Publishable Summary for 17NRM03 EUCoM
Standards for the evaluation of the uncertainty of coordinate measurements in industry

Overview

The project aims to deliver two methods for evaluating the uncertainty of coordinate measurement. These methods will be suitable for inclusion in international standards and applicable to common cases in industry. Correct evaluation of uncertainty during inspections is necessary to avoid false decisions such as accepting nonconforming parts. The most popular technique for dimensional inspection in industry is coordinate measurement. Recognised and viable methods for uncertainty evaluation will improve quality assurance and impact positively the European manufacturing sector.

Need

In the last decade, the GDP due to manufacturing grew in Europe less than the accumulated inflation (11.7 % vs. 15.7 %), with a net contraction of the European manufacturing. The key to staying competitive with low-wage developing countries is advanced manufacturing of high-quality products. This is impossible without high standards for intermediate and final inspections, primarily on dimensional and geometrical quantities (GPS – Geometrical Product Specification). It is noted that even a tiny improvement in this area would result in a very large economic impact due to the large GDP fraction of manufacturing in Europe.

Inspections provide factual evidence for decision-making. Standardised rules exist (EN ISO 14253-1, ISO/TR 14253-6) to decide upon part conformity or nonconformity with specifications (tolerances) taking account of the inevitable uncertainty incurred in measurement. Unfortunately, the evaluation of the uncertainty in coordinate measurement is technically very difficult, little guidance is available in international standards, and industry often overlooks it.

New viable and standardised methods for evaluating the uncertainty in coordinate measurement would make inspections in manufacturing more reliable, ensure better quality of products, and help maintaining and possibly strengthening the EU competitiveness on the global market.

Objectives

The overall objective of the project is to develop viable methods for evaluating the measurement uncertainty in coordinate measurement in industry, to support the competent standardisation body (ISO/TC213/WG10) in further development of related standards (in the ISO 15530 series).

The specific objectives of the project are:

1. To develop traceable and standardised methods for evaluating the uncertainty of coordinate measurement a posteriori using type A evaluation.
2. To develop a simplified and validated method for predicting the uncertainty of coordinate measurements a priori using type B evaluation (i.e. expert judgement).
3. To demonstrate the validity of existing methods and those from objectives 1 & 2 in industrial conditions and evaluate their consistency and accuracy against the Guide to the Expression of Uncertainty in Measurement (GUM) and its supplements.
4. To contribute to revisions of the EN ISO 15530 and the EN ISO 14253-2 by providing the necessary data, methods, guidelines and recommendations, in a form that can be incorporated into the standards at the earliest opportunity. In addition, to collaborate with the technical committees CEN/TC290 and ISO/TC213/WG10 and the users of the standards they develop to ensure that the outputs of the project

are aligned with their needs and recommendations for incorporation of this information into future standards at the earliest opportunity. To promote early dissemination of the developed methods to industry.

Progress beyond the state of the art

General state of the art. Most companies overlook the uncertainty of coordinate measurement in their routine inspections of manufactured products: as evaluating the uncertainty is difficult and time-consuming in coordinate measurements, this is very often not done at all, or is very coarse. The consequence is that not only are the requirements of the EN ISO 14253-1 not fulfilled, but also the decisions made on the basis of inspections are unreliable. This is particularly dangerous for critical parts, whose functional failure may result in serious or even catastrophic failure of the overall product, e.g. an aircraft falling down because of a faulty turbine blade. The uncertainty of measurement is key in supporting reliable decision-making. Coordinate measurements suffer from the lack of recognised viable methods for evaluating the uncertainty. This has large economic impact on EU manufacturing because the lack of reliable information on part conformity may induce designers to over-specify tolerances to ensure product functionality, thus increasing the manufacturing cost unnecessarily. The prevailing guidance for users is given in the EN ISO 15530 series of standards. However as valuable as this guidance is to industry part 1, albeit very informative and tutorial, it is not intended to provide operative evaluation tools, and the methods described in Part 3 and Part 4 are often impossible to apply in practical cases. The EN ISO 14253-2 also provides guidance in uncertainty evaluation, but it addresses dimensional measurements at large with no focus on coordinate measurements: in fact, the tutorial examples given in Annexes A, B, C cover simple measurements compared with those done with coordinate measuring machines (CMMs). The EN ISO 14253-5 as well as its specialisations for CMM, ISO/TS 17865 and ISO/TS 23165, are about the uncertainty evaluation in the special case when an indicating measuring instrument, and a CMM in particular, is being tested. This is useful in acceptance and reverification testing of CMMs, but it is not useful for the intended CMM use, i.e. the inspections of parts.

Beyond the state of the art. The project will provide specific guidance on the evaluation of coordinate measurement uncertainty, in a form suitable for an intake in international standards. Specifically, it targets two missing Parts of the ISO 15530 series: Part 2 on a repetition and reversal method, and Part 5 on a method based on prior information and expert judgement. This aligns with the ISO/TC213/WG10's original plan formulated when designing the ISO 15530 series: two Parts on similar subjects were conceived but abandoned for a lack of resources in that particular Working Group. In addition to that, these methods will be disseminated to industry by means of a set of industrial EUCoM seminars spread in 10 different countries. This will provide early impact, given that the average time to publish ISO/TC213/WG10 standards is on the scale of several years.

Results

The project will provide two methods for evaluating the coordinate measurement uncertainty, in a form suitable for an inclusion in international standards. They are based on a posteriori (type A) and a priori (type B) evaluations and are candidates to become two missing Parts of the ISO 15530 series mentioned above.

Objective 1: The EN ISO 15530-3 provides an a posteriori method based on measurements of a calibrated workpiece. This calibrated workpiece is required to be identical to the actual workpieces. Effectively, the burden of the uncertainty evaluation is down to the person who calibrates the calibrated workpiece. The project will remove this limitation by restricting the experimental investigation to the workpiece under inspection. This will be applicable to a broad range of measurands (sizes, angles and geometrical features - related to datums and not related to datums) and probing conditions (discrete points and scanning).

Objective 2: The relevant ISO standards offer no guidance on uncertainty prediction. Currently, experts use their own knowledge while ordinary CMM users are unable to predict the uncertainty on their own. The project will overcome this problem by providing guidance to practitioners so they can predict the coordinate measurement uncertainty. The guidance will include a number of practical cases and uncertainty components.

Objective 3: The two proposed methods will be validated thoroughly. Several experienced partners from different countries, equipped with different CMMs, will provide robust evidence and ascertain the validity limits. The validation results will be made widely available to the public through country-based EUCoM seminars, an open source data repository, and ISO/CEN standards.

Objective 4: The ISO 15530-2 is currently under preliminary study in the ISO/TC213/WG10 (CMMs). No activity is foreseen for the new ISO 15530-5. The EN ISO 14253-2 is being considered for possible revision in ISO/TC213/WG4 (Uncertainty and decision rules). The project will provide input to the ISO/TC213/WG10 for developing ISO 15530-2 and ISO 15530-5. Some input may be given for a possible revision of the EN ISO 15530-3. If a revision of the EN ISO 14253-2 will be initiated by the ISO/TC213/WG4, an example in the field of coordinate measurement will be provided.

Impact

Impact on industrial and other user communities

The early impact of the project is concentrated on companies performing inspections. The project will provide them with viable methods for evaluating the uncertainty. This will enable them to make more reliable inspection-based decisions – such as acceptance or rejection of parts.

Many manufacturing companies are in an urgent need of guidance on evaluating the uncertainty, virtually all those with capabilities of coordinate measurement. The same applies to companies providing measurement services. The project will facilitate training between companies and EUCoM. Several EUCoM seminars in different countries and local languages will be given while EUCoM experts will participate in trade fairs and industrial conferences.

Impact on the metrology and scientific communities

The metrology community will benefit from the scientific contribution of the two developed methods in handling the long-standing scientific problem of evaluating the uncertainty in coordinate metrology.

Coordinate measurements are often instrumental for research in diverse scientific fields. The proposed methods will provide scientists – not necessarily metrologists – guidance to make their coordinate measurements metrologically sound in support of their researches.

Impact on relevant standards

ISO/TC213/WG10 (CMM) with ISO/WD 15530-2 on an a posteriori method and ISO 15530-5 on an a priori method will be impacted by this project. The former is currently at a preliminary stage while the latter is new. This project will also provide input for a possible revision of the EN ISO 15530-3. If the ISO/TC213/WG4 opens a revision on the EN ISO 14253-2, the project will provide an example in the field of coordinate measurement.

Longer-term economic, social and environmental impacts

A complete EN ISO 15530 series of standards covering diverse methods for evaluating the coordinate measurement uncertainty will help the CMM users in many years to come.

Economic impact: When a part or product is being inspected for acceptance, the uncertainty effectively competes with the manufacturing: given a certain tolerance, the larger the uncertainty, the larger the guard bands, and the narrower the acceptance zone left for production. Better control on the uncertainty evaluation will reduce conservative overestimation, and result in more margin.

A more reliable uncertainty evaluation will reduce either risk of false decisions, false acceptance (the consumer's risk) or false rejection (producer's risk). The former is about employment of nonconforming parts, with potential negative consequences such as faults in the assembly line, final rejection and waste of complete products, commercial loss in acceptance, loss of reputation to customers or to the market at large, disputes and even court cases. The latter is about waste of conforming parts, with potential consequences of direct loss of the production cost, delays in the subsequent manufacturing operations, and disputes with suppliers.

Environmental impact: A systematic and wide-spread reduction of false decisions in acceptance/rejection will lead to reduced waste. In false rejection, the conforming parts are wasted. When the material is recycled – e.g. aluminium – energy is spent on recycling; when it is not, disposal is required, with potential pollution issues. In acceptance testing of products, a false rejection leads to undue extra transportation to withdraw and then reinstate the product, which is a particularly sensible problem for heavy items. In false acceptance, the same consequences having a negative economic impact have an environmental one too. Faults in the assembly line results in a waste of energy (and time) in recovery of items or in resolving the issue. Wasting final products is even worse than wasting simpler parts.

Project start date and duration:	1st June 2018, 36 months	
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