EMRP Call 2010 - Industry & Environment

Topic number: SRT-21i

Title: High pressure metrology for industrial applications

Abstract

Advances in high-pressure technologies are increasingly utilised in the automotive, general engineering, petrochemical, pharmaceutical and food industries. The pressures being used in the leading applications have outstripped the current European calibration capability, which is limited to around 1 GPa. New measurement standards are required to extend the current metrology capability up to 1.6 GPa, which will underpin these growing and high added value high-pressure technologies.

Conformity with the Work Programme

This topic conforms to the EMRP 2008, "Innovative set-ups for new industrial and societal needs" of Section II.6.2, Subsection "Mass and related mechanical quantities" of the EMRP outline 2008 stating on p. 37 that "*With important applications in car industries, in engineering, in petrochemical and pharmaceutical industries, but also for elaborations of specific materials, the developments of new high pressure technologies and standards are required*".

Keywords

High pressure, pressure transducer, pressure balance, autofrettage, common rail diesel injection, food sterilisation, water jet cutting, high pressure technology, standardisation, traceability.

Background to the Metrological Challenges

New high pressure technologies such as autofrettage, hydroforming and isostatic pressing are intensively being developed and used in the car industry, diesel engineering, vessel production for the petrochemical and pharmaceutical industry, manufacturing water cutting machines, new material fabrication and, recently, for food sterilisation. With the new technologies the quality and lifetime of products and efficiency of processes can be increased, material and energy resources saved, and the emission of pollutants reduced.

New transducers for measuring pressures up to 1.5 GPa have recently been used in the new high pressure applications. Several European consultancy groups predict high pressure sensing will grow from the current 1 % up to 5 % of the total pressure measurement market in the near future. No adequate standards for pressures higher than 1 GPa are available in the EU today with which the modern pressure transducers could be adequately calibrated. Without calibration service provided for companies using high-pressure technologies, their quality assurance and safety requirements cannot be fulfilled, which hinders expected technologies improvements if the process pressure would increase.

Application of high, continuously increasing pressures plays a vital role in the manufacture of common rail diesel direct injection fuel systems, which underpin to a large degree the vastly improved performance of automotive petrol and diesel engines. The trend for higher injector pressures began in the 1980s with systems operating initially at around 130 MPa, then rapidly increasing to well over 200 MPa. With the increasing injection pressure, a finer dispersion of the fuel, more efficient combustion and lower exhaust-gas pollutant values can be achieved. However, a higher working pressure combined with a cycling load of the injection systems requires a strengthening of their components (rails, pipes, pumps) in order to reach appropriate durability and lifetime of the systems. The technique used is autofrettage, in which components are subjected to enormous pressure, causing internal portions of the part to yield and resulting in internal compressive residual stresses. The goal of autofrettage is to increase the durability of the final product. Pressures required for the

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EMRP
European Metrology Research Programme
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The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

autofrettage are typically between 0.7 GPa and 1.5 GPa depending on the material. Too low a pressure causes insufficient plastic deformation, which reduces the strengthening effect. Too high a pressure can lead to a total plastic deformation of the part with the risk of its damage. To optimise fuel injection systems and to produce reliable high-pressure components injection system manufacturers need pressure transducers that operate effectively and are calibrated up to 1.5 GPa. To meet the demands of the car industry, efforts are being undertaken by manufacturers of pressure transducers to increase the robustness and lifetime of their 1.5 GPa transducers at acceptable accuracy levels. Optimisation of these pressure transducers requires their investigation up to 1.5 GPa. Calibration of the existing transducers and development of better 1.5 GPa pressure transducers required by the automotive industry need reference pressure standards which currently do not exist.

Other technologies also require pressure calibration above 1 GPa directly, or through the use of isostatic pressing or autofrettage during manufacture, for example high pressure processing (HPP) of food to achieve microbial inactivation, testing of high pressure equipment and water jet cutting systems which are used intensively in the manufacturing industry.

In addition to the lack of primary pressure standards, no reliable, sufficiently investigated transfer pressure standards for pressures up to 1.5 GPa exist.

In industry due to the lack of high-pressure standards, the measurement characteristics of pressure transducers calibrated at lower pressures are extrapolated to higher pressure. This approach allows only a vague estimation of pressure outside of the transducers' calibrated range with negative consequences for the efficiency, effectiveness and safety of the industrial processes.

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.

The focus of this research topic is to provide industry with traceability for pressure measurement in the range from 0.5 GPa to 1.6 GPa.

The specific objectives are:

1. Development of pressure balances capable of measuring pressures up to 1.6 GPa. This may require modelling such as by finite-element based methods (FEM) and measurements to understand mechanical deformation processes at these pressures
2. Investigation of potential high-pressure transmitting liquids to be used in the pressure balances and industrial applications
3. Development of transfer standards and calibration methods for the range 0.5 GPa to 1.6 GPa.

The resources needed to meet these objectives are expected to be less than for an average joint research project in TP industry.

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 with 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 impact 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 high pressure transducer manufacturers and the users of high-pressure technologies in the automotive, food processing, aerospace, glass and manufacturing 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.