Title: Flow metrology for industrial process control

Abstract

European industry requires correct, reliable and traceable measurements of the flowrate of liquids and gases in nearly all fields of manufacturing and trade. Process conditions and product properties vary over wide ranges, which can significantly reduce measurement confidence. Better systems are needed to support reliable and efficient process engineering and control for sustainable quality assurance of products and cost reduction. Modelling and characterisation would support data collection and processing for real industrial conditions, especially where processes produce 'difficult' flow profiles or operate in challenging external environments that make measurements difficult. Further support for industrial processes is needed in the area of transfer standards and techniques for monitoring and testing/calibrating flow sensors, ideally by using non-invasive techniques including meter diagnostics.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008, section on "*Metrology R&D for applied and fundamental metrology"* related to *Industry* on pages 12 and pages 37 and 42.

Keywords

Flowrate measurement, traceability, transfer standards, fluid properties, dynamic influences, process control, industrial field conditions, uncertainties, dynamic modelling, simulation, velocity profile measurement, flowmeter calibration, diagnostics, condition based monitoring.

Background to the Metrological Challenges

Correct fluid flow measurements are of importance for the majority of branches of industry: They define the quality of products and production processes in chemical, petrochemical, pharmaceutical, paper, food, aerospace and automotive industries as well as in energy and environment businesses. They are also necessary for economical and safe process operation, and they play an important role in consumer and health protection. Last, but not least, they have a direct application in the manufacturing of high-quality flow measuring devices. A market analysis provided by Frost & Sullivan shows an annual sales volume of flow measuring devices (excluding utility meters for legal metrology) of more than $1\text{x}10^9$ € in Western Europe alone.

The required uncertainties for these flow rate measurements lie between 0.2 % and 1.5 % for legal applications [1] and reducing to 0.1 % and better for some applications in process engineering and control, however, the current measuring practice is far away from fulfilling these requirements. The international flow measurement community agrees that likely measurement errors in the field are around a number of percent, and under extreme conditions the errors can amount to 10 % and more. Additionally, EN ISO 9001, Chapter 7.6 "Control of monitoring and measuring equipment" [2] prescribes the calibration or verification of the measuring equipment against measurement standards traceable to international or national measurement standards for all cases where valid results are needed, a requirement which is not fulfilled at present.

The measurement of flow is a dynamic process that strongly depends on the conditions under which the measurements are made. Any variation of the process parameters, fluid properties or ambient conditions leads to changes in the interaction of the flow sensor with the flowing fluid and may result in considerable measurement errors. In principal each flow sensor should be individually calibrated under its specific conditions of use, but as a rule calibrations are currently carried out in laboratories under ideal and well known conditions. Methods or devices for metrological monitoring or even testing of the sensor's behaviour under the real, diversified conditions of use do not exist. Therefore the compliance with requirements concerning accuracy and safety-relevant aspects cannot be proved for most of the flow measurements under current industrial conditions. In particular, improvements in technical or process performance are often not accessible for a quantitative evaluation.

The positioning of flow meters in industrial production installations sometimes leads to a distorted velocity profile of the flow inside the meter. In large pipe diameters flow meters sensitive to the velocity profile are used (electromagnetic or ultrasonic meters), and in these cases velocity profile measurement are needed to increase the accuracy e.g. the verification of calibration test rigs where the flow-conditions should be well defined according to a standard. Other situations in industry which require velocity profile determination, or at least methods of flow-rate measurement which are not sensitive to velocity profile, are installations of flow-meters downstream from disturbing elements like elbows, valves, etc. In some cases the problem cannot be avoided by installation of straight pipes of appropriate length in front of the meter and this results in the meters being calibrated under different flow conditions from the conditions of installation, therefore reducing the reliability of the measurement results.

To avoid the problems regarding the additional influence of different fluid properties, some European NMIs have established their own primary flow facilities for selected fluids for which they can realise autonomous traceability chains. This approach however enables only point solutions and is highly cost-intensive. A harmonisation of the different traceability chains and the unification of the measurements in the field, however, cannot be achieved in this way – neither nationally nor internationally.

Still worse is the situation concerning the dynamic effects in flow measurements. Up to now the quality of a flow rate facility is mainly defined by its ability to keep all relevant parameters constant – flow rate, temperature and pressure as well as density and viscosity of the fluid, and if possible the ambient conditions. Uncertainties better than one percent or even of some hundredths of percent are related exclusively to such static, invariant cases. The very first steps have been taken to realise defined dynamic process conditions and to investigate their influence on several flow measuring techniques, however suitable results are not available yet.

Modern flow meters can now record and store a vast amount of flow measurement related data, and alongside the improved data acquisition techniques, signal processing abilities have greatly improved. This has allowed the detailed monitoring of all the recorded data to be used as diagnostic tools to identify any problems within the meter and to complete a 'health-check' of the meter in operation. This is of great interest to industry worldwide, as detailed knowledge of how meters are operating would give confidence in the interpretations of how their industrial processes are running. Careful monitoring and understanding of the trends of these diagnostic parameters can lead to detailed knowledge of how the meters operate over long periods of time. There is a view that if this data could be used to prove that the meters have remained stable since calibration, that calibration intervals could be extended or even in some cases that further calibration is unnecessary.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them, in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP protocol.

Proposals responding to this SRT will aim at the development of new and more accurate methods and instrumentation for the quantity and flow rate of liquid and gaseous fluids measurement over a wide range of industrial applications, covering:

- process parameters (flowrate, velocity profile, temperature, pressure, pipe diameter),
- fluid properties (viscosity, density, temperature, pressure, composition),
- operating regimes (constant flowrates, alternating or intermittent flows, start and stop processes, batch processing, fluid injection and mixing, emergency shutdown)
- ambient parameters (humidity, temperature, pressure, wind, vibration, shock, explosive atmosphere, electromagnetic field).

The specific objectives are:

1. Modelling and characterisation of the influences and mutual dependencies of the real industrial conditions
2. Development of transfer standards and methods independent or nearly independent of the industrial conditions
3. Development of techniques for monitoring and testing/calibrating the flow sensors in the application field preferably by contactless, non-intrusive techniques including internal flow meter diagnostics,
4. Uncertainty evaluations under the conditions of real industrial applications

Proposers shall give priority to work that meets documented industrial needs and that which supports transfer into industry e.g. by cooperation and/or by standardisation.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project. In your JRP submission please detail the impact that your proposed JRP will have on any Directives:

You should also detail other Impacts of your proposed JRP as detailed in the document “Guidance for writing a JRP”

You should detail how your JRP results are going to:

- feed into the development of urgent standards through appropriate standards bodies
- transfer knowledge to the chemical, pharmaceutical, process engineering & production, food, automotive, aerospace, energy and water supply industrial sectors.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] OIML R 117: 2007 “Dynamic measuring systems for liquids other than water”

[2] EN ISO 9001: 2008 “Quality management systems – Requirements”

[3] Magdalena Reichel: Ungebrochener Trend zur Automatisierung in Pharma, Food and Kosmetik. Pharma+Food, 02/2010

[4] International Food Standard IFS, Version 5.0 of August 01, 2007