Publishable Summary for 16ENG07 MultiFlowMet II
Multiphase flow reference metrology

Overview

Europe, and the world, will be dependent for many decades to come on the production of oil and gas for its underpinning energy needs. Multiphase flow measurement is a fundamental enabling metrology in subsea oil and gas production. However, field measurements exhibit high measurement uncertainty, costing industry billions of euros in financial exposure and production inefficiencies. To improve this situation requires a reference measurement capability that is consistent and comparable across different test laboratories that offer this service. This project will address this need by establishing harmonisation of measurements between multiphase flow reference laboratories.

Need

Over half of the world’s energy demand is satisfied from oil and gas. The world economic value of oil and gas production is vast – around $3,000bn p.a. for oil (2014) and $1,000bn p.a. for gas (2013). When fluid is extracted from a well it typically comprises time-varying ratios of oil, water and gas. Multiphase flow measurement, where each component is individually metered, is a key enabling metrology that is vital for operational decision-making as well a prerequisite for allocation and fiscal measurement. However, currently field-based multiphase flow measurement is subject to high levels of uncertainty (up to c. 20 %, greater in some conditions), which has serious ongoing financial implications in all these areas of application. The lack of standardised facilities (and procedures) for testing multiphase flow meters (MPFMs) leads to variances in test results between laboratories which erodes confidence in the measurement system, and hence confidence in the meters themselves. Which in turn leads to a need for harmonisation of multiphase flow measurement methods and data.

The preceding EMRP project ENG58 MultiFlowMet developed and piloted an approach for such harmonisation. However, this approach now needs trialling and applying across an enlarged network of laboratories and a wider range of different multiphase meter types, which the current project will address. To achieve harmonisation, existing measurement comparability first has to be quantified through an extended intercomparison testing programme, which the current project will conduct involving seven multiphase laboratories. This, in turn, requires the design and provision of a mobile suite of instrumentation that can be moved around different laboratories in order to enable comparison measurements to be taken. To understand any variances in the laboratory datasets this project will gain an understanding of the factors that influence the measurements, such as the geometrical features of each laboratory and the structure of the flow that develops in each set of flow conditions. Finally, this project will apply these findings to the intercomparison data, to see what insights can be developed in order to provide the maximum possible level of harmonisation between laboratories.

Objectives

1. To optimise, and fully prepare for, the intercomparison testing programme by building a transfer package) whilst taking into account leading-edge methods of flow pattern visualisation and producing a comprehensive set of test matrices and protocols.

2. To carry out intercomparison testing across a network of laboratories with appropriate facilities in order to significantly extend the test envelope, in terms of flow rates (up to 120 m^3/hr for liquid and 1000 m^3/hr for gas), pressure (8 bar to 24 bar), and fluid properties (oil viscosity including the range of 3 cSt to 9 cSt). The intercomparison testing will include appropriate leading-edge methods of flow pattern visualisation and will be done across meters incorporating a range of technologies (e.g. Venturi, cross-correlation, gamma ray absorption, electrical impedance sensing, Coriolis and phase separation technologies).

3. To further develop modelling (e.g. computational fluid dynamics (CFD) techniques for significantly improving the metrological characterisation of multiphase flows, using small and full-scale experimental testing. Improvements will come from new data that will allow flow regime map(s) to be extended and/or new one(s) created. This will include additional research to understand geometrical influences and the influence of gas phase activity.
4. To make statistical cross-comparisons between the measurements undertaken in each intercomparison laboratory with a view to establishing comparability of measurement between test laboratories. The analysis will compare findings, identify anomalies, deduce their method of investigation and state the resolutions achieved.

Progress beyond the state of the art

Reference infrastructure (Objectives 1, 2 and 4)

In the preceding EMRP project ENG58, a small reference network (of three laboratories) was established based on a single multiphase metering technology. This project will expand the reference network itself and incorporate a wider range of industrially-relevant flow conditions that are proven across a more representative range of field- deployed MPFM technologies.

Flow Pattern Visualisation by Tomography (Objectives 1 and 2)

In the preceding project ENG58, an experimental, multiphase visualisation and characterisation platform was developed with realistic and necessary spatial and temporal resolutions for multiphase flow metrology. This project will migrate software implementations of the appropriate advancements from an offline to an online (real-time) platform. Also, in this project the tomography platform will be deployed for the first time ever in live intercomparison testing, which will greatly enhance the experimental capability.

CFD Modelling (Objective 3)

Multiphase flow modelling using CFD is extremely challenging. In the preceding project ENG58, key advancements in techniques were made and a number of insightful simulations performed in both OpenFOAM and ANSYS Fluent software. Further advancements will be made in this project, by defining and applying more exact inflow (boundary) conditions, which have a big influence on the resulting flow pattern.

Data analysis & conclusions (Objective 4)

The proven methods from the preceding project ENG58 will be adapted and extended to cope with the much greater number of test laboratory variants and metering technologies. The analysis in this project will draw upon the theoretical background of multiphase flow in terms of dimensionless numbers.

Results

Objective 1 – Preparation for the intercomparison testing programme

Results anticipated are:

- Specification and provision of the transfer package. This will consist of common instrumentation and other physical elements that will be deployed alongside each MPFM in turn. The transfer package will include flow pattern observation and visualisation technology.
- Test matrix and protocols. A test matrix defining the test points, in terms of laboratory flow conditions, for optimally selected permutations of test laboratories and MPFMs will be developed. An agreed set of intercomparison testing protocols (methods) will also be agreed as well as a logistics plan.
- Logistics plan. This will include testing schedules, shipping details, detailing of customs requirements by country and definition of special licensing and/or certification requirements and the means of obtaining them.

Objective 2 – Execution of the intercomparison testing programme across the laboratories

Results anticipated are:

- Test laboratory data. Component flow rates will be measured for each test matrix point from each test laboratory in turn. Reference meter outputs, pressure and temperature will also be measured.
- MPFM data. Component flow rates and appropriate raw data outputs e.g. differential pressure will be measured for each of the MPFMs.
- Two sets of data (laboratory reference meters + MPFMs) from the NEL facility will be taken under identical conditions, at the start and end of the test programme, to rule-out (or detect) drift in any of the instrumentation.
- Flow pattern experimental evidence - tomography and viewing section video footage. This data will require subsequent analysis before yielding numerical or other results e.g. flow pattern categorisation.

Objective 3 - Further development of modelling techniques

Results anticipated are:

- Inter-laboratory analysis. An analysis of the inter-laboratory differences will be carried out, including the geometrical variances, as a focus for the modelling work.
- Small-scale modelling. Results from small-scale experimental modelling will be conducted to better quantify the key inter-laboratory influences, such as those above.
- CFD simulations. A number of CFD simulations will be produced that can be validated against small-scale and full-scale experimental data and, thereby, support data rationalisation in the intercomparison test programme.
- Full scale experimental research. Using the NEL and DNV GL facilities further experimental research at full scale will be carried out, to both assist with intercomparison data rationalisation directly as well as provide appropriate verification data for CFD modelling.

Objective 4 - Cross-comparisons between measurements undertaken in each laboratory

Results anticipated are:

- Intercomparison analysis. A full analysis of intercomparison will be undertaken, to compare findings, identify anomalies, deduce their method of investigation and the resolutions achieved.
- Intercomparison conclusions. A set of conclusions will be produced, summarising where good measurement agreement has been obtained between laboratories across a range of MPFM technologies.
- Intercomparison comparison. A case-by-case summary will be written covering any areas where good measurement agreement is not obtained, detailing the analysis carried out to rationalise any measurement variances together with the results.

Impact

Impact on industrial and other user communities

The results of this project will impact the oil and gas community that is becoming increasing reliant on multiphase metrology as part of subsea engineering allowing lower-cost exploitation of new fields. It will do so by creating an enlarged, comparable network of multiphase flow measurement reference facilities. This will provide oil and gas operators (the instrumentation end-users) and instrumentation developers with a renewed confidence in the testing and reference measurement infrastructure. In turn, this will lead to lower uncertainty of measurement and greater confidence in the deployment of multiphase metering technology.

Increased confidence and lower uncertainties of measurement associated with multiphase metering reduces both financial exposure and risk, as well as enabling better operational efficiency. This occurs at two levels;

- Operational decision-making – multiphase flow measurement data are key to deciding if (at the assessment stage), when and how a particular field will be exploited, balancing capital investment against revenue potential at set-up, then optimising conditions when the well is in production.

- Allocation (and fiscal) exposure – arising from uncertainty regarding how much of each operators production is being commingled into common networked flowlines. There is also significant financial exposure related to uncertainty of measurement for the application of taxation

- Further to this, the project will produce a case study for demonstrating to end users how the outputs of the project could be used, to reduce uncertainty and increase end-user confidence in the metering technology being evaluated. The partners will work with the end user advisory group to develop a case-study that is realistic, to maximise impact. The case study will then be advertised through the end user advisory group and on the project website.

Impact on the metrology and scientific communities

A key benefit for the European flow metrology community is that it is the first step in establishing a long-term Key Comparisons programme for NMIs and other commercial and non-commercial laboratories. Key elements will be harmonised uncertainty budgets, intercomparisons, auditing and accreditation, as has existed for single phase flow metrology activity for some decades. For multiphase flow metrology, the preceding EMRP project ENG58 has already made significant progress in the former two and this project will build on these as well as producing three Good Practice guides for practitioners from end-user groups. The Good Practice guides will be on 1) Good Practice guide on general preparation and approach to multiphase intercomparison testing, 2) Good Practice guide on the acquisition of experimental data for the determination of multiphase flow patterns and 3) Good Practice guide for minimising uncertainty of laboratory flow reference measurement. The Good Practice guides will be published on the project webpage and will also be disseminated to the metrology community and end users through the end- user advisory group and project partners.

Impact on relevant standards

- There exists an extremely timely and unique opportunity for this project to influence standardisation in a major way, as ISO TC/28 (Petroleum products) has begun work on a new ISO standard on Multiphase Flow Measurement. The project team will meet on a regular basis with the drafting committee to both influence, and be influenced by the new standard as it develops. Other standards committees through whom the project outputs may also be exploited include ISO TC/30 (Flow measurement in Close Conduits), ISO TC/193 (Natural gas), the Energy Institute's Hydrocarbon Management Committee, EURAMET TC Flow and the American Petroleum Institute Manual of Petroleum Measurement Standards (API MPMS) Chapter 20.3 - Measurement of Multiphase Flow.

Project start date and duration:	01 June 2017, 36 months	
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