Title: Enhancing process efficiency through improved temperature measurement

Abstract

Modern high value manufacturing suffers from many unsolved temperature measurement problems which impede effective efficient production. Improvements are required over temperatures from near ambient to high. At high temperatures sensor drift leads to problems including: process inefficiency (e.g. energy and scrap); imprecise surface temperatures (particularly <500 °C) in materials processing/joining, leading to production inefficiencies. Also improved combustion temperature measurement is essential for the next generation of heat engines for enhanced fuel efficiency and lower emissions.

Keywords

Temperature, combustion, thermocouples, temperature sensors, surface temperature, aerospace, heat engines, materials processing.

Background to the Metrological Challenges

The current state of the art for contact thermometry measurements between 1300 °C and 1600 °C are noble metal thermocouples, type R, S or B. These are known to drift sometimes significantly and in an unpredictable manner so their performance is insufficient for advanced manufacturing environments such as specialist casting and heat treatment of critical aerospace components, so much so that zero waste manufacture *in-process* is currently unobtainable. Above about 1600 °C only the tungsten rhenium thermocouple contact sensor is available, this has drifts of >10 °C and an uncertainty when new of 1 % of temperature (20 °C at 2000 °C).

For temperatures in the region of 500 °C, surface temperature measurement by contact thermometry is very problematic, and yet critical for a wide range of industrial processes. In shipbuilding for example the use of temperature sensitive crayons to determine pre-weld temperature range is widespread, but the results are very subjective and non-traceable. Surface contact sensors are used but poorly characterised and also prone to subjectivity. Infra-red thermometry is beset with emissivity problems and is unsuitable for routine use in heavy industry.

The temperatures of combustion processes are generally determined by optical methods such as Coherent Anti-Stokes Raman Spectroscopy (CARS), Degenerate Four Wave Mixing (DFWM) or more recently Laser Induced Grating Spectroscopy (LIGS). Thermographic phosphors are also sometimes deployed to measure the temperature of the flame. However despite the sophistication of these optical methods the absolute temperatures have uncertainties of typically 5-10% of temperature. This situation limits the efficiency of combustion processes and hinders the improvement of heat engine efficiency.

For all of the above current state of the art traceability is degraded and lost in the measurement process, or currently traceability to national standards does not exist (e.g. for combustion).

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 proposal.

The JRP shall focus on the traceable measurement and characterisation of high temperatures used in the efficient manufacturing of high value components

The specific objectives are

1. To develop novel low drift temperature sensors for enhanced production and temperature control. The objective is to develop novel sensors, suitable for high data capture rate, in the same format as current sensors that have in-process traceable uncertainty of better than 3 °C at temperatures around 1450 °C and better than 5 °C at temperatures > 2000 °C.
2. To develop non-drift contact sensors optimised for heat treatment applications at temperatures ≈ 1350 °C. The sensors should be able to remain in service with an instability of <1 °C for at least 6 months and should be implemented in-process in at least one industrial setting.
3. To develop traceable surface temperature measurement methods to enhance materials/chemical processing to ≈ 500 °C. The methods should allow the calibration of surface temperature sensors, using at least one novel surface temperature approach and be used to demonstrate improved temperature measurement in at least two industrial settings.
4. To develop an in-situ combustion standard of known temperature for the validation of flame temperatures. The combustion standard should have an uncertainty a factor of 10 lower than current methods and be tested in at least two industrial settings.
5. To ensure that the outputs from the JRP are effectively disseminated to and exploited by the temperature measurement, high component value casting and heat treatment industries. To facilitate the take up of the technology and measurement infrastructure developed by the project, and to support the development of new, innovative products and services and thereby enhance the competitiveness of EU industry.

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 IND01 HiTeMS and how their proposal will build on this.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any 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 deviation from this must be justified.

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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the temperature measurement sector.

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

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.