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Mathematical Models of Dynamics Multiphase Flows in Complex Geometric Shape Channels

A.L. Kartashev*, M.A. Kartasheva, A.A.Terekhin

South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, The Russian Federation

Abstract

The most important problem in fluid-flow mechanics is to determine the parameters of multiphase mediums. Such media, which are a mixture of different substances, each of which may be various aggregative states, are widely distributed in technical systems used in various industries.

The problem of mathematical modeling of the dynamics of multiphase flows in multiphase flowmeters without separation used to measure the flow rate of liquid and gaseous hydrocarbons is considered. Mathematical models of multiphase flow dynamics, which can be used to calculate the flow parameters in multiphase flowmeters without separation, are proposed. A mathematical model for calculating the two-phase flow monodisperse is considered. A mathematical model for calculating the polydisperse multiphase flows is considered. The results of mathematical modeling of multiphase mediums by means of high-performance computing are presented.

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Keywords: Mathematical modeling; multiphase flows; multiphase flowmeters without separation of flows; monodisperse and polydisperse flows.

1. Introduction

The most important problem in fluid-flow mechanics is to determine the parameters of multiphase mediums. Such media, which are a mixture of different substances, each of which may be in various aggregative states, are widely distributed in technical systems used in various industries.

At present, actual problem is to measure the flow of liquid and gaseous hydrocarbons without separation. One of the problems associated with the definition of the parameters of motion multiphase mixtures, is to determine the

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* Corresponding author. Tel.: +7-919-345-8556.
E-mail address: al_kartashev@mail.ru

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parameters flows liquid and gaseous hydrocarbons of multiphase flow for multiphase meters that make measurement without separation of the hydrocarbon mixture into individual phases and fractions. The use of such flow measuring devices can greatly simplify the process of measuring the flow of hydrocarbon mixture to make it more responsive (including the use for mobile multiphase flow and compact subsea devices) and more cost effective.

Multiphase flowmeters, provide accurate flow measurement mixtures simultaneous flows of oil, water and gas, and various solid admixtures without separation the phases. Flow measurement of multiphase mediums without prior phase separation (without separation) is complicate technical problem, which associated with the presence in the flow various mixture of different substances (for example, natural gas, liquefied petroleum gas, the multicomponent gas, etc.).

Actual problems related to the development and application of multiphase flowmeters is not fully resolved. Including issues related to the lack of a rigorous theory describing the measurement process, the complexity of the formulation of physical and numerical experiment, the operation mode setting complexity (adjustment is normally carried out using empirical approaches), the problems of increasing the accuracy of measurements and research the total uncertainty of measurements and so on.

Mathematical models describing the motion of a two-phase monodisperse medium and polydisperse multiphase medium considered for the mathematical modeling of multiphase flows in multiphase flowmeters without separation of flows.

The results of testing of these mathematical models for modeling of flows with condensed phase in the annular nozzles are presented.

2. Main part

2.1. Mathematical modeling of two-phase monodisperse flow

Two-phase monodisperse flow in a multiphase flowmeters is described by equations set of an axisymmetric flow of a two-phase mixture in the integral form [1-3], permitting to realize the «transparent» calculation without preliminary selection of discontinuity in computational field.

The system is recorded for a plane of flow *XY* for the fixed square Ω, restricted a contour of *G*:

$$\begin{gathered}
\frac{d}{dt}\iint\limits_{\sigma}\rho u y dxdy+\iint\limits_{\sigma}\rho_s f_x y dxdy+\oint\limits_{G} y\left(\left(p+\rho u^2\right)dy-\rho u v dx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho y dxdy+\oint\limits_{G}\rho y\left(udy-vdx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho_s y dxdy+\oint\limits_{G}\rho_s y\left(u_s dy-v_s dx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho_s u_s y dxdy-\iint\limits_{\sigma}\rho_s f_x y dxdy+\oint\limits_{G} y\rho_s u_s\left(u_s dy-v_s dx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho_s v_s y dxdy-\iint\limits_{\sigma}\rho_s f_x y dxdy+\oint\limits_{G} y\rho_s v_s\left(u_s dy-v_s dx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho y\left(\frac{V^2}{2}+e\right)dxdy+\iint\limits_{\sigma}\rho_s y\left(\vec{V}_s\cdot\vec{f}+q\right)dxdy+\oint\limits_{G}\rho y\left(\frac{V^2}{2}+i\right)\left(udy-vdx\right)=0\\
\frac{d}{dt}\iint\limits_{\sigma}\rho_s e_s y dxdy-\iint\limits_{\sigma}\rho_s q y dxdy+\oint\limits_{G}\rho_s e_s y\left(u_s dy-v_s dx\right)=0
\end{gathered}\tag{1}$$

where ρ and ρ_{s} − densities gas and particles, p − pressure of gas, u and v − axial and radial components of a vector of a velocity of gas $\vec{V}$; u_s and v_{s} − axial and radial components of a vector of a velocity of particles $\vec{V}_s$, x and y − axial and radial coordinates, $e=e\left(p,T\right)$ − specific internal energy of gas, $e_s=e_s\left(T_s\right)=c_в T_s$ − specific