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

Syed F. A. Bukhari, Francesco Coletti, Carola S. König, Tassos G. Karayiannis

***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 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 multi-phase 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 systems 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 MPF 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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Charles Adam Uleh

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Multiphase Flow Metering Gioia Falcone,2011 **Plant Flow Measurement and Control Handbook** Swapan Basu,2018-08-22 Plant Flow Measurement and Control Handbook is a comprehensive reference source for practicing engineers in the field of instrumentation and controls It covers many practical topics such as installation maintenance and potential issues giving an overview of available techniques along with recommendations for application In addition it covers available flow sensors such as automation and control The author brings his 35 years of experience in working in instrumentation and control within the industry to this title with a focus on fluid flow measurement its importance in plant design and the appropriate control of processes The book provides a good balance between practical issues and theory and is fully supported with industry case studies and a high level of illustrations to assist learning It is unique in its coverage of multiphase flow solid flow process connection to the plant flow computation and control Readers will not only further understand design but they will also further comprehend integration tactics that can be applied to the plant through a step by step design process that goes from installation to operation Provides specification sheets engineering drawings calibration procedures and installation practices for each type of measurement Presents the correct flow meter that is suitable for a particular application Includes a selection table and step by step guide to help users make the best decision Cover examples and applications from engineering practice that will aid in understanding and application *Multiphase Production* Jean Falcimaigne,Sandrine Decarre,2008 Annotation This book presents the fundamentals of multiphase production with regard to flow simulations in multiphase pipelines multiphase pumping and multiphase metering It gives a large range of information on approaches and technologies which can be used today It is designed for engineers involved in field development but also for petroleum engineering students Multiphase Flow Metering Gioia Falcone,Geoffrey Hewitt,C. Alimonti,2009-11-16 Over the last two decades the development evaluation and use of MFM systems has been a major focus for the Oil Gas industry worldwide Since the early 1990 s when the first commercial meters started to appear there have been around 2 000 field applications of MFM for field allocation production optimisation and well testing So far many alternative metering systems have been developed but none of them can be referred to as generally applicable or universally accurate Both established and novel technologies suitable to measure the flow rates of gas oil and water in a three phase flow are reviewed and assessed within this book Those technologies already implemented in the various commercial meters are evaluated in terms of operational and economical advantages or shortcomings from an operator point of view The lessons learned about the practical reliability accuracy and use of the available technology is discussed The book suggests where the research to develop the next generation of MFM devices will be focused in order to meet the as yet unsolved problems The book provides a critical and independent review of the current status and future trends of MFM supported by the authors strong background on multiphase flow and by practical examples These are based on the authors direct experience on MFM gained

over many years of research in connection with both operators and service companies As there are currently no books on the subject of Multiphase Flow Metering for the Oil Gas industry this book will fill in the gap and provide a theoretical and practical reference for professionals academics and students Written by leading scholars and industry experts of international standing Includes strong coverage of the theoretical background yet also provides practical examples and current developments Provides practical reference for professionals students and academics **Handbook of Multiphase Flow Metering** Sidsel Corneliussen,2005 **An Investigation of Multiphase Flow Metering Techniques** Khamis H. Albusaidi,1997 **Intelligent Multiphase Flow Measurement** ,2009 The oil and gas industry s goal of developing high performing multiphase flow metering systems capable of reducing costs in the exploitation of marginal oil and gas reserves especially in remote environments cannot be over emphasised Development of a cost effective multiphase flow meter to determine the individual phase flow rates of oil water and gas was experimentally investigated by means of low cost simple and non intrusive commercially available sensors Features from absolute pressure differential pressure axial gamma densitometer conductivity and capacitance meters in combination with pattern recognition techniques were used to detect shifts in flow conditions such as flow structure pressure and salinity changes and measured multiphase flow parameters simultaneously without the need for preconditioning or prior knowledge of either phase The experiments were carried out at the National Engineering Laboratory NEL Multiphase facility Data was sampled at 250 Hz across a wide spectrum of flow conditions Fluids used were nitrogen gas oil Forties and Beryl crude oil D80 33o API gravity and water salinity levels of 50 and 100 g l MgSO4 The sensor spool piece was horizontally mounted on a 4 inch 102mm pipe and the database was obtained from two different locations on the flow loop The ability to learn from experience is a feature of neural networks The use of neural networks allows re calibration of the measuring system on line through a retraining process when new information becomes available Some benefits and capabilities of intelligent multiphase flow systems include Reduction in the physical size of installations Sensor fusion by merging the operating envelopes of different sensors employed provided even better results Monitoring of flow conditions not just flow rate but also composition of components Using conventional sensors within the system will present the industry with a much lower cost multiphase meter and A Study of Multiphase Flow Metering at Prevailing Condition of Pressure and Temperature Charles Adam Uleh,2013 *MULTIPHASE FLOW METERING USING A PRESSURE DROP BASED METERING DEVICE.* Chaitanya Nagabathula,2018 A dual pressure drop based flow measurement device DPDE was developed taking advantage of the compressibility of two phase flow By creating a pressure drop between two crimped pipe elements with restrictions a variation in density and volumetric flow rate was created This variation caused by flow expansion is used to predict mass flow rate and gas fraction of two phase flow An air water ethanol mixture was used and the device was tested for gas fractions ranging from 0 85% with mass flow rates varying from 30 100 kg h The predicted mass flow rate and density are compared to results obtained from a Coriolis meter and gas liquid feed

rates to the system Average errors of 5 kg h and 100 kg m3 were observed for mass flow rate and density respectively

Multiphase Flow Metering with High Gas Content Using Successive Venturi Devices J.A.P. Silva Filho,2000

State of the Art Multiphase Flow Metering ,2004 *Multiphase Flow* S. Hernández,P. Vorobieff,2020-06-03 The research included in this volume focuses on using synergies between experimental and computational techniques to gain a better understanding of all classes of multiphase and complex flow The included papers illustrate the close interaction between numerical modellers and researchers working to gradually resolve the many outstanding issues in our understanding of multiphase flow Recently multiphase fluid dynamics have generated a great deal of attention leading to many notable advances in experimental analytical and numerical studies Progress in numerical methods has permitted the solution of many practical problems helping to improve our understanding of the physics involved Multiphase flows are found in all areas of technology and the range of related problems of interest is vast including astrophysics biology geophysics atmospheric process and many areas of engineering **Temperature Effect in Multiphase Flow Meter Using Slotted Orifice Plate** Dohar Jono Sihombing,2015 Multiphase flow metering is one of the major focuses to develop in oil and gas industries A combination of slotted orifice plate and electrical impedance technique was investigated in order to provide further development of a new type of multiphase flow meter Flow visualization was conducted in this study to show the performance of the slotted orifice plate to homogenize the mixture flow and continued with the pattern flow discussion The visualization studied showed that the slotted orifice plate can be applied as a flow conditioner for two phase flow in the pipe in many patterns flow An existing pattern flow map based on the velocity of the each component in the mixture showed that the flow regime is a volumetric flow rate and gas volume fraction GVF dependant Temperature affected the measurement results based on the mixture conductivity behavior Using a combination of linearization technique and curve fit method the effect of the temperature to the measurement results can be eliminated for GVF range from 2 5% to 97 5% The slotted orifice characteristics were then investigated with using the calibration factor Euler number and Morrison number with respect to differential pressure and pressure of the mixture flow The electronic version of this dissertation is accessible from http hdl handle net 1969 1 155098 **Multiphase Flow in Oil and Gas Production Wells and Pipelines** Andrew Joseph,2015-05-14 This extensively research book assembles a tremendous amount of practical information on Multi phase flow in oil and gas production wells and pipelines The book summarizes those fundamental concepts with relevance to a broad spectrum of multiphase ows This book is organized as follows Chapter 2 gives an overview of multiphase flows looking at the flow regimes that are generally used trends in multiphase flow modelling Chapter 3 gives a detailed overview of the physical model of wellbore flow used The concept of drift flux is briefly discussed Methods used to the solve model equations numerically are discussed in Chapter 4 It is shown that the traditional central schemes are unable to capture properly the physics of the flow For the complex flow systems which include several non linear coupled differential equations a new

computation algorithm is proposed First a Jacobian splitting must be applied accounting for different directions of the propagation of information In Chapter 5 an assessment is performed of the impact of the chosen time integration scheme on results of data assimilation based on the extended Kalman filter approach and also discusses the use of the implicit Euler scheme Chapter 6 starts from analysis of the transient pressure signal generated in the wellbore due to inflow from the reservoir The possibilities of indirect multiphase flow metering are then discussed Finally the method which was limited to a rapid inflow scenario is extended in Chapter 7 to a gas coning control application in which the relevant quantities are estimated from multiple pressure measurements and single multiphase flow measurement at the outflow The performance of both techniques proposed is evaluated using a series of simulation based test cases and measurements generated by the OLGA simulator This book is targeted at final year students graduate students and researchers at the cutting edge of investigations into the fundamental nature of multiphase ows it is intended as a reference book for the basic methods used in the treatment of multiphase ows **Computational Methods in Multiphase Flow IV** A.A. Mammoli,C.A. Brebbia,2007-05-11 Fluid Dynamics is one of the most important topics of applied mathematics and physics Together with complex flows and turbulence multiphase flows remains one of the most challenging areas of computational mechanics and even seemingly simple problems remain unsolved to date Multiphase flows are found in all areas of technology at all length scales and flow regimes The fluids involved can be compressible or incompressible linear or nonlinear Because of the complexity of the problem it is often essential to utilize advanced computational and experimental methods to solve the complex equations that describe them Challenges in these simulations include nonlinear fluids treating drop breakup and coalescence characterizing phase structures and many others This volume brings together work presented at the Fourth International Conference on Computational and Experimental Methods in Multiphase and Complex Flows Featured topics include Suspensions Bubble and Drop Dynamics Flow in Porous Media Interfaces Turbulent Flow Injectors and Nozzles Particle Image Velocimetry Macroscale Constitutive Models Large Eddy Simulation Finite Volumes Interface Tracking Methods Biological Flows Environmental Multiphase Flow Phase Changes and Stochastic Modelling **Multiphase Transport of Hydrocarbons in Pipes** Juan J. Manzano-Ruiz,Jose G. Carballo,2024-03-26 Multiphase Transport of Hydrocarbons in Pipes An introduction to multiphase flows in the oil and gas industry The term multiphase flow refers to the concurrent flow of oil and or gas alongside other substances or materials such as production water chemical inhibitors and solids e g sand This is a critical topic in the oil and gas industry where the presence of multiple flow phases in pipelines affects deliverability generates serious complications in predicting flow performance for system design and operation and requires specific risk mitigation actions and continuous maintenance Chemical and Mechanical Engineers interested in working in this industry will benefit from understanding the basic theories and practices required to model and operate multiphase flows through pipelines wells and other components of the production system Multiphase Transport of

Hydrocarbons in Pipes meets this need with a comprehensive overview of five decades of research into multiphase flow Incorporating fundamental theories historic and cutting edge multiphase flow models and concrete examples of current and future applications This book provides a sound technical background for prospective or working engineers in need of understanding this crucial area of industry Readers will also find Fundamental principles supporting commercial software Detailed tools for estimating multiphase flow rates through flowlines wells and more Integration of conservation principles with thermodynamic and transport properties Coverage of legacy and modern simulation models This book is ideal for flow assurance engineers facilities engineers oil and gas production engineers and process engineers as well as chemical and mechanical engineering students looking to work in any of these roles **Multiphase Flow Measurement and Metering "Electric-Probes Two-Phase Measurement System Development (Slug Flow)"** Salah AlMuhaish,2019 **Ultrasonic Rate Measurement of Multiphase Flow** ,1993 On of the most important tools in production logging and well testing is the downhole flowmeter Unfortunately existing tools are inaccurate outside of an idealized single phase flow regime Spinner tools are inaccurate at extremely high or low flow rates and when the flow rate is variable Radioactive tracer tools have similar inaccuracies and are extremely sensitive to the flow regime Both tools completely fail in the presence of multiphase flow whether gas oil gas water or fluid solid Downhole flowmetering is important for locating producing zones and thief zones and monitoring production and injection rates The effects of stimulation can also be determined This goal of this project is the investigation of accurate downhole flowmetering techniques for all single phase flow regimes and multiphase flows The measurement method investigated in this report is the use of ultrasound There are two ways to use ultrasound for fluid velocity measurement The first method examined in Chapter 2 is the contrapropagation or transit time method which compares travel times with and against fluid flow Chapter 3 details the second method which measures the Doppler frequency shift of a reflected sound wave in the moving fluid Both of these technologies need to be incorporated in order to build a true multiphase flowmeter Chapter 4 describes the proposed downhole multiphase flowmeter It has many advantages besides the ones previously mentioned and is in full in that chapter **Gamma Radiation Methods for Clamp-on Multiphase Flow Metering** S. Blaney,2008 The development of a cost effective multiphase flow meter to determine the individualphase flow rates of oil water and gas was investigated through the exploitation of asingle clamp on gamma densitometer and signal processing techniques A fast sampling 250 Hz gamma densitometer was installed at the top of the 10 5 m high 108 2 mminternal diameter stainless steel catenary riser in the Cranfield University multiphaseflow test facility Gamma radiation attenuation data was collected for two photonenergy ranges of the caesium 137 radioisotope based densitometer for a range of air water and oil flow mixtures spanning the facility s delivery range Signal analysis of the gamma densitometer data revealed the presence of quasi periodicwaveforms in the time varying multiphase flow densities and discriminatorycorrelations between statistical features of the gamma count data and key multiphaseflow parameters The

development of a mechanistic approach to infer the multiphase flow rates from thegamma attenuation information was investigated A model for the determination of theindividual phase flow rates was proposed based on the gamma attenuation levels whilequasi periodic waveforms identified in the multiphase fluid density were observed toexhibit a strong correlation with the gas and liquid superficial phase velocity parametersat fixed water cuts Analysis of the use of pattern recognition techniques to correlate the gammadensitometer data with the individual phase superficial velocities and the water cut wasundertaken Two neural network models were developed for comparison a singlemultilayer perceptron and a multilayer hierarchical flow regime dependent model Thepattern recognition systems were trained to map the temporal fluctuations in themultiphase mixture density with the individual phase flow rates using statistical featuresextracted from the gamma count signals as their inputs Initial results yielded individualphase flow rate predictions to within 10% based on flow regime specific correlations *Multiphase Flow Measurement Based on Conventional Flowmeters Using Signal Analysis* Mongkol Pusayatanont,University of Sussex,University of Sussex. School of Engineering and Information Technology,2002

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