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Analysis of Two-phase Mixture Flow in Vertical Pipeline

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ABSTRACT

This paper presents a theoretical model of two-phase flow of mixtures of water and solids in vertical pipelines. This model includes several factors, which can be analytically interpreted. Simplified equations for approximate calculations have been also derived. Using the equations of two-phase flow presented in this paper, cases for different systems of vertical hydraulic transport can be calculated. Model was validated by comparison with the experimental results from industrial hydraulic systems for transport of coal from underground mines. Also presented are some examples of analyses of head loss and slip velocity changes in function on concentration of solids in mixture, diameter of the pipe and diameter of solids.

KEY WORDS: Multiphase flow, mathematical model of flow, two-phase mixtures.

INTRODUCTION

Transport in pipelines belong to for years intensively developed methods of bulk transportation. Progress in this field forced more and more intense scientific research (Sobota, Plewa 2000). Research related to pipeline transport is concentrated in three main subjects, (Plewa, 2002):

- Development of methods for calculation parameters of flow of mixtures in pipelines,
- Construction of feed-batching devices, which deliver carrier fluid (water) and bulk material (grained minerals)into the transportation system
- Design of automated control and monitoring systems.

A large number of factors, which influence phenomena that occur by multiphase flows, resulted in construction of simplified equations, being valid only for specific type of flow or composition of a mixture. However, industrial practice has proven that such an approach does not ensure sufficient accuracy of calculations by design of industrial hydrotransport systems. Moreover, simplified equations do not allow to carry on deeply penetrating theoretical analyses, which could lead to creation of new solutions or methods, i.e. in the range of minimization of energy losses or pipe wear. Obviously such a problems exist in pipeline systems, which have lift height of few hundreds meters or even few kilometers. Such a systems operate in coal mines for haulage of coal in deep sea mining projects.

Specificity of extraction of minerals from sea floor requires use of such a methods, which are highly reliable and easy to control. The most reliable are such a deep sea mining systems, which do not contain moving parts (valves, pistons, impellers) in their transportation devices

CHARACTERISTICS OF EXISTING METHODS FOR CALCULATION OF PARAMETERS OF TWO-PHASE MIXTURES FLOW IN VERTICAL PIPELINES

Scientific research in the field of multiphase mixtures flow in vertical closed channels are directed mainly on measurement of energetic losses and minimal velocity of flow, above which starts lifting and transport of grains. It must be pointed out that flow of two-phase mixtures in pipelines has been considered mainly as a flow of an equivalent homogenous liquid, which density is relevant to the density of water-solids mixture.

Because in vertical pipelines grains of solids flow mainly in the core of the stream, often an assumption is accepted that flow resistance of a mixture is equal to the flow resistance of homogenous liquid. By these simplifications, a number of authors present following equation for calculation of necessary pressure difference Δp required to lift up mixture in pipeline with diameter D on the height H with average velocity v_m:

$$\Delta p = H\rho_m g + \lambda_m \frac{\rho_m v_m^2}{2D} H \qquad (1)$$

where:
ρ_m – density of mixture,
g – acceleration of gravity,
λ_m – coefficient of resistance for mixture flow.

In spite of determination of pressure losses, in vertical transportation necessary is to know the minimal velocity of flow, which allow the solid particles to lift up. General rule says that velocity of flow must be higher than fall velocity of particles in mixture (or the largest particles in case of variously graded material).

Fall velocity of a single solid particle in water v_{w-s} is often calculated from the formula: