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Hydrodynamic entrance length with the laminar diffuser flow in the constant width coaxial conic channel

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The laminar diffuser flow development incompressible Newtonian liquid in the constant width coaxial conic channel waas investigated in this paper. For this purpose the diffuser flow in the pointed channels was approximated by radial divergent flow in the flat cylinder sector (Figure). This approximation is quite acceptable for condition R = 2.22hctga [1].

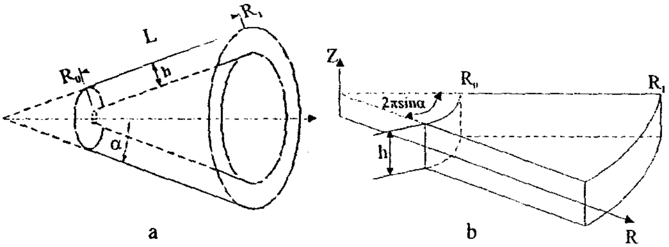

Figure. Geometry of the coaxial conic channel: ? – coaxial conic channel; ? – flat approximate channel. L – length of the generatrix, R_0, R_1 – radial coordinates of entry in the channel and exit from it , h – width of the channel, α – half-corner of the conic surfaces opening , Z – axial cylindrical coordinate

The flow in approximated channel is described well in the cylindrical coordinates connected with the channel geometry. It was shown in paper [1] that the condition $V_Z = o(V_R)$ is realized in such channels, and it allows to write the hydrodynamic equation of Oseen for isothermal laminar axial-symmetrical flow in the form:

$$\rho U \frac{\partial V_R}{\partial R} = -\frac{\partial P}{\partial R} + \mu \frac{\partial^2 V_R}{\partial Z^2}, \qquad (1)$$

$$\frac{1}{R}\frac{\partial}{\partial R}\left(R V_R\right) = 0, \qquad (2)$$

with the boundary conditions:

$$V_R = 0, \; Z = \pm\frac{h}{2}, \qquad (3)$$

$$\frac{\partial V_R}{\partial Z} = 0, \; Z = 0, \qquad (4)$$

and initial condition is:

$$V_{R,} = V_0, \; Z = 0, \qquad (5)$$

$$P = P_0, \; R = R_0. \qquad (6)$$

where $V_0 = \frac{Q}{2\pi r_0 h \sin\alpha}$ – average velocity at the channel entrance.

Farther the received equations set is transformed with the help of linearization which is analogous to Targ linearization and it is solved by the Laplace – Karson method.
The solution of the set (1) – (6) with the help of dimensionless variables and parameters:

$$\xi=\frac{r}{r_0},\chi=\frac{2z}{h},v=\frac{V_r}{V_0},RE=\frac{\rho V_0 h^2}{4\mu r_0},\ y=\xi^2\text{-}1,\ \Pi=\frac{\left(P\text{-}P_0\right)h^2}{4\mu V_0 r_0} \tag{7}$$

is written in the form:

$$v=\frac{3}{2}\left(1-\chi^2\right)\frac{1}{\xi}+\sum_{k=1}^{\infty}\frac{1}{v_k^2}\left(1-\frac{\cos v_k\chi}{\cos v_k}\right)\left[\int_0^{\xi^2-1}\frac{e^{-\frac{v_k^2\tau}{2RE}}}{\sqrt{\left(\xi^2-\tau\right)^3}}d\tau-2e^{-\frac{v_k^2\left(\xi^2-1\right)}{2RE}}\right], \tag{8}$$

$$\frac{\partial\Pi}{\partial\xi}=\frac{RE}{\xi^3}+\left.\frac{\partial v}{\partial\chi}\right|_{\chi=1}. \tag{9}$$

It is shown in the paper that for arbitrary value of RE parameter (RE is analogous of Reynolds number) with increase ξ the velocity distribution in the channel approximates to dependence:

$$v=\frac{3}{2}\left(1-\chi^2\right)\frac{1}{\xi}. \tag{10}$$

It means that the automodel diffuser fluid flow in the coaxial conic channel with the velocity distribution (10) may be considered as the stabilized flow. Farther in the paper it is supposed that hydrodynamic entrance length in the coaxial conic diffuser is equal to distance from the channel entrance to radial coordinate where relative deviation of the velocity for developing flow from velocity of stabilized flow taken at the middle surface of the channel decreases to 1 %. It is analogous to Prandtl suppose for developing flow in the circular tube.

Farther from that proposal we received the expressions for definition undimension radial coordinate ξ_{hy} where hydrodynamic stabilization of flow occurred and the undimension hydrodynamic entrance length $\Delta\xi_{hy}$:

$$\xi_{hy}=1+0.1445RE,\ \Delta\xi_{hy}=0.1445RE,\ 0<RE\le 0.95, \tag{11}$$

$$\xi_{hy}=1.354\sqrt{RE},\ \Delta\xi_{hy}=1.354\sqrt{RE}-1,\ 0.95<RE<170. \tag{12}$$

Nomenclature:
h – channel width, m; V – velocity, ms^{-1}; P, P_0 – continue and entry pressure, Pa; Q – flowrate, m^3s^{-1}; R, R_0, R_1 – continue, entry and exit radial coordinate, m; U – average at the cross-section of the channel velocity, ms^{-1}; α – half of conical surfaces aperture angle, degree; ρ – density, $kg{\cdot}m^{-3}$, μ – viscosity, Pa·s.

References:
1. Ulyev L.M. Solution of Slow Steady State Flow Problem in a Coustant Width of Channel with Taking into Account Curvature Distinction of its Boundaries // Materials of the 15h International Congress of Chemical and Process Engineering. CHISA'2002, 25 – 30 August 2002. Praha, Czech Republic. Summaries 3. Fluid Multiphase System. Praha. 2002. P. 178 – 179. (paper No. P5.105. P. 11).