EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT-i20**
Version: 1.0

Title: Development of measurement and calibration techniques for dynamic pressures and temperatures

Abstract

Dynamic pressure and temperature sensors are widely used for measurements in harsh conditions, such as inside internal combustion engines, or nuclear power plants. However, the reliability of the measurement results produced by these sensors cannot currently be ensured in dynamically changing conditions, especially if they are calibrated using static techniques. Therefore, traceable measurement and calibration techniques are urgently needed for the dynamic characterisation of pressure and temperature sensors. Such advances could lead to the development of a new generation of dynamic pressure sensors with novel applications, such as in-cylinder pressure sensors which could be used to reduce engine emissions and fuel consumption.

Keywords

Dynamic pressure, dynamic temperature, signal frequency, calibration, traceability, dynamic pressure sensor, dynamic temperature sensor, industry

Background to the Metrological Challenges

Dynamic measurements of pressure and temperature are widely performed as part of manufacturing, product testing, process control, and hence the accuracy and reliability of these measurements has a direct impact on both product quality and/or price competitiveness through energy and material efficiency. However the challenge with such industrial measurements is that they need to be performed under highly dynamic conditions where the pressure is constantly changing.

The development of primary dynamic measurement standards is ongoing: currently shock tubes are available in the pressure range up to 7 MPa and drop weight systems are available in the pressure range 20 MPa – 300 MPa. However, the gap between these measurement ranges is significant and traceability for the primary standards has not been established through intercomparison.

In terms of their calibration, dynamic pressure sensors are currently calibrated against static pressure measurement standards. However, as the dynamic and static pressure characteristics of sensors may differ significantly, this calibration procedure can result in errors. Therefore, in order to improve the accuracy of dynamic pressure measurements, dynamic pressure sensors need to be calibrated under conditions that better resemble their actual use and hence traceable primary dynamic pressure standards and validated calibration procedures up to 400 MPa are needed.

Reliable dynamic temperature measurements are required in many demanding industrial applications, such as inside internal combustion engines where temperature changes of up to 2000 °C (combustion gas), are possible. The dynamic calibration of temperature sensors can be performed by measuring the response time in plunge tests into flowing fluid. Additionally, temperature sensors can be characterised, in situ, by the ‘Loop Current Step Response” technique, by the self-heating index or by noise analysis techniques. However, in real conditions the time constants of temperature sensors are rather high (sometimes up to minutes) and the low immersion of the sensors can produce huge differences from the calibration conditions. Therefore, reliable methods and calibration benches for measuring dynamic temperature changes up to 3000 °C need to be developed.

In addition to this industrial end-users need to be able to characterise the behaviour of dynamic pressure sensors under conditions where the dynamic pressure and temperature change simultaneously. Dynamic pressure sensors are currently calibrated at room temperature using a pressure balance as a reference and a quick-opening valve for introducing a pressure step. However, in actual measurement applications the temperatures can be much higher and the frequency of the signal differs. Manufacturers currently try to compensate for these effects, but it is unknown if the calibration is still valid in actual measurement applications. Therefore, the effects of influencing quantities such as, pressure, temperature, signal frequency (e.g. from seconds to nanoseconds) and measuring media (oils versus gases) on the response of dynamic pressure and temperature sensors need to be quantified.

Further to this, dynamic pressure sensors have a short lifetime when used in harsh environments which is costly (up to approx. 4 000 € per sensor), compromises the validity of results, reduces product quality and increases scrap due to poor process control. Therefore, there is a need for a new generation of dynamic pressure sensors, which can handle short-term overloading by pressure and temperature without breaking, and which can withstand an unprecedented number of pressure pulses during their lifetime.

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 traceable measurement and calibration techniques for dynamic pressures and temperatures.

The specific objectives are

1. To develop traceable primary dynamic pressure standards and validated calibration procedures with industrially relevant uncertainties up to 400 MPa.
2. To develop reliable methods and calibration benches for measuring dynamic temperature changes up to 3000 °C in demanding industrial applications, with relevant uncertainties. Novel simulation models for analysis of the effect of transient conditions on the measurement result should also be proposed.
3. To reliably and accurately quantify parameters affecting the response of dynamic pressure and temperature sensors such as pressure, temperature, signal frequency, and measurement media, and from this develop calibration procedures and determine measurement uncertainties for industrial measurements.
4. To develop novel and validated technologies for improving durability of dynamic pressure sensors used in harsh conditions, such as inside an internal combustion engine.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (accredited laboratories, instrument manufacturers), standards developing organisations (CENELEC TC 31, CIPM, ISO/TC108/SC3 WG6, C.I.P. working group GT 1-13 and standards associated with Directive 2014/34/EU) and end users (the automotive, maritime and manufacturing industries). In addition, to develop Good Practice Guidelines for the measurement and calibration of dynamic pressures and temperatures including an estimation of the uncertainty.

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 IND09 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 to the project.

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 automotive, maritime and manufacturing sectors.

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.