EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-s14**
Version: 1.0

Title: Force traceability within the meganewton range

Abstract

Force is an important quantity for many industrial processes in sectors such as mechanical engineering, aerospace, energy and buildings, and is applied in a widening range from mN to MN. The demand for higher nominal values, for example forces above 30 MN is increasing. In addition the application of the measuring devices is often totally different from the calibration environment. The calibration chain from the NMIs to the industrial application requires the use of transfer standards, and significant gains can be achieved if these standards can be optimised. The challenges come from the inherent nature of force, which is a vector quantity in which non-axial loading causes additional parasitic effects that can significantly influence the uncertainty of measurement. There is a need to investigate these effects and to reduce the uncertainty in the dissemination of force from primary standards through to industry, and to develop improved transfer standards and measurement procedures that can reflect the industrial application, particularly focusing on the reduced uncertainty at the extreme (high end) of the industrial ranges that are needed.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 12, 36 and 37.

Keywords

Force measurement, parasitic components, multi-component measurements, creep and loading effects, static calibration, continuous calibration, measurement uncertainty, force build up systems.

Background to the Metrological Challenges

In Europe there are many industrial applications in force measurement such as civil engineering, the steel industry, offshore, and oil industry, and there is an increased demand for higher nominal values of these quantities. In civil engineering, tests up to 10 MN are common in many laboratories but there is a demand for increases to higher values up to 30 MN, for example for the monitoring of forces on bridges and also for the testing of steel and concrete materials for civil engineering. The results of these tests depend on the way the force is applied and on parasitic components. The uncertainty is limited by the uncertainty of the calibration and the uncertainty during the application.

Testing of wind power system bearings is just one application requiring force measurements. Very high bending moments, similar to those occurring in actual operation, are applied to these bearings for testing and development. Such bearings are tested on test stands, which currently require force transducers with a range of 5 MN, and potentially up to 15 MN in the medium to long term as the size of wind turbines increases. Since 2000, the wind and water power systems market has increased significantly, driven in part by the need to support the European Union’s ambitious energy and climate change objectives which aim amongst others to increase the share of renewable energy to 20 % by 2020. In another application aeroplanes are tested by the measurement of force in multi-axial directions. Projects such as the Airbus A380 have made it evident that significantly larger airplanes are and will be built now and in the future. Various components, for example the wings, the mounting parts of the turbine engines, and the cabin are subjected to considerably higher forces during operation than their smaller predecessors and it is therefore necessary to implement these high forces in test stands on the ground and to control and measure them. As a result, force transducers with nominal ranges well into the MN range are required. Force sensors with bending moment bridges are used and there is an increase in forces into the MN range to test panels and components.

As a result, force transducers with suitably high capacities will have to be calibrated at regular intervals, with high precision and at low cost. This requires reference transducers with sufficiently high capacities and accuracies.

In situations where calibration over only a partial load range is possible for reasons of cost or practicality, it is absolutely necessary to assess the accuracy that can be attained at full load. Reliable models for extrapolation are thus needed. Moreover, the special requirements for calibrating these transducers are not yet fully understood (e.g. longer delay before installation in the testing machine because of higher thermal capacity). In addition, the key question to be answered is what transducer principles may be suitable for reference transducers with high nominal capacities.

The calibration of transducers on different calibration machines can show significant deviations up to several percent due to parasitic effects from the interaction of the force or moment vector with the calibration machine and from the different loading profile of the machines and the sensitivity of the transducer to these effects. These effects can contribute significantly to the overall uncertainty in an industrial application, but the user has no information in order to effectively account for these effects.

In the field of force, NMIs and industrial calibration laboratories use force standard machines with dead-weights, hydraulic amplification, lever amplification, reference transducer or build-up systems to cover the force range from low to high nominal values of 1 N up to 15 MN. For the high force range build-up systems the evaluation of the overall uncertainty of the entire system needs to be addressed, rather than just the calibration of the individual transducers as at present.

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 JRP shall focus on a step-change improvement of the uncertainties in the dissemination of the unit of force from a primary level to calibration laboratories in industry and industrial applications.

The specific objectives are

1. To extend the range of primary force standards to cover the range from 1 MN to 30 MN or higher up to 50 MN, with uncertainties of the order of 0.002 % up to 2 MN, 0.01 % up to 15 MN and 0.05 % up to 30 MN.
2. To develop improved transfer standards for forces up to 30 MN, in order to enable both more reliable dissemination of the unit of force and improvements in the measurement of force in industry. The effect on the overall uncertainty in use due to parasitic components and loading procedures that are different to the static calibration procedure, for example in the case of continuous or non-axial loading should be evaluated.
3. To develop methods to determine the uncertainty of the whole measurement system for high force range build-up systems, rather than addressing the calibration of single transducers.
4. To develop methods to extrapolate calibration results for values higher than 15 MN force, including evaluation of the associated uncertainties.
5. To develop new procedures and EURAMET technical guides for end users on the use of high force measurement devices, the methods of uncertainty calculation and on the improvements in the dissemination of force from primary standards to calibration services and testing laboratories.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

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

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 42 months of effort.

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.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the mechanical and civil engineering, aerospace industry, energy industry, safety engineering and testing sectors.

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

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 and includes 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 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 up to 3 years duration.