A Study on Design of Artefact for Probe Type Co-Ordinate Measuring Machine Calibration

Ramesh Sanas[1] V.A. Kulkarni[2]
[1]PG Student in Production Engineering (Manufacturing and Automation),
[2]Assistant Professor in Production Engineering,
[1, 2] D. Y. Patil College of Engineering, Akurdi, Pune, India

Abstract--- The Co-ordinate measuring machines (CMM's) in industrial environments have become an important resource for the quality systems, monitoring manufacturing processes, reduction errors during manufacturing process, inspection of product specifications and in continuous quality improvement. Calibration means to identify the error behavior of measuring instruments and all planned applications. Parametric calibration, kinematic reference standard and artefact based method are types of calibrations which are used for CMM. Artefact is standard object from which measured results are compared with dimensions of the artefact to determine the errors in the machine. In this paper we present a study on optimal design of ball and plate type artefact used for calibration of probe type CMM. The study is more likely concern of size, shape & positioning of the balls on base plate.

Keywords: CMM, Calibration, Artefact.

I. INTRODUCTION

International standard ISO 10360-1 defines a co-ordinate measuring machine (CMM) as a measuring system with the means to move a probing system and capability to determine spatial coordinates on a workpiece surface. With the advent of numerically controlled machine tools, the demand has grown for some means to support this equipment. There has been growing need to have an apparatus that can do faster first piece inspection and many times, 100% dimensional inspection. The CMM plays a vital role in the mechanisation of the inspection process. Some of the CMMs can even be used as layout machines before machining and for checking feature locations after machining.

CMM's are relatively recent developments in measurement technology. Basically, they consist of a platform on which the workpiece being measured is placed and moved linearly or rotated. A probe attached to a head capable of lateral and vertical movements records all measurements.

CMM's are also called measuring machines. They are versatile in their capability to record measurement of complex profiles with high sensitivity (0.25 μm) and speed

CMM's are built rigidly and are very precise. They are equipped with digital readout or can be linked to computers for online inspection of parts. These machines can be placed close to machine tools for efficient inspection and rapid feedback for correction of processing parameter before the next part is made. They are also made more rugged to resist environmental effects in manufacturing plants such as temperature variations, vibration and dirt.

To give maximum rigidity to machines without excessive weight, all the moving members, the bridge structure, Z-axis carriage, and Z-column are made of hollow box construction. A map of systematic errors in machine is built up and fed into the computer system so that the error compensation is built up into the software. All machines are provided with their own computers with interactive dialogue facility and friendly software. Thermocouples are incorporated throughout the machine and interfaced with the computer to be used for compensation of temperature gradients and thus provide increased accuracy and repeatability.

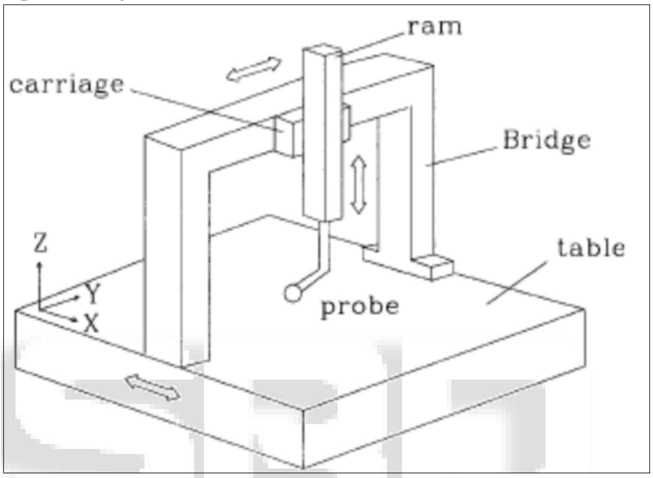

Fig. 1: Moving Bridge Type CMM.

II. ANALYSING THE PROBLEM

CMM as a measuring system with the means to move a probing system and capability to determine spatial coordinates on a workpiece. Growing need for flexible production system, CMMs are more and more placed outside the protective environment of metrology room, close to the production process.

The imperfections of the elements of machines (such as carriage & guide ways) can significantly influence the reported measurements results and manufacturing accuracy. At the temperature of 20 deg C geometric errors can be considered constant. Geometric errors compose the most representative fraction of the volumetric errors. Thermal effects were considered during design and development of the artefact which is the standard object used to calibrate CMMs.

III. PARAMETRIC CALIBRATION

The terms measurement error means the difference between the 'true value' and value found by a measurement. The evaluation of measurement uncertainty is complex as there are a variety of sources of errors and variation.

For a linear movable carriage, there are six types of parametric errors, the positioning errors along its linear moving direction, two mutually perpendicular straightness errors, three angular error motions which are roll, pitch and yaw. For a 3-axis machine, there exist 21 parametric errors which are expressed as the functions of the position co-ordinates [5]. For each axis, there are one positioning errors, 3 angular errors, and 2 straightness errors. In addition there are three orthogonality errors between each axis. The volumetric error of any particular point within the working zone can be calculated by using rigid body kinematics.

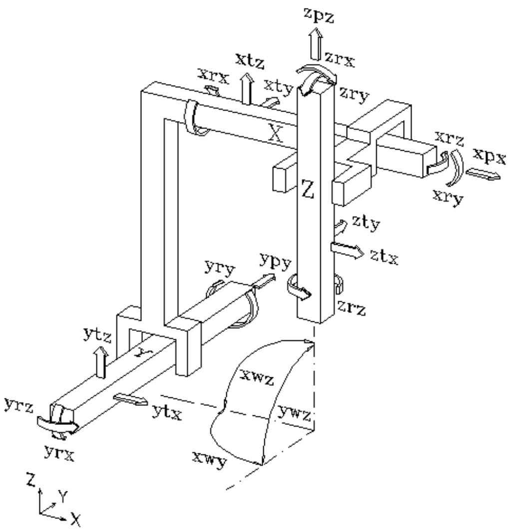

Fig. 2: Parametric errors of a three-axis CMM

The uncertainty for every individual CMM is specific to a particular task and depends on various issues like sampling strategies, probe errors, residual systematic errors, fitting algorithms used and the ambient conditions.

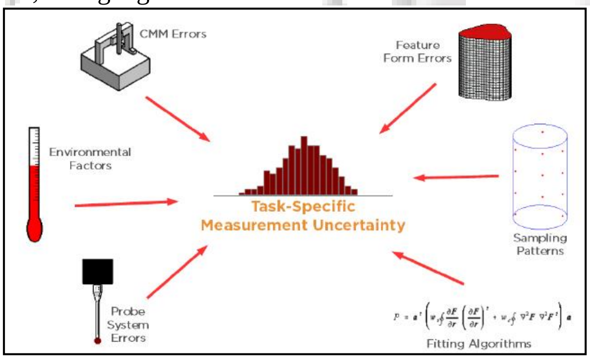

Fig. 3 – Factors affecting Uncertainty

IV. Calibration Of CMM & Practices Followed

The term calibration means to identify the error behaviour of a measuring instrument and all planned applications. Completely known error behaviour would allow for the prediction of the final accuracy of the measurement task.

A large variety of methods for calibrating and checking CMMs and machine tools have been suggested and applied during the past several years. These methods can be basically classified into three types, [6]

A. *Parametric calibration*.-

Machine are generally composed of moving carriage, tables or other elements whose purpose is to position the workpiece with respect to the probe or cutting tool. A typical linear carriage has six degrees of freedom. It is traditional to design it to behave as a rigid body with five of its six degrees of freedom eliminated, then to drive the element in the remaining direction. Errors in the motion of the individual element are referred to as 'parametric error'. In this calibration method all or part of 21 parametric errors has taken into consideration.

B. *Kinematic reference standard (KRS)-*

This method is based on measuring volumetric errors with some type of kinematic reference standard. The most popular kinematic reference used is a ball bar. When the ball bar is used on the machine, it realizes circular paths supper positioned with deviations due to different errors of the tested machine.

C. *Artefact based method-*

This method is based on measuring a standard artefact object by the machine. The measured results are compared with the dimensions of the artefact to determine the error of the machine. Such artefact can take a multiplicity of forms, but are usually according to the number of spatial coordinates associated with the principal calibrated features.

V. Artefact & Types

Artefact is standard object. Measured results are compared with the dimensions of the artefact to determine the errors of the machine. Below are the some of the commonly used artefacts for calibration of CMMs.

A. *Kinematically Mounted Ball Bar.*
B. *Test Sphere.*
C. *Step Gauge.*
D. *Hole Plates.*
E. *Pivoting Ball Ended Arm*
F. *Ring Gauge*
G. *Ball Plates with Spheres in the Neutral Bending Plane.*

VI. Proposed Design Of Artefact

A. *Base plate material and manufacturing method selection*
B. *Layout drawing of the Base plate*
C. *Number of holes in line on the plates and size of the hole*
D. *Combination of plate and round ball.*
E. *Positioning of balls on the plate.*
F. *Flatness, perpendicularity and parallelism are within 10 microns.*
G. *Hard chrome balls of Grade-10 used.*
H. *Determination of Plate and ball shape and size for CMM measuring volume*
I. *Deflection analysis of the Base plate*

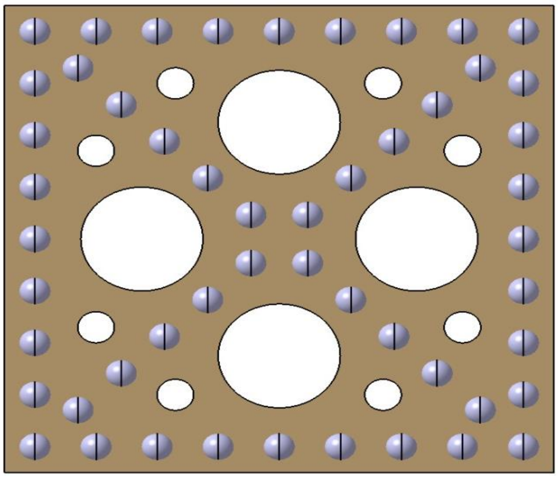

Fig. 4: Proposed Artefact design

VII. CONCLUSIONS

At this stage study of various artefact used for calibration of CMMs are carried out. Size, shape, material and effect of environmental factors are considered for artefact design. ISO 10360-1standard is referred for while design of the artefact.

VIII. FUTURE SCOPE

Design intended artefact to be manufacture as per tolerances consideration. Temperature stability analysis at different environmental conditions should be carried out. This can be considered for the future work.

The analysis results can be imported from FEA and correlated with actual results obtained from test carried at experimental conditions.

ACKNOWLEDGMENT

I would like to express my special thanks of gratitude to our Head of Department & project guide Mr. V. A. Kulkarni who gave me the golden opportunity to do this paper presentation on the topic “A Study on Design of Artefact for Calibration of Probe Type Co-Ordinate Measuring Machine”. The same which has also helped me in doing a lot of Research and came to know about so many new things. Secondly I would also like to thank my parents and friends who helped me a lot in preparing this paper within the limited time frame.

REFERENCES

[1] E.S.Lee and M. Burdekin, “A Hole-Plate Design for the Volumetric Error Calibration of CMM”, Int J Adv Manuf Technol, Springer-Verlag London Limited, 2001
[2] Valdes R. A., B. Di Giacomo and F. T. Paziani, “Syntesization of Thermally induced Errors in Coordinate Measuring Machines”, J. of the Braz. Soc. Of Mech. Sci. & Eng., Volume XXVII Issue 2, PP 170-177, April-June 2005
[3] Jean-Pierre Kruth, Paul Vanherck, Christophe Van den Bergh, Benny Schacht, “Interaction between workpiece and CMM during geometrical quality control in non-standard thermal conditions ”, Precision Engineering, Volume 26, pp 93-98, April 2002.
[4] Makoto Abbe, Kiyoshi Takamasu and Shigeo Ozono, “Calibration Of Cmm By 3-dimensional Coordinate Comparison”, Tsukuba Institute of Research and Development, Mitutoyo Corporation.
[5] F.P. d’Hooghe, P. Schellekens and L. Levasier “Geometric Calibration Of CMMs Using 3d Length Measurements”, Section Precision Engineering, Eindhoven University of Technology The Netherlands.
[6] Y. Wang, K.S. Moon and J.W. Sutherland, “Theoretical Examination of A new Calibration method for Multi-Axis Machines”, Manufacturing Science and technology, Volume 2, pp 427 -433, 1997.
[7] L. Arriba, E. Trapet, M. Bartscher, M. Franke, A. Balsamo,G. Costelli, S. Torre, F. Kitzsteiner, F. San Martín, “Methods and Artifacts to Calibrate Large CMMs”
[8] Ryoshu Furutani, Kotaro Kamahora, “Development of a new artifact for the calibration of large scale Instruments ”. Measurement, volume 30, PP 139-143, 2001.

