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Extended Abstract

Application of the Magnetic Resonance Multiphase Flowmeter to Challenging Process Conditions

Jankees Hogendoorn, KROHNE
André Boer, KROHNE
Mark van der Zande, KROHNE

1 INTRODUCTION

Multiphase applications in the upstream oil and gas industry are renowned for the wide range of process conditions that can be encountered. To be able to measure multiphase flowrates under these challenging process conditions, KROHNE has developed a multiphase flowmeter based on magnetic resonance. In the current poster, some examples of applications are given, and the results obtained with the magnetic resonance multiphase flowmeter are discussed.

Figure 1*: The magnetic resonance multiphase flowmeter (M-PHASE 5000).*

2 Magnetic Resonance Measurement Principle

Magnetic resonance is a physics principle well known from its application in medical imaging. Magnetic resonance makes use of a fundamental property of hydrogen atoms (its magnetic moment) and in effect makes it possible to 'count' hydrogen atoms. Since oil, gas and water all contain hydrogen atoms, multiphase flow in oil and gas production can be measured by using this magnetic resonance technology [1].

For this purpose the fluids are magnetised and subsequently excited by radio frequency pulses. The hydrogen atoms respond to the pulses and send back echoes which are recorded. The amplitude of the echoes and the rate at which they decay is used to calculate the flow rates of oil, gas and water. The difference in magnetic resonance properties allows for making a distinction between oil, water and gas (see [2] and [3] for a more detailed explanation of the magnetic resonance principle and its application to a multiphase flowmeter).

3 High water cut applications

During the life cycle of oil wells it is generally observed that the water cut increases over time. Various mechanisms can contribute to this phenomenon, for example water drive from an aquifer and secondary recovery by means of water flooding. As the water cut increases, the amount of produced net oil decreases and consequently the profitability of the well decreases. Especially when (costly) enhanced oil recovery methods are applied, it is evident that accurate knowledge of the amount of net oil produced is needed to determine whether a well is still economically viable.

In a well testing campaign in which a mobile version of the M-PHASE 5000 is applied, several wells producing at high water cut are measured. For wells producing at 95% water cut the accuracy in the measured water cut was better than 1% and for wells producing above 99% water cut the accuracy even improved to better than 0.3%. This increasing performance at high water cut is in line with the theoretical prediction based on the physics model as applied in the magnetic resonance flowmeter.

As described in [2] the contrast in longitudal relaxation time between oil and water is exploited by the magnetic resonance flowmeter to determine the water liquid ratio. The build-up of magnetization and consequently of magnetic resonance signal is different for oil and water. At high water cuts this difference becomes more pronounced leading to improved accuracy for higher water cuts.

4 Inversion of emulsions

A particular aspect of multiphase flowmeters in which metering experts are interested, is the behaviour of the multiphase flowmeter during phase inversion of emulsions. With increasing water cut, oil-water mixtures change from water-in-oil emulsion to oil-in-water emulsions. This change in morphology of the emulsion has a dramatic effect on the conductivity and permittivity of the mixture. The exact water cut at which the inversion occurs is hard to predict and depends on various parameters. Typically for low to medium viscosity oil the phase inversion occurs at a water cut between 20% to 40%. It is safe to state that for most oil wells during their lifetime, phase inversion will take place.

To demonstrate the performance of the magnetic resonance multiphase flowmeter during phase inversion, test matrices have been executed at independent multiphase flow facilities. For gas volume fractions ranging from less than 20% up to values higher than 50% the water liquid ratio was varied between 15% to 95%. Especially in the water liquid ratio range of 20% to 40% the water liquid ratio was changed up and down. To test the effect on the flowmeter the reading of the net oil was monitored. The accuracy of the net oil reading was not affected over the tested range of water liquid ratios.

The fact that the magnetic resonance multiphase flowmeter is unaffected by phase inversion is in line with the expected behaviour based on physics. The fluid properties that are used in the magnetic resonance measurement (relaxation time and hydrogen index) are related to molecular properties. The properties are not depending on the morphology of the mixture.

5 High viscosity oil

As the cost of production for heavy oils is higher than for conventional oil, the need for accurate multiphase flow measurements to optimize the well and reservoir management is even more apparent for these demanding applications. There are, however, quite some challenges in the measurement of multiphase flows of heavy oil. The challenges are related amongst others to the tendency to form emulsions and the complex composition of heavy oil. However, the magnetic resonance multiphase flowmeter has a full bore design and makes use of a fundamentally different measurement principle which measures at molecular level.

In the multiphase flow loop at KROHNE Research and Development lab, measurements have been performed to demonstrate the performance of the multiphase flowmeter for high viscosity oil [4]. For oil/water/gas mixtures with oil viscosity between 190 cSt and 2200 cSt, the WLR has been varied between 0% to 40% and the GVF has been varied between 23% and 90%. The accuracy achieved in the volumetric flowrate was better than 5% of the MV for the liquid flowrates, better than 10% of the MV for the gas flowrates and better than 1% absolute for the WLR; this demonstrates that magnetic resonance is indeed a suitable measurement principle to measure multiphase flow of high viscosity oil.

6 REFERENCES

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