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# Fluid Mechanics of Gas-Liquid Systems

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**Abstract:** The study of gas-liquid systems in fluid mechanics is essential for understanding multiphase flows, particularly in industries such as oil and gas field development. This research explores the key parameters that govern the behavior of such systems, including volume flow, velocity, area, dynamic viscosity, and diameter. Volume flow represents the quantity of fluid moving through a system per unit time, while velocity determines the rate at which the fluid particles travel. The cross-sectional area of the conduit directly influences the flow regime, and the dynamic viscosity defines the fluid's internal resistance to flow, significantly impacting pressure drops and flow patterns. The pipe diameter plays a critical role in determining flow characteristics such as Reynolds number and transition between laminar and turbulent flow. By analyzing these factors, this study provides insights into optimizing gas-liquid systems for improved performance and efficiency in industrial applications.

**Keywords:** Volume Flow; Velocity; Area; Dynamic Viscosity; Diameter.

## 1. Introduction

Practice shows that in all industries we face two-phase flow, vapour or gas-liquid systems. All ships, floating platforms, tugboats, etc. are equipped with a marine hydraulic system which consists of a pumping unit and a pipe network. The system consists of receiving and pressure tanks, piping connecting the tanks to the pumps, control valves and other isolation valves providing the required requirements, heat exchangers, filters moving single-phase or two-phase systems, depending on the equipment connected to the given circuit. Such systems include condensate systems of steam turbine installations, charts of fuel systems of ships with diesel power plants.

The main parameters of the system are the flow and pressure of the pipeline network. The network flow rate is the amount of liquid or gaseous phase that passes through the piping system per unit of time [1-6].

The aim of this work is to provide experts with calculation methods for calculating pressure drops and flow rates during the flow of vapour and gas-liquid mixtures in pipelines and heat exchangers.

It is worth noting that despite the extensive research on gas-liquid flow, in many cases the error of the proposed method reaches ±50%. In many areas of mechanics, mechanical engineers must rely on their own experience to estimate the values required for design parameters. Greater prediction uncertainty is associated a large number of variables characterising the gas-liquid flow. In such cases, an extremely extensive research programme is required to obtain accurate correlations. Note that values relating to liquid or gas single-phase flow are largely empirical.

## 2. Problem Statement

This paper discusses some of the variable parameters that characterise the flow in gas-liquid systems; volumetric flow rate of liquids, gases (vapours), gas content, density, viscosity, etc.

Methods of calculating the main parameters of two-phase flow of liquids, gases, etc. are also proposed; based on the mode of motion of each phase.

In this case, we will consider the steady laminar motion of the mixture in a circular pipe under the conditions of fully formed flow, i.e. it is assumed that the distance of the initial cross-section of the fluid from the inlet of the pipe is sufficient to ensure a steady distribution of velocities in the cross-section.

## 3. The Main Part

Based on Newton's assumption that the law of friction for gas-liquid systems contradicts the Coulomb friction law for solids, it is possible to propose, on the basis of a large number of experiments, a mathematical model that takes full account of mixtures. Interphase viscous friction and relative slip laws.

In general, a large number of studies have shown that there are several ways to determine the shear stress of a two-phase mixture as it moves through a pipe. Analyses have shown that these experimental points can be well estimated by the equation

$$\tau_c = \tau_l + \tau_g + k\sqrt{\tau_l \tau_g} \tag{1}$$

where $\tau_c$ is the tangential stress on the sides of the pipe when a gas-liquid mixture is moving in the pipe;

$\tau_l, \tau_g$ are the tangential stresses on only the liquid and gas moving in the pipe, respectively;

k-coefficient;

The analysis shows that for the two-phase system where the Reynolds parameters of the liquid and gas vary within the limits, $Re_g = 465 \div 40800$ and $Re_l = 3000 \div 15300$, the Froude parameters of the liquid and gas, respectively, are within the limits of $Fr_l = 9.7 \div 1358$ and $Fr_g = 0.28 \div 2173$ for parameter values k =26.

Considering the above, let us consider the uniform motion of the gas-liquid mixture. Let us determine the velocity distribution in the cross-section of the pipe. In this case, the problem of velocity distribution in the cross-section is reduced to determining the dependence of the velocity on the radius of the pipe and the volumetric gas content.

$$\pi r^2 \Delta P = 2\pi r L \tau_c \tag{2}$$

where $\Delta P$ is the pressure drop;

L is the length of the cylinder under discussion.

The tangential stress on the side of a given cylinder can be determined from equation (1). To solve this problem, the tangential shear stresses in liquids and gases can be determined from the velocity gradient. Then

$$\tau_c = \mu_l \frac{d\delta_l}{dr} + \mu_g \frac{d\delta_g}{dr} + k\sqrt{\mu_l \frac{d\delta_l}{dr} \cdot \mu_g \frac{d\delta_g}{dr}} \qquad (3)$$

where $\mu_l$and $\mu_g$ are the dynamic viscosities of the liquid and gas, respectively;

$\delta_l$ and $\delta_g$ are the average velocities of the liquid and gas, respectively.

Let us take the axis of the pipe as the velocity axis and the straight line perpendicular to the pipe as the radius axis.

According to the laws of hydraulics for homogeneous liquids or gases, particles near the pipe wall stick and remain motionless. The velocity then increases from the peripheral direction and reaches a maximum towards the centre.

From the course on fluid dynamics of two-phase systems, we know that the individual phase velocities can be correlated with each other through the volume flow parameters.

Then, for liquids and gases, the mean velocities can be determined respectively as

$$\delta_g = \frac{\beta}{1-\beta}\delta_l \qquad (4)$$

$$\delta_l = \frac{\beta}{1-\beta}\delta_g \qquad (5)$$

Therefore, equation (3) can be written as

$$\tau_c = -(\mu_l \frac{d\delta_l}{dr} + \mu_g \frac{\beta}{1-\beta}\frac{d\delta_g}{dr} + k\sqrt{\mu_l \frac{d\delta_l}{dr} \cdot \mu_g \frac{\beta}{1-\beta}\frac{d\delta_g}{dr}}\ ) \qquad (6)$$

Then, accordingly we have

$$\frac{\Delta P}{L} = \lambda_l \frac{Fr_l}{2}\rho_l + \frac{Fr_g}{2}\frac{\delta_g^2}{2gD}\rho_g + k\sqrt{\lambda_l \frac{Fr_l}{2}\rho_l \lambda_g \frac{Fr_G}{2}\rho_g} \qquad (7)$$

In the case of $\delta_g = 0$, we have the Darcy-Weisbach formula for homogeneous liquids or gases.

Empirical and computational data

**Table 1.** Table Experimental data.

| Pipe diameter,m | Volume Gas content | Liquid Froude parameters | Gas Froude Parameters | Liquid Reynolds parameter | Gas Reynolds parameter | Fluid Hydraulic Resistance Coefficient | Liquid hydraulic resistance coefficient | Experimental data | Experimental data |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 | 0.378 | 2.902 | 1.070 | 167.73 | 68.37 | 0.015 | 0.035 | 0.041 | 0.040 |
|  | 0.422 | 2.502 | 1.338 | 155.57 | 76.37 | 0.016 | 0.034 | 0.038 | 0.037 |
|  | 0.482 | 2.015 | 1.739 | 139.76 | 87.09 | 0.016 | 0.032 | 0.034 | 0.035 |
|  | 0.571 | 1.383 | 2.442 | 115.79 | 103.17 | 0.017 | 0.031 | 0.028 | 0.026 |
|  | 0.800 | 0.299 | 4.803 | 53.85 | 144.71 | 0.020 | 0.029 | 0.014 | 0.015 |

# 4. Conclusion

Thus, the proposed method is a generalised formula for determining the pressure loss due to friction, applicable to both laminar and turbulent modes of motion of liquids and gases constituting gas-liquid mixtures.

The results show that in turbulent modes, the hydraulic resistance coefficients for the liquid or gas phase can be determined using the Blasius, Altschul or Shifrinson formulae.

The calculations are based on data borrowed from the work of A.I. Guzova. A comparison of the measured and calculated data is shown in the table.

As can be seen from the table, the error arising between these parameters are insignificant, which gives the right to propose this technique for practical calculations.

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