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Accurate Volumetric Flow Rate and Density Based Water-Cut Measurement in Bubbly Liquid Hydrocarbon Flow

Abstract

Oil and gas production is inherently multiphase. A significant cost of production is directed toward accurately measuring and allocating produced hydrocarbons. The presence of gas phase in liquid flow impairs accurate measurement, introducing errors in well and field production allocation. These errors distort the reservoir engineer production information and directly affect the fiscal allocation from multiple owners. A SONAR-based system to measure the gas void fraction (GVF) next to turbine and Coriolis meters is proposed as a method to correct for gas bubbles. A test was conducted at Southwest Research Institute (SwRI) to validate this concept on realistic multiphase fluids. The SwRI test was designed to simulate separator liquid out-flow conditions and to assess the ability of GVF measurement to correct for the errors introduced by entrained gas in turbine and Coriolis meters.

The data show that both the turbine and Coriolis meters over-report the volumetric flow rate in proportion to the amount of entrained gas. Using a GVF measurement provides a simple correction to the primary measurement of both meter types to within ±1% of the reference liquid flow rate for 0-8% GVF. The Coriolis meter correctly measured the mixture (liquid + gas) density within ±1% of the reference, independent of entrained gas levels. The liquid density is required to determine water-cut and in this test it was calculated by correcting the measured mixture density for GVF. Using a simple GVF correction, the liquid density was reported to within ±1% for 0-10% GVF. An accurate measure of liquid hydrocarbon volumetric flow rate and density independent of the amount of entrained gas can be achieved using turbine and Coriolis meters in conjunction with a SONAR-based GVF measurement. This capability enables improved reservoir management as well as increased separator design flexibility, reducing complexity, cost and weight.

Introduction

The vast majority of the world's oil production is allocated using separator-based measurements. Measurements from test and production separators are often used to allocate production from individual wells and fields prior to commingling of produced fluids for further processing. The accuracy of separator-based measurements is often limited by incomplete separation of the gas / liquid separation prior to measurement due to gas carry-under and gas breakout. Most test-separator based measurement methodologies are based on the assumption of complete separation of the gas and liquid phases prior to measurement. In practice, however, complete separation is often difficult, if not impractical, to achieve. Separation efficiency within a specific process is typically a complex function of multiple parameters including fluid properties, production rate, water cut, gas-oil ratio, pressure and temperature. Separator design rules do exist with the goal of achieving complete separation, however the variability of input parameters, along with economic drivers to maximize throughput and minimize footprint often conspire to decrease realized separator effectiveness.

In practice, small, variable, and unknown amounts of gas are often entrained within in the liquid outflow from the separator during measurement. The entrained gases cause most liquid volumetric flow measurements to report the gas flow as liquid, resulting in an over-reporting of the liquid rate in direct proportion to the GVF within the meter. Errors due to entrained gases are compounded for separator-based measurements that involve a watercut measurement in addition to a flow measurement. Although entrained gases impact each watercut measurement principle differently, water cut meters tend to view the entrained gases as oil, resulting in additional over-reporting of net oil.