Title: Sustainable advanced flow meter calibration for transport sector

Abstract

Emissions reduction in the transport sector will contribute to mitigating climate change. Recent measures to meet this objective have focused on alternative fuels, improvements in engine testing and setting up tight emission standards. However, advances also need to be made in flow metrology as these new measures directly depend on the quality of these measurements for determining engine efficiency through fuel consumption and emissions measurements. Therefore, harmonised flow measurement methods should be developed, which consider alternative fuels, actual operational conditions and the most recent test cycles, for the assessment of fuel flow meters deployed in close-to-engine applications. Sustainable advanced flow meter calibrations should enable end users to improve the accuracy of their engine efficiency and emissions measurements.

Keywords

Alternative fuels, automotive transport, consumption measurements, conventional fuels, dynamic calibration, flow meters, flow metrology, maritime transport

Background to the Metrological Challenges

The mitigation of climate change requires emissions reduction in the ever-expanding transport sector. Short-range transport in urban areas is being successfully electrified and hybridised. However, this is difficult to realise for mid- and long-range automotive and maritime freight transport. In the long-term alternative powertrains and future proof route infrastructures are required. However, short- and medium-term solutions are required today in order to meet current regulations and standards. The total measurement uncertainty needs to be extended from the calibration of a single flow meter to an all-encompassing fuel consumption measuring system. For test cycle measurements, a dynamic calibration procedure needs to be developed which includes the determination of a measurement error for accumulated consumption measurements. In addition, the measuring dynamics for this need to be provided up to 100 Hz in order to obtain a qualitative comparison, of the reference value from the engine control unit, with the value of the measured consumption.

The fuel efficiency of car and truck engines is currently determined using procedures which depend on the amount of fuel supplied. In heavy duty vehicles, for example, the fuel supply is regulated by the duration and pressure of the injection, rather than by actual operational fuel consumption. In addition, on engine test benches the fuel flow rate is measure using devices that have only been calibrated with one liquid (water, cold cleaner) under static flow and ambient conditions. This does not correspond with real use conditions. The measuring systems used in test cycles have a T90 time of approx. 60 ms and are therefore suitable for the qualitative representation of such processes. The integrated displacement flow meter delivers pulses proportional to speed down to "zero". However, calibration ends at 0.2 l/h in the lower measuring range. Therefore, there is a risk of incorrect measurements in each thrust phase. The accumulated error is not yet known for the consumption measuring instruments that deliver the flow rate "zero" from a defined value below the calibration range. Therefore, a metrological infrastructure for evaluating the accuracy of the flow meters and other systems, which are used to measure the consumption of fuels (e.g. water, hydrocarbons, and alternative fuels), under the New European Driving Cycle, the Worldwide harmonised Light vehicles Test Cycle, or the World Harmonised Transient Cycle, is required.

There is a binding monitoring, reporting and verification system for CO_2 emissions testing in the maritime sector. The owners of ships that exceed the limits face severe penalties. Emission control is performed by calculating emissions using models which rely on the fuel’s chemical composition and on the amount of fuel consumed. The fuel flow meters used to determine the amount of fuel consumed are currently only calibrated under static conditions and consumption measurements are carried out in two ways: 1) measurement of fuel consumption between the inlet and outlet circuits with a single fuel flow meter; or 2) measurement of fuel consumption with one fuel flow meter on the engine inlet and a second fuel flow meter on the engine return line. This results in an estimated uncertainty of > 10 % of fuel consumption which is an avoidable cost increase. In addition, appropriate calibrations for the measuring range from 200 kg/h to 8000 kg/h are missing and there are no estimates of the influence of fuel type, and operational conditions, on the measurement accuracy of fuel flow meters. Consequently, imprecise consumption measurements lead directly to the inaccurate determination of emissions. Therefore, a metrological infrastructure and procedures to evaluate the accuracy of flow meters, with the potential for measuring the consumption of alternative fuels under close to real world conditions, is required. Measurements of dynamic flow and *en route* fuel consumption, with uncertainties, are also needed. These developments will enable ship owners to comply with emissions legislation, which is becoming ever stricter, and it will aid compliance in Emission Control Areas.

Efforts are being made to replace conventional fuels with cleaner-burning alternatives such as bio-diesel, bio-alcohol and synthetic fuels in order to reduce harmful emissions. However, the fuels' transport properties, under different operating conditions, and the potential effects of this on the measurement performance of flow meters, are unknown. This issue is compounded by the fact that flow meters are usually calibrated with one liquid e.g. water or cold cleaner. In addition, close to real world consumption measurements, including *in situ* measurements of density and viscosity, need to be performed. Measurement facilities also need to be developed for performing consumption measurements using flow meters that accurately capture zero flows and dynamic loads. Therefore, a fluid property matrix needs to be prepared for the transport properties of alternative fuels in order to be able to transfer calibrations between fuels and to extrapolate to higher temperatures and pressures. Meters also need to be developed for traceably measuring density and viscosity *in situ*.

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 protocol.

The JRP shall focus on the traceable measurement and characterisation of flow meters for use in the transport sector.

The specific objectives are

1. To develop the infrastructure required for evaluating the accuracy of the flow sensors and other systems, which are used in cars and trucks to measure the consumption of fuel, under the New European Driving Cycle, the Worldwide harmonised Light vehicles Test Cycle, or the World Harmonised Transient Cycle. Test liquids should include e.g. water, hydrocarbons, and alternative fuels, with densities > 400 kg/m³, viscosities > 0.01 mPa·s, pressures ≤ 300 bar, and flow rates 0.0001 m³/h - 8 m³/h.
2. To develop the infrastructure and procedures required for evaluating the accuracy of flow sensors, which have potential for measuring the consumption of alternative fuels in the maritime sector, under close to real world conditions. The selected alternative fuels should have the same range of densities, viscosities, pressures and flow rates as specified in objective 1. This objective should include measurements of dynamic flow and *en route* fuel consumption, with uncertainties.
3. To prepare a fluid property matrix of the transport properties of alternative fuels e.g. bio-diesel, bio-alcohol and synthetic fuels. This should enable the transfer of calibrations between fuels and extrapolation to higher temperatures and pressures. The selected fuels should have densities > 400 kg/m³, viscosities > 0.01 mPa·s, temperatures ≤ 620 K, pressures ≤ 300 bar and flow rates ≤ 2 m³/h. Sensors should also be developed for traceably measuring density and viscosity *in situ*.
4. To provide metrological input, and pre-normative research, for the further development of international standards with a focus on close to real-world flow calibrations in the transport sector. In addition, to contribute to the development of a pan-European harmonised framework, which will enable the emission targets set by the International Maritime Organization, the European Conference of Ministers of Transport and the Fédération Internationale de l'Automobile to be met and controlled.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrumentation manufacturers), standards developing organisations (IMO, ISO) and end users (transport sector).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP project ENG09 Biofuels and the EMPIR project 17IND13 Metrowamet and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the transport sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.