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THEORETICAL STUDY OF THE PRODUCTION OF AIRCRAFT POLYMER PIPELINES

The article presents the results of theoretical studies of the production pipeline for military aircraft, the equations describing the local distribution of velocities and pressure drop across the hydrodynamic initial site.

Keywords: *liquids, pipelines.*

Introduction

Problem definition. The question of calculation of technological parameters of manufacture of polymeric pipelines for the aviation techniques is considered. Speed characteristics are received at a polymer current on an initial site. Such characteristics are important for definition of time of heating of polymer and other technical characteristics by manufacture of pipelines. Definition of the above-stated characteristics is necessary for avoidance of the subsequent sudden destruction of the pipeline during operation and increase of safety of flights.

Analysis of recent researches and publications. To research of flow of non-Newtonian liquids in a double pipes area the de-voted row of researches in particular Leybenzon, Mak-Kelvi of Fridrikson and Bird et al. In existing studies lack information about the hydrodynamic length of the initial section and the distribution of velocities and stresses in it.

The formulation of the problem of article. The aim of this work is to determine the analytical dependences for determination of the local velocity of stress and pressure ratio on the hydrodynamic initial site.

The main material

Calculation of technological parameters of manufacture of polymeric pipelines becomes complicated that high-speed characteristics of a stream non-Newtonian liquids on an initial site in a backlash between cylindrical surfaces cannot be defined in the regular way. Complexity of definition is connected with influence convection accelerations. Safety of flights depends on accuracy of calculation of technological parameters of manufacture of pipelines. Now such characteristics are defined experimentally.

The liquid current is described by the equations [1]:

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right) = \rho g_r -$$

$$-\frac{\partial P}{\partial r} - \left(\frac{1}{r}\frac{\partial(r\tau_{rr})}{\partial r} + \frac{1}{r}\frac{\partial \tau_{r\theta}}{\partial y} - \frac{\tau_{\theta\theta}}{r} + \frac{\partial \tau_{rz}}{\partial z}\right) + S_r;$$

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right) =$$

$$= -\left(\frac{1}{r^2}\frac{\partial\left(r^2\tau_{r\theta}\right)}{\partial r} + \frac{1}{r}\frac{\partial \tau_{\theta\theta}}{\partial \theta} - \frac{\tau_{\theta\theta}}{r} + \frac{\partial \tau_{\theta z}}{\partial z}\right) +$$

$$+\rho g_\theta - \frac{\partial P}{\partial \theta} + S_\theta;$$

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_r}{\partial z}\right) =$$

$$= -\left(\frac{1}{r}\frac{\partial(r\tau_{rz})}{\partial r} + \frac{1}{r}\frac{\partial \tau_{\theta z}}{\partial \theta} + \frac{\partial \tau_{zz}}{\partial z}\right) +$$

$$+S_z + \rho g_z - \frac{\partial P}{\partial z};$$

$$\tau_r = -k\left(\frac{\partial u}{\partial y}\right)^n,$$

where u, v – local velocity along the axes, n – the current index, k – grease a constant.

The boundary conditions are conditions appropriate stableman of fluid flow in the hydrodynamic end of the initial section. It is assumed that the shear stresses on the surface of large and small pipes is equal to:

$$\tau_{r=R_1} = -knv_{z_{R_1}}^{n-1}\left\{\left(\frac{\Delta P}{2Lk}\right)\left[R_1 - \frac{(\chi R_2)^2}{R_1}\right]\right\}^n;$$

$$\tau_{r=R_2} = -knv_{z_{R_2}}^{n-1}\left\{\left(\frac{\Delta P}{2Lk}\right)\left[R_2 - \frac{(\chi R_2)^2}{R_2}\right]\right\}^n,$$

where R – the radius of the inner and outer pipes respectively, depending on the index 1 or 2.

On the basis of these equations for one-dimensional asymmetric stable flow in laminar regime we can write the following equation

$$\frac{\partial P}{\partial z} = \rho g z - \frac{1}{r}\frac{\partial(r, \tau_{rz})}{\partial r}.$$

The solution of this equation for the axial velocity are shown in

$$u_x = \\ = \frac{1}{4\mu}\frac{\partial p}{\partial x}\left[\frac{R^2 - r_1^2}{\ln(R/r_1)}\ln r + \frac{r_1^2 \ln R - R^2 \ln r_1}{\ln(R/r_1)} - r^2\right].$$

In the case of unregulated flow value is a function of the coordinates z and can be represented as:

$$\frac{\partial P}{\partial z} = \left(\frac{\partial P}{\partial z}\right)_c + \delta\left(\frac{\partial P}{\partial z}\right),$$

where the value associated with the manifestation of the inertia force from the convective acceleration. In accordance with experiments Adolfi this Supplement complies with the forces of inertia of the fluid particles moving radially and axially

In addition to the loss of pressure affects the energy of the slide is connected with the forces of viscous friction:

$$\mu\left(\frac{\partial^2 U_x}{\partial r^2} + \frac{1}{r}\frac{\partial U_x}{\partial r}\right).$$

The solution of the relevant equations allow to obtain the distribution law of velocities for liquid Oswald de Ville

$$U(z,y) = \frac{b(z)+2}{b(z)}\left[1 - \left(\frac{y^2 - \lambda^2\varepsilon^2}{1 - \lambda^2\varepsilon^2}\right)^{b(z)}\right];$$

$$y \in [\lambda\varepsilon, 1];$$

$$U(z,y) = \frac{b(z)+2}{b(z)}\left[1 - \left(\frac{\lambda^2\varepsilon^2 - y^2}{\varepsilon^2(\lambda^2 - 1)}\right)^{b(z)}\right],$$

$$\varepsilon \le y \le \lambda\varepsilon,$$

where $\lambda\varepsilon$ – the location of the maximum plot speed, ε – the radius of the inner pipe, b(z) – the function of cross linking on the coordinate.

The value of b(z) (z – longitudinal coordinate) is determined from the equation:

$$Z = -\frac{(\lambda^2-1)^2}{2\varepsilon^2}\{[b(z) - b_0(z)] \times \\ \times\left[\frac{\overline{D} - 2\overline{C_2}}{[b(z)-\beta_2][b_0(z)-\beta_2]} + \right. \\ + \frac{2\overline{E}}{[2b(z)+1][2b_0(z)+1]} + \\ \left. + \frac{\overline{K}}{[b(z)+1][b_0(z)+1]}\right] + \overline{A}\ln\left[\frac{b(z)+1}{b_0(z)+1}\right] + \\ +2\overline{B}\ln\left[\frac{b(z)+1}{b_0(z)+1}\right] + 2\overline{C_1}\ln\left[\frac{b(z)-\beta_2}{b_0(z)-\beta_2}\right]\}.$$

For different values of flow index n in the law of Ostwald de Ville of the value of b(z) is defined by the formulas:

for n = 1:

$$Z = (1-\lambda^2\varepsilon^2)^2 \times \\ \times[b(z)-b_0(z)]\cdot\left\{\left[\frac{D-2C_2}{[b(z)-\alpha_1][b_0(z)-\alpha_1]} + \right.\right. \\ + \frac{2E}{[2b(z)+1][2b_0(z)+1]} + \\ \left. + \frac{K}{[b(z)+1][b_0(z)+1]}\right] + A\ln\left[\frac{2b_0(z)+1}{2b(z)+1}\right] + \\ \left. +2B\ln\left[\frac{b_0+1}{b+1}\right] + 2C_1\ln\left[\frac{b_0(z)-\alpha_1}{b(z)-\alpha_1}\right]\right\},$$

for n = 0,5:

$$Z = -\frac{(\lambda^2-1)^2}{2\varepsilon^2}\cdot\{[b(z)-b_0(z)] \times \\ \times\left[\frac{\overline{D}-2\overline{C_2}}{[b(z)-\beta_2][b_0(z)-\beta_2]} + \right. \\ + \frac{2\overline{E}}{[2b(z)+1][2b_0(z)+1]} + \\ \left. + \frac{\overline{K}}{[b(z)+1][b_0(z)+1]}\right] + \overline{A}\ln\left[\frac{b(z)+1}{b_0(z)+1}\right] + \\ +2\overline{B}\ln\left[\frac{b(z)+1}{b_0(z)+1}\right] + 2\overline{C_1}\ln\left[\frac{b(z)-\beta_2}{b_0(z)-\beta_2}\right]\}.$$

According to the results it is possible to judge the influence of the index of flow on the deformation plot of the velocities at the initial site of the observed hydrodynamic type annular gaps is critical to determine the residence time considering my polymer melt in the working element of the forming tool. Based on the analysis of the deformation plot of the velocities were obtained dependences characterizing changes in pressure along the length of the crack gap in Fig. 1 shows an example of a curve of change of pressure for the case when the flow index is n=0,8 such dependence became the basis for determining the coefficient of hydraulic friction.

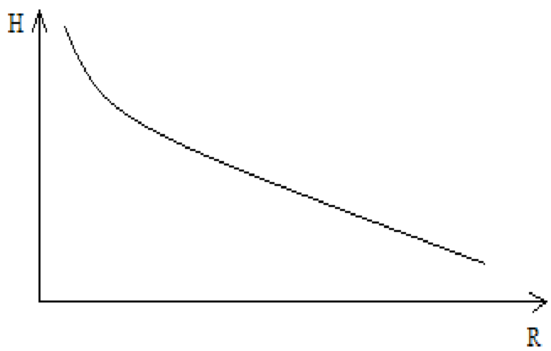

Fig. 1. The pressure variation along the length of the initial section

The received dependences of speed of a stream in a backlash between cylindrical surfaces allow to calculate technological parameters of manufacture of pipelines including time of heating of polymer. The decision of the equations is spent taking into account different curvature of a surface of an external and internal pipe of the channel on which polymer flows. Comparison of the received analytical dependences with experimental data allow to draw a conclusion on convergence of results of experiment and the analytical decision.

Research L.C. Liebenson proposed amendment to the coefficient λ.

The coefficient of friction λ in the annular gap increases in A' time. Here

$$A' = \frac{(1-\varepsilon)^2}{\left(1+\varepsilon^2\right)+\left(1-\varepsilon^2\right)\big/\ln\varepsilon},$$

where $\lambda = AA'\big/\mathrm{Re}$.

The experimental curve of the pressure distribution along the length corresponds to an equation of the form $y = \dfrac{1}{x+1}$.

To verify compliance with the adopted equation of the curve of the present value A and $\dfrac{Z\cdot 10^3}{2\mathrm{Re}(R_2 - R_1)}$ in fractions of a unit, and the unit of the ordinate axis has a limit A=140, and the abscissa axis 28,78, i.e., at the end of the initial phase.

Substituting the dimensionless distance, i.e. asking a fraction Z (0,06; 0,125; 0,5; …) get the number of values A.

In the fitted equation with the substitution of the existing value and get

$$A = \frac{10^3}{\dfrac{Z}{2\mathrm{Re}(R_2 - R_1)} + 1}$$

or

$$A = \frac{2\mathrm{Re}(R_2 - R_1)10^3}{Z + 2\mathrm{Re}(R_2 - R_1)},$$

where Re is the Reynolds number for power-law fluid and the annular gap pipe.

The number of Re can be determined by the formula

$$\mathrm{Re} = \frac{2v_{zcp}(R_2 - R_1)}{K}\rho,$$

where K – consistent constant, V_{zcp} – average speed.

The obtained data allow to determine the pressure loss in the initial part, the annulus of the pipe by the formula Darcy-Weisbach

$$P_{H.J.} = \frac{AA'}{\mathrm{Re}}\cdot\frac{L_{n.y.}}{2(R_2 - R_1)}\cdot\frac{V_{zcp}^2}{2g}\cdot\rho g.$$

Substituting the value of and have

$$P_{h.y.} = \frac{\rho A' L_{n.y.} V_{zcp}^2 10^3}{Z + 2\mathrm{Re}(R_2 - R_1)}.$$

To determine the pressure gradient in the initial part of the expression with respect and will receive

$$\frac{dP_{h.y.}}{dz} = -\frac{\rho A' L_{n.y.} V_{zcp}^2 10^3}{[Z + 2\mathrm{Re}(R_2 - R_1)]^2}.$$

The minus sign indicates a decrease in the pressure gradient with increasing Z. This increased pressure gradient must be considered in the initial part.

Conclusion

Derived new analytical expressions for calculation of local velocities and pressure drop across the hydrodynamic initial site in a two-dimensional region.

References

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ТЕОРЕТИЧНЕ ВИВЧЕННЯ ВИРОБНИЦТВА АВІАЦІЙНИХ ПОЛІМЕРНИХ ТРУБОПРОВОДІВ

С.В. Копилов

У статті представлені результати теоретичних досліджень виробництва авіаційних полімерних трубопроводів *для військових літаків, рівняння, що описують локальний розподіл швидкостей і перепаду тиску в гідродинамічному початковому ділянці.*

Ключові слова: *рідини, трубопроводи.*

ТЕОРЕТИЧЕСКОЕ ИЗУЧЕНИЕ ПРОИЗВОДСТВА АВИАЦИОННЫХ ПОЛИМЕРНЫХ ТРУБОПРОВОДОВ

С.В. Копылов

В статье представлены результаты теоретических исследований производства авиационных полимерных трубопроводов для военных самолетов, уравнения, описывающие локальное распределение скоростей и перепада давления в гидродинамическом начальном участке.

Ключевые слова: *жидкости, трубопроводы.*