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Pooled Error Mapping of Probe Type Coordinate Measuring Machine

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Abstract— Ball plate made up of Zirconia-Dolerite material is developed for extracting error maping of coordinate measuring machine in the entire measuring volume. CMM is used for measuring a discrete point in 3D space. Therefore a point is most adequate artefact to the CMM, which advocates usage of Sphere.A high flextural strength of Zirconia delivers the special requirement of chipping resistance required in ball plate. Specially planned experimental setups, demonstrate geometrical error determination.

Index Terms— CMM, Ball Plate, Zirconia-Doleriate, Geometricla Errors, Error Mapping, Measuring Volume, Flextural Strength, Discrete Points, Experimental Setups

1 INTRODUCTION

The CMM (Coordinate Measuring Machine) as a measuring system with means to move a probing system and capability to determine spatial coordinates on work piece surface. National and International standards prescribe special tests on simple artefacts for CMM verifications. Various materials for different artefacts are referred by researchers. B. Bringmann, A. Kung (2005) had explained the application of kinematic artefact on a three axes machine tool. Carmignato, Voltan et al (2010) used optomechanical hole plate with distances between the centers of 25 holes on a steel sheet of 0.1 mm thickness.

In this paper, planned experimental method is demonstrated for pooled error mapping of probe type coordinate measuring machine on a specially designed and developed ball plate artifact.

2 ZIRCONIA-DOLERITE BALL PLATE

A ball plate formed by Zirconia (Ball)-Dolerite (Plate) material is designed, processed, manufactured and developed for the purpose of interim check of CMM. The developed Zirconia – Dolerite ball plate demonstrated less coefficient of thermal expansion, better scratch resistance, high degree of compactness and considerable flexural Strength, very low thermal conductivity, less weight movable by operator, wide coverage of entire measurement volume.

Zirconia balls are glued using Structural bond adhesive Loctite H3101. This eliminates the requirement of a blind hole in Zirconia balls for fixing on ball plate with T-slots. A specially designed through groove of 5 mm as shown in Figure 1 eliminates the problems of air pocketing during structural bonding of zirconia balls with dolerite plate.

CMM is used for measuring a discrete point in 3D space. Therefore a point is most adequate artefact to the CMM, which advocates usage of Sphere. This also provides advantage of using Centre of spheres as reference points.

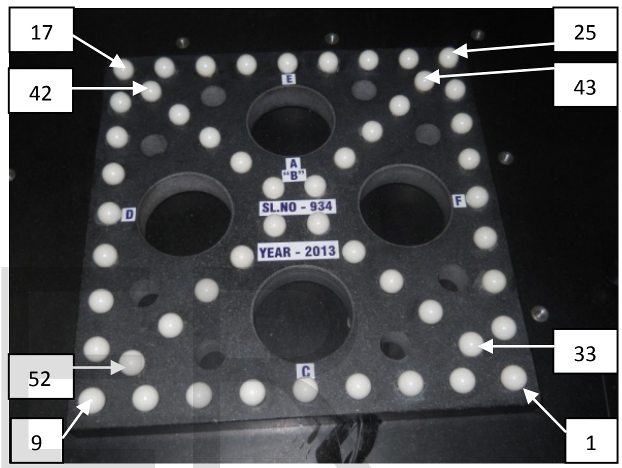

Fig. 1. Zirconia-Dolerite Ball Plate

2.1 Error Mapping of CMM

Distances between balls are measured for error map.
At 20^0C, ball paltes distances are picked up by high acuurate CMM and are refered as reference values for further measurement.

Table 1: Distance between Balls

Ball Distance	Unit (mm)	Element No.	Unit (mm)
1-2	49.9654	1-32	50.0464
1-3	99.9061	9-10	49.858
1-4	149.9338	9-11	99.8829
1-5	200.1647	9-12	149.8905
1-6	250.0814	9-13	199.8033
1-7	299.8975	9-14	249.9483
1-8	349.8052	9-15	299.8911
1-9	399.9123	9-16	349.9368
1-25	400.1492	9-17	399.8921
1-26	350.1116	17-18	50.0005
1-27	300.1497	17-19	100.0238
1-28	250.1574	17-20	149.9551
1-29	200.0519	17-21	199.9534
1-30	150.1383	17-22	249.9106
1-31	100.0441	17-23	299.804

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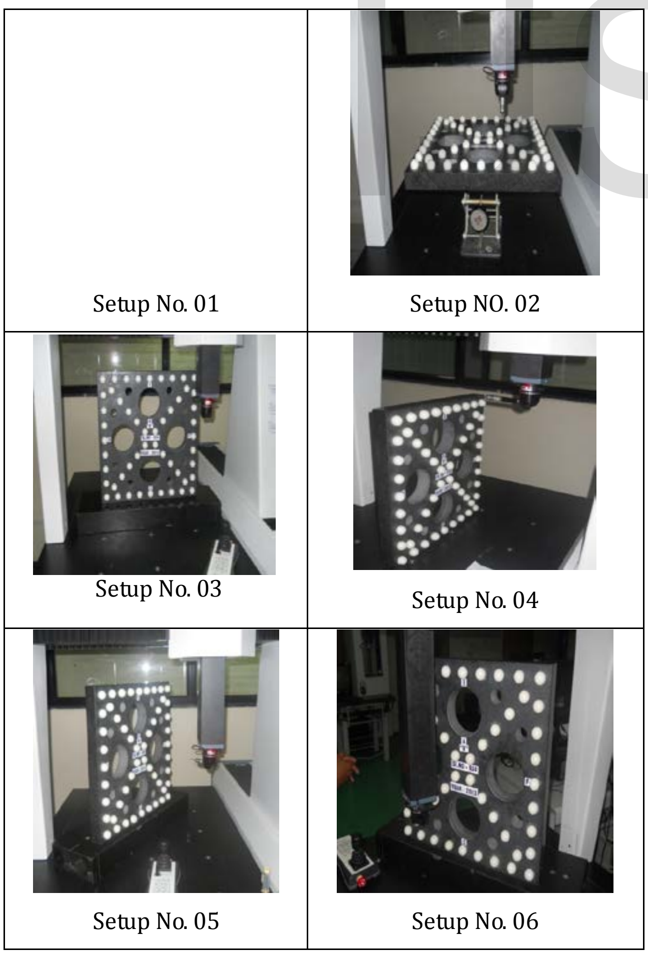
Ball Distance	Unit (mm)	Ball Distance	Unit (mm)
17-24	349.7521	1-17	565.7309
17-25	399.7637	9-52	49.3748
1-33	49.9835	9-51	100.0488
1-34	99.9726	9-50	149.6783
1-35	149.9113	9-49	199.9566
1-36	199.8623	9-48	249.5523
1-37	249.9107	9-47	315.4193
1-38	315.5788	9-46	365.6003
1-39	365.3787	9-45	414.8572
1-40	415.5511	9-44	465.7893
1-41	465.6812	9-43	515.5453
1-42	515.7218	9-25	565.4408

Error Measurements of CMM described in ISO 10360 series contain tests with a different concept. By using an Artefact such as ball plate, all the three-dimensional position error components (in X,Y and Z) for the given reference location are directly measured over the entire measuring volume.

2.2 Error Map of CMM machine by using Ball Plate

A CMM is selected for the trials. On the CMM this artefact is placed in different locations and orientations. The recommended locations, orientations and corresponding experimental setup are shown in fig 2



Setup No. 01 | Setup NO. 02 | Setup No. 03 | Setup No. 04 | Setup No. 05 | Setup No. 06

Fig 2: Experimental Setup for CMM Error Map

Setup No. 1:-

1. Keep the ball plate in XY plane. Ball No. 1 should be very close to Y zero and ball No. 9 should be very close to X zero.
2. Measure distances between balls 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 1-9.
3. Measure distances between balls 1-32, 1-31, 1-30, 1-29, 1-28, 1-27, 1-26, 1-25.
4. Measure distances between balls 9-10, 9-11, 9-12, 9-13, 9-14, 9-15, 9-16, 9-17.
5. Find the difference values from right deviations to left deviations. Differences at every point are the Yaw of Y-Axis.
6. On the straight edge side along X axis measure points to find the X horizontal straightness.
7. On the straight edge side along Y axis measure points to find the Y horizontal straightness.
8. Find the angle between straight edges along Y and X axes to find the XY squareness.

Setup No. 2:-

1. Keep the ball plate in XY plane at best height possible. Ball No. 1 should be very close to Y zero and ball No. 9 should be very close to X zero.
2. Measure distances between balls 1-32, 1-31, 1-30, 1-29, 1-28, 1-27, 1-26, 1-25. It is Y linear.
3. Find the difference values from right deviations to left deviations. Differences at every point are the Pitch of Y-Axis.
4. Measure distances between balls 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8, 1-9. It is X linear.
5. Find the difference values from bottom deviations to top deviations. Differences at every point are the Pitch of X-Axis.

Setup No. 3:-

1. Keep the ball plate on surface C and in ZX plane.
2. Measure distances between balls 1-32, 1-31, 1-30, 1-29, 1-28, 1-27, 1-26, 1-25. It is measured for Linear Z.
3. On the surface E measure points at every 50 mm distances to measure X vertical straightness.
4. On the surface D measure points at every 50 mm distances to measure Z horizontal straightness.
5. ZX squareness is measured on the surface D with respect to surface C.
6. Measure distances between balls 17-18, 17-19, 17-20, 17-21, 17-22, 17-23, 17-24, 17-25 with minimum probe extension.
7. Measure distances between balls 17-18, 17-19, 17-20, 17-21, 17-22, 17-23, 17-24, 17-25 with maximum probe extension.
8. Find the difference values from maximum (50 mm extension is used) and minimum probe extension. Differences at every point are the Yaw of X-Axis.

Setup No. 4:-

1. Keep a ball plate on surface C and in YZ plane probing direction in X negative.
2. On the surface E measure points at every 50 mm distances to measure Y vertical straightness.
3. On the surface D measure points at every 50 mm distances to measure Z Vertical straightness.
4. ZY squareness is measured on the surface D with respect to surface C.
5. Measure points on surface D with horizontal probe with minimum extension in X negative direction. Again measure same points with maximum extension. The difference is a roll of Z Axis.

Setup No. 5:-

1. Keep a ball plate on surface C and in diagonal direction to measure the volumetric readings
2. Measure distance between balls 1-33, 1-34, 1-35, 1-36, 1-37, 1-38, 1-39, 1-40, 1-41, 1-42, 1-17

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3.Measure distances between balls 9-52, 9-51, 9-50, 9-49, 9-48, 9-47, 9-46, 9-45, 9-44, 9-43, 9-25

Setup No. 6:-

1. Keep a ball plate on surface C and in diagonal direction 90 degrees to previous to measure the volumetric readings.
2. Measure distances between balls 1-33, 1-34, 1-35, 1-36, 1-37, 1-38, 1-39, 1-40, 1-41, 1-42, 1-17
3. Measure distances between balls 9-52, 9-51, 9-50, 9-49, 9-48, 9-47, 9-46, 9-45, 9-44, 9-43, 9-25

Tables (2-4) shows experimental results for corresponding setups followed by radar charts showing graphical distribution of error values in entire measuring range of CMM.

	Table 2: Geometrical Error Values of X- AXIS				
Position	Linear	Pitch	Yaw	V-Straightness	H-Straightness
0	0	0	0	0	0
50	-0.0005	-0.0022	0.0008	-0.001	-0.0012
100	0.002	0.0014	0.001	0.0008	0.0025
150	-0.0011	-0.0022	0.0009	0.0001	-0.0033
200	-0.0021	-0.0029	0.0016	0.0015	-0.0047
250	0.0766	-0.0082	0.0019	0.0008	0.0005
300	-0.0063	-0.0089	0.0025	0.0016	-0.0082
350	-0.0073	-0.0041	0.0032	0.002	-0.0095
400	-0.0027	0.001	0.0024	0.0008	-0.0067

	Table 3: Geometrical Error Values of Y AXIS				
Position	Linear	Pitch	Yaw	V-Straightness	H-Straightness
0	0	0	0	0	0
50	-0.0142	-0.0196	0.0008	-0.0015	-0.0013
100	-0.0275	-0.029	-0.0015	0.0016	-0.0044
150	-0.0109	-0.0104	0.0012	-0.0006	-0.0017
200	-0.0217	-0.0233	-0.002	-0.0004	-0.0047
250	-0.0138	-0.0158	-0.0009	-0.0015	-0.0006
300	-0.0174	-0.0176	-0.0033	-0.0024	-0.0031
350	-0.0135	-0.017	0.0001	-0.0057	-0.0009
400	-0.0449	-0.0444	-0.0088	-0.0018	-0.0074

	Table 4: Geometrical Error Values of Z AXIS					
Position	Linear	Pitch	Yaw	Roll	V-Straightness	H-Straightness
0	0	0.0000	0	0	0	0
50	-0.0065	-0.0015	0.0030	0.0003	0.0002	-0.001
100	-0.0084	0.0006	0.0028	-0.0004	-0.0003	0.0008
150	-0.0049	0.0031	0.0030	-0.0016	0.0002	0.0001
200	-0.011	0.0063	0.0030	-0.0009	0.0005	0.0015
250	-0.0045	0.0079	0.0031	-0.0004	0.0006	0.0008
300	0.0176	0.0060	0.0032	0.0002	0.0004	0.0016
350	-0.0018	0.0057	0.0028	-0.0009	-0.0004	0.002
400	0.0022	0.0024	0.0033	-0.0013	-0.0003	0.0008

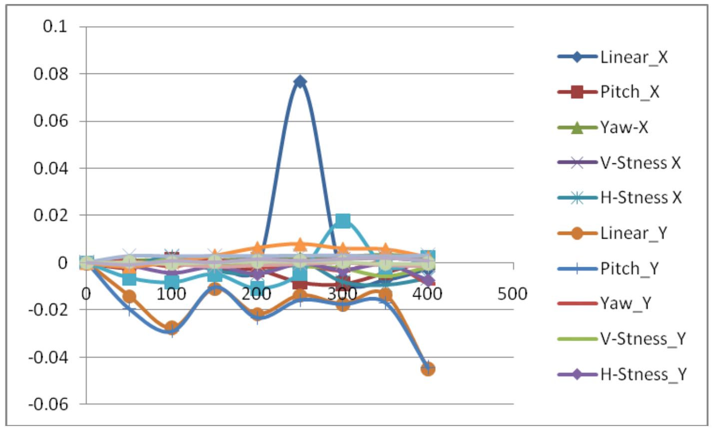

Fig 3.: Resulting Error Map

As shown in Fig 3, the resulting error map shows maximum deviation in Linear X from 200 to 300 mm distance and next deivation is observed in Lineary Y and pitch Y.
The measuring volume therefore should be good indication for job placement for measurement.

Conclusion

A Zirconia-Dolerite plate for a specific geometry is developed on which Zirconia balls are glued using Structural bond adhesive Loctite H3101. Dolerite is better than granite as it provides no porosity. The manufacturing and operating cost of this ball plate is considerably low and requires one time setup for entire calibration of ball plate.
The Zirconia-Dolerite Ball plate shows the measuring volume of CMM that can be mapped with Geometrical Errors.

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