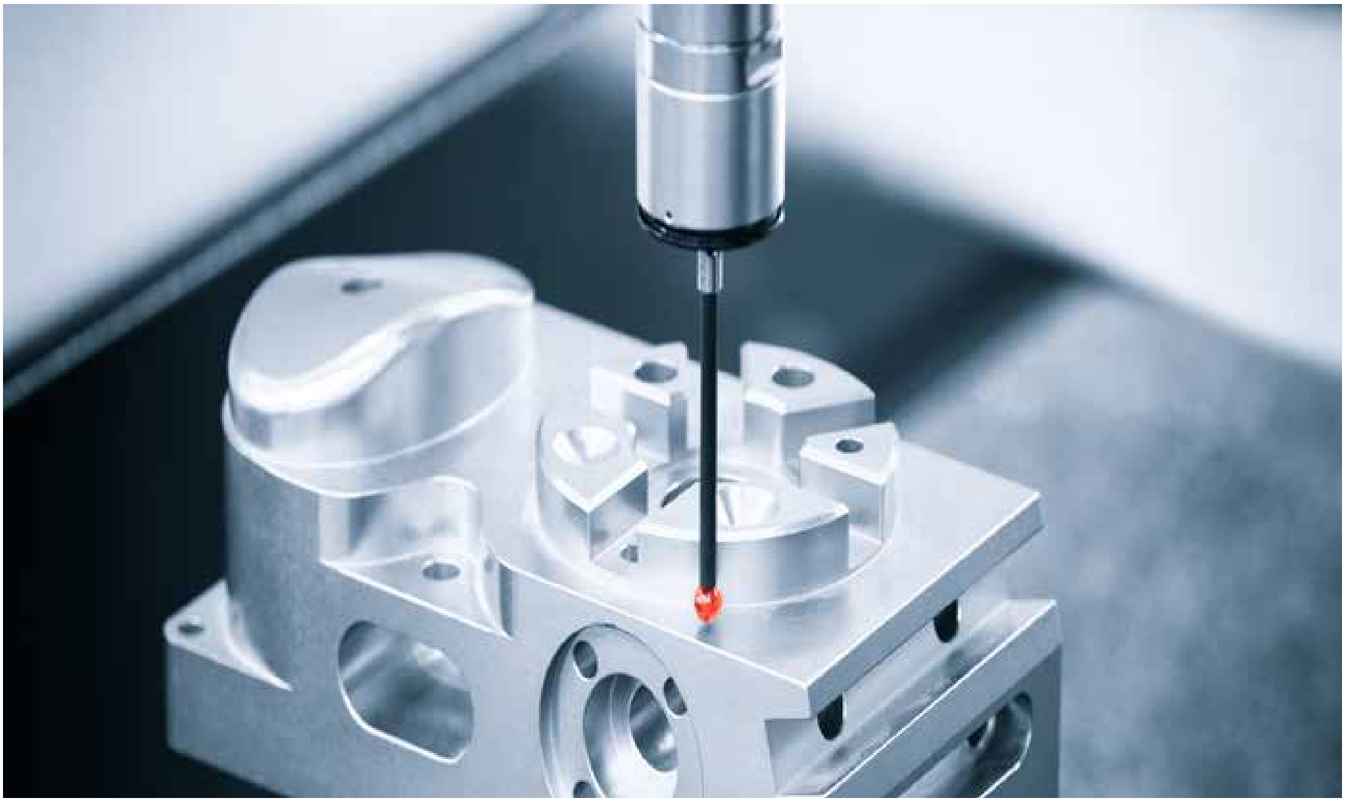

TECH FRONTIERS

Measurement challenges in coordinating measuring machines

Overcoming the challenges faced by industries in measurements with coordinating measuring machines (CMM)

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MANUFACTURING processes are driven by set objectives in achieving quality output with constraints in time and cost. It is always possible to achieve the quality objectives with less lost time and lower cost; higher quality standards are set and driven by stringent design tolerances and reliable measurements.

If we recall the industrial development over decades, we observe a fact that production parts are getting smaller and smaller. This has been made possible by the development of more accurate and faster metrology equipment and methods. The introduction of metrology laboratories, callipers, micrometers, dial indicators, and high accuracy gauging have all played their part in improving the measuring accuracy and quality control of products.

In order to measure increasingly stringent tolerances, the formula devised by Prof. Georg Berndt, known as the 'golden rule of metrology,' should be adhered to – the measuring uncertainty should not exceed 1/10 of the permissible tolerance.

Design tolerances are categorised as:
Conventional +/- tolerancing:
- linear dimensions and tolerances
- angular dimensions and tolerances

Geometric tolerancing:
- form tolerances
- location tolerances
- orientation tolerances
- runout tolerances
- profile tolerances.

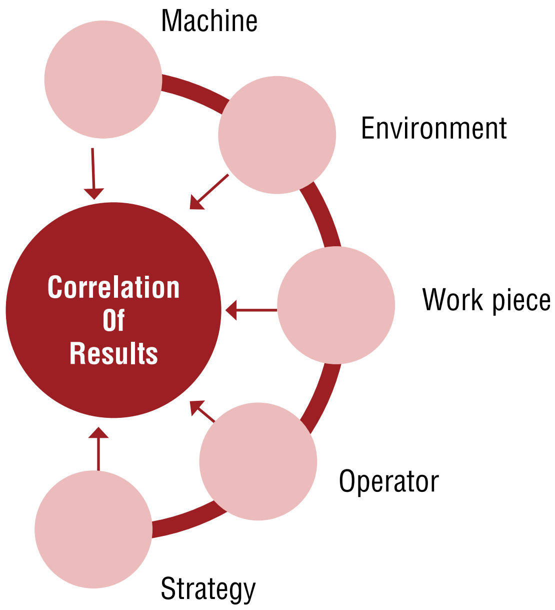
While we look at challenges of the measurements, there are various influencing factors classified under measuring machines, environment, work piece, operator, and measurement strategy.

To address these challenges, AUKOM Germany, along with its research partners, had carried out a three-year research project providing a machine-independent training concept, including established and practice-tested procedures with interfaces for the manufacturer-specific machine.

The overall goal was to create a uniform metrology industry to help streamline best practices of coordinate metrology on a global scale.

Some of the challenges observed are listed here.

Figure1: Factors influencing measurements



CONCENTRICITY

Coaxiality tolerance according to ISO 1101

One of the most complex tasks that are carried out by coordinate measuring machines (CMM) is the verification of coaxial deviation of cylindrical features.

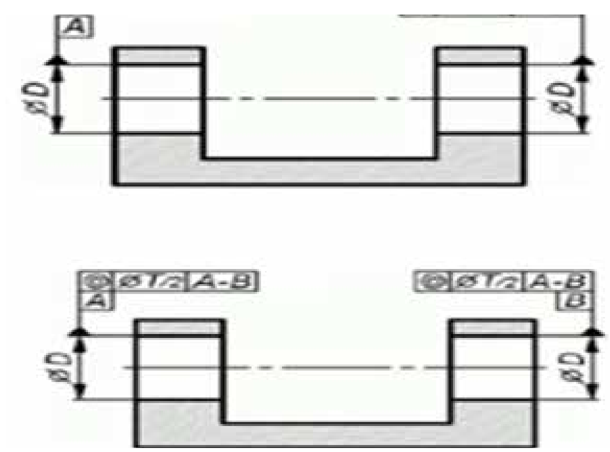
Measuring challenges – concentricity

The reliability of CMM concentricity and coaxiality deviation measurements depends on:
- The length of the datum feature.
- The intermediate distance between the controlled feature and the datum feature.

Developed approach – concentricity

The developed approach is illustrated in **Figure2** and encompasses the following

Figure2: Developed approach – concentricity



steps:
i. A series of circular cross-sections, typically four to eight, are taken on the full length, of the toleranced feature and their centres are established.
ii. The set of points created in Step i are used by the CMM measurement software for the construction of the 3D axis of the toleranced feature.
iii. A series of circular cross-sections, typically four to eight, are taken on the full length, LD, of the datum feature and their centres are established.
iv. The set of points created in Step iii are used by the CMM measurement software for the construction of the 3D axis of the datum feature.
v. The full set of points created in both Steps i and iii are used by the CMM measurement software for the construction of a 3D axis.
vi. The coaxiality deviations of the toleranced feature and the datum feature's axes from the axis constructed in Step v are evaluated with the standard measurement procedure of the CMM software.
vii. The component is in tolerance only if the coaxiality deviations of both the toleranced and the datum feature are within half the originally designated TCOX cylindrical tolerance zone (T/2) established from the common 3D axis that was constructed in Step v.

The proposed CMM measurement approach allows for an alternative kind of specific control of feature-to-feature coaxiality.

It is strongly based on the concept of compound datum feature that appears in ISO 1101 and ISO 5459 [18] and allows for a common axis construction that can be used as a single datum.

Moreover, the proposed approach offers high repeatability of CMM coaxiality measurement results which cannot be achieved by the standard CMM strategy for components/equipment that do not meet the standard criteria.

Figure1: Factors influencing measurements

Datum feature

A datum feature is selected on the basis of its functional relationship to the toleranced feature and the requirements of the design. To ensure proper assembly, corresponding interfacing features of mating parts should be selected as datum features.

However, a datum feature should be accessible on the part and of sufficient size to permit its use.

Datum features shall be readily discernible on the part. Therefore, in the case of symmetrical parts or parts with identical features, physical identification of the datum feature on the part may be necessary.

The approach of the above steps can only be considered as an alternative under the following conditions:
a. On both the datum and the measured features certain accuracy and geometrical characteristics (e.g. tolerances of form, limits of size, surface roughness, nominal diameter, symmetrical location on the part) are identical and/ or of the same range.
b. All members of the engineering team involved in product development (design, manufacturing, inspection, assembly, …) concurrently approve the modified coaxiality CMM verification method, being aware that it does not directly correspond to the design intend as denoted on the

original blueprints.

Reference: ASME Y 14.5 – 2018

Case study – Developed approach for concentricity

The effectiveness of the proposed approach for this kind of engineering problem is illustrated in a typical industrial case study. A rotary shaft with overall length of 540 mm has an ISO 1101 coaxiality tolerance specification of TCOX=0.08 mm that concerns the two cylindrical features on its left and right ends.

In the engineering drawings the designated datum for coaxiality is the cylinder in the right end of the component and the toleranced feature is the cylinder in its left end. Their lengths are 72 mm (LD) and 80 mm (LF) respectively.

Measurements were performed by means of a direct computer controlled CMM (Mistral, Brown & Sharpe-DEA) with ISO 10360-2 max. permissible error, 3.5(μm)+L(mm)/250 and PC-DMIS v.4.2 measurement software.

The numerical result produced for coaxiality deviation by the standard CMM measurement procedure was 0.096 mm, which means that the feature is out of tolerance and that the part has either to be reworked or rejected. However, according to the coaxiality tolerance verification methodology the coaxiality deviation of the toleranced feature was 0.008 mm and that of the datum feature was 0.013 mm. These measured values are considerably lower than half the designated coaxiality tolerance (TCOX/2), thus the component is accepted.

Using the designated datum feature the total runout deviation of the toleranced feature was also measured and found to be 0.074 mm. In the case that the coaxiality tolerance was specified as per ASME Y14.5 in its engineering drawings,the approach presented, the component would also have been accepted.

The fact that the application example component actually fulfils the design requirements that are implied by the coaxiality tolerance allocation was experimentally verified and well approved by fitting the specific component in an existing assembly.

The interchangeability and the conformance with functional requirements of a component that without the application of the proposed approach should have been rejected, demonstrate its effectiveness.

TEMPERATURE COEFFICIENT

Most materials expand with increase in temperature; for this reason 20°Celsius has been established as the standard reference temperature.

The standards ISO 1 establishes that all the dimensions are specified at this temperature. Even small deviations have significant effects on dimensions. Thus, a 1m (at 20°C) long piece of steel will be 10 micro metre longer in size at 21°C.

Case study – Temperature effects on CMM

A fully environmental controlled quality room is prepared where the specifications are as follows:

- ***Room size***:
- ***Temperature control***: 20 +/- 0.5°C
- ***Temperature gradient***: 0.5°C per hour
- ***Relative humidity***: 45-55%
- ***Dust control***: Double room arrangement for the entry
- ***Illumination***: 500 Lux

Figure4: Differing temperature gradients

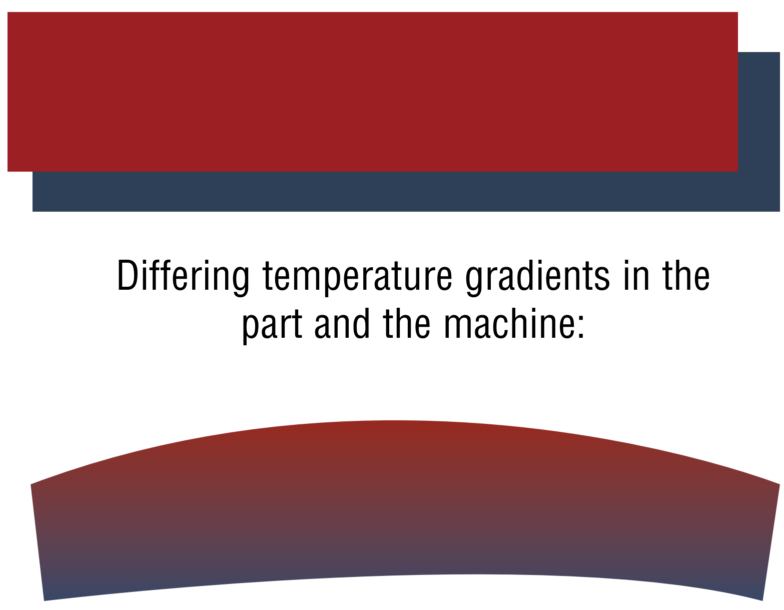
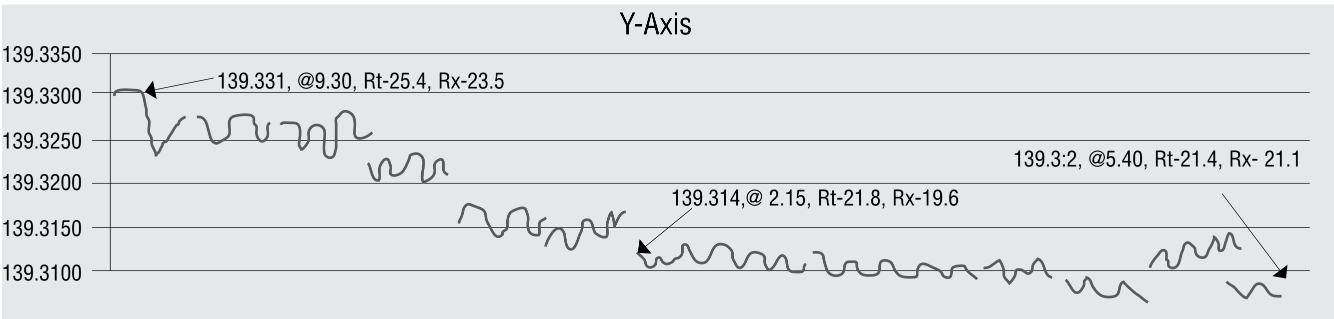


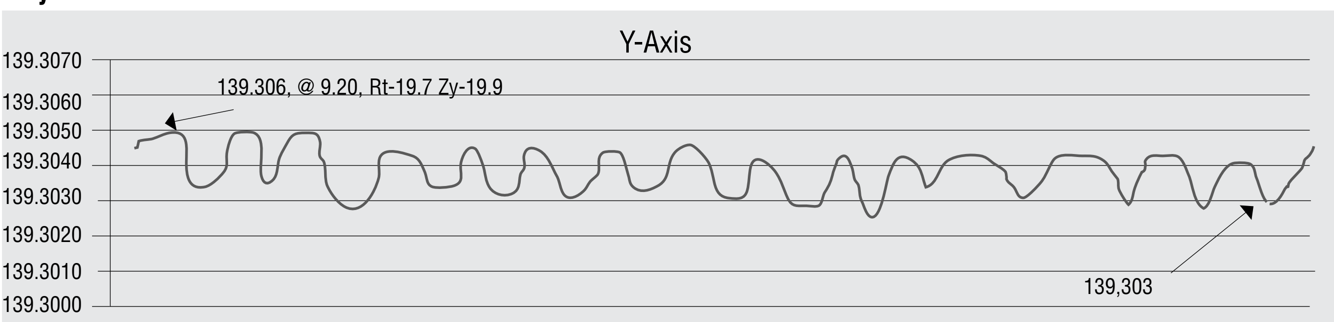
Figure5: Environmental controlled quality room



Comments: (Full Day)

1. Axis- Y-Axis
2. Reading Stabilization Time - 4.45 Hours
3. Room temperature at the beginning - 25.4 Degrees
4. Room Temperature at stable reading- 21.8 Degrees
5. Reading difference at stable point from beginning - 0.017 mm.
6. Reading difference in stable time span - 0.002 mm.

Day 07-24.09.2019



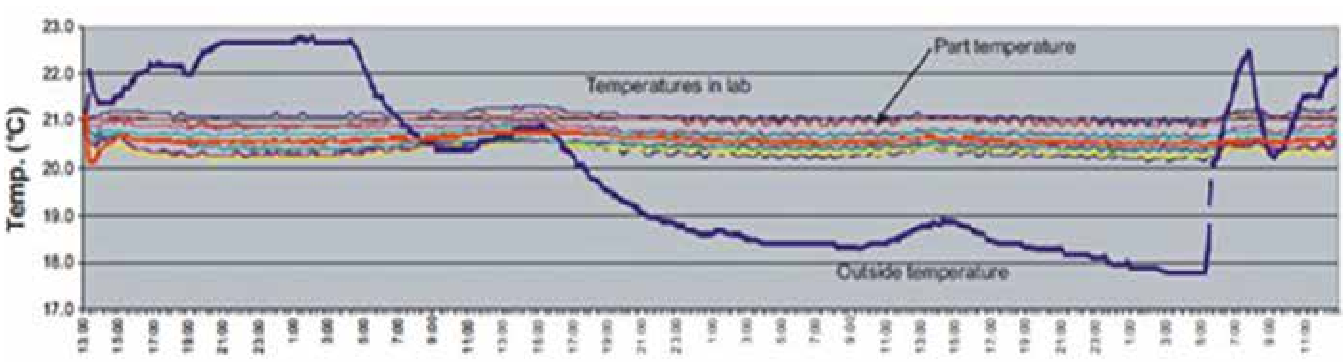
Comments: (Full Day)

1. Axis- Y-Axis
2. Reading Stabilization Time - AC run overnight
3. Room temperature at the beginning - 19.7 Degrees
4. Room Temperature at stable reading-
5. Reading difference at stable point from beginning - 0.002 mm. from last evening
6. Reading difference in stable time span - 0.003

Summary Table

Date	Day	Axis	Reading Stabilisati on Time in Minutes	Room Temp. Stabilisati	Room Temp. Stabilisati on	Reading dift. start & Stabilisati on	Reading Variation in Stabilisati on	Remarks
17.09.19	1	Y	120	21.8	19.3	7	5	Started Afternoon
18.09.19	2	Y	245	25.4	22.1	17	2	Full Day
19.09.19	3	Y	180	24.1	20.5	15	NA	Half Day
20.09.19	4	Y	NA	24.1	NA	11	2	Half Day
21.09.19	5	Y	NA	24.1	NA	10	1	Half Day
23.09.19	6	Y	300	23.9	20.8	19	1	After Sunday Off
24.09.19	7	Y	0	19.7	19.7	2	2	AC Overnight
11.10.19	8	Y	300	20.8	20.8	12	NA	Two Weeks Gap
12.10.19	9	Y	180	20.8	20.1	6	NA	Half Day

Temperature Characteristic

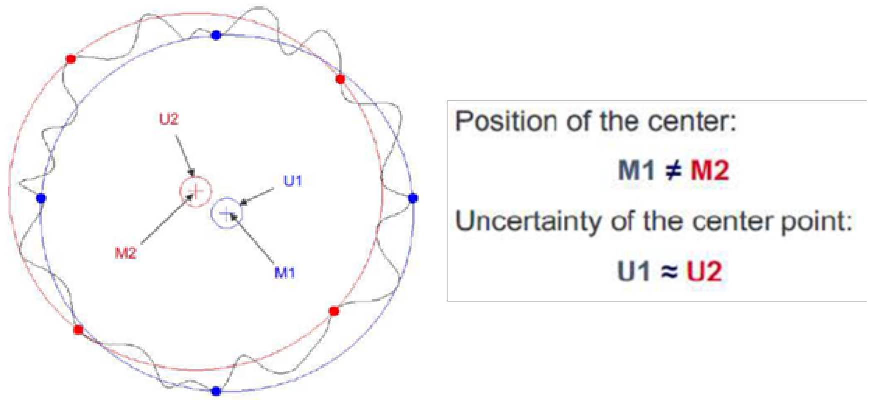


Time

MEASUREMENT UNCERTAINTY

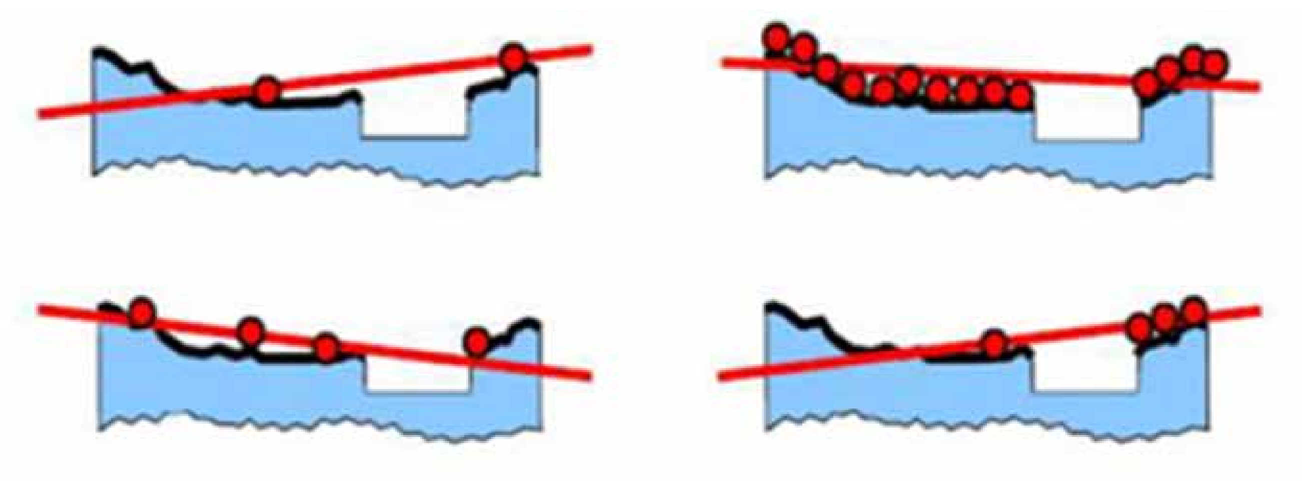
Influence of the form deviation on the part: for a circle with a form error, the location of the points has an influence on the position of the calculated centre point.

Form tolerances critical to function or interchangeability are specified where the tolerances of size do not provide sufficient control. A tolerance of form may be specified where no tolerance of size is given, e.g. in the control of flatness after assembly of the parts.

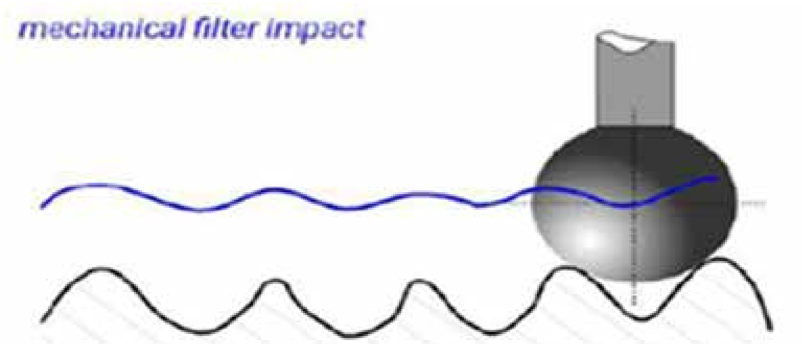


MEASUREMENT WITH CONTACT STYLUS - ANALYSIS

The number and distribution of the measurement points influence the associated feature.



Probing strategy: Different styli diameters act like a mechanical filter



References

1. Aukom Germany

2. Research paper published

3. Research at Accurate Gauging & Instruments Pvt. Ltd