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MULTIPHASE FLOW RATE MEASUREMENT THROUGH A CONDUCTANCE VENTURI METER: EXPERIMENTAL AND THEORETICAL STUDY IN DIFFERENT FLOW REGIMES

by Abbas H.A.M. Hasan Supervised by G.P. Lucas

OVERVIEW AND RESEARCH OBJECTIVES

Multiphase flows, where two or even three fluids flow simultaneously in a pipe, are becoming increasingly important in the oil industry. Although much research has been done to measure the phase flow rates of two-phase flows in a Venturi meter, accurate flow rate measurement of two/three phase flows with a Venturi meter in different flow regimes remains elusive. The aim of the research is to develop a new solution for non-invasive multiphase flow rate measurement with a targeted accuracy of 5% per phase in unsteady two-phase water/gas, water continuous, vertical and horizontal flows. However, the instrument will be based on an advanced Conductance Multiphase Venturi Meter (CMVM) which is capable of measuring the gas volume fractions at the inlet and the throat of the CMVM. A new model was investigated to measure the gas flow rate. This model is based on the measurement of the gas volume fractions at the inlet and the throat of the Venturi meter using a conductance technique rather than relying on the prior knowledge of the mass quality $x$. The objectives, providing the solution to achieve the aims, are outlined below:

- To measure the flow rate of the gas/water mixture with a Venturi flow meter and flow density meter (FDM) in a homogenous flow.
- To design a novel conductive multiphase Venturi meter (CMVM) and conductive inlet void fraction meter which capable to extract the gas volume fraction at the inlet and the throat of the Venturi.
- To measure the gas flow rate and the gas volume fractions at the inlet and the throat of the CMVM in vertical annular and slug flows.
- To measure the gas flow rate and the gas volume fractions at the inlet and the throat of the CMVM in horizontal slug and stratified flows.
- To measure the liquid flow rate in vertical annular and slug flows.
- To measure the liquid flow rate in horizontal slug and stratified flows.

MATERIALS AND THEORETICAL FRAMEWORK

Since for non-homogenous flow the gas volume fraction at the inlet, $\alpha_1$ differs from the gas volume fraction at the throat, $\alpha_2$ (and also the mixture density at the inlet and the throat, $\rho_1$ and $\rho_2$ respectively), it is necessary to measure the gas volume fractions at the inlet and the throat of the Venturi. To do so, a new Venturi with two ring electrodes at the throat was designed and manufactured. The system comprises two sections; CMVM (to extract $\alpha_1$) and the CIVF (to extract $\alpha_2$).

FINITE ELEMENT MODELLING OF THE CONDUCTANCE METER

Finite element software called “COMSOL” was used to simulate vertical annular flow in which the gas forms a core at the pipe centre and the liquid forms a film between the gas core and the pipe wall. In the simulation model, the electrical conductance of the mixture can be calculated from the current density at the virtual earth electrode and the applied potential. It is therefore possible to obtain the conductance of the mixture in the CMVM comprising two ring electrodes (a virtual earth electrode and an excitation electrode) by integrating the current flow over the area of the virtual earth electrode and dividing by the potential of the excitation electrode.

MATHEMATICAL MODELS

Homogenous flow model

In case of homogenous flow where the two phases are normally well mixed, the gas and water are assumed to have the same velocity ($v=4$). The mixture volumetric flow rate $Q_m$ can be written as:

$$Q_m = Q_g + Q_w$$

$$\rho_m = \rho_g + \rho_w$$

It is clear from the above equations that, in homogenous flow it is possible to assume that the gas volume fraction at the inlet and the throat are equal to $\alpha$.

Separated flow model

The assumption of equal mixture densities at Venturi is no longer valid for a separated flow and therefore, the measurement of the gas volume fraction at the throat must also be introduced. The study of multiphase flow through contraction meters is described for example by: Murdock, Chisholm, Lin, Smith and Leang, de Leeuw and Steven.

The new separated flow model is given by:

$$\alpha_1 = \frac{C_{dm1} \Delta P_1 + \alpha_1 \rho_1 - \alpha_2 \rho_2}{\rho_1 - \rho_2}$$

For slug flow, the conductance model is a mixture of two flow regimes: a stratified flow regime and a homogeneous flow regime and the correlation is given as:

$$\alpha_1 = \frac{C_{dm1} \Delta P_1 + \alpha_1 \rho_1 - \alpha_2 \rho_2}{\rho_1 - \rho_2}$$

EXPERIMENTAL SETUP FOR HOMOGENEOUS AND SEPARATED FLOW

EXPERIMENTAL RESULTS

HOMOGENEOUS FLOW RESULTS

SEPARATED FLOW RESULTS

CONCLUSION AND FURTHER WORK

- The Homogenous flow results showed that, for $0 \% - 95\%$, the error was within $\pm 2.95\%$. After that the homogenous flow model has broken due to the transition from bubbly to slug flow regimes.
- Therefore, an advance conductance multiphase Venturi meter was designed and constructed to measure the phase flow rate in a separated flow regime.
- A good results was obtained from a new separated flow model in which the error in the gas flow rate (vertical annular flow regime) was within $\pm 1.95\%$.
- The multiphase flow loop has to be modified to achieve the horizontal stratified and slug flow regimes.
- An intermittent model for slug flow has to be investigated which may combine the homogenous and separated flow models described in this poster.