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A new concept of continuous measurement and error correction in Coordinate Measuring Technique using a PC

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ABSTRACT

This article presents a new method of daily accuracy measurement with the employment of a Coordinate Measuring Machine (CMM) based on the mapping error procedure and the reduction of the error level through automatic corrections saved onto the matrix of CAA (Computer Aided Accuracy). Currently, measurements conducted using the Coordinate Measuring Machine do not guarantee credible and accurate results, owing to the fluctuation of CMM parameters over time as a consequence of its considerable dynamics of functioning. It would appear that the period in between the reverification test and interim checks is excessively long in the case of CMM. Automatic corrections saved onto the matrix of CAA are only optimal for the particular day on which those measuring procedures were conducted and there is no guarantee whatsoever that the above-mentioned corrections would be optimal for every single measurement conducted over time. For the purpose of establishing whether repeatedly performed measurements conducted in the same conditions would also retain the same value over time, four measurements were carried out, consisting in the verification of results of establishing the effective radius of the stylus tip over the course of ten consecutive working days. Those tests were conducted with the use of two CMMs (Kemco 600 CNC and Dea Global Image Clima (simplified test)) at five measurement speeds (5–50 mm/s). The results were presented of unadjusted and adjusted stylus/probing system qualification procedures. The procedure suggested and then tested in practice was based on the analysis of results in an external and independent Certification Centre. In addition, a practical test of the integration of the PS-20plus electronic module and a commercial measuring probe (Bipropol) was conducted.

1. Introduction

One of the key features of advanced manufacturing technologies is the metrology of geometric quantities. The instrument used to perform relevant measurements is the currently widely used Coordinate Measuring Machine (CMM) [1,2]. The CMM is employed for measuring features with a complicated structure in all applications where the capacity of “conventional” metrology is significantly limited. Sample applications include: measurements of 3D workpiece, form error, gears, cams and cutting tools. It should also be noted that the CMM makes it possible to carry out measuring tasks which, before the advent of this technique, could only be performed with the use of highly specialist devices (instruments for measuring roundness deviation). A general conclusion is, therefore, that this multi-purpose measuring technique has contributed to reducing the duration and costs of production, which is undeniably a major asset in the face of strong competition. Unfortunately, in spite of the indisputable benefits of the Coordinate Measuring Technique (CMT), a technique standing in opposition to traditional measuring methods, CMT also has one major fault in the form of

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incompatibility of results despite using CMMs with similar technical parameters and comparable conditions of measurement [3].

Most phenomena in our environment, as well as the problems related to them, are mathematically complex [4–7]. It is extremely difficult, and sometimes even impossible, to describe such phenomena using classic analytical methods [8–13]. This inspired the need to develop an appropriate and universal tool for solving this type of problem. Numerical methods are such a tool, as they allow the user to convert specific mathematical tasks to a form which can be used for Personal Computer (PC) computations [2]. Obviously, one of the problems related to this issue is the occurrence of certain types of errors, which are unavoidable for the simple reason that all numeric methods only approximate mathematical problems. As a consequence of the above, it would appear that it is necessary to fully test the errors resulting from the PC (with software) [11–26] or CMM [1–3,27–37] in order to minimise such errors.

2. Tests

In order to find out whether the repeatedly conducted measurement performed in identical conditions would have the constant value over time four tests were conducted, which consisted in the verification of the results of establishing the effective radius of the stylus tip over the course of ten consecutive working days. This is the first activity performed after CMM activation and the correct establishing of this value, which has a crucial importance on every measurement conducted at a later date. At the same time, the calculated radius of the stylus tip is a sufficient parameter on the basis of which it is possible to test the CMM's accuracy over time. Obviously, even when the majority of the CMM's components are functioning properly, it is necessary to take into consideration the influence of random error on the measurement results, but its value in "stabilized conditions" should be relatively insignificant. It was assumed that the reference point for all of the four tests conducted was the result of a reverification test which had been performed on the previous day. The procedure for stylus/probing system qualification was conducted at a very low speed (5 mm/s) and subsequently a motor body measurement was performed in the CNC (Computer Numeric Control) mode while employing a scanning speed of 10, 30, 40 and 50 mm/s. The CNC measurement was written in such a way that it was repeated on multiple occasions so that it might last two hours. The purpose of this multiple repeating procedure was to ensure the constant and steady functioning of the CMM in a precisely established time frame. Apart from the aforementioned activities, during the course of the test the CMM did not perform any additional measurements. Two CMMs were tested with similar values of Maximum Permissible Error (CMM Kemco 600 CNC → $E_{L,\ MPE}$ = 2.5 + L/350 μm and CMM Dea Global Image Clima → $E_{L,\ MPE}$ = 1.5 + L/333 μm) and equipped with different probes (Kemco → Bipropol and Dea → SP25 M (Renishaw).

In the case of Dea CMM the tests concerned the change caused by the stylus/probing system qualification conducted after one day's intensive scanning at high speed (difference: 0.3 μm). These two measurement systems were chosen because the characteristics of error correction in the function of scanning speed was known (it was obtained by the author). It was also noticed that although newer solutions were used in CMM Dea, compared to CMM Kemco, similar phenomena are observed in both cases. Therefore it may be safely said that highly intensive work at high speed may have a significant impact on the result of the stylus/probing system qualification), performer on the following day. Moreover, communication with other users of this measuring technique, mostly applicable in industrial environments, leads to the conclusion that this problem occurs even in highly intensive use of a CMM with ultra-accurate parameters (e.g. CMM UPMC CARAT (Zeiss), CMM Legex (Mitutoyo), CMM PMM (Leitz)). However, in this case, due to an elaborate system of sensors and an error correcting system, these differences are negligible, therefore in practice this unwanted phenomenon is hardly noticeable. Additionally, safe, low-speed measurements are recommended in ultra-accurate measurements [38–39].

The test was conducted in rooms with a maximum temperature drift amounting to 0.1°K. All the measurements were performed using a 20 mm long stylus tip with a ruby ball (with a radius of 0.5 mm) at its tip. It should also be noted that the reference part was screwed to the CMM table and its position was not altered during the duration of the test. The test results (for CMM Kemco 600 CNC) are presented in Fig. 1.

It is easy to notice that all the measurements are characterised by a certain diversification of results caused primarily by the values of $E_{L,\ MPE}$ parameter assigned to a given CMM and the set speed of performing the measurement procedure. Even a relatively low speed of conducting the measurement (10 – 30 mm/s) will cause a change in the characteristics of the stylus/probing system qualification procedure. On the other hand, increasing the measurement speed from a level of 40–50 mm/s in a significant way would deform the measuring volume of the CMM. It therefore needs to be assumed that those differences are so significant for "standard"-accurate CMMs. In such a case, approaching the level of the stylus/probing system qualification procedure result established on the very first day of the test (which is conducted on the day following

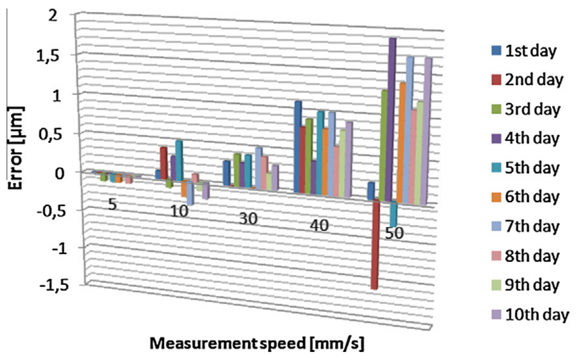

Fig. 1. The results of the stylus/probing system qualification procedure over the course of 10 consecutive working days (CMM Kemco 600 CNC).