Issues in the testing of Portable Coordinate Measuring Systems (CMS)

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Learning Objectives

If I am successful, you may gain some insight into …

1) additional challenges and ambiguities in the testing and calibration of portable coordinate measuring systems (e.g., articulating arm CMMs and laser trackers).

2) how to choose the environmental and operational conditions that are appropriate for testing their instruments.

Outline

- Motivation
- CMS Testing
- Operator Influences
- Environmental Influences
- Conclusion

Motivation

- Portable Coordinate Measuring Systems (CMS) are used in more and more situations.
- Due to their portable nature, these instruments are not used in a dedicated, controlled environment.
- Therefore, the instrument calibration is usually performed in a different environment than that in which the instrument is used.
- Is this a problem? Maybe.

Instruments out in the shop …

[Cartesian] CMM testing

- Cartesian CMMs are big and heavy. Their installation is usually 'permanent.'
- These CMMs are (usually) installed in laboratories where the environment is controlled.
- Acceptance testing of the CMM takes place once the CMM is installed – it will be used in this same environment.
- The majority of CMMs are now computer controlled – the performance of the instrument during testing is largely independent of the operator.

Basic tests of a CMM

- Volumetric tests are performed by measuring a series of reference lengths within the CMM volume.

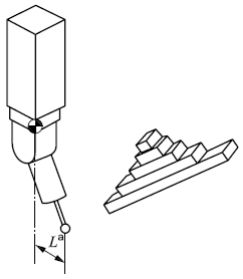


Figure from ISO 10360-2

Basic tests of a CMM

- Volumetric tests are performed by measuring a series of reference lengths within the CMM volume.
- Additional tests with a *ram axis stylus tip offset* of 150mm

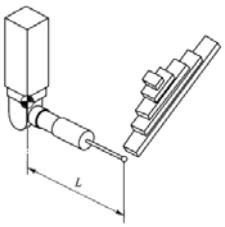


Figure from ISO 10360-2

Basic tests of a CMM

- Volumetric tests are performed by measuring a series of reference lengths within the CMM volume.
- Additional tests with a *ram axis stylus tip offset* of 150mm
- Probe tests are performed on a test sphere

Philosophy of testing

- The point-to-point measurements taken within the CMM volume are a sufficient sample to claim, with reasonable confidence, that the CMM specification for length measurements is met within the volume.
- The choice of lengths and positions for the measurements in the standard are based on revealing the known error sources of Cartesian CMMs.

Error sources (all types of CMS)

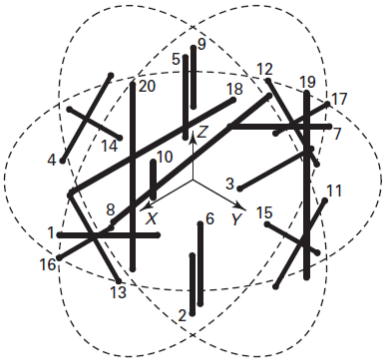
1. Instrument geometry: straightness of linear guideways, perpendicularity of both linear and rotary axes, eccentricity of rotary axes, and other (usually mechanical) relationships in the CMS structure.
2. Scales: linearity, expansion, hysteresis, and other properties of the transducers that measure displacement of linear or angular movement.
3. Sensor: repeatability of measurements, and variation in response due to different approach directions.

Testing of Portable CMS

- The focus is again on point-to-point length measurements.
- Additional tests are added that either reveal specific errors in the instruments, or provide a quick test that the CMS is operating properly.

Articulating Arm CMM testing

The figure at right shows the positions of two-point reference lengths (ball bars) within the measuring volume of the Articulating Arm CMM.



(d) Isometric View

Figure from ASME B89.4.22

Articulating Arm CMM testing

The figure at right shows the Articulating Arm CMM configurations for the performance of the Single Point Articulation Test (SPAT).

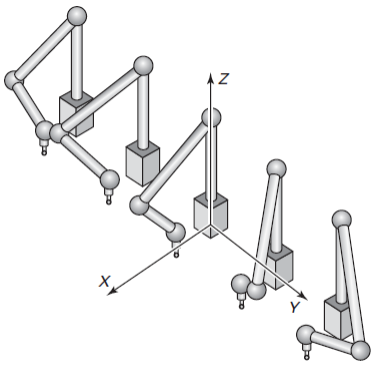


Fig. 12 Isometric View of Default Articulations

Figure from ASME B89.4.22

Laser Tracker testing

The figure at right shows the positions of a two-point reference length used to evaluate the Laser Tracker.

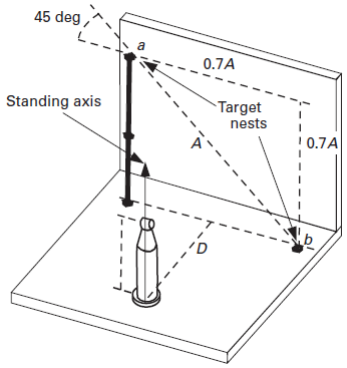
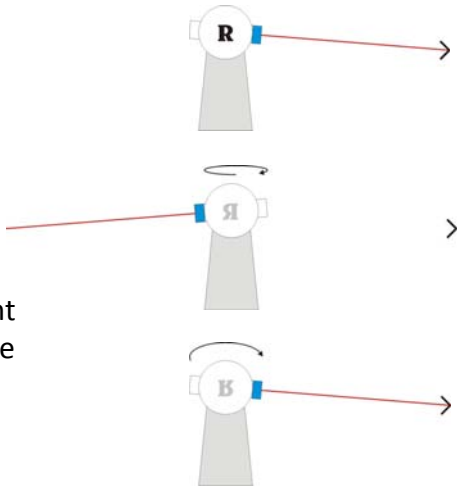


Figure from ASME B89.4.19

Laser Tracker testing

An additional test for Laser Trackers is the two-face, or plunge-and-reverse, test.

A fixed point is measured in both front-sight and back-sight modes. The apparent distance between these points is reported.



Operator influence

- Experience in the handling of the SMR can result in measurement errors. Placing the SMR in a nest (left) can be a solution for length tests.

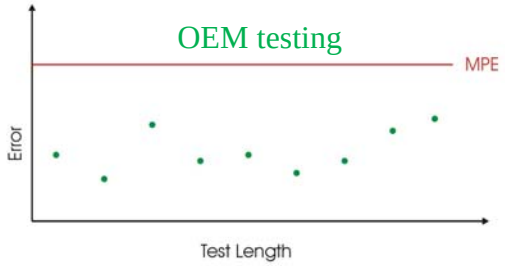
Operator influence

- The use of an articulating arm CMM requires some skill. The (tactile) probe must be held firmly, yet gently, against the part. The arm must be supported so that there is no unnecessary strain on the joints of the arm.

Operator-dependent results

- What happens when the customer is unable to get the instrument to pass, but the OEM service person is able to get good results?

Operator-dependent results



- What happens when the customer is unable to get the instrument to pass, but the OEM service person is able to get good results?
- Obviously there is a need for training, but the standards do not give guidance in this area!

Environmental influences

- Dimensional metrology is influenced by the environment, especially temperature.
- Conventional CMMs are often specified for relatively narrow temperature ranges [18 °C – 22 °C, for example].
- Portable CMSs have very broad operating ranges [10 °C – 40 °C, for example].

Environment choices

- From ISO 10360-2:2009

5.1 Environmental conditions

Limits for permissible environmental conditions, such as temperature conditions, air humidity and vibration at the site of installation, that influence the measurements shall be specified by:

— the manufacturer, in the case of acceptance tests;

— the user, in the case of reverification tests.

In both cases, the user is free to choose the environmental conditions under which the ISO 10360-2 testing will be performed within the specified limits (as supplied in the data sheet of the manufacturer; see ISO 10360-1, Amendment 1).

The user is responsible for providing the environment enclosing the CMM, as specified by the manufacturer in the data sheet.

Managing the influence of temperature

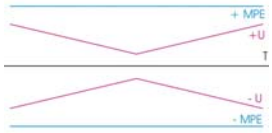
- Portable CMS often have field-compensation routines that are performed periodically to accommodate the current environment.
- Instruments are designed to be insensitive to temperature changes.
- Compensation is applied to instrument.
- Part temperature sensors allow additional compensation.

Calibration (Performance Verification)

- Due to their portability, and the special testing apparatus required for instrument verification, it is common to send these instruments to the OEM (or other calibration laboratory) for calibration.
- These facilities tend to perform the verification tests in an environment that is close to 20 ^{o}C.
- The question remains: *How am I assured that the instrument works throughout its stated range?*

Calibration requirements

- Recall from ISO 10360-2 that *the user is free to choose* the environmental conditions of the verification test.
- However, if the customer chooses 35 ^{o}C as the temperature, there may be significant additional cost for this testing.



What to do?

- In the standards world:
  - Find language to describe a "reasonable operator"
  - Be more clear on how the "operating conditions" are specified
  - Consider sampling of the environmental range in addition to sampling the measurement volume
- In the real world:
  - Increase awareness of potential problems

Learning Objectives

1) Why is portable CMS testing harder?

Environmental Issues

Operator Influence

Learning Objectives

2) Which conditions are appropriate for these instruments when they are calibrated ?

In general, a stable environment will allow for lower uncertainty in the calibration

However, tests at different temperatures that represent the 'real world' would provide useful information over the specified range of operating conditions.

Food for thought

- Are the potential problems described here relevant for other instruments?
  - Calipers? What if my operator is unable to get good results when measuring gage blocks as an interim check?
  - Cartesian CMMs where adjustments are made to the instrument to update the "scale factors" prior to verification?

    If the CMM is specified for 18 ^{0}C – 22 ^{0}C, and the CMM is "installed and checked" at 22 ^{0}C, do I really know it will be within specification at 18 ^{0}C? at 20 ^{0}C?

Thank you

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