Studies related the measurement errors determination in case of inclined surfaces measurement on Coordinate Measurement Machines

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Abstract. Coordinate measurement machines (CMM) are an important part of production process technology that help and give a fast response in complex measurement situations. Although the technologies advance in high speed, old coordinate measurement machines are capable to give accurate results. The present paper will give an alternative to use this type of machines, machines that are operated manual or with rudimental software that are not upgraded with actual technologies. In order to be possible to measure an inclined surface with a coordinate measurement machine we need to consider that the contact approach between the coordinate measurement machine tool and the measured part must respect some elementary steps: the movement of the coordinate measurement machine probe must be on same direction as the surface vector that we want to measure, the contact force must be the same as the force used for calibration of the probe. All this are very difficult to be respected with a manual or oldcoordinate measurement machine. During measurement with machines that doesn't allow probe angle control an error can appear for surfaces that are positioned at an angle to the reference surface. This article presents one way to can eliminate measurement errors on Coordinate measurementmachines for inclined surfaces.

1. Introduction

The appeared error for surfaces that are positioned at an angle to the reference surface is due to the fact that the stylus enters in contact earlier with the work piece. It is supposed that calculated dimension will take into account Point 1 from the surface of the stylus, but in fact the stylus is coming in contact with the work piece in Point 2, phenomenon graphically illustrated on Figure 1.

This difference will generate a measurement error, and the measured value can be lower or higher than the real distance, in function of inner or outer surface is measured.

This error was observed by measuring control points on complex surfaces of the electrodes used for spark erosion in the manufacturing of the cavities of the high pressure diecasting tools.

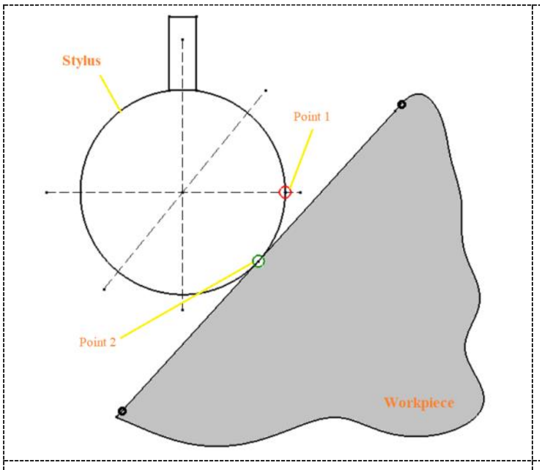

Figure 1. Theoretical and real contact points between the stylus the work piece

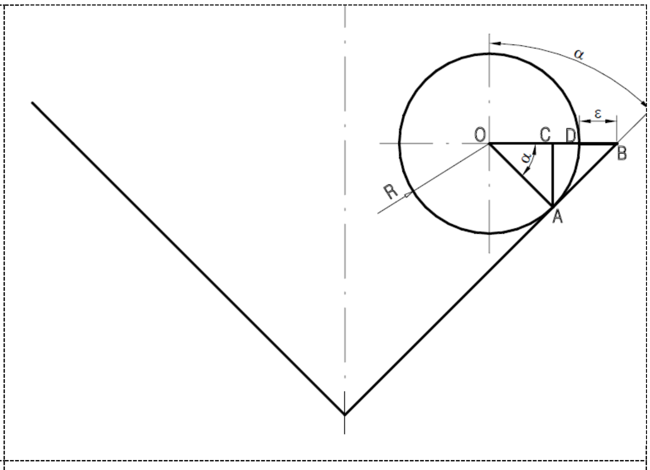

Figure 2. Schematical representation of the stylus in contact with the work piece

2. Theoretical consideration

In the Figure 2 are represented the main parameters that have influence on the error determination: ε – measurement error.

These parameters are:

R – Radius of the stylus used during the measurement
α – draft angle of the surface on which the asked length is measured

3. Methodology and material .Working procedure

For the determination of the measurement error ε was used the following algorithm:

$$\Delta OAB: \cos\alpha = \frac{OA}{OB} = \frac{OA}{OD + DB} = \frac{R}{R + \varepsilon} \Rightarrow \tag{1}$$

$$\cos\alpha \cdot (R + \varepsilon) = R \Rightarrow \tag{2}$$

$$\varepsilon = \frac{R - R\cos\alpha}{\cos\alpha} = \frac{R \cdot (1 - \cos\alpha)}{\cos\alpha} \tag{3}$$

The relation has been verified by measuring a prism with $2 \cdot \alpha = 90^\circ$, respectively a prism with $2 \cdot \alpha = 130^\circ$ on a Zeiss Vista CMM machine.
In the tables 1 and 2 are summarized the values of the errors for exact draft angles in case of stylus with a sphere diameter of 1 mm, respectively 2 mm.

Table 1. Measurement errors in function of draft angle with stylus diameter of 1 mm

D	R	α	ε	D	R	α	ε
1	0.5	1	0.0001	1	0.5	46	0.2198
1	0.5	2	0.0003	1	0.5	47	0.2331
1	0.5	3	0.0007	1	0.5	48	0.2472
1	0.5	4	0.0012	1	0.5	49	0.2621
1	0.5	5	0.0019	1	0.5	50	0.2779
1	0.5	6	0.0028	1	0.5	51	0.2945
1	0.5	7	0.0038	1	0.5	52	0.3121
1	0.5	8	0.0049	1	0.5	53	0.3308
1	0.5	9	0.0062	1	0.5	54	0.3507
1	0.5	10	0.0077	1	0.5	55	0.3717
1	0.5	11	0.0094	1	0.5	56	0.3941
1	0.5	12	0.0112	1	0.5	57	0.4180
1	0.5	13	0.0132	1	0.5	58	0.4435
1	0.5	14	0.0153	1	0.5	59	0.4708
1	0.5	15	0.0176	1	0.5	60	0.5000
1	0.5	16	0.0201	1	0.5	61	0.5313
1	0.5	17	0.0228	1	0.5	62	0.5650
1	0.5	18	0.0257	1	0.5	63	0.6013
1	0.5	19	0.0288	1	0.5	64	0.6406
1	0.5	20	0.0321	1	0.5	65	0.6831
1	0.5	21	0.0356	1	0.5	66	0.7293
1	0.5	22	0.0393	1	0.5	67	0.7797
1	0.5	23	0.0432	1	0.5	68	0.8347
1	0.5	24	0.0473	1	0.5	69	0.8952
1	0.5	25	0.0517	1	0.5	70	0.9619
1	0.5	26	0.0563	1	0.5	71	1.0358
1	0.5	27	0.0612	1	0.5	72	1.1180
1	0.5	28	0.0663	1	0.5	73	1.2102
1	0.5	29	0.0717	1	0.5	74	1.3140
1	0.5	30	0.0774	1	0.5	75	1.4319
1	0.5	31	0.0833	1	0.5	76	1.5668
1	0.5	32	0.0896	1	0.5	77	1.7227
1	0.5	33	0.0962	1	0.5	78	1.9049
1	0.5	34	0.1031	1	0.5	79	2.1204
1	0.5	35	0.1104	1	0.5	80	2.3794
1	0.5	36	0.1180	1	0.5	81	2.6962
1	0.5	37	0.1261	1	0.5	82	3.0926
1	0.5	38	0.1345	1	0.5	83	3.6028
1	0.5	39	0.1434	1	0.5	84	4.2834
1	0.5	40	0.1527	1	0.5	85	5.2369
1	0.5	41	0.1625	1	0.5	86	6.6678
1	0.5	42	0.1728	1	0.5	87	9.0537
1	0.5	43	0.1837	1	0.5	88	13.8269
1	0.5	44	0.1951	1	0.5	89	28.1493
1	0.5	45	0.2071				

Table 2. Measurement errors in function of draft angle with stylus diameter of 2 mm

D	R	α	ε	D	R	α	ε
2	1	1	0.0002	2	1	46	0.4396
2	1	2	0.0006	2	1	47	0.4663
2	1	3	0.0014	2	1	48	0.4945
2	1	4	0.0024	2	1	49	0.5243
2	1	5	0.0038	2	1	50	0.5557
2	1	6	0.0055	2	1	51	0.5890
2	1	7	0.0075	2	1	52	0.6243
2	1	8	0.0098	2	1	53	0.6616
2	1	9	0.0125	2	1	54	0.7013
2	1	10	0.0154	2	1	55	0.7434
2	1	11	0.0187	2	1	56	0.7883
2	1	12	0.0223	2	1	57	0.8361
2	1	13	0.0263	2	1	58	0.8871
2	1	14	0.0306	2	1	59	0.9416
2	1	15	0.0353	2	1	60	1.0000
2	1	16	0.0403	2	1	61	1.0627
2	1	17	0.0457	2	1	62	1.1301
2	1	18	0.0515	2	1	63	1.2027
2	1	19	0.0576	2	1	64	1.2812
2	1	20	0.0642	2	1	65	1.3662
2	1	21	0.0711	2	1	66	1.4586
2	1	22	0.0785	2	1	67	1.5593
2	1	23	0.0864	2	1	68	1.6695
2	1	24	0.0946	2	1	69	1.7904
2	1	25	0.1034	2	1	70	1.9238
2	1	26	0.1126	2	1	71	2.0716
2	1	27	0.1223	2	1	72	2.2361
2	1	28	0.1326	2	1	73	2.4203
2	1	29	0.1434	2	1	74	2.6280
2	1	30	0.1547	2	1	75	2.8637
2	1	31	0.1666	2	1	76	3.1336
2	1	32	0.1792	2	1	77	3.4454
2	1	33	0.1924	2	1	78	3.8097
2	1	34	0.2062	2	1	79	4.2408
2	1	35	0.2208	2	1	80	4.7588
2	1	36	0.2361	2	1	81	5.3925
2	1	37	0.2521	2	1	82	6.1853
2	1	38	0.2690	2	1	83	7.2055
2	1	39	0.2868	2	1	84	8.5668
2	1	40	0.3054	2	1	85	10.4737
2	1	41	0.3250	2	1	86	13.3356
2	1	42	0.3456	2	1	87	18.1073
2	1	43	0.3673	2	1	88	27.6537
2	1	44	0.3902	2	1	89	56.2987
2	1	45	0.4142				

4. Conclusions

It is recommended that during the measurements of inclined surfaces on CMM machines that doesn't allow probe angle controlthe value of this determinate error to be taken into account, respectively the calculated correction to be applied. Under the correction appliance is understood the adding or subtracting of the value of the correction.

Under correction is understood the value which has to be added or subtracted to the/ from the measured value.

This value is determinate as follows:

- For internal conical or inclined surfaces when the inner diameter or dimension is determinate, to the measured value will be added 2 ε
- For external conical or inclined surfaces when the external diameter is determinate ,from the measured value will be subtracted 2 ε
- For the internal inclined surfaces when the distance of a point or axis is determinate to a reference, to the measured value is added ε;
- For the external inclined surfaces when the distance of a point or axis is determinate to a reference, from the measured value is subtracted ε;

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