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Identification of flow regime and estimation of volume fraction independent of liquid phase density in gas-liquid two-phase flow

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A B S T R A C T

Changes of fluid properties, especially density, strongly affect the performance of radiation-based multiphase flow meter and could cause error in volume fraction measuring. One solution in such situations is continuous recalibration of the system, which is a difficult and long time task. In this study, a new methodology is presented for identifying flow regime and estimating the void fraction in gas-liquid flows independent of liquid phase density changes. The approach is based on gamma-ray attenuation and scattering combined with artificial neural networks (ANNs). The detection system uses a fan beam geometry, comprised of one ^{137}Cs source and three NaI(Tl) detectors. Two of these three detectors were implemented to measure transmitted photons and the third one was used to measure scattered photons. Also, four ANNs were used in this study, the first one for identifying the flow regime independent of liquid phase density changes and the other three ANNs for predicting void fraction independent of liquid phase density changes. Using this methodology, three flow regimes of annular, stratified and bubbly were correctly distinguished in liquid phase density changes range of 0.735–0.980 g/cm^3 and void fraction was predicted with a mean relative error (MRE) of less than 4.3%.

1. Introduction

The accurate flow metering of oil well products is of great importance to the oil industry. The high cost of sub-sea production has led to the use of multiphase pipelines to transfer mixture of oil and gas. This provides a requirement for multiphase metering in which the flow rates of oil and gas can be determined with sufficient accuracy for reservoir management, for monitoring the withdrawal of fluids from a reservoir, and for custody transfer purposes. Ideally the measurements should be carried out non-intrusively. To this end, nuclear techniques, notably neutron interrogation and activation and also gamma densitometry have an important part to play (Bishop and James, 1992). Using gamma attenuation techniques are also more conventional in comparison with neutron scattering and attenuation techniques. Difficulty in obtaining a sufficiently strong neutron source to provide an adequate counting statistics for transient measurements, is one of the limitations of using neutron techniques.

In recent years, some studies have been done on measuring the volume fraction and determining the flow regime in multiphase flows by means of gamma-ray attenuation techniques. El Abd showed that usage of Compton-Compton scattering is more precise than transmission and traditional Compton scattering for determining the void fraction in stratified regime of two phase flows (El Abd, 2014). Roshani et al. also proposed a method based on dual modality densitometry using ANN to first identify the flow regime and then predict the void fraction in gas-liquid two-phase flows (Roshani et al., 2015). They used the total count in the scattering detector, the full energy peak and photon counts of Compton edge in transmission detector which were obtained by simulations, as the three inputs of the ANN. By applying this method, they correctly distinguished all the three regimes of stratified, homogenous and annular and estimated the void fraction of each phase in the range of 5–95% with error of less than 1.1%. Faghihi et al. modeled three basis two-phase flow regimes including homogenous, stratified and annular in a vertical pipe by using polyethylene phantoms (Faghihi et al., 2015). For all three modeled flow regimes all transmitted and scattered gamma rays in all directions were measured by setting a gamma ray source and detector around the pipe. Finally, they presented innovative correlations to predict the void fraction in two-phase flow in a vertical pipe. Also it has been shown

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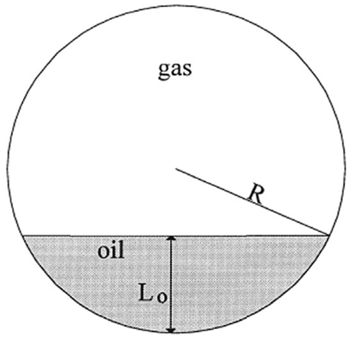

Fig. 1. Defined parameters in stratified regime.

that artificial neural networks could be used for predicting, classification and optimization for radiation-based multiphase flow meters and generally industrial nuclear gauges specially in cases that lots of parameters could influence the operation of the system (Salgado et al., 2009, 2010, 2014; Jing et al., 2006; Roshani et al., 2014a,b, 2016a,b, 2017a,b; Cong et al., 2013; Jing and Bai, 2009; Nazemi et al., 2016a; Yadollahi et al., 2016a,b; Eftekharizadeh et al., 2016; Zahakifar et al., 2017).

Calibration of radiation-based multi-phase flow meters (MPFMs), depends strongly on the fluid properties (Corneliussen et al., 2005). By changing the fluid properties such as density, recalibration is required. Performance of MPFMs would be improved by eliminating any dependency on the fluid properties. In

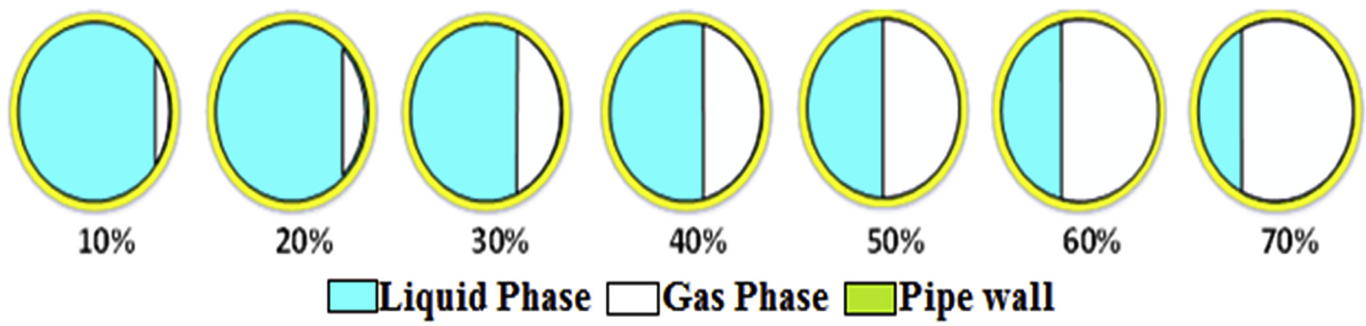

Fig. 2. Schematic cross sectional view of different void fractions in the range of 10%–70% in stratified regime.

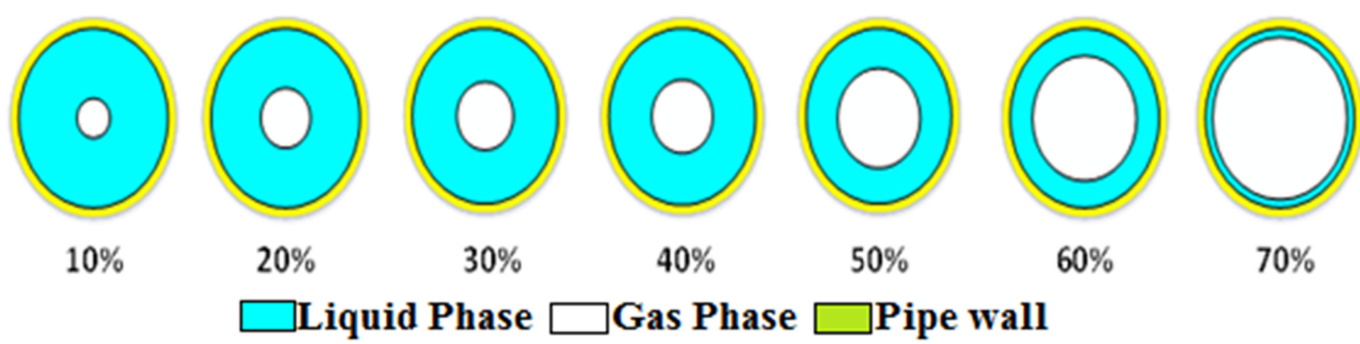

Fig. 3. Schematic cross sectional view of different void fractions in the range of 10%–70% in annular regime.

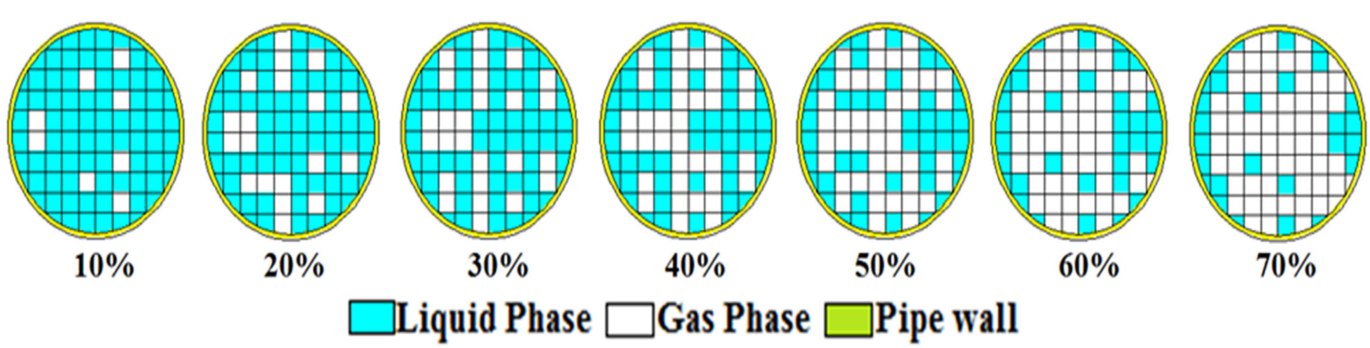

Fig. 4. Schematic cross sectional view of different void fractions in the range of 10%–70% in bubbly regime.

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