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Surface Plate Based Method for Quick Check CMM Accuracy Measurement

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Abstract: ***Coordinate Measuring Machine is now mandatory in Industries for not only dimensional measurement but also form measurement of jobs. However, due to changes in temperature in Indian Scenario, Rigidity of guide ways, frictional bearings, it is always susceptible for error development. These errors if not addressed, integrates into dimensional measurement of workpart, which remains induced due to measurement system error. Best position of job in entire volume of CMM affects the accuracy of measurand and is the deciding factor in CMM measurement.***

An attempt is made in this paper, to establish low cost surface plate based method for quick check CMM accuracy measurement by operator only without requirement of Laser CMM expert. The outcome of method depicts closeness within 3 µm with laser interferometer.

This saves at least two lakhs rupees per three months and the total saving will be 6 lakhs rupees, annually.

Index Terms**:** ***CMM, Surface Plate, Quick Check, Error***

I. INTRODUCTION

Coordinate Measuring Machine (CMM) is a measurement system with coordinate measuring probes, computer assisted measurement systems, guideway systems for probing. Due to inertia, hysteresis loss, rigid body errors gets induced in CMM, which in turn affects the measurement uncertainty of the measurand.

ANSI/ASME B89.4-2004 recommends performance test by using specially designed kinematic model with material standards like Ball Bar, coupled with original machine coordinate test [1]. The Guide to expression of uncertainty in measurement (GUM) method and ISO 15530 method impacts the maximum permissible error of CMM and are close to the CMM measurement system chosen [2]. Also the precise definitions of uncertainty points reflects the total accuracy of CMM [2]. The Type B GUM method is not a practical solution for CMM, as material properties continuously varies and cost of repetitive measurements are very high [3]. On the contrast Type A GUM method recommends evaluation of condition under the same repeated measurements with Standard Deviation as the indictor of uncertainty measurement. Simulation measurement presented in [3] is a time consuming process.

2D dimensional standards like hole plate artefact, ball plate artefact, ball bars effectively measures the performance of CMM, as they can be oriented in 3D space effectively, provided that no external support is given to them. External support increases the complexity of thermal interactions and in turn affects uncertainty in measurement [3, 4].

The calibration comparison of 2D dimensional standard is taken into consideration for error computation [4].

ISO/DIS 8512/2-1988 derives the standard for usage of granite surface plate. The surface plate is made of stable, wear resistant and scratch free steel surfaces. The surface plate is manufactured holding uniform texture close grained and free from flaws. Surface plate therefore makes it perfect job for measurement and also as reference standard for further processing. Surface plate is easily available in CMM environment.

II. EXISTING METHOD

Existing method of quick check is done by using a Tetrahedron Artefact and Endurance part inspection.

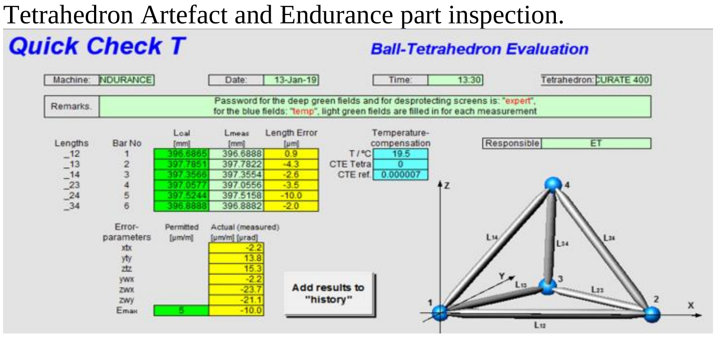

Fig 1: Quick Check using Tetrahedron Artefact

Tetrahedron is an artefact with induced rigid body errors like deflection, non-covering of orientation in entire measuring volume of CMM. The length error maximum, shows 10 µm which is much more than acceptable 5 µm norms as shown in fig 1. The expanded Uncertainty is given by, $U = k(a^2+b^2L^2)^{1/2}$ µm, where k is material constant, a and b are method variants and L is length of the measurand [4].

The surface plate is a 2D artefact which is free from rigid body errors and also less temperature variant. It is used a material sensor for measuring orientation errors resulted due to measurement of pitch, yaw and roll errors, that is not approximated and eliminated by CMM.

III. OBJECTIVE OF RESEARCH

Research needs to be carried out for quick check accuracy of CMM, to be self-carried out by operator and using Surface Plate. The resulted procedure is then validated with Laser to make it as a standard operating procedure.

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IV. NEW METHOD

Surface plate is oriented in different planes of CMM and errors are computed.

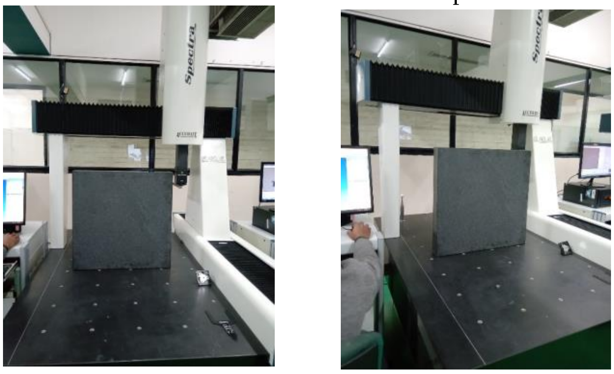


Fig 2: Orientation of Surface Plate and coordinate computation by using CMM a) Side Orientation computation (XY Computation) b) Back orientation computation (YX Computation)

Similarly, Surface plate can be oriented in ZX plane.

Errors reflected Keeping in ZX Plane [3]

1. Straightness of Z in Y axis.
2. Straightness of X in Y Axis.
3. Roll of Z Axis.
4. Pitch of Z Axis
5. Roll of X Axis.
6. Yaw of X Axis

Distribution points are then collected and entire machine table can be modeled as shown in figure 3

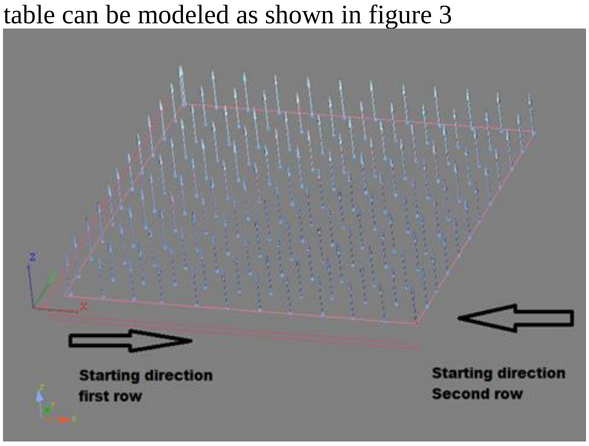


Fig 3: Distribution Points Modelled To Reflect CMM Work Table.

It is therefore evident that, If error is larger than 5 µm, then distribution points shows the error at every point.

The resultant flatness measured, by using Surface Plate are Flatness Measured in XY, ZX and YZ plane:

1. Flatness in XY…………………..7 Microns
2. Flatness in ZX…………………...6 Microns
3. Flatness in YZ…………………...6 Microns

At the time of calibration of CMM, the value of flatness is 4 microns, therefore actual errors in machine are up to 4 microns as shown in following table 1.

Sr. No.	Flatness Measurement by using Surface Plate	Flatness Error at the Calibration of CMM	Effective Flatness error resulted in CMM
1.	XY – 7 µm	4 µm	3 µm
2.	ZX – 6 µm	4 µm	2 µm
3.	YZ – 6 µm	4 µm	2 µm

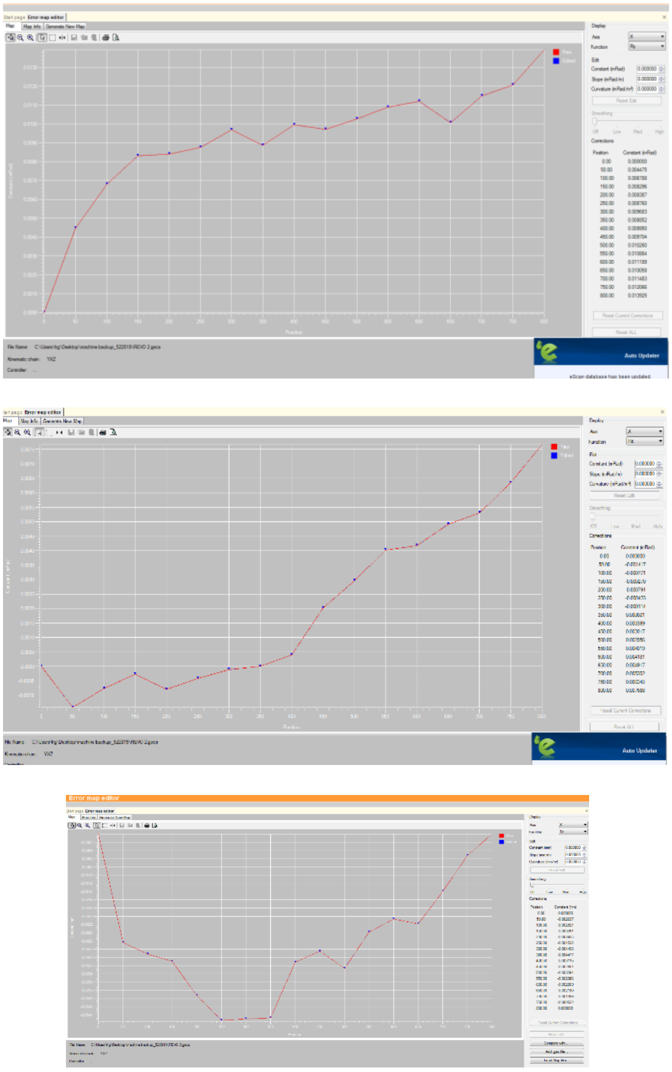
Calibration value of flatness is 4 microns of CMM therefore actual errors in machine are very less and within the 5 µm value.

If flatness errors are within 3 µm in all plane indicates that, machine is well error mapped and machine is mechanically lapped.

V. VALIDATION BY LASER INTERFEROMETER

Laser Interferometer is used for flatness error induced in CMM machine [5]. The flatness test is used to evaluate uncertainty in error measurement and sources of identification of error.

Fig 4, shows the flatness errors resulted in all three measurement plane.



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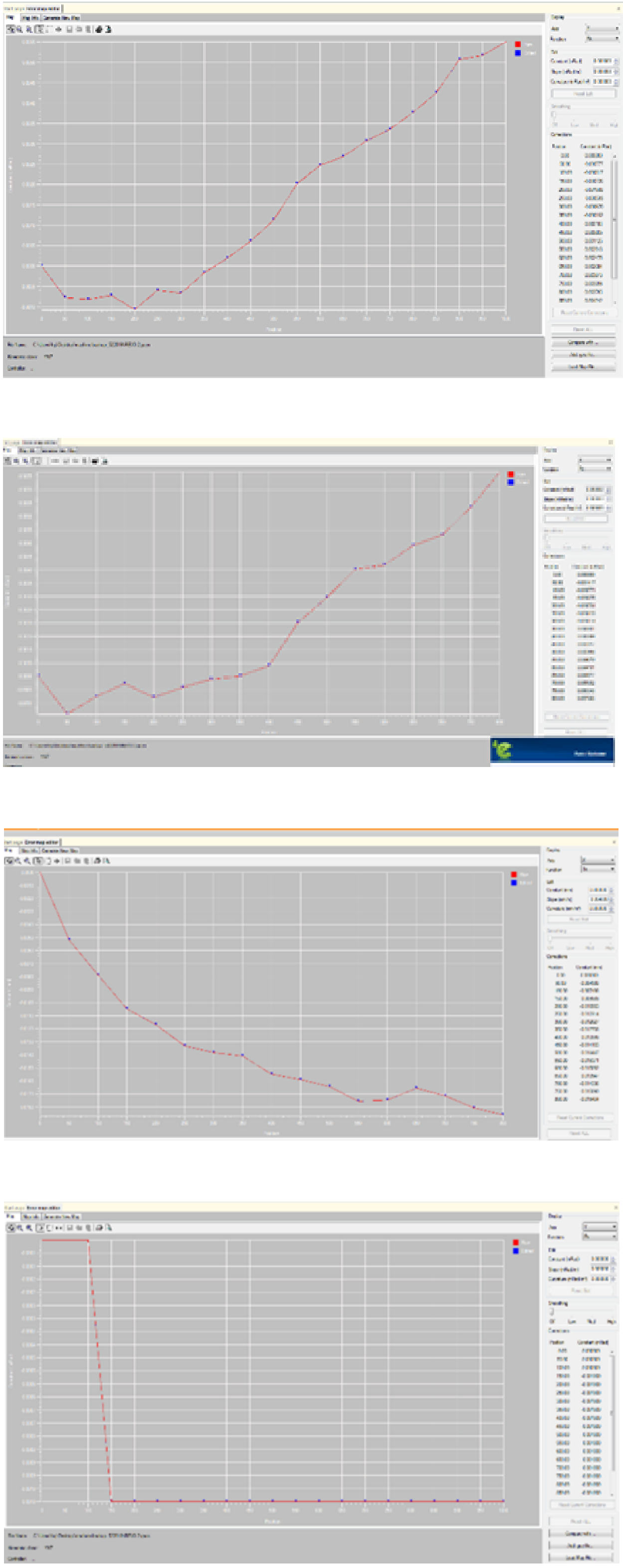


Fig: 4: Laser Data Of Flatness Error Measurement Various Planes.

From figure it is evident that, machine flatness errors induced in CMM, reflected by Laser is less than 3 µm.

Therefore surface plate data, reflected in Table 1 is validated by using Laser Interferometer flatness testing.

VI. CONCLUSION

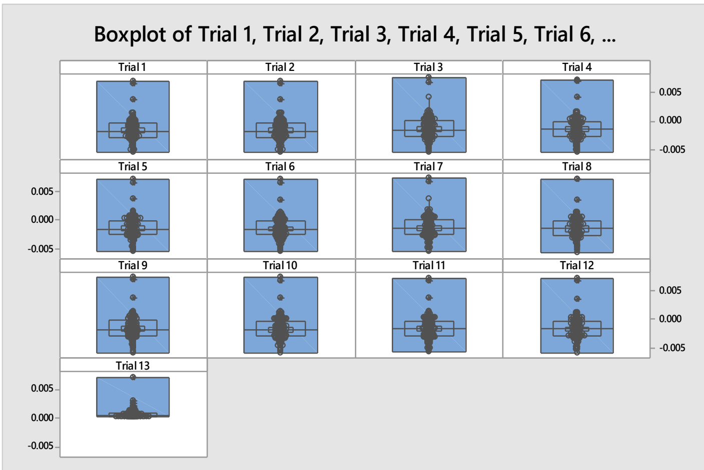
The CMM is extensively used in nearby manufacturing premises. CMM hence used is susceptible for variations due to inherent rigid body errors and nearby nonstandard metrological conditions. This increases, the risk of error build up faster than specified in calibration conditions. CMM therefore is required to undergo frequent interim checks at regular intervals. The error should not be more than 5 µm at any point of time during the operations of CMM.

ISO prescribes low cost, material standards to be developed, which can be self-operated by machine operators enabling frequent checks.

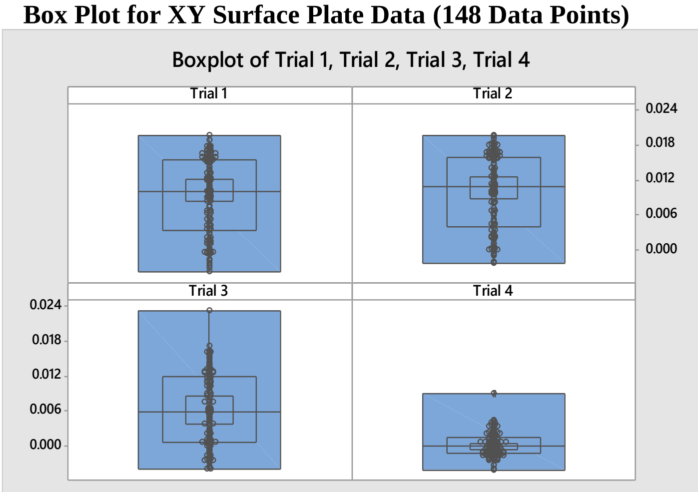
Attempt is made in this paper, to utilize highly rigid, wear and scratch resistant artefact as Surface Plate and its point distribution system as indicated in above research work.

The Laser operations requires 2 lakhs rupees per visit without machine compensation that can be directly saved by flatness measurement through surface plate by operator themselves. This results into 6 lakhs rupees saving per annum enabling the low cost solution.

APPENDIX



Box Plot for XY Surface Plate Data (148 Data Points)



Box Plot for XZ Surface Plate Data (133 Data Points)

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Inspection Report							
Company:	External-Array Software(DEMO).19.10930						
Date:	Monday, February 04, 2019						
Time:							3:05:16 PM
Part Temperature:	20.0C						
WITH ERROR MAP	RUN1						
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0023	0.0023	0.0010	0.0013		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0059	0.0059	0.0010	0.0049		
RUN 2							
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0025	0.0025	0.0010	0.0015		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0066	0.0066	0.0010	0.0056		
RUN 3							
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0023	0.0023	0.0010	0.0013		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0062	0.0062	0.0010	0.0052		
WITHOUT ERROR MAP							
RUN 1							
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0023	0.0023	0.0010	0.0013		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0054	0.0054	0.0010	0.0044		
RUN 2							
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0024	0.0024	0.0010	0.0014		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0054	0.0054	0.0010	0.0044		
RUN 3							
TFLT2 [DEMO Version] Eval Feat = PLN_BF_4_POINTS CRD2/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0023	0.0023	0.0010	0.0013		
TFLT3 [DEMO Version] Eval Feat = PLN_BF_132_POINTS CRD3/MM/ANGDEC							
	Nom	Act	Dev	TolZone	Trend		
	0.0000	0.0063	0.0063	0.0010	0.0053		

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