THE EFFECT OF POLYMER ADDITIVES ON THE CHARACTERISTICS OF A CENTRIFUGAL PUMP

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The effect of polymer additives at various concentration levels on the parameters of a centrifugal pump is demonstrated experimentally. Optimal polyacrylamide concentrations for a centrifugal pump are determined.

The effect of reduction in hydraulic resistance upon addition of certain high molecular weight polymers to a liquid flowing along a hard surface was discovered by Toms in 1948 [1]. Further studies have shown that this phenomenon is evidently connected with formation of large associations of polymer macromolecules and solvent molecules, which affect the development of pulsations in the layer directly next to the wall.

Experimental studies of the flow of water solutions of polymers in the gap between a rotating disk and enclosing shield [2] showed a significant reduction in torque in comparison to experiments with water, and raised the question of the effect of polymer additives on the characteristics of centrifugal pumps.

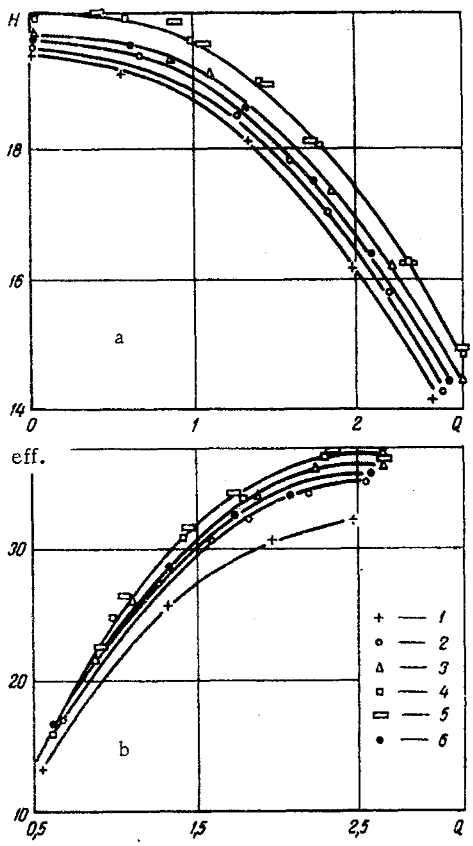

Fig. 1. Effect of various polymer concentrations on the characteristics H and Q of a centrifugal pump (H, m; Q, liters/sec), a: Pump efficiency versus flow rate Q and polymer concentration C (efficiency, %; C, %) b: 1) water, 2) C = 0.005%, 3) 0.01, 4) 0.03, 5) 0.05, 6) 0.1%.

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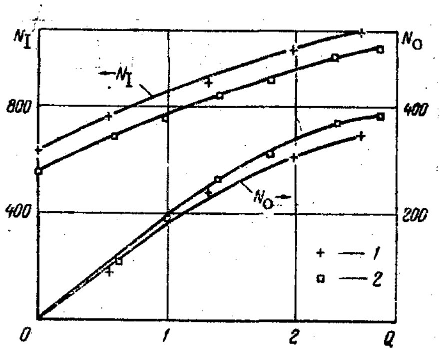

Fig. 2

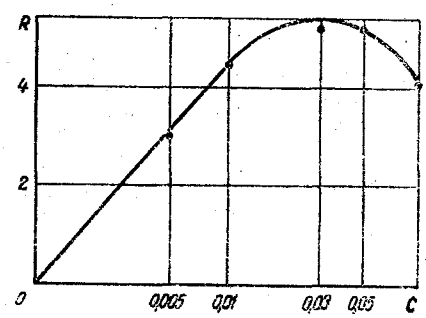

Fig. 3

Fig. 2. Effect of polymer additive on useful power N_O and input power N_I of centrifugal pump for various flow rates (N_O and N_I, W; Q, liters/sec). 1) Water; 2) C = 0.03%.

Fig. 3. Increase in efficiency (%) versus solution concentration (%).

In [3] results were obtained which indicated improvement of pump characteristics upon addition to water of AMF type polyacrylamide (PAA) at a concentration level of 0.05%. The pump efficiency increased by 10%, and drive power required was reduced.

The purpose of this present study is the determination of the dependence of centrifugal pump parameters on the concentration level of polymer additives used to reduce friction.

The experimental apparatus consisted of a 1.5K-6 pump with electric motor, supplied by a 200 liter tank, short connecting pipes between pump and tank, a valve at the pump output, and a measurement tank. The pressure at the pump output P_M was measured by an MO 160 × 4 manometer (accuracy range 0.5), the vacuum at the pump input P_I was measured by a vacuum gauge (accuracy range 0.5), the flow rate was measured by the volumetric method using the measurement tank and a chronometer, and the power consumed by each phase by the electric motor was measured by a K-50 portable wattmeter (accuracy range 0.5). The pump speed was maintained constant at 2800 rpm for all the experiments.

Error in flow rate Q measurement did not exceed 1.3%, error in pressure head H, 1.8%; in power consumed N_I, 2.1%, in useful power N_O, 1.9%, and in efficiency, 3.5% (1.1% in absolute units).

All experiments were conducted with AMF ammonia polyacrylamide. Two to three days before the experiment a 1% solution of the polymer was prepared, then diluted to the required concentration on the day of the experiment.

During the experiments the solutions were pumped through the system no more than three to four times, to avoid degradation of the solutions and the resultant effect on measurements. Moreover, degradation was monitored by measurements of the solution viscosity. At each concentration level measurements were made at the beginning and end of the experiment, and under the above conditions no difference in measurements was observed.

Tests were made on solutions of the following concentrations: 0.005, 0.01, 0.03, 0.05, 0.1%. The viscosity of these solutions in water supply water at 20°C was 1.22, 1.46, 2.03, 2.54, 3.24 centistokes, respectively.

The efficiency of the pump was determined from the relationship

$$\frac{N_O}{N_I} = \frac{Q(P_O + P_I)}{N_I} \cdot 100\%.$$

The experimental results are presented in the form of curves of pump head H, efficiency, useful power N_O, and input power N_I as functions of flow rate Q (Figs. 1 and 2).

It is evident from examination of the pump characteristics H, Q (Fig. 1) that even at a concentration of 0.005% the basic pump parameters are improved. Concentration increase to 0.03% improves the characteristics further, while increase to 0.1% causes degradation as compared to the 0.03% concentration. It is evident that concentration increase above 0.03% produces no further decrease in friction losses, as has been confirmed by experiments with AMF polyacrylamide in tubes, while on the other hand, with increasing concentration the viscosity of the solution exerts a greater effect.

Addition of polymer to a concentration of 0.03% increases the flow rate Q in the working portion of the characteristic (at constant head H = const) by approximately 15%, and improves the head H (at flow rate Q = const) by about 7%.

Figure 1b shows the pump efficiency as a function of flow rate Q for PAA solutions of various concentrations. It is evident that polymer addition has the greatest effect in the high flow rate range, i.e., in the working part of the characteristic. The absolute value of the efficiency at a 0.03% concentration comprises 37.2% as opposed to ~32% for water, i.e., a relative increase of 16%. With increase in concentration to 0.1% the efficiency decreases to ~35.2%.

The curves for N_O and N_I versus flow rate Q were constructed only for water and the 0.03% concentration, since the curves for the other concentrations lie between these two.

From Figs. 1b, 2 it is evident that the increase in pump efficiency and useful power N_O with a polymer solution as compared to water increases with increase in flow rate Q. It is possible that this is related to a decrease in hydraulic losses in the pump with increased flow rate.

On the basis of these experiments it may be proposed that the greatest effect from use of polymer additives will be produced in high speed pumps.

The decrease in input power over the entire flow rate range from 0 (with valve completely closed) to maximum was constant, being about 14%. The reduction in input power at zero flow rate permits the assumption that the reduction occurs due to a decrease in losses from disk friction, since only these losses can be reduced at zero output.

The growth in useful power at high flow rates is probably caused by a decrease in pump hydraulic losses. The curve of efficiency increase R versus polymer concentration (difference in efficiencies for operation with polymer and water in the working portion of the characteristic) (Fig. 3) allows the concentration range 0.02-0.05% to be considered optimal for PAA solutions. Further concentration increase leads to degradation of characteristics.

Thus, for operation with polymer solutions pump efficiency is raised, the H—Q characteristic is improved, useful power increases and power input decreases. It has been established that for solutions of AMF ammonia polyacrylamide in a centrifugal pump the optimum concentration range is 0.02-0.05%.

NOTATION

P_O	is the pressure at pump output, N/m^2;
P_I	is the pressure at pump input, N/m^2;
Q	is the flow rate, liters/sec;
N_I	is the power consumed, W;
N_O	is the useful power, W;
R	is the difference in efficiency for operation with polymer solution and water.

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