and 700 rpm.

Figure 4 illustrates the experimental stand in closed hydraulic circuit, with tank for suction and discharge and also for injection of the polymer additives, with pump, electric drive and measurement apparatus.

The results of experimental researches are presented in operating characteristics for clean water and for 3 polymer additives concentrations: 0.01, 0.04, and 0.1% equivalent with 100, 400 and 1000 ppm. Analysing the characteristic curves of pump - rate flow and pumping head in figure 5, absorbed power in figure 6 and pump efficiency in figure 7, for rotation speed of 1420 rpm.

Analysing the characteristic curves, one can conclude that:

-the best behaviour was found at a concentration of 0.04%.

- the hydraulic losses were significantly reduced, the pumping head increased with about 10%.

- absorbed power decreases with about 8%, so, in pump with polymeric additives the efficiency increases between 8-10%, at the optimal working point;

- when the polymer additives concentration increases to 0.1%, the fluid viscosity increases over 3 cSt. Therefore, the absorbed power increases and causes an important efficiency decrease.

Results were confirmed in other previous papers [7, 8] and even better regarding the hydrodynamic and energetic performances.

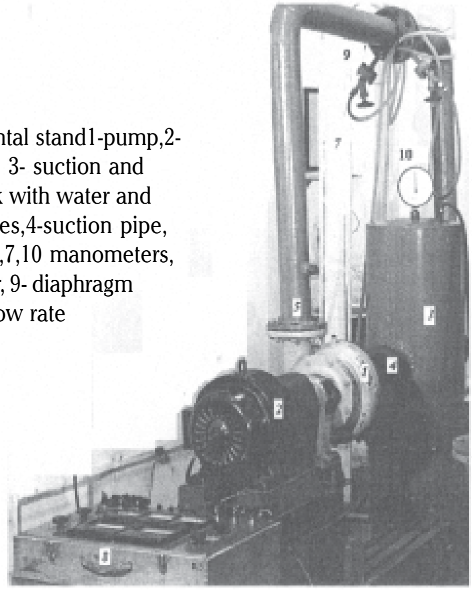

Fig. 4. Experimental stand1-pump,2-electric drive, 3- suction and discharge tank with water and polymer additives,4-suction pipe, 5-discharge pipe,7,10 manometers, 8- wattmeter, 9- diaphragm for flow rate

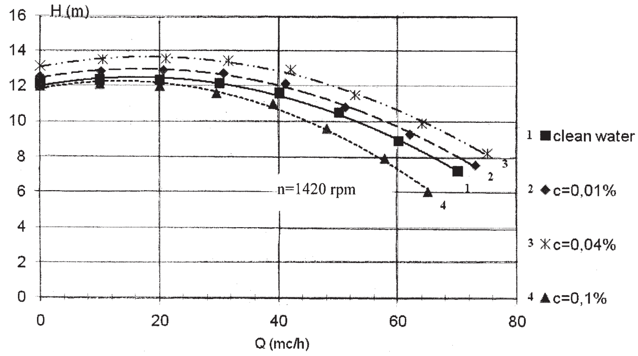

Fig. 5. Flow rate and pumping head with clean water 1 and polymer aditives solution with different concentrations 2 -0.01%, 3 – 0.04%, 4 – 0.1%

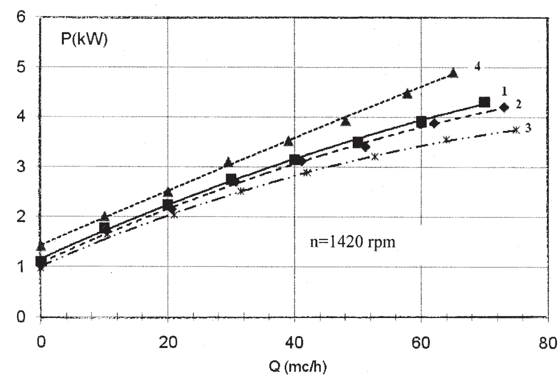

Fig. 6. Flow rate and absorbed power for 1-clean water and polymer aditives solution with different concentrations 2 -0.01%, 3 – 0.04%, 4 – 0.1%

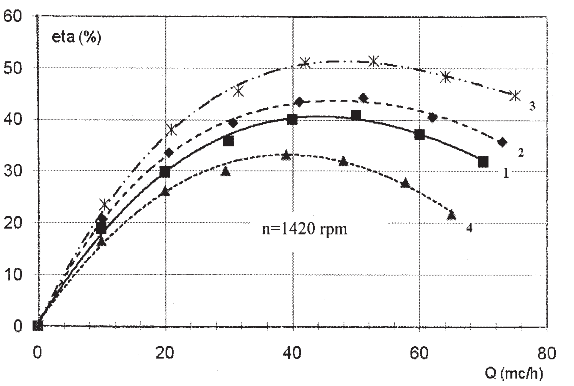

Fig. 7. The efficiency curves for 1-clean water and polymer aditives solution with different concentrations 2 -0.01%, 3 – 0.04%, 4 – 0.1%

Conclusions

Researches regarding the polymer additives influence and complex phenomenon, referring to Toms effect, have interesting applications by considerable reduction of energy required in turbulent flows in hydrodynamic engineering.

Experiments of flowing in channels with COLAGEN (40 ppm) in water confirmed the increase of the mean velocity between 60-65% percent.

Experiments realised with Romanian polymer SOLACRIL RPC type, demonstrated the reducing of the pumping pressure losses with 22.5%.

The experimental researches presented in this paper highlight significantly increasing of the efficiency of a hydraulic machine. The best polymer additives concentration was about 0.04%. Over this value the viscosity increases above 2.5-3 cSt, Reynolds number decreases and need corrections for hydraulic and energetic performances of pumps.

The results from this paper could increase the interest to continue research in this attractive and complex field.

References

1. CHIUJDEA C.M., GEORGESCU A., Turbulent drag reduction in Maxwell viscoelastic fluid, XIIIth International Congress on Rheology, Cambridge, UK, **2,** ,2000, p. 271-274.

2. CHIUJDEA C.M, BUDEA S., Flow of non-newtonian fluids in a pipe and considerations regarding dynamics of dilute polymer solutions, CIEM 2009, Bucharest, CD proceeding, ISSN 2067-00893, 2009, sect. **6**.

3. CHIUJDEA C.M,, GEORGESCU A., Linear stability of turbulent flow of Maxwell fluids in pipes, in Bulletin Universite de Metz, France, **21**, 1991.

4. CHIUJDEA C. M., BUDEA S., Using polymer additives in hydro-energetic system and pumping plants, 6-th Conference of Hydro engineering 5. Dorin Pavel, Bucharest, CD proceeding, sect.**1,** 2010, p. 43-49.

6. GEORGESCU A, Hydrodynamic stability theory , in Kluwer Dordrecht, 1985, p.117-142.

6. JOSEF D., Fluid Dynamics of visco elastic liquids, Springer Verlag, 1990, p.418-455.

7. LADOUANI A., NEMDILI A., Experimental study of effects of polymer additives on the performances of a centrifugal pump, the 6-th Conference on Hydraulic Machinery and Hydrodinamics, Timisoara, 2004, sect.**3**.

8. POLISHOHUK A.M , RAISKII YN.D., TEMKIN A.Z., The effect of polymer additives on the characteristics of a centrifugal pump, Journal of engineering physics and thermo physics, **25**, 1973, p.1551-1553.

9. SELLIN R.H.J, Application of polymer drag reduction to sewer flow problems, AIAA paper **88**, 1988, p. 36-66.

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