The uniformity of polymer melt metering to the spinning machine and the linear densities of the fibres spun depend on large measure on the quality of gear-pump (GP) operation [1, 2]. Therefore, all pumps are subjected to careful checking before fibre spinning. Evaluation of GP quality is carried out in accordance with All-Union Standard 27-20-815-86 [3] with respect to the deviation of the actual liquid delivery by the pump from the nominal figure and with respect to nonuniformity in metering. However, in plants for the manufacture of man-made fibres and yarns, GP tests are carried out with violations of the requirements of the All-Union Standard, particularly because of the use of liquids with various dynamic viscosities - from 0.154 to 5.790 Pa·sec [4], which leads to incorrect evaluation of the quality of operation of pumps of a single type. It is of interest to determine the effect of the viscosity of the metered polymer on evaluating the accuracy of melt metering by the pump.

We have investigated the operation of a type 21NSh-1.2KZ pump, which is a typical representative of the pumps installed on machines for spinning textile purpose yarns. For our studies we used mineral oils having viscosities of 0.07 Pa·sec (T22 oil), 0.26 (Tsv), 0.45 (a composite oil), 1.00 Pa·sec (MS-20 oil), and melted polycaproamide (PCA) having a Newtonian viscosity of 200 ± 5 Pa·sec.

For our research we chose a lot of serial type 21NSh-1.2KZ pumps of a single group, whose uniformity in delivery was 0.66; 1.17; 2.12; 3.08; 3.97; and 4.90%. The studies were carried out using the procedure and test stand recommended by the All-Union Standard. Preliminary experiments showed that it was sufficient to carry out 50 measurements to attain the necessary accuracy in measuring metering (0.1%) with a confidence of 0.95.

To study the uniformity of liquid metering by the pumps we used a PCA melt having a relative viscosity of 2.79-2.81, which had a low-molecular compound content of 1.5% by wt., a relative moisture content of 0.05%, and a mean molecular weight of 19,200. To obtain a Newtonian viscosity of the PCA melt of 200 ± 5 Pa·sec, the temperature of the melt was held in the range 280 ± 1°C [5, p. 86]; its density was 0.948 ± 0.0004 g/cm³.

At a frequency of pump gears rotation of 20 rpm, the pressures at the inlet to the pump (Pin) and at the outlet from it (Pout) were as follows:

regime I: Pin - 2.0 MPa; Pout = 4.9 MPa; pump pressure ΔP₁ = 2.0 MPa;
regime II: Pin - 2.0 MPa; Pout = 8.0 MPa; pump pressure, ΔP₉ = 6.0 MPa.

Regimes I and II were alternated in the process of our studies. Thus, the requirements of the All-Union Standard for pressure drops were maintained.

The pressure of the PCA melt was monitored and recorded using a pneumatic pressure sensor and a PV4-3E instrument having an accuracy class of 1.0. The Pin was maintained in the range 1.6-2.4 MPa by an automated system; Pout was regulated with a throttling device. The frequency of pump shaft rotation was maintained with an accuracy of ±0.03 rpm. The temperature of the pump block was kept equal to the temperature of the melted PCA with an accuracy of ±1°C.

The start and end of melt sample collection was carried out by cutting off the jet at the very same height from the pump block, using knives lubricated with silicone fluid. The time of melt sample collected was recorded with a type SDSpr-1 second-meter having scale divisions of 0.1 sec.

The volumetric delivery of the pump, Q, per gear revolution is given by the equation

\[ Q = \frac{V}{N} = \frac{G}{nN}, \]  \hspace{1cm} (1)
Fig. 1. Dependence of relative delivery \( Q_{rel} \) by type 21NSH-1.2KZ pump (at \( E = 3.08\% \)) on dynamic viscosity of liquid \( \eta \).

Fig. 2. Dependence of nonuniformity in delivery of liquid \( E \) by 21SH-1.2KZ pump on dynamic viscosity \( \eta \) of liquid. Nonuniformity in delivery by All-Union Standard 27-20-815-86 (in \% as follows: 1) 0.66; 2) 1.17; 3) 2.12; 4) 3.08; 5) 3.97; 6) 4.90.

where \( V \) is the volumetric delivery during the established test time; \( N \) is the duration of the test (number of pump gears rotations); and \( G \) and \( \rho \) are the mass and density of the melted PCA.

To ensure an assigned relative error in \( Q \), from Eq. (1) we determined its differential

\[
d\bar{Q} = \frac{1}{\bar{\rho}} \frac{d\bar{G}}{N} - \frac{\bar{G}}{\bar{\rho}N^2} d\bar{\rho},
\]

where \( \bar{\rho}, \bar{N}, \bar{G} \) are the mean values of the measured quantities.

We shall replace the differential by the absolute values of the errors in measuring \( \Delta \rho \), \( \Delta N \), and \( \Delta G \). Dividing Eq. (2) by Eq. (1), and remembering that \( \bar{G} = \bar{Q}\bar{\rho}\bar{N} \), we obtain an expression for determining the relative error in volumetric delivery \( \delta Q \):

\[
\delta Q = \left( \frac{\Delta G}{\bar{Q}\bar{\rho}\bar{N}} + \frac{\Delta \rho}{\bar{\rho}} + \frac{\Delta N}{\bar{N}} \right) 100.
\]

To determine the volumetric delivery with an accuracy of 0.1%, we find the minimum test time necessary for this, \( N_{\text{min}} \).

Absolute errors in measuring quantities were as follows: \( \bar{G} = 0.01 \text{ g}; \bar{\rho} = \pm 0.0004 \text{ g/cm}^3; \) and \( \bar{N} = 0.1 \text{ revolution.} \)

Substituting the values indicated above into Eq. (3), we obtain the minimum pump test duration which is necessary; this is 188.2 rotations. We shall round this quantity off to 200; then the time for collected melted PCA will be 10 min.

In Fig. 1 we show the dependence of pump delivery on the dynamic viscosity of the metered liquid. We studied five type 21NSH-1.2KZ pumps of a single group, having a delivery nonuniformity of 3.08% by the All-Union Standard. Test results are shown in the form of two curves which describe the dependence of the amount of liquid delivered by the pump on its viscosity at \( \Delta P_{I} = 2.0 \text{ MPa} \) (curve 1) and \( \Delta P_{II} = 6.0 \text{ MPa} \) (curve 2).

The segments of the ordinate axis which are bounded by curves 1 and 2 characterize the absolute nonuniformity in delivery \( \Delta Q \), which is caused by the change in pressure developed by the pump at various liquid viscosities:

\[
\Delta Q = Q_{I} - Q_{II},
\]

where \( Q_{I} \) and \( Q_{II} \) are the amounts of liquid delivery by the pump in tests under regimes I and II, respectively.