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STUDY OF THE MOVEMENT OF TWO-PHASE SYSTEMS BASED ON PHYSICAL MODELS OF LIQUID AND GAS FLUID MECHANICS

Abstract

The movement of two-phase systems is often found in nature and in practice. The analysis shows that in the absence of a model, we have to be satisfied with laboratory experiments, the empirical analysis of their results is limited. Currently, there are many laboratory works where a large number of experiments are collected. In this study, a large amount of systematization and analysis of these data, which is an important stage of the research, was carried out.

Numerous works published in the last ten years include an overview of the current state of the issue and analysis of individual processes, mainly empirical methods. This work includes analytical studies of two-phase flow hydrodynamic processes with subsequent field applications This method allows to determine the result and feasibility of application when determining the parameters of practical interest in some engineering problems in production.

Keywords: *tangential shear stress, density, true gas composition, two different flows, gas-liquid mixture*

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Maye və qaz maye mexanikasının fiziki modelləri əsasında ikifazalı sistemlərin hərəkətinin tədqiqi

Xülasə

İkifazalı sistemlərin hərəkətinə təbiətdə və praktikada tez-tez rast gəlinir. Təhlil göstərir ki, model olmadıqda, biz laboratoriya təcrübələri ilə kifayətlənməli oluruq, onların nəticələrinin empirik təhlili məhduddur. Hal-hazırda çox sayda təcrübələrin toplandığı bir çox laboratoriya işləri var. Bu araşdırmada tədqiqatın mühüm mərhələsi olan bu məlumatların böyük həcmdə sistemləşdirilməsi və təhlili aparılmışdır.

Son on ildə nəşr olunan çoxsaylı əsərlərə məsələnin cari vəziyyətinin icmalı və ayrı-ayrı proseslərin, əsasən, empirik metodların təhlili daxildir. Bu işə ikifazalı axın hidrodinamik proseslərin sonrakı sahə tətbiqləri ilə analitik tədqiqatları daxildir. Bu üsul istehsalatda bəzi mühəndislik problemlərində praktiki maraq doğuran parametrləri təyin edərkən nəticəsini və tətbiqinin mümkünlüyünü müəyyən etməyə imkan verir.

Açar sözlər: *tangensial kəsmə gərginliyi, sıxlıq, həqiqi qaz tərkibi, iki fərqli axın, qaz-maye qarışığı*

Introduction

Numerous analyzes show that two-phase flows obey all the basic laws of fluid mechanics. It should be noted that the equations of gas-liquid systems are more complex and numerous than those of single-phase flows of liquid and gas. The method of analysis of one-dimensional flows is divided into several classes according to their complexity, depending on the amount of information required for the flow of two-phase systems.

It is known that various equations and methods are used to describe real physical processes. As the least used and developed method to describe the physical processes during the movement of two-phase systems, fluid mechanics uses the assumption of flow continuity, the laws and methods of whole medium mechanics. Based on this, hydromechanics of gas-liquid mixture can be considered a special field of all environmental mechanics.

A two-phase, gas-liquid system can be considered a medium with different physical nature, which can change in time and space. The main laws maintained in this section of mechanics are the laws of conservation of mass, momentum (pulses, angular momentum , energy and energy balance) (Mehendafe, Jacobi, 2000).

To solve multiple problems, one needs to have models. As the study shows, studying a model representation means studying a physical process using a model; using modeling, you can study the relevant process in various details to obtain reliable information or confirm a hypothesis.

It is based on A. A. Armand's model

For the mixture

$\tau_{\text{см}} = \tau_m \times (1 - \varphi)^{-1,53}$

Or $\tau_{\text{см}} = \mu_{\text{м}} \times \frac{dU_m}{dr} \times (1-\varphi)^{-1,53}$

Acting on the fluid is the pressure force and the Newtonian friction force, which, due to the equilibrium condition, sum to zero.

$P_1 - P_2 + \text{T} = 0$

P_1 və P_2 – pressure force

T – frictional force

$\mu_{\text{м}}$ - dynamic viscosity

$\tau_{\text{см}}$ – tangential shear stress of the mixture

τ_m – tangential shear stress for a homogeneous fluid .

P_1 və P_2 – pressure force

$P_1\pi r^2 - P_2\pi r^2 + \mu \times \frac{dU_m}{dr} \times 2\pi r L(1-\varphi)^{-1,53} = 0$

After shortening, where is πr^2, we get this.

$P_1 - P_2 = \Delta P = -\mu_m \times \frac{dU_m}{dr} \times \frac{2}{r} \times \text{L}\ (1-\varphi)^{-1,53}$

From there

$\Delta P \times \frac{r}{2L} \times (1-\varphi)^{1,53}\ \text{dr} = -\mu_{\text{м}}\ dU_m$

or

$\Delta P \times \frac{(1-\varphi)^{1,53}}{2L\mu_m} \times \text{rdr} = -\ dU_m$

where $\frac{dU_m}{dr}$ is the gradient of a homogeneous liquid

L – length

φ – It is the ratio of the area occupied by the gas in the pipe to the total area of the pipe.

Integrating this equation gives the following velocity distribution across a uniform gas-liquid flow cross-section in a circular tube (Bennet, Hewitt, 2019).

$U_m = -\frac{r^2}{4\mu_m} \times \frac{\Delta P\ (1-\varphi)^{1.53}}{L} + \mathrm{C}$

This equation is the equation of a parabola. The integrated constant is determined from the following boundary conditions: the partial velocity at the pipe walls is zero, i.e. hour r = r_o ; $U_m = 0$

Then

$0 = -\frac{r_o^2}{4\mu_m} \times \frac{\Delta P(1-\varphi)^{1.53}}{L} + \mathrm{C}$

Or $\mathrm{C} = \frac{r_o^2}{4\mu_m} \times \frac{\Delta P}{L} \times (1-\varphi)^{1,53}$

therefore

$U_m = -\frac{r^2}{4\mu_m} \times \frac{\Delta P\ (1-\varphi)^{1.53}}{L} + \frac{r_o^2}{4\mu_m} \times \frac{\Delta P\ (1-\varphi)^{1.53}}{L}$

Or

$U_m = \frac{\Delta P}{4\mu_m L} \times (1-\varphi)^{1,53} \times (r_0^2 - r^2)$

where r_0 pipe radius

from there

$U_m = \frac{\Delta P\ r_o^2}{4\mu_m L} \times (1-\varphi)^{1,53} \times (1 - \frac{r^2}{r_o^2})$

where ΔP – pressure drop

This equation allows determining the velocity of the gas-liquid mixture in a uniform flow. If P = 0 then

$U_m = \frac{\Delta P r_o^2}{4\mu_m L} \times (1 - \frac{r^2}{r_o^2})$

This equation was first created by Stokes in 1867 and expresses the law for determining the velocities of a homogeneous fluid by applying a pipe in the laminar motion regime. That's why it's called Stokes' parabolic law (Fogarasi, 2012).

The maximum speed is determined . r =0

after

$U_{max\,m} = \frac{\Delta P(1-\varphi)^{1,53}}{4\mu_m L} \times r_o^2$

The ratio of velocities along the pipe axis is listed below.

$\frac{U_m}{U_{\max m}} = 1 - \frac{r^2}{r_0}$

It is clear from the formula that the distribution of dimensionless velocities is likely to be the same in all cases of laminar fluid motion in round tubes. Then it can be said that in all cases of laminar motion, in the gas-liquid mixture system, liquid and gas in the gas system, regardless of the viscosity of the mixture and therefore the Reynolds number, with the same value of dimensionless velocities, all phenomena observed in liquids will be similar. Such phenomena are called self-similar when similarity occurs at different values of Reynolds. In this case, the actual composition studied is, as it were, a model of itself, since it is possible to study the picture of the motion of the two-phase system in multiple reductions against the actual speed (Guzhov, 2017).

As the scientist says, in the cavity of the flow intersection there is a ring with an inner radius and width in the radial direction, which coincides with the axis of the tube. The area of this ring is d F = 2πrdr. Taking into account the above, we determine the elementary flow rate through this annular area.

$d\ Q = U2\pi \mathrm{r} d\mathrm{r}$

We get the speed value by substituting from the appropriate formulas.

$dQ = U2\pi\ \mathrm{r}d\mathrm{r} = \frac{\Delta P\ r_o^2}{4\mu_m L} \times (1-\varphi)^{1,53} \times (1 - \frac{r^2}{r_o^2}) \times 2\pi r d\mathrm{r} =$

$= \frac{\Delta P r_o^2\ \pi}{2\mu_m L} \times (1-\varphi)^{1,53} \times (\mathrm{rdr} - \frac{r^3}{r_o^2} d\mathrm{r}) =$

$= \frac{\Delta P r_o^2\ \pi}{2\mu_m L} \times (1-\varphi)^{1,53} \times (\int_0^{r_0} r\, d\mathrm{r} - \frac{1}{r_o^2} \int_0^{r_0} r^3\, d\mathrm{r}) =$

$$=\frac{\pi \Delta P r_o^2}{2\mu_m} \times \frac{\Delta P}{L} \times (1 - \varphi)^{1,53} \times \left(\frac{r_o^2}{2} - \frac{1}{r_o^2} \times \frac{r_o^4}{4}\right) =$$

$$= \frac{\pi \Delta P r_o^2}{2\mu_m} \times \frac{\Delta P}{L} \times (1 - \varphi)^{1,53} \times \left(\frac{r_o^2}{2} - \frac{r_o^2}{4}\right) = \frac{\pi \Delta P}{2\mu_m} \times \frac{\Delta P}{L} \times (1 - \varphi)^{1,5} \times \frac{r_o^2}{4} \times r_o^2$$

or

$$Q = \frac{\pi \Delta P r_o^4}{8\mu_m L} \times (1 - \varphi)^{1,53}$$

Where Q is the consumption of liquid.

If we assume that $\varphi = 0$, then we get

$$Q = \frac{\pi}{8\mu_m} \times \frac{\Delta P}{L} \times r_o^4$$

This formula was obtained experimentally for the first time in 1840 by the French doctor Poiseuille (Baykov, Pozdnyshev, 2009).

The formula for volumetric flow is:

$$Q = \upsilon_m \pi r_o^2$$

However, we can determine the average velocity from Eq .

$$\upsilon_m = \frac{Q}{\pi r_o^2} = \frac{\pi}{8\mu_m} \times \frac{\Delta P}{L} r_o^4 (1 - \varphi)^{1,53} \times \frac{1}{\pi r_o^2}$$

Then we have

$$\upsilon_m = \frac{1}{8\mu_m} \times \frac{\Delta P}{L} \times r_o^2 (1 - \varphi)^{1,53}$$

For the average velocity of the liquid phase, the law of hydraulic resistance can be deduced from this equation, which determines the pressure loss during the laminar movement of the liquid phase in pipes (Bretschneider, 2014).

$$8\mu_m \nu_m \mathrm{L} = \Delta P r_o^2 (1 - \varphi)^{1,53}$$

We replace the radius with the diameter we have

$$8\mu_m \nu_m L = \Delta P \times \frac{D^2}{4} \times (1 - \varphi)^{1,53}$$

or

$$\Delta P = 8 \times \frac{4\mu_m \upsilon_m L}{D^2 (1 - \varphi)^{1,53}} = \frac{32\mu_m \upsilon_m}{D^2 (1 - \varphi)^{1,53}} \times \mathrm{L}$$

$$h_w = \frac{\Delta P}{\gamma} = \frac{32\mu_m \upsilon_m L}{\gamma D^2 (1 - \varphi)^{1,53}}$$

This equation is a mathematical expression of the law of hydraulic resistance. In cases where $\varphi = 0$, we have the formula for a homogeneous fluid (Shao, Gavriilidis, Angeli, 2009).

We hit accordingly, we find

$$h_w = \frac{32\mu_m \upsilon_m L}{\gamma D^2 (1 - \varphi)^{1,53}} \times \frac{2\nu_m}{2\nu_m} = \frac{64\mu_m}{\gamma \upsilon_m D} \times \frac{L}{D} \times \frac{\upsilon_m^2}{2} \times \frac{1}{(1 - \varphi)^{1,53}}$$

We replace specific viscosity with density $\gamma = \rho g$ and dynamic viscosity with kinematic viscosity $\mu_m = \rho_m g$.

$$h_w = \frac{64\upsilon_m \rho_m}{\rho_m g D \upsilon_m} \times \frac{L}{D} \times \frac{\upsilon_m^2}{2} \times \frac{1}{(1 - \varphi)^{1,53}} = \frac{64\upsilon_m}{\upsilon_m D} \times \frac{L}{D} \times \frac{\upsilon_m^2}{2g} \times \frac{1}{(1 - \varphi)^{1,53}}$$

In this equation, we introduce the concept of Reynolds number.

$$h_w = \frac{64}{Re_m} \times \frac{L}{D} \times \frac{\upsilon_m^2}{2g} \times \frac{1}{(1 - \varphi)^{1,53}}$$

The analysis shows that for a uniform flow of a gas-liquid mixture at a certain average speed in a fixed pipe, the loss section at a given cross-section will be directly proportional to its length and inversely proportional to the diameters of the pipes (Belogortsev, Vasiliev, Guzhov, 2011).

we multiply the expression $(\rho_m g)$ and find the pressure loss due to friction .

$$\Delta P_w = \frac{64}{Re_m} \times \frac{L}{D} \times \frac{\upsilon_m^2}{2g} \times \rho_m g \times \frac{1}{(1 - \varphi)^{1,53}}$$

The formula $\frac{64}{Re_m}$ expresses the coefficient of hydraulic resistance.

$$\lambda = \frac{64}{Re_m}$$

$$\Delta P = \lambda \frac{L}{D} \times \frac{\upsilon_m^2}{2} \times \rho_m \times \frac{1}{(1-\varphi)^{1,53}}$$

If φ =0, we have the Darcy-Weissbach formula for a homogeneous fluid.

However, the gas-liquid mixture moves turbulently. In this case, the formula for homogeneous liquids is sufficient. Darcy-Weissbach takes into account the coefficient of hydraulic resistance. This length parameter is one of the most important parameters on which the energy or pressure loss during the movement of liquid, gas and gas-liquid mixture depends. Taking into account the above, this coefficient is an engineering, technical issue necessary for solving problems related to the movement of fluids (Armand, 2010).

The resistance coefficient cannot be determined purely theoretically, because it is mainly explained by the effect of the pipe roughness on the hydraulic resistance, which depends on many factors, is not constant and can be very different in different conditions .

Roughness is one of the main parameters that have an effective effect . This parameter wall damage contributes to the formation of eddies and causes additional hydraulic and energy losses to the flow.

Laboratory studies have shown that wall roughness contributes to the formation of vortices near the surface and is an additional hydraulic resistance and energy loss for flows moving both in a homogeneous fluid and in a two-phase mixture such as gas and liquid. Experiments have shown that the drag coefficient during advanced turbulent motion depends not only on the Reynolds number, but also on the relative roughness (Kong, Kim, Bajorek, 2018).

Since the liquid is dominant in the gas-liquid flow conditions in our model, the consideration of its physical properties in our model is the main issue in the calculations (Bohdal, Sikora, 2011).

The analysis showed that the Blasius formula is the most accessible in the case of homogeneous fluid movement for mostly smooth pipes, while A.D. Altshul.

According to Blasius $\lambda = \frac{64}{Re}$

According to Altshul $\lambda = 0,11 \left(\frac{68}{Re} + \frac{\Delta}{D}\right)^{0,25}$

Based on this model, a comparison of the laboratory experiments of the A.A. Armada was made. As it can be seen, there is an error between the laboratory and the calculated minimums, which gives the right to propose this technique for practical use (Wallis, 2008).

Results:

1) Based on laboratory experiments, a model was proposed to study the main properties of gas-liquid mixtures.

2) Based on this model, the proposal is based on the method of determining the pressure loss in horizontal pipes dominated by the liquid phase.

3) These methods (allow to determine the main parameters of the two-phase system (such as liquid oil, condensate) and the pipeline where natural gas (air) is transported and separated.

Conclusion

A model description of the movement of gas-liquid mixture in horizontal pipes is proposed. It is known that physical modeling is basically the study of the phenomenon we are interested in in practice in order to study a similar phenomenon in a smaller or larger scale model. , usually under special, specialized laboratory conditions. Basically, physical models have the same physical nature as the studied volume in practice. The theoretical and experimental study of the size of the studied phenomenon on physical models is studied .

This work covers the study of the motions of a two-phase system in a horizontal pipe. Taking into account the general regularities of the hydrolysis of homogeneous liquids and gases, which play a special role in the practical transportation process. This allows us to determine the nature of the levels based on the fact that they are expressed by the same conservation principles (mass, momentum, energy, etc.) that underlie many physical processes.

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