Journal of ELECTRICAL ENGINEERING, VOL 63. NO 7s, 2012, 43-45

MULTIPHASE FRACTIONAL COMPONENT SENSOR

Vlastimil Masek* — Javier Ortiz**

Accurate measurements of multiphase flows is needed in many industries including the oil and gas sector. Generally in the oil industry multiphase flow is separated into different phases, and then each flow is measured individually by a single phase meter. Since the early 1980's many methods have been proposed to measure the phase fractions of oil, gas, and water in multiphase flows, however, most of these sensors have low accuracies and require frequency recalibration. This paper presents a novel electromagnetic composition sensor, including its theory of operation and experimental results, which in combination with another previously designed capacitive sensor, offers an alternative solution to the commercial systems that exist in the market.

Keywords: multiphase flow sensor, multiphase metering, hydrocyclone

1 INTRODUCTION

Multiphase flow measurement is a challenging task. The accurate measurements of the phase components of oil, water, and gas plays an important role in the oil and gas industry. An accurate measurement of the flow allows better management of oil fields and production allocation at the processing facility. Many different methods have been proposed since the 1980's, the traditional methods require test separators which are bulky and expensive [1]. Well testing through a test separator to determine phase rates is time consuming, which result in loses of revenue. Some of the sensors available today in the market have an accuracy of 2% to 5% [2]. These sensors usually need to be recalibrated periodically, which is often difficult and expensive. This paper presents the work in developing a new magnetic based sensor to measure the phase fraction of a multiphase flow.

2 THEORY OF OPERATION

The flow from an oil well is a multiphase flow, which is a very difficult phenomenon to understand and model. The electrical and magnetical properties of the multiphase flow depends on different factors including the ratio of phases, velocity of each phase, orientation and geometry of pipes, etc. In order to overcome this modelling problem two methods are used, fluid mixing and fluid stratifying. In the first method a homogeneous mixture is prepared before being measured, whereas in the second method the flow is stratified into phases before entering the sensor. Multiphase flow can be stratified using a hydrocyclone, a device which spins the flow and separates it by centrifugal force based on the differences in desities of the constituent flows. In this work a hydrocyclone shaped sensor is proposed which stratifies and measures the flow at the same time. A coil located on the exterior of the hydrocyclone surface is excited with an ac signal. The time varying associated magnetic field induces a current in the water phase. The induced currents in the water generate a magnetic field which opposes the primary magnetic field. As a result of the magnetic field interactions, an ac signal is induced in a secondary coil located inside of the sensor. The amplitude of this signal depends on the conductivity and the permeability of the phases, the physical dimensions of the coils, and the volumetric ratio of the individual phases. This paper tests the principles basic to the hydrocyclone measurement technique.

3 EXPERIMENTAL SETUP

In order to simulate an ideally separated flow into single phases at different component fraction, two different setups were made. The first setup consists of two 50cm long PVC pipes, one inside the other, and a thin funnel shape wall which separates the space between the two walls in two sections. The external portion of the cone was filled with water and the inner section with mineral oil. The excitation coil was on the outside of the external pipe whereas the detection coil was located inside the inner pipe, Fig. 1.

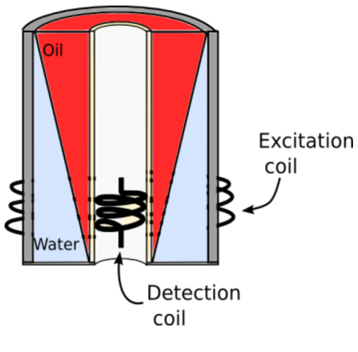

Fig. 1 Cross section of analyzed sensor

Both coils, the internal and the external, slide vertically along the pipes, keeping the same horizontal position respect to each other and keeping the distance between them constant at all the time. By increasing the elevation of the coils along the hydrocyclone shaped set-up, differ-

*Memorial University of Newfoundland, Faculty of Engineering and Applied Science, St John's, Newfounland, Canada, A1B 3X5, masek@mun.ca
**Memorial University of Newfoundland, Faculty of Engineering and Applied Science, St John's, Newfounland, Canada, A1B 3X5, jo5117@mun.ca

ISSN 1335-3632 © 2012 FEI STU

Fig. 2 Two concentric 10 cm long plastic pipes; the space between the pipes is filled with several low density plastic layers

ent water-oil ratios can be measured. The sensor response was then measured in the whole range of water-oil concentrations, ie from 0% Water (100% Oil) to 100% Water (0% Oil). The applied signal to the excitation coil had an amplitude of 1Vrms with a frequency of 500kHz. The signal was obtained from a function generator and the detected signal was sampled with a data acquisition card at 2 Msps.

A second setup was constructed in order to study the effect of the conductivity of the water phase as well as the volume. This setup consists of two concentric 10 cm long plastic pipes, in which the space between the two pipes was filled with a variable number of a low density plastic layers. Increasing the number of layers, effectively increased the outer diameter of the inner pipe, thereby decreasing the water layer volume. This allows for the effect of the water layer thickness on the induced signal to be studied (Fig. 2). Altering the salinity of the water by the addition of salt allows for the effect of water conductivity to be measured. The signals applied were generated from an AG1020 LF Generator and the currents were measured with a 2700 Keithley Multimeter/DAQ.

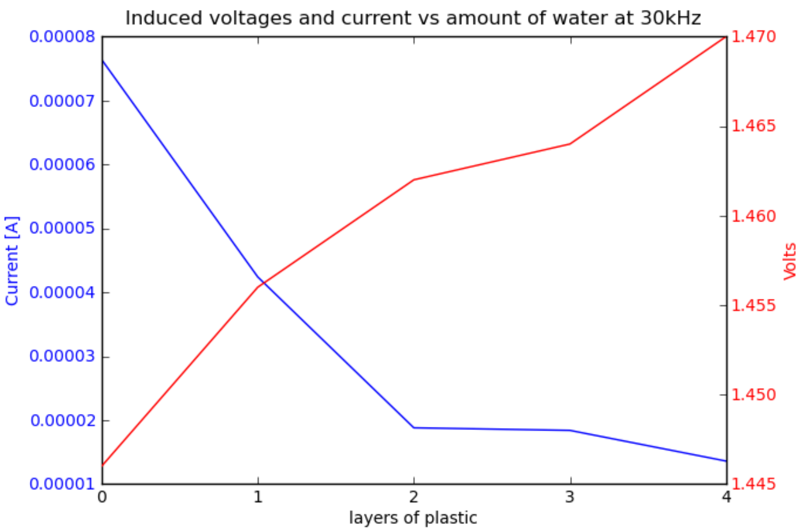

Fig. 4 Dependences of indeuced voltage and current on the amount of water at a frequency of 30 kHz

4 RESULTS

4.1 Hydrocyclone shaped setup

During the experiments performed with the first setup, frequencies in the range of 100 to 500 kHz were tested. The position of the excitation and detection coils were also switched, and several experiments were performed shielding the sensor, and also grounding the water phase. With respect to the position of the excitation coil, the best response was obtained when the excitation was on the outside and the detection coil was in the inside. With respect to grounding of the water phase, a better response is obtained when the water phase is not grounded. The tests were performed by using 100, 200, 300, 400 and 500 kHz. Based on the collected data, the better response was obtained by using a signal of 500 kHz. At this frequency, 500 kHz, with the water phase not grounded, a decreasing curve is obtained as shown in Fig. 3. A curve similar to this curve is expected when measuring water-oil ratios using a functioning hydrocyclone.

4.2 Water effects on induced signal

Experiments to determine the effect of water conductivity were inconclusive however, the experiments performed to determine the effect of water layer thickness were positive. Results have shown that when all of the space between the pipes is water filled, the measured currents reached a maximum value and the induced voltage is at the minimum. As the thickness of water layer decreases, the induced voltage in the inner coil increases. These results are in accordance with the results of the previous experiments which involved oil and water measurements.

5 CONCLUSIONS

The preliminary results from these experiments suggest that a magnetic method could be used in combination with a hydrocyclone to measure the volume fraction of oil and water in a multiphase flow.

Magnetic method with hydrocyclone could be used in combination with a capacitance method for greater measurement accuracy. One electrode could be in the inner core of the hydrocyclone and the second could be located on the outside wall. This combination could be used as an alternative to other methods currently being used for water-oil measurement, which are more complicated and expensive.

REFERENCES

[1] THORN, R. — JOHANSEN, G.A. — HAMMER, E.A.: Recent developments in three-phase flow measurement. Meas. Sci. Technol 8 (1997) 691-701

[2] ATKINSON, I. et al: A New Horizon in Multiphase Flow Measurement. Oilfield Review, Volume 16, Issue 4, 12/01/2004.

[3] MASEK, V.: Cyclonic Sensor For Multiphase Composition Measurement, US Provisional Patent, EFS ID: 6532540, Application Number: 61264765, 2009/11

[4] SCHLUMBERGER Ltd.: Fundamentals of Multiphase Metering. ISBN-13: 978-097885305-1, ISBN-10: 097885305-9.

Received 24 August 2012

Masek, Vlastimil (Dipl.Ing, MSc., PhD), Completed a Dipl. Ing. Degree in mechanical engineering at the University of West Bohemia in Czech Republick. In Japan, he completed a MSc. and a PhD degree in mechatronics with a focus on airborne ultrasonic sensors. At the present he is an assistant professor of electrical and computer engineering. His teaching activities cover areas of process control and instrumentation, such as signal conditioning, sensors, and automatic control. He is also actively involved in the Oil and Gas Development Group by teaching supervisory control and data acquisition, remote sensing, oil and gas process control, and electronic instrumentation.

Ortiz, **Javier** (Ing MIng) received a BEng degree in Electrical Engineering at the Engineering Faculty from the National Autonomous University of Mexico (UNAM), and a MIng in Telecommunications from the same University. Currently he is pursuing a PhD degree at the Memorial University of Newfoundland under the supervision of Dr. Masek.