15th International Congress of Chemical and Process Engineering

CHISA 2002

25-29 August 2002
Praha • Czech Republic

ČSCHI ČESKÁ SPOLEČNOST CHEMICKÉHO INŽENÝRSTVÍ
CZECH SOCIETY OF CHEMICAL ENGINEERING

EFCE European Federation of Chemical Engineering Congress Event 631

Summaries

3

Fluid Flow
Multiphase Systems

P5.102

SOLUTION OF SLOW STEADY STATE FLOW PROBLEM IN A CONSTANT WIDTH CHANNEL WITH TAKING INTO ACCOUNT CURVATURE DISTINCTION OF ITS BOUNDARIES

L.M.Ulyev
Chemical Engineering Department, National Technical University "Kharkiv Polytechnic Institute", 21, Frunze St, 61002, Kharkiv, Ukraine; Tel. (380) 572-400-001,
E-mail: ulm@kpi.kharkov.ua

Exploration and definition of properties for viscous liquid flow in the different geometry channels is one of the fundamental problems in liquid mechanics as exploration of number problem arising from creation of flowing components for industrial apparatuses. Coaxial conic flow is often occurred in different construction of extrusion machines. The problem of high-viscosity liquid slow flow between coaxial conic surfaces with common top and between equidistant conic surfaces was solved in paper [1], but solution was obtained without taking into consideration difference in their curvature. In this paper the last problem is solved taking into account difference in boundary curvatures for slow flow of Newtonian liquid. The solution was obtained in biconical co-ordinates (Fig. 1) which are defined by transformation:

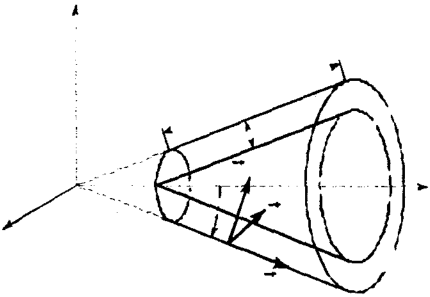

Fig. 1. Geometry of the constant width conical gap, L – length of the channel, м; h – width of gap, м; i_R, i_X, i_ψ – orts of a biconical co-ordinate system

$$z' = R\cos\alpha + X\sin\alpha, \tag{1}$$

$$y' = (R\sin\alpha - X\cos\alpha)\sin\psi = \Omega\sin\psi, \tag{2}$$

$$x' = (R\sin\alpha - X\cos\alpha)\cos\psi = \Omega\cos\psi \tag{3}$$

The terms of hydrodynamic equations estimation allows to reduce the set to two equations:

$$\frac{\partial\Pi}{\partial\xi} = \frac{1}{\sigma}\frac{\partial}{\partial\chi}\left(\sigma\frac{\partial v}{\partial\chi}\right), \tag{4}$$

$$\frac{\partial}{\partial\xi}(\sigma v) = 0, \tag{5}$$

where $\xi = \frac{R}{h}$, $\chi = \frac{X}{h}$, $v = \frac{V_R}{V_0}$, $V_0 = \frac{Q}{\pi h(2R_0\sin\alpha - h\cos\alpha)}$, $\Pi = \frac{(P-P_0)h}{\mu V_0}$, $\sigma = \frac{\Omega}{h}$.

The boundary conditions for (4) and (5) are written as:

$$v = 0,\ \chi = 0, \tag{6}$$

$$v = 0,\ \chi = 1, \tag{7}$$

$$\Pi = 0,\ \xi = \xi_0. \tag{8}$$

The solution of equations set (4) – (8) is:

$$v=\frac{1}{4}\frac{d\Pi}{d\xi}\left[\chi^2-2\chi\xi tg\alpha+(2\xi tg\alpha-1)\frac{\ln\left(1-\frac{\chi}{\xi}ctg\alpha\right)}{\ln\left(1-\frac{1}{\xi}ctg\alpha\right)}\right], \tag{9}$$

$$\frac{d\Pi}{d\xi}=\frac{8(2\xi_0\sin\alpha-\cos\alpha)}{4\xi\sin\alpha(1-\xi tg\alpha)-\cos\alpha+\frac{(2\xi\sin\alpha-\cos\alpha)E}{\ln\left(1-\frac{1}{\xi tg\alpha}\right)}}, \tag{10}$$

where $E=(\xi tg\alpha-1)^2\left[1-2\ln\left(1-\frac{1}{\xi tg\alpha}\right)\right]-(\xi tg\alpha)^2$.

The pressure distribution along the channel is got with the help of equation (9) numerical integration. Both diffuser and confuser flow are investigated in this paper.

The solution obtained here is compared with the solution earlier obtained without taking into account difference in boundary curvatures [1, 2]. The differences in definition of velocity distributions in the channel for these solutions are represented on Fig. 2.

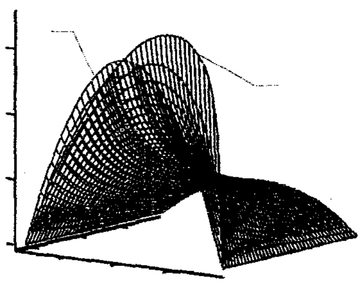

Fig.2. Distribution dimensionless velocity in the channel with parameters: $\xi_0 = 3.7$; $\xi_1 = 10$; $\alpha = 15°$. 1 – obtained without taking into account difference in boundary curvatures, 2 – with taking into account this difference

Deviation of maximum velocity value from middle surface of the channel was chosen as criterion for difference in solutions as the maximum velocity value for solution without taking into account difference in boundary curvatures is localized on the middle surface of the channel.

It is shown that with $R \geq 2.22h ctg\alpha$ the deviation in maximum velocity values localization does not exceed 5 %. This inequality is proposed as criterion for neglecting the influence of distinction in boundary surface curvatures with calculation of velocity and pressure distribution for slow liquid flow in constant width coaxial conical channel.

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; α – half of conical surfaces aperture angle, degree.

References:

1. Ulyev L.M. Slow flow between coaxial conic surfaces // Inzh.- Fiz. Zh.. 1998. Vol. 71, No. 6. P. 1092-1098.
2. Ulyev L.M. Laminar Heat Transfer in a Liquid Flowing in a Diverging Conical Annular Channel with a Varied Inner-Wall Temperature // Theor. Found. Chem. Eng. 2001. Vol. 35. No. 1. P. 28 – 38.