

Multiphase flow metering for the oil and gas industry using a visualisation technique

Syed F. A. Balkhani, Francesco Coletti, Carola S. König, Tassos G. Karayannidis

Abstract—Measuring multiphase flows accurately and reliably, particularly when three or more phases are involved, is a challenging and long-standing problem in the upstream oil-and-gas industry. Crude oil extracted from the reservoir is a complex mixture that contains oil, water, gas and sand. Before it is further transported downstream, the crude oil is typically processed in a pressure vessel that separates oil, water and gas. To reduce costs and increase safety, it is critical to accurately measure the streams flow rate (two- and three-phase) at this stage. The conventional metering systems require test separators, where the flow is diverted and measured. This method requires additional capital equipment, large maintenance cost and constant operator intervention. In this paper, a non-intrusive technology that continuously measures multi-phase flow is proposed to overcome the limitations of traditional systems. The novel multiphase flow metering system is based on the combined use of electrical capacitance tomography (ECT) images and knowledge base which is envisaged to provide continuous accurate, reliable, non-intrusive measurements at a minimal cost. In this technique, two ECT sensors are placed at two different locations in an oil pipeline. A hybrid technique is used to evaluate ECT images based on principal component analysis (PCA) and cluster analysis (CA) to identify the time interval, when a specific process condition is detected in both sensors. Once this information is obtained, volumetric flow rate and mass flow rate can then be calculated using the cross sectional area of the pipeline and the average velocity. Initial results with imaging sensors at two points indicate that an error of less than 5% can be achieved, which is acceptable for most applications in the oil and gas industry. This measurement method can be further extended by using three or more points for increased reliability and accuracy.

Keywords— cross correlation, flow meter, multiphase flow, oil-and-gas, visualisation technique.

I. INTRODUCTION

In many industries, particularly in oil and gas, measuring accurately and reliably multiphase flows is of paramount importance. The traditional flow include high cost, inaccuracies especially for multiphase flows, insensitivity to small changes and provide no insight about the process on the contrary visualisation techniques have the advantage that they

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are accurate, have high sensitivity and can provide visual knowledge of the process condition. Therefore by using visualisation technique timely corrective actions can be taken to avoid any undesirable situation in the process, e.g. blockage in oil pipe line. In recent years, extensive research has focused on measurement and control of different industrial processes using various visualisation techniques, such as electrical capacitance tomography (ECT), electrical resistance tomography (ERT) and high-speed, high-resolution cameras [1]-[3]. These techniques have successfully been used to visualise flow in oil separators and fluidized beds in the past [15]-[16]. Based on initial results, this visualising technique provides promising method than conventional techniques for multiphase flow metering.

Research using ECT for example is in progress at the University of Manchester [4]. Flow visualisation systems based on ECT are available commercially [5]. However, traditional applications focus on treating water and oil as two separate continuous liquid phases using one ECT sensor. As a result, the velocity profile of the flow cannot be estimated. In this paper, we propose the use of a novel approach to multiphase flow metering that entails the use of two or more ECT sensors placed at different points in the pipeline. This approach, combined with statistical techniques and a knowledge base system will allow calculating the velocity profile inside a pipeline transporting oil and gas flows.

A. Challenges Associated with Visualisation Techniques

For visualisation techniques to be effectively applied to multiphase flow metering, the overall device should be accurate, relatively inexpensive and inherently insensitive to the variations in flow regime. Table 1.1 summarises different features of the various techniques available.

While flow visualisation techniques have distinct benefits for example the flow regime can be determined in order to compensate the non-linearity of currently available MPPF meter, however, there are some challenges associated with these techniques. The most important one is the development of accurate mathematical model that enable an accurate estimation of volume flows. A related challenge is the computational time needed to solve such models. This is because accurate image reconstruction and image processing for knowledge base are both computation intensive. Another practical aspect is the mechanical and electronic hardware design for safe and reliable use in the harsh environment typical of the oil and gas industry.

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