Title: Force and torque for industrial applications

Abstract

Force and torque are important quantities for many industrial processes in sectors such as mechanical engineering, aerospace, energy and buildings, and are applied in a widening range, from mN to MN force and from mN·m to MN·m moment respectively. The demand for higher nominal values, for example forces above 15 MN and torques above 1 MN·m, 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 and torque, which are vectorial quantities in which non-axial loading causes additional components that can significantly influence the uncertainty of measurement.

This topic aims to investigate these effects and reduce the uncertainty of force and torque measurement in industry by developing 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 topic conforms to the EMRP 2008, section on "*Metrology R&D for applied and fundamental metrology"* related to *Industry* on page 12 subsection "*Mass and related mechanical quantities*", page 36 subsection "*Fundamental research in mechanics*" and page 37 subsection "*Innovative set-ups for new industrial and societal needs*".

Keywords

Force measurement, torque measurement, parasitic components, multi-component measurements, creep and loading effects, static calibration, continuous calibration, measurement uncertainty.

Background to the Metrological Challenges

In Europe there are many industrial applications in force and torque and there is an increased demand for higher nominal values of these quantities. In civil engineering, tests in the range 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 of the application of the force and on parasitic components.

Testing of wind power system bearings is just one application requiring force and torque 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. Leading industrial customers have meanwhile requested force transducers with a range of 30 MN. Since 2000, the wind and water power systems market has increased by 86%, from 127 petajoule in 2000 to 236 petajoule in 2008. By the end of 2008 around 20,230 wind power systems had been installed in Germany. In countries like the UK there is a requirement for around 25 % of the power demand to be provided by wind power by 2020, and in Germany the figure is even higher at 46 %. Although these wind turbines are considerably bigger and taller than in the past, the installation of a total of about 6,000 wind turbines is envisioned in the UK.

As a result, force transducers with suitably high capacities will have to be calibrated at regular intervals on several fronts, 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, 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.

Aeroplanes developed by the aerospace industry are tested by the measurement of force in multi-axial directions. Projects such as the Airbus A380 or A300M 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. It has therefore become 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 mega Newton 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.

Furthermore there are applications that require an increase of the torque range. Wind energy facilities generate torques up to 1 MN·m, and new facilities up to 5 MW are under development that will generate torques of up to 3 MN·m. Accurate measurement of the torque is an important requirement in order to define and improve the efficiency of the generator. Precise information of high-range torques is also essential for the measurement of the efficiency of gas turbines for energy generation.

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, however 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. In the field of torque dead-weights and reference transducers are used in torque standard machines from low to high nominal values from 1 mN·m up to 1 MN·m.

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 investigate existing systems and develop new force and torque transfer standards up to highest nominal values for industrial applications. Improvements overall are dependent on an improved understanding of parasitic components and different loading effects that come into play in the use of the transfer device in the industrial application.

The specific objectives are:

1. Development of transfer standards for static force in the range of or exceeding 15 MN and for static torque in the range of or exceeding 1 MN·m
2. Development of methods to determine the uncertainty of a whole measurement system rather than addressing the calibration of the single transducers
3. Development of methods to extrapolate calibration results to values higher than 15 MN force or 1 MN·m torque, including uncertainties.

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.

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 standards through appropriate standards bodies
- transfer knowledge to the mechanical engineering, aerospace, energy and building industrial 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.