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Ensuring Precision: Understanding the ASME B89.4.1-1997 Standard for Coordinate Measuring Machines

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The American Society of Mechanical Engineers (ASME) issued the ASME B89.4.1-1997 standard, titled “Methods for Performance Evaluation of the Coordinate Measuring Machines,” on February 8, 2002.

The standard outlines the procedures for specifying and testing the performance of coordinate measuring machines (CMMs) with three linear axes. It aims to unify terminology, machine classification, and the treatment of environmental effects to facilitate performance comparisons among machines.

In this article, we explore the importance of this procedure, its various testing routines, and how Hexagon service teams work to meet these requirements.

Standard testing concepts

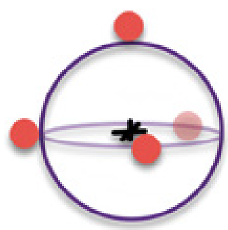
- **Repeatability testing:** Repeatability testing must evaluate a complete system including machine characteristics, human operators, and computer algorithms, and should be performed in a manner closely representing actual use.

  - **Common features of repeatability tests:** Repeatability is measured by determining the center coordinates of a precision reference ball mounted on the workpiece surface, with ten determinations made rapidly, and the machine repeatability reported as the largest range in coordinate values.

  - **Standard tests for repeatability:** Different tests are specified for computer-controlled modes, manual modes with various probes, and passive probes, with specific procedures outlined for each type.

  - **Repeatability tests for large machines:** For large machines, repeatability testing involves two different traverse speeds and may require testing at additional work zone locations for better accuracy.

Artifact utilized in field to measure repeatability.

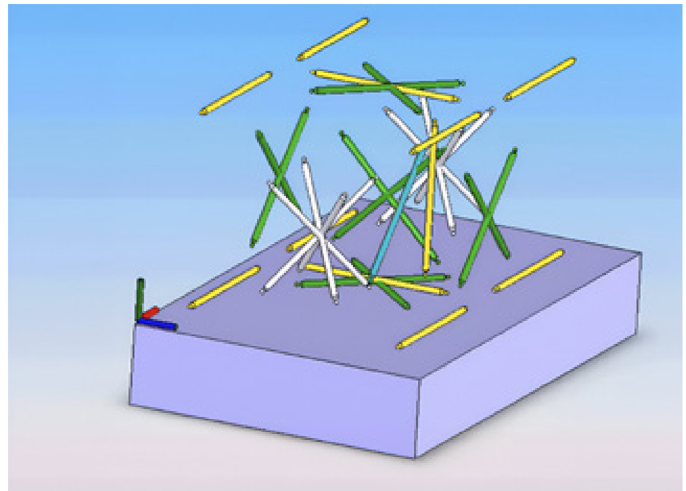


Points taken as part of B89 report to locate center of sphere.

- **Volumetric performance using ball bars:** Ball bar tests involve measuring the bar in multiple positions within the work zone to check machine volumetric performance, with specific procedures for large machines and those with rotary axes.

  - **Offset probe performance test:** This test evaluates machine performance with offset probes by measuring ball bar lengths with the probe in different orientations and calculating the differences.

Example of a 121 pattern, defined as the second axis is twice the shortest axis



Ball bar (volumetric performance)

- Yellow – X, Y, and Z linear test
- White – 3-dimensional square test
- Green – XY, XZ, YZ Squares. X Roll and Y Roll test
- Teal – Z roll test

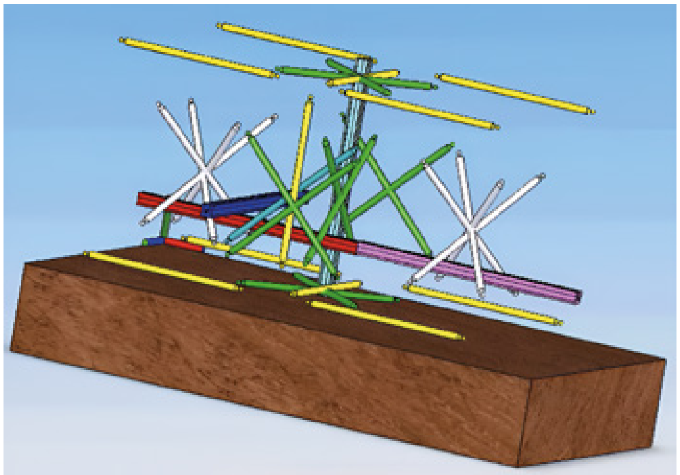
Standard testing concepts

- **Linear displacement accuracy (LDA):** LDA is assessed using a step gage or laser interferometer to measure the conformance of machine scales to international length standards.

  - **Step gage test procedure:** The step gage test involves mounting the gage properly, measuring intervals along three orthogonal lines, and making three sets of measurements for each axis to determine linear displacement accuracy.

  - **Laser interferometer test:** The laser interferometer test requires alignment to minimize cosine error, wavelength correction, and measuring intervals similar to the step gage test, with three sets of measurements taken along each line.

Step gage or laser (scales verified against a known length standard)



- Pink and red – Y LDA
- Dark blue – X LDA
- Light blue – Z LDA

Environmental impact

The ASME B89.4.1-1997 standard also allows for environmental differences from the manufacturer specification with **environmental responsibility**. The machine user is responsible for ensuring the environment meets the parameters specified by the machine supplier, which affects performance specifications.

• **Derating procedure:** If the user does not conform to the environmental specifications, a derating procedure on machine performance is provided.

• **Deferred environmental testing:** The supplier and user may agree to defer environmental testing until after performance testing, using diagnostic processes if performance fails.

• **Thermal test conditions:** Thermal tests must be performed under conditions equivalent to performance tests, and the thermal error index should not exceed 50%.

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• **Thermal test conditions:** Thermal tests must be performed under conditions equivalent to performance tests, and the thermal error index should not exceed 50%.

• **Thermal error index (TEI) calculation:** The TEI is calculated using the formula $TEI = [(UNDE + TVE)/WT] \times 100$.
*UNDE: uncertainty of nominal differential expansion. TVE: temperature variation error.

- **Uncertainty of nominal differential expansion:** UNDE is based on an uncertainty of 1 ppm/°C for the scale and step gage, calculated as $UNDE = (0.000002)(L)\,|\,(T_m — 20)\,|$.

- **Temperature variation error (TVE):** TVE is determined by a drift test conducted for a period equal to the longest performance test, with specific procedures for different machine types.

For example, if the machine volumetric performance specification is 6.0 microns and the TVE measured at 4.0 microns over 24 hours, then the volumetric performance specification would increase to 8.0 microns according to the process.

Hexagon has two levels of calibration for B89.4.1 specification:

1 **Basic certification:** Repeatability and volumetric performance.

2 **Advanced calibration:** Repeatability, LDA, volumetric performance. This level can be non-accredited or accredited to ISO 17025.

Hexagon's software tools allow the manipulation of the compensation map to align the machines geometry to known calibrated artifacts making the machine meet manufacturing standards.

Conclusion

In conclusion, the ASME B89.4.1-1997 standard plays a crucial role in ensuring the precision and reliability of coordinate measuring machines. By providing a unified framework for performance evaluation, it helps manufacturers and users maintain consistency and accuracy across different machines and environments. The comprehensive testing procedures outlined in the standard, including repeatability, linear displacement accuracy, and volumetric performance, are essential for meeting industry demands for high-quality measurements.

Hexagon's commitment to these standards, through various calibration levels and advanced software tools, underscores its dedication to helping clients achieve optimal machine performance. Adhering to these guidelines not only enhances measurement accuracy but also supports the continuous improvement of manufacturing processes, ultimately contributing to the advancement of engineering and technology.

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Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

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