Publishable Summary for 21SCP02 TRaMM
Traceability Routes for Magnetic Measurements

Overview

Magnetic measurements are vital to support European challenges in areas such as electric vehicles; health; power transformation and harvesting; clean, affordable and secure energy; information and sensor technology. However, only very few (4) European NMIs have the capabilities to perform traceable measurements of all of the most important magnetic quantities. Consequently, the adoption of novel technologies and materials is hindered by the lack of local metrological expertise that research and development activities in academia and industry could exploit. An experienced NMI (INRIM) will extend their capability to perform traceable magnetic measurements to two less developed NMIs in this field (CEM, NSAI). This will enable them to address market and stakeholder requirements in their countries. A smart-specialisation concept will also be outlined, which may be further developed in future projects.

Need

Magnetic measurements are relatively common in academia and in industrial research and development, as they are widely employed for the measurement of magnetic fields and for the characterisation of the magnetic cores in sensors or electronics. In addition, they are used in applications such as earth observation, biomedicine and health and safety requirements regarding exposure to electromagnetic fields (The Electromagnetic Fields Directive 2013/35/EU). However, so far, the industrial and scientific communities have been unable to fully benefit from traceable and reliable measurement results because of limited access to suitable calibration facilities. With the global magnetic materials market continuously increasing at an annual growth rate of about 9.6 %, it is crucial to develop sustainable magnetic measurement capabilities that will support these end-users.

Even though the calibration of teslameters and coils, or the measurement of the magnetic properties of steel sheets for power applications (electrical motors, transformers) are already standardised, very few (4) European NMIs are capable, for historic reasons, of providing a comprehensive set of measurement and calibration services in these areas, which require very specific instruments and techniques. This is different from other electrical measurements. In addition, new research activities and industrial products, in the fields of biomedicine, theragnostics, water remediation, and security are expanding the need for traceable magnetic measurements for e.g. the characterisation of magnetic nanoparticles, rings, ribbons or bulk materials, or for sensing devices involving magneto-electric phenomena.

Other fields requiring traceable and reliable magnetic measurements are all those where magnetic materials are exploited for energy conversion, harvesting and storage, such as automotive and powertrains, aerospace, and smart grids. All these applications attract both scientific research and industry, and offer development and market opportunities especially for SMEs that wish to be dynamic and innovative, offering breakthrough technologies and solutions to new potential customers and markets. In spite of this exciting innovation and development, easy access to the measurement and calibration capabilities for magnetic field and magnetic material characterisations are still mostly lacking, leaving industry and academia with the unaddressed need to properly validate their technological solutions through traceable magnetic measurements.

Relevant stakeholders will therefore belong to the following categories: academia and research centres working on magnetic materials and applied magnetism (for energy transformation, actuation, sensing, biomedicine); industries belonging to electric vehicle supply chains (electric motors) and power application supply chains (electric motors and transformers); industries belonging to sensor supply chains (magnetic field probes, position, rotation, angle, speed, vibration, etc., detectors, bit detectors and systems for magnetic registration); industries belonging to the magnetic field monitoring supply chain (measurement of magnetic fields in or around industrial equipment, biomedical devices such as NMR, personal exposure meters, etc.); industries involved in medical device manufacturing; industries in the food supply chain (metal detection in food processing); industries involved in electric and electronic components (e.g. microwave

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components); academia and research centres working on geomagnetism; industries belonging to the steel supply chain (manufacturers and industries processing semifinished products) and to the weakly magnetic steel supply chains (aerospace, naval and military industries).

The stakeholders' high-level needs and the metrology services provided or planned by the NMIs/DIs need to be determined and aligned (Objective 1). At present, the developing NMIs (CEM, NSAI) are not able to fulfil these needs due to the lack of relevant resources and experience. They are unable to quickly solve this problem to help their stakeholders. Therefore, an experienced NMI (INRIM) is needed to provide the know-how through customised training for each partner (Objective 2). In addition, each partner must develop a plan in order to acquire the capability needed to address their stakeholders' needs. This plan needs to include the definition of a smart-specialisation concept, which will be further developed and implemented in future projects (Objective 3).

Objectives

The overall objective of this project is to make traceable magnetic measurements more widely available in the EU, by disseminating the knowledge and expertise of an expert NMI (INRIM) to those NMIs with less developed capabilities (CEM, NSAI) that have market and stakeholder needs in this field. This project aims at establishing the foundations for the development of relevant and reliable magnetic measurement and calibration services at CEM and NSAI by raising their level of understanding of the fundamental techniques used in this field.

The specific objectives of the project are:

1. To identify existing stakeholder needs in the area of magnetic measurements and related calibration services and to establish contact with other European NMIs in order to understand their current capabilities and future plans. To analyse the alignment between the stakeholders' high-level needs and the metrology services provided or planned by the NMIs/DIs.
2. To transfer knowledge and expertise related to magnetic measurement and calibration techniques from the expert NMI (INRIM) to the developing NMIs (CEM, NSAI) by delivering training that is customised to include the capabilities that they need to acquire in order to address the stakeholders' needs.
3. For each partner to develop a plan, including the sourcing of suitable hardware, the development of measurement procedures and quality schemes, in order to acquire the capability needed to address the stakeholders' needs. The plan will include definition of the smart-specialisation concept and coordination among the participating NMIs and other NMIs/DIs to pave the way for the future development of smart-specialisation in magnetic measurements and calibration services, possibly through follow-on projects.

Results

1. *To identify existing stakeholder needs in the area of magnetic measurements and related calibration services and to establish contact with other European NMIs in order to understand their current capabilities and future plans. To analyse the alignment between the stakeholders' high-level needs and the metrology services provided or planned by the NMIs/DIs.*

   This project will have stakeholders from universities, research centres, other NMIs, and different supply chains, such as: measurement equipment manufacturers (flux meters, tesla meters, NMR equipment, fluxgates, etc., but also medical equipment); space; automotive; health (hospitals or companies monitoring the environmental magnetic field surrounding medical or industrial equipment); electronics; food processing. The project will identify the needs of these stakeholders and prepare a list of capabilities that NMIs need to have in order to address not only the current needs, but also those for the foreseeable mid- to long-term. These needs and the European NMIs' capabilities and future plans will be analysed to determine their alignment. This information will be used to determine the knowledge and expertise that needs to be transferred to the developing NMIs (CEM, NSAI) in Objective 2. Ultimately, a report will be prepared detailing the alignment between the stakeholders' high-level needs for magnetic measurements and calibration services and the metrology services provided or planned by the NMIs/DIs.

In this first reporting period, stakeholders from universities, research centres, other NMIs, and different supply chains, such as: measurement equipment manufacturers; space; automotive; health; electronics; have been identified and contacted to investigate their metrological needs concerning magnetic measurements and calibrations. One closed-form questionnaire and one open-ended questionnaire have been developed, allowing the interested stakeholders to share anonymously more technical details concerning their metrological needs and also their vision on the future of magnetic measurements in the European Union and worldwide. The data collected from these two questionnaires give, for the first time, a systematic view at the European level of the current and future measurement and calibration needs of academia and industries exploiting magnetic sensors or magnetic materials. A challenging landscape has emerged, where the traditional metrological services on a few kinds of magnetic field sensors (e.g. Hall probes) and on a few standardised magnetic properties (e.g. power losses on steel sheets) turn out to have a comparable importance to new, currently unsupported services, that will have to address novel kinds of magnetic field sensors (e.g. magnetoresistance sensors) of growing importance in technological applications, and new paradigms in the characterisation of magnetic materials, where a traceable and reliable measurement method will need to find an application on semi-finished products, such as nanoparticles, 3D-printed components or magnetic elements in their working conditions (as opposed to standardised laboratory conditions).

2. *To transfer knowledge and expertise related to magnetic measurement and calibration techniques from the expert NMI (INRIM) to the developing NMIs (CEM, NSAI) by delivering training that is customised to include the capabilities that they need to acquire in order to address the stakeholders' needs.*

   The developing NMIs (CEM, NSAI) will acquire the knowledge and expertise common to all magnetic measurements and calibration services in order to address the stakeholders' needs. Follow-up training will be provided that will be targeted to specific magnetic materials and calibration capabilities. Suitable training material will be produced (lessons, presentations, technical documents, videos, etc.), shared with stakeholders, and made publicly available online. In this first reporting period, the results of the survey described in Objective 1 allowed us to conceive an innovative training programme to transfer knowledge from INRIM to CEM and NSAI, focussing not only on the traditional measurement and calibration methods exploited for magnetic quantities, but also on novel aspects where measurement techniques typically belonging to research laboratories will need to be inserted into a well-established metrological context to make them useful to address the stakeholders' needs. The training programme, therefore, has been developed through a PhD course, attended by CEM and NSAI researchers, aimed at giving the fundamentals of magnetism and magnetic measurements, but also the deeper critical analysis of magnetic measurement procedures that is required to understand how the new metrological challenges emerged from the questionnaires will impact the metrological chain in this field. Additionally, a set of training videos, based both on traditional and innovative measurement and calibration techniques, has been created.

   The activities are planned to go on with active training of CEM and NSAI researchers at INRIM laboratories, where they will have the opportunity of applying the new concepts learned and to become familiar with many of the measurement techniques that are required by the stakeholders. The training will finally proceed in CEM and NSAI laboratories, addressing specific local issues and needs.

3. *For each partner to develop a plan, including the sourcing of suitable hardware, the development of measurement procedures and quality schemes, in order to acquire the capability needed to address the stakeholders' needs. The plan will include definition of the smart-specialisation concept and coordination among the participating NMIs and other NMIs/DIs to pave the way for the future development of smart-specialisation in magnetic measurements and calibration services, possibly through follow-on projects.*

   Each partner will prepare a development plan, which will include the sourcing of suitable hardware, and the development of measurement procedures and quality schemes, in order to acquire the capability needed to address the stakeholders' needs. The plan will include a definition of the smart-specialisation concept and coordination among the participating NMIs, and other NMIs/DIs, to pave the way for the future development of smart-specialisation in magnetic measurements and calibration services, possibly through follow-on projects.

Impact

In this first reporting period, the project was presented at the EURAMET TC-EM committee (low frequency subcommittee). At the very beginning of the activity (October 2022) the aim of the project was presented, and after a few months (May 2023) the consolidated results of the stakeholders surveys were presented. To further promote the project's activities, several presentations have been made at conferences and expos: IMEKO TC4 conference in September 2022 (target: mostly scientists, metrological community), AIM conference in January 2023 (target: IEEE scientific association, mostly scientists from academia), CIM conference and expo in March 2023 (target: mostly European industry), IMEKO TC4 conference in September 2023 (scheduled, accepted contribution, target: mostly scientists, metrological community).

Twenty-three stakeholders have so far joined the project, covering industry, academia, public research organisations from 10 different European countries. Two questionnaires (one closed-form and one open-ended) have been submitted, and their responses allowed us to conceive a training programme from CEM and NSAI researchers. A PhD course and eighteen videos have consequently been prepared and published online, with free access, both on TRaMM's website and on a dedicated YouTube channel, presenting theoretical and experimental aspects of magnetic calibrations and measurements. A promotional video addressed to the general public has also been prepared and shared online.

Early impact on user communities

The developing NMIs will analyse the alignment between their stakeholders' high-level needs and the metrology services provided or planned by other NMIs/DIs. This will enable them to plan their development, in collaboration with INRIM, in order to meet these needs (Objective 1). This will promote maximum impact, as the future development of CEM's and NSAI's measurement and calibration facilities will be driven by the expectations of the stakeholder community and avoid overlap with the metrology services that are currently provided or planned by other NMIs/DIs.

CEM and NSAI will develop the level of knowledge needed to address the stakeholders' needs in the field of magnetic measurements and calibration services (Objective 2). In addition to developing reference standards and calibration set-ups (after the end of the project), which can be accessed by users who require reliable and traceable measurement results (e.g. academic and research centres working on magnetic materials, medical device manufacturers, measurement equipment manufacturers, companies and agencies involved in the monitoring of the magnetic fields surrounding medical or industrial equipment, etc.), the developing NMIs, as well as creating impact for themselves, will be in a position to generate impact by offering sound technical advice to those involved in magnetic measurements. This means that stakeholders will have local, affordable access to the new consultancy services that they need. If the developing NMIs are able to set up instrumentation for magnetic measurements or calibrations before the end of the project, the stakeholders will immediately benefit from the NMIs' new capabilities.

The definition of the smart-specialisation concept will pave the way for the future development of smart-specialisation in magnetic measurements and calibration services (Objective 3). It is expected that the smart-specialisation concept will create impact by widening the offering of magnetic measurement and calibration capabilities in the European Union, both through an increased number of expert NMIs in the field, and through an increased awareness, among the stakeholders, of the availability of these capabilities. This will raise stakeholder awareness of the importance of traceable measurements, and it will improve the quality of research outcomes. It will also be possible for the partners to become reference collaborators with academic research centres and with industrial partners that need specific magnetic measurements or calibrations to develop, test or market a certain material, product, technological device, or service. The early impact will therefore be to lift those restrictions that are currently slowing down or hindering the adoption of new technologies, processes or materials by the stakeholders, from a magnetic measurement and calibration point of view.

To promote the uptake of the project's outcomes by the user community, all of the training material and published documents (such as measurement and calibration needs, specialisation plans, etc.) produced within the project's framework (including hands-on training videos) will be shared with EURAMET TC-EM and other NMIs and it will be made publicly available e.g. via the project website, videos on YouTube, the BIPM's forthcoming Moodle platform, etc. Additionally, the project will organise a 1-day stakeholder workshop, which will be promoted via the project website and also through EURAMET TC-EM, at the beginning of 2024.

Longer-term economic, social and environmental impacts

In the longer term, the impact of the project is threefold. Firstly, NMIs that have not been trained during the project's timeframe will be able to benefit from training material in the future. Although INRIM does not plan to maintain a training facility for continuous use, it will be available after the end of this project for direct collaboration with other NMIs that would be interested in magnetic measurements and calibration facilities. This will improve the common knowledge base, and extend the network of metrology institutes that will be capable of distributing measurement and calibration expertise on magnetic materials and devices across the EU.

Secondly, the knowledge base established at the NMIs that have participated in this project will enable them to be key players in new actions and future development opportunities. This will include participation in research projects where magnetic measurement capabilities are required, participation in forthcoming projects aiming at smart-specialisation, and the expansion of their capabilities to address new stakeholder needs in the field of magnetic measurements.

Finally, more reliable traceable magnetic measurements will positively impact society and the environment. For example, reliable magnetic measurements will allow for a much more accurate estimate of the converted energy losses in power applications (with less wasted power), an optimisation of the performance of magnetic materials in technology applications (with reduced raw material requirements and final product weight, which is especially important in the automotive and aerospace industries) and in biomedicine (with optimisation of the amount of magnetic material required to achieve a certain therapeutic or diagnostic result), and an improved performance of safety-critical devices that exploit magnetic materials in the information technology industry (cryptography, anti-counterfeiting, anti-adulteration, etc.).

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