11.0 Conclusion and Future Scope

11.1 Conclusion

Metrology in recent years has witnessed growing requirements in terms of reduction in measurement lead time and human intervention coupled with increased accuracy and reliability. CMM (Coordinate Measuring Machine) fulfils this requirement. CMM is a device which enables dimensional and form measurements to users, even for complicated 3D objects. Numerous techniques for monitoring the long term stability and accuracy of CMM are required to be studied and modified according to growing dynamic needs of user. One of them involves used of artifacts. These artifacts are not only used for CMM evaluation but also for interim checks of CMM. There are numerous types and configurations of artifact used in industry. As artifacts of suitable design can reveal probing errors in addition to axis movement errors that are normally calibrated using laser interferometers, artifacts usage is most preferred. The objective of work was therefore to design, fabricate and test an artifact suitable for industrial application. After summarizing the existing artifacts for CMM Calibration and studying their relative advantages and limitations, desirable qualities of the artifact that could be used for CMM interim checks were finalized. Normally, in practice, calibration period is always kept in mind and errors occurring during in between calibration are not addressed upon. The “Ball-Plate” is the most popularly used artifact made up of various materials, geometries and configurations. Continual desire to produce a ball plate mimicking measurement process to actual workpiece is the primary need for interim check. In this work, a Ball Plate is produced with various advantages made up of Zironia (Ball Material) and Dolerite (Plate Material). Zirconia (Ball material) having less coefficient of thermal expansion \( (6.3 \times 10^{-6}/\degree C) \) and high flexural strength is used. Use of Zirconia eliminates the requirement of existing practice of producing a blind hole to fix the sphere to the plate by T-slot, reducing \( \frac{1}{10} \) th of the cost of production. This low cost feature enables, more use of spherical balls in array of 50 mm, with added advantage of estimating volumetric error. Use of Loctite H3101 structural to mount the sphere on plate enables replacement of balls without any damage to plate. Dolerite (Plate Material) indigenized granite having very less coefficient of thermal expansion \( (2.4 \times 10^{-6}/\degree C) \) and nil porosity percentage is used. The developed artifact is recommended to be used up to 22.5\( ^\circ C \) with a total directional deformation below 2\( \mu m \) and even up to 24\( ^\circ C \) its average deformation is...
1.503 µm. Flatness, Parallelism, Straightness of all faces of dolerite plate is within 2.5 µm. The cost of artifact is ₹1,19,041/- and can be kept at operator end for interim checks as and when required. The geometrical calibration of CMM in contrast costs about ₹ 3,00,000/- for one time setup as per present practice. The total weight of plate is 18 Kg and it can therefore be easily transported by operators as and when required. The linear distance between balls is only computed for geometrical error estimation by CMM itself, eliminating special measurement requirements and instruments. The ball plate is used without any external support in all measurement process.

The cross-correlation indicates that the ball plate can retain its dimensions for 10 months without any requirement of recalibration even if the plate is not kept continuously in standard metrological conditions. The auto-correlation indicates good closeness of ball distances over the span of interim check for 1 year. The ball plate can be used for computing 19 geometrical errors out of 21 and also its diagonal arrangement of spherical balls enables volumetric error determination. These geometrical errors can be pooled for characterizing error maps for given CMM and look up table is established. Due to symmetricity of ball plate, formation of CMM program is much easy which also enables operator for quick interim check. The program required 22 minutes for measurement in each plane. The total interim check with 20 errors (19 Geometrical and 1 Volumetric) will require 75 minutes. Operator himself can conduct all necessary steps without requirement of calibration expert. The ball plate artifact enables mathematical compensation of linear distance measurement as individual geometrical errors can be computed. Every time, interim checks are conducted, their records of ball distances are used for further analysis. This record can be used for process capability analysis (coupled with simulation, if required) can lead to identification of best job position computation of a CMM under test.

11.2 Future Scope

1. With the advent of enhanced manufacturing features in future, instead of circular grooves on ball plate, other shapes such as triangular or hexagonal grooves, can be formed for reduction in weight.

2. The width of the plate also can be reduced from 40 mm to thinnest possible without hindering feature of “Usage without external support”
3. Further research can be carried out for volumetric determination in array of less than 50 mm for enhanced accuracy.

4. Efforts can be made to form non-linear compensation in measuring volume of CMM.