ELECTROMAGNETIC WAVE SENSOR FOR MULTIPHASE FLOW MEASUREMENT IN THE OIL AND GAS INDUSTRY

C.S. Oon, A. Al-Shamma'a, S.R. Wylie, M. Ateeq, S.N. Kazi and A. Badarudin

1. INTRODUCTION

The product of an oil and gas reservoir consists of a mixture of oil, gas, and water. During the oil extraction, gas and water are produced as by-products as a natural phenomenon, which occurs in the petroleum field. In order to maximize the amount of oil that can be retrieved, water and gas are often injected at various locations into the well. Thus, monitoring and measuring the output of oil, gas and water mixture are crucial requirements. The information not only can be used to optimize both the operation and transportation management but to enhance the quality of production (Al-Hejeri et al., 2009).

Traditionally, the flow rates of well fluids have been measured by separating the phases and measuring the outputs of the separated fluids by conventional single-phase techniques. The disadvantages of this practice, for oil well control, are that it takes several hours to determine the flow rates for each well, while there may be more than 10 wells to be monitored in the oil fields. In addition, the oil-water-gas separators are expensive and maintenance-intensive (Wang et al., 1998). One alternative to replace the use of separators is the utilization of multiphase flow meters. Within the oil and gas industry, it is generally recognized that MPF (multiphase flow) meters could lead to great benefits in terms of reservoir management, layout of production facilities, well testing, production allocation and monitoring (Thorn et al., 1997). Figure 1 shows the offshore oil and gas production that involve several adjacent wells. The data captured during the production of these wells can help in estimating the performance of each individual well. The data gathered can be used as a reference in locating a production anomaly, such as a water or gas breakthrough in the actual well.

Over the past two decades, many researchers have developed different means of measuring rates of extraction multiphase flow meters (Thorn et al., 1997) involving the γ-ray (Roach and Watt, 1996) or microwave (Ashton et al., 1994) impedance techniques (Dykesteen et al., 1985), possibly by process tomography, which are inaccurate and expensive (Wang et al., 1998).

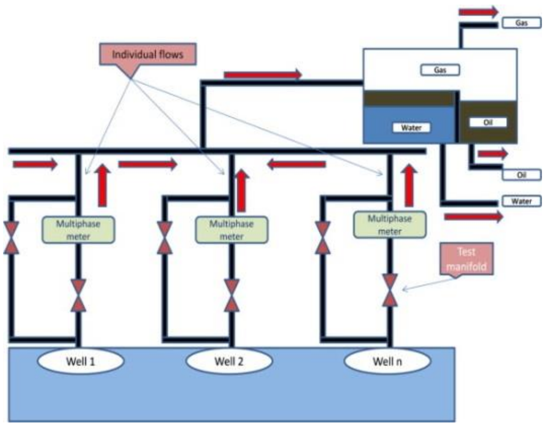

Figure 1. Application of Multiphase flow meters in multiple wells (Al-Kizwini et al., 2013).

2. METHODOLOGY

The multiphase flow sensor proposed in this research is based upon a cylindrical cavity and it uses the relationship between the resonant frequencies that occur and the permittivity of the fluid flowing through it. Due to its polarity, the permittivity of water (ε_r = 80, at 15 ^{o}C) is higher than the gas (ε_r = 1), so any small change in the water fraction produces a large frequency shift. The fundamental modes for cylindrical cavities are the TE_{111} and TM_{010} modes. TE Modes (Transverse Electric) have a magnetic component in the propagation direction and TM Modes (Transverse Magnetic) have an electric component in the propagation direction. Each mode will generate a resonant peak with a quality factor (Q), which is inversely proportional to the power dissipated in the cavity for each applied EM wave oscillation. A high Q indicates a sharp resonant peak that will be more readily analysed and improve the accuracy of the sensor. The resonant frequency for a TM_{nm1} mode in a cylindrical cavity can be calculated using equation (1).

C.S.Oon@2013.ljmu.ac.uk

$$f_{nml} = \frac{c}{2\pi\sqrt{\mu_r \varepsilon_r}}\left[\left(\frac{P_{nm}}{b}\right)^2 + \left(\frac{l\pi}{d}\right)^2\right]^{1/2} \quad (1)$$

For this research, the sensor has to be fitted to a pipeline, so the cavity must be open at both ends. By making the cavity diameter larger than the pipeline diameter, the pipeline can be made to appear continuous as shown in Figure 2. The outer cavity is filled with air and different percentage of water is flow inside the pipeline.

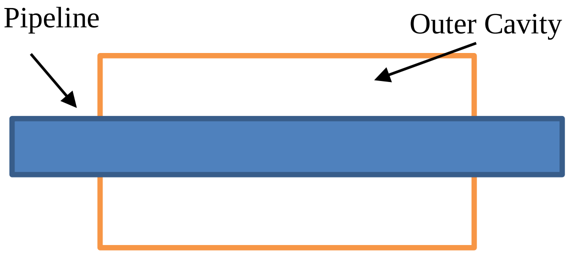

Figure 2. Pipeline cavity.

3. RESULTS

The experimental results obtained using resonant frequency of TM_{010} mode is plotted in figure 3. There is only one peak for each percentage of water, except for 0% of water which has two peaks.

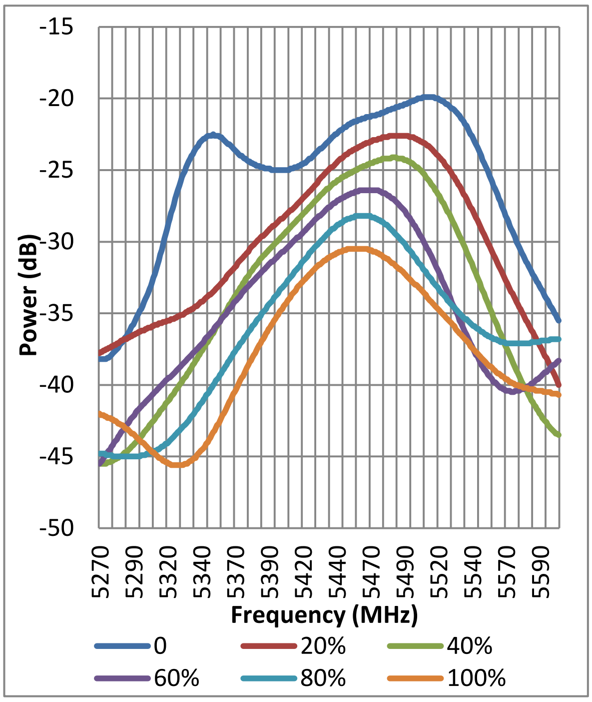

Figure 3. Experimental results from the cylindrical resonant cavity sensor for various fraction of water percentage.

4. CONCLUSION

A cylindrical resonant cavity has been designed to detect the changes in permittivity for multiphase flow measurement. The results show promise in detecting the percentages of water flow in the pipe.

5. REFERENCES

AL-HEJERI, S., WYLIE, S. R., SHAW, A. & AL-SHAMMA'A, A. I. 2009. Real Time EM waves monitoring system for oil industry three phase flow measurement. *Journal of Physics: Conference Series 178*.

AL-KIZWINI, M. A., WYLIE, S. R., AL-KHAFAJI, D. A. & AL-SHAMMA'A, A. I. 2013. The monitoring of the two phase flow-annular flow type regime using microwave sensor technique. *Measurement,* 46**,** 45-51.

ASHTON, S. L., CUTMORE, N. G., ROACH, G. J., WATT, J. S., ZASTAWNY, H. W. & MCEWAN, A. J. Development and trial of microwave techniques for measurement of multiphase flow of oil, water and gas. SPE Asia Pacific Oil and Gas Conference, 1994 Melbourne, Australia.

DYKESTEEN, E., HALLANGER, A., HAMMER, E., SAMNOY, E. & THORN, R. 1985. Non-intrusive three-component ratio measurement using an impedance sensor. *Journal of Physics E: Scientific Instruments,* 18**,** 540-544.

ROACH, G. J. & WATT, J. S. Current status of development of the CSIRO gamma-ray multiphase flow meter. 14th North Sea Flow Measurement Workshop, 1996 Peebles, Scotland. 1-11.

THORN, R., JOHANSEN, G. A. & HAMMER, E. A. 1997. Recent developments in three-phase flow measurement *Measurement Science and Technology,* 8**,** 691-701.

WANG, H., PRIESTMAN, G. H., BECK, S. B. M. & BOUCHER, R. F. 1998. A remote measuring flow meter for petroleum and other industrial applications. *Measurement Science and Technology,* 9**,** 779.

C.S.Oon@2013.ljmu.ac.uk