Publishable JRP Summary Report for JRP SIB63 Force
Force traceability within the meganewton range

Background

In mechanical engineering, aerospace industry, power production, building industry, safety engineering and testing, forces with nominal values in excess of 15 MN are measured. The application conditions of force measuring devices can be totally different from the conditions during their calibration. For example, mounting conditions, force introduction components, loading profiles of a force transducer as well as temperature and waiting times before taking the readings can vary. In most of the cases the deviant conditions are not taken into account. But they influence the measurement result and its uncertainty. Traceable calibration of suitable transfer standards should improve the measurement of forces in industrial applications. In order to reduce the uncertainty of measurement in practical applications, parasitic components and effects that are related to real loading procedures (which might be very different from the static calibration procedures) have to be taken into account. Furthermore, due to the increasing demand for traceable calibrations in the range of forces up to 30 MN and in future even up to 50 MN, the force range that can be traced back to standards needs to be extended to larger nominal values.

Therefore, newly developed highest nominal value force transfer standards have to be investigated in order to improve the measurement of forces and the dissemination of the quantity of force. In addition, parasitic components and different loading effects will be analyzed to consider these effects when the device is used in industrial applications.

In the highest force range, build-up systems are used, however, open questions exist regarding uncertainty evaluation of such systems. It is therefore necessary to provide end users with procedures on using this kind of force measurement device in this highest force range and to develop corresponding methods of uncertainty calculation.

Need for the project

JRP SIB63 Force will address the needs of the European Industry in the field of force metrology. In Europe, there are many industrial applications for force measurement and there is an increased demand for higher nominal forces. In civil engineering, material testing in the range up to 10 MN is common in many laboratories but there is also an increased demand for higher values of up to 30 MN, for example, for the measurement of forces in bridges and for the testing of steel and concrete materials for civil engineering. Forces up to 30 MN and higher are also applied to test drilling equipment for gas and oil companies. The results of these tests are dependent on the method and time of the force application, on ambient air conditions and on acting parasitic force and moment components.

In the field of force, NMIs and calibration laboratories in industry use force standard machines with dead-weights, hydraulic amplification, lever amplification, reference transducer or build-up systems to cover the force range from nominal values of 1 N up to 15 MN. However, there are neither written standards nor technical regulations for the consideration of parasitic components or multi-component influences as well as for different time dependencies. These are required to avoid considerable errors in the applications of force measurement and in the dissemination of the quantity of force. For higher forces, build-up systems can be used but there are also no standards or guidelines available for the uncertainty calculation of such systems. There is no traceability in Europe for forces up to 50 MN and for forces up to 30 MN the relative expanded uncertainty (k = 2) is limited to 0.15 %. The increased demand for accurate calibrations with nominal force values of up to 50 MN coming from the main stakeholders in the European industry such as producers of material test equipment and force transducers, laboratories for material testing, civil engineering and off-shore industry, cannot be covered by NMIs so far.

Reliable models for the extrapolation of measurement results for the range exceeding the traceable measuring range of calibration laboratories have to be developed to cover forces up to 50 MN. Moreover, special requirements to the calibration of transducers that are intended to be used for extrapolations need to

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

be identified. This approach entails a risk for the application in the high-force range which can hardly be quantified.

Scientific and technical objectives

This JRP addresses the following scientific and technical objectives:

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 will be evaluated.

3. To develop uncertainty models to determine the uncertainty of the whole build-up force measurement system (including all of its single transducers and force distribution parts) for the extended force range, 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 guidelines for calibration and material testing laboratories 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.

Expected results and potential impact

This JRP will strengthen and improve European force measuring devices and calibration methods in the high force range. The collaboration of different NMIs in the field of force will have an impact for many industrial applications and will improve efficiency in this field. The JRP-Partners will give recommendations to a range of European industries in order to reduce the uncertainty of force measurement in the different applications by improving traceability. The advantage of the collaboration is that the JRP-Partners will exchange their knowledge in this field and that the JRP-Partners will also carry out comparisons in respect of the use of force measurement devices in industrial applications.

This JRP will provide a reduced measurement uncertainty in a wide field of industrial applications up to the highest nominal force values. The JRP-Partners will collaborate to improve traceability from NMIs to industry by considering the influences in industrial applications which are currently not considered in the NMI calibrations.

The impact of this JRP on the stakeholders will be realised by workshops and training, newly published recommendations and papers and by a web data base which will be used by the stakeholders to reduce the uncertainty of measurement in their application.

The range of primary force standards developed in the JRP will cover the range from 1 MN to 50 MN, with uncertainties of the order of 0.002 % up to 2 MN, 0.01 % up to 15 MN, 0.05 % up to 30 MN and 0.1 % up to 50 MN. These new primary force standards and reduced uncertainties will create the following direct impacts. The stakeholders of this JRP are manufactures of force transducers and testing machines as well as calibration laboratories which are accredited for the calibration of force transducers and for the calibration of testing machines. Calibration laboratories in industry will have the possibility to reduce the uncertainty of measurement by considering the influences which are investigated in this project. The models and uncertainty guides proposed in this project can be considered by industrial calibration laboratories to calculate a more realistic uncertainty of measurement. This will also have a benefit for the manufactures of force transducers and testing machines, because a more precise calibration will be possible by considering the results of this JRP.

The improved transfer standards for forces up to 50 MN and evaluation of uncertainty due to parasitic components and loading procedures developed in the JRP will create the following direct impacts. For the calibration of large testing machines, build-up systems (BUS) will be available in Europe for traceable force measurements up to 30 MN and 50 MN. After the end of this project the use of the large build-up systems can be offered to European industry.

The methods to be developed in this JRP for the determination of uncertainty for a high force range BUS will create the following direct impacts. The participating NMIs will have better methods for the own traceability chain up to higher force values in the MN range. The main advantage is that these model are validated by the investigations carried out by different laboratories.

The methods to be developed in this JRP for extrapolating calibration results to values higher than 15 MN force, including evaluation of the associated uncertainties, will create the following direct impacts. In future, industrial calibration laboratories can use the proposed models for the extrapolation to higher forces including the uncertainty calculation of this extrapolation. Up to now there are no models available and the laboratories have to develop own methods which can be a risk in the high force range. This risk can be reduced by using validated procedures investigated in this JRP.

The new procedures and EURAMET technical guides to be developed in this JRP will create the following direct impacts. Industrial calibration laboratories can directly use the technical guides for force measurement in future. The advantages are unified procedures which are recommended by the participants of this JRP.

Indirect (medium to long term) impact

The more precise measurement of force will allow improved products to be developed in mechanical engineering, in aerospace industry and power production, building industry, safety engineering and testing. In the field of energy generation by wind energy or gas turbines and engines, the efficiency and safety can be improved by more precise measurements.

Financial Impact

Material testing in the high force range above 1 MN is very expensive and the uncertainties are limited due to different unknown effects. For safety reasons, larger safety factors have to be taken into account for large mechanical structures. Force transducers and their calibration in the high range are very expensive too. If the force measurement is improved in the large range, the results of mechanical tests are more safe which will have a financial impact on the applications mentioned before.

Social Impact

Large buildings, bridges as well as big airplanes and ships are used by many people and are important for the European market. Better force measurement in the high range can help to improved their design and lead to safer constructions and give a social impact in Europe.

Environmental Impact

The improved traceability of material tests in the high force range is important for many applications in, for example, mechanical engineering, power production using renewable energy sources and building industry, which will also have an environmental impact.

JRP start date and duration: 1. July 2013, 36 months	
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The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union