Ain Shams University

Performance comparison of error mapping techniques for coordinate measuring machines "CMMs"

A THESIS

BY

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Statement

This thesis is submitted in partial fulfilment for the degree of Doctor of philosophy in Mechanical Engineering (Production), to the faculty of Engineering, Ain Shams University.

The work included in this thesis was carried out by the author at the laboratories of the department of Dimensional Engineering and surfaces, National Institute for Standard, Egypt, and Physikalisch – Technische Bundesanstalt (PTB), Germany.

No part of this thesis has been submitted for a degree or qualification at any other University.

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The undersigned certify that they have read and recommend to the Faculty of Engineering, Ain Shams University for acceptance a thesis entitled **(Performance comparison of error mapping techniques for coordinate measuring machines "CMMs")**, submitted by Shaban Ibrahim Moustafa, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Mechanical Engineering (Production).

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Dedications

I dedicate this thesis to my parents, my wife and my kids (Osama – Omar - Ranin)

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Performance comparison of error mapping techniques for coordinate measuring machines "CMMs"

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Abstract

Mechanical components must be measured to insure that they satisfy their design specifications. As one of the most powerful metrological instruments, coordinate measuring machines (CMMs) are nowadays widely used for a large range of such measurement tasks. The increased accuracies of mechanical components require a reduction in the uncertainties of measuring operation. This creates the need for higher accuracy performance of CMMs. The accuracy of CMMs strongly depends on its geometrical errors. As the geometrical errors can change significantly due to machine usage, hence the resulting accuracy variation has to be checked periodically.

On the other side, most of the standards and guidelines on the field of performance evaluation of CMMs require measurements to be traceable and measurement uncertainties be known. The evaluation of the measurement uncertainty is important and necessary when deciding whether a part conforms to design specification and to meet traceability requirements. Uncertainty in CMMs comes from many sources.Evaluation of the total uncertainty is difficult, due to the characteristic of a CMM as a multi-purpose measuring instrument. Moreover uncertainties vary with the task being performed, the

environment, the operator and the chosen measurement methodologies.

The research described in this thesis is divided into two closely related parts. The first part deals with the assessing of the geometrical errors and their influences on the accuracy of CMM .The second part deals with the evaluation of the uncertainty of CMM measurements. In the first part of the thesis, a comparison between the well-established reference plate method and the new laser tracer technique with multilateration approach for assessing the geometrical errors of CMM is presented and discussed. In the second part of the thesis, the uncertainty contributions during the measurement process is described and studied .The effect of the long term stability of the machine due to changes of the geometrical errors on the uncertainty budget is measured and presented. Finally, the length measuring uncertainty of CMM is constructed based on the measurement results obtained from the well-established reference plate method and the new laser tracer technique with multilateration approach.

The assessment of the geometrical errors of CMM and the evaluation of the measurement uncertainty described in this thesis consists of five chapters.

In chapter 1, the concept of coordinate metrology and types of Cartesian coordinate systems is given. The main components of CMMs and various design configurations and their characteristics are described. An overview of national and international standards regarding the performance evaluation of CMMs is discussed. The

chapter will end by the principle of traceability chain in coordinate measurements.

In chapter 2, an overview for the most of error sources affecting the accuracy of a CMM is given. The methods for measuring and compensating the geometrical errors are discussed. In addition, the sources of uncertainty in CMMs measurements and the methods for assessing these uncertainties are presented. Finally, the research objectives and the contents of the thesis are presented.

In chapter 3, the reference plate method for assessing the geometrical errors of CMMs is investigated and presented. The determination of geometrical errors by using the well established reference plate method and the new multilateration approach so called laser tracer is presented and discussed. The chapter will be ended with a comparison between the two methods for assessing the geometrical errors of CMMs.

Chapter 4 deals with evaluation of CMM measurement uncertainty. First, the uncertainty contributions on CMM measurements are given and the concept of the virtual method for assessing the uncertainties associated with CMMs is discussed. Then, the influence of the long term stability is considered and mathematically modelled with the other contributors according to the techniques outlined in the Guide to the Expression of Uncertainty in Measurement (GUM). Finally, the length measuring uncertainty of the CMM using the reference plate method and laser tracer technique is constructed and

discussed taking into account the influence of the long term stability on the uncertainty of the CMM.

This thesis will be ended by conclusions and recommendations given in Chapter 5

Keywords: coordinate measuring machines CMMs, calibration, geometrical errors, uncertainty and traceability.

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