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TESTING VISION CMMS AND THE INTERNATIONAL STANDARD, ISO 10360-7

A TECHNICAL PAPER FROM THE LEADING MANUFACTURER OF METROLOGY INSTRUMENTS

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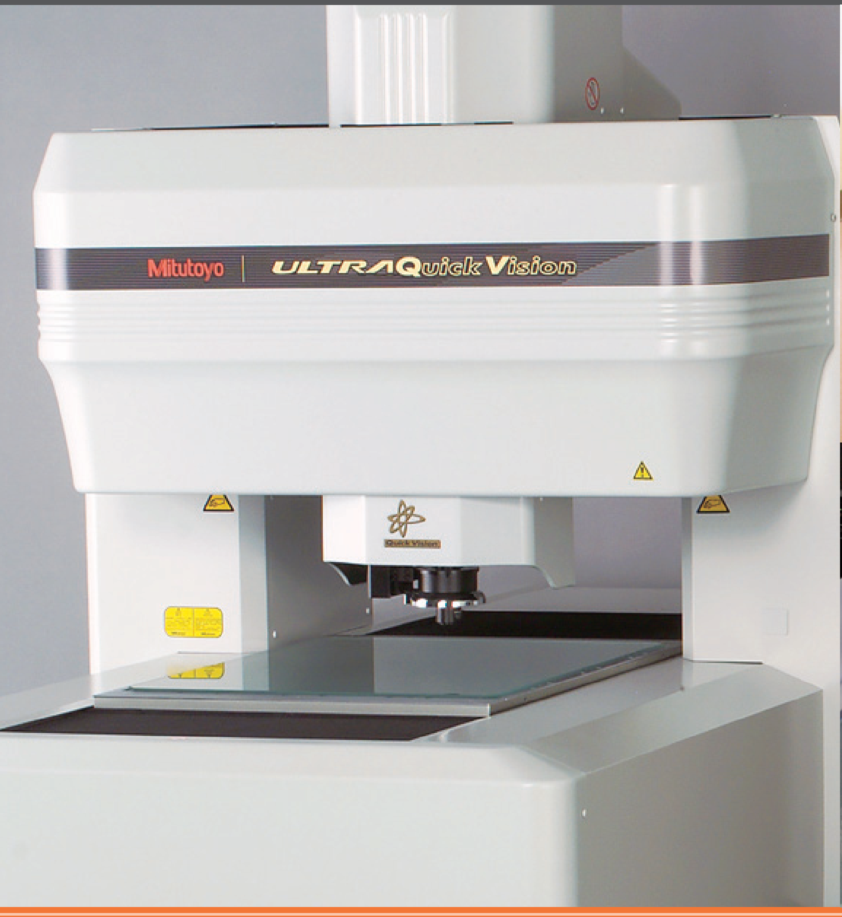

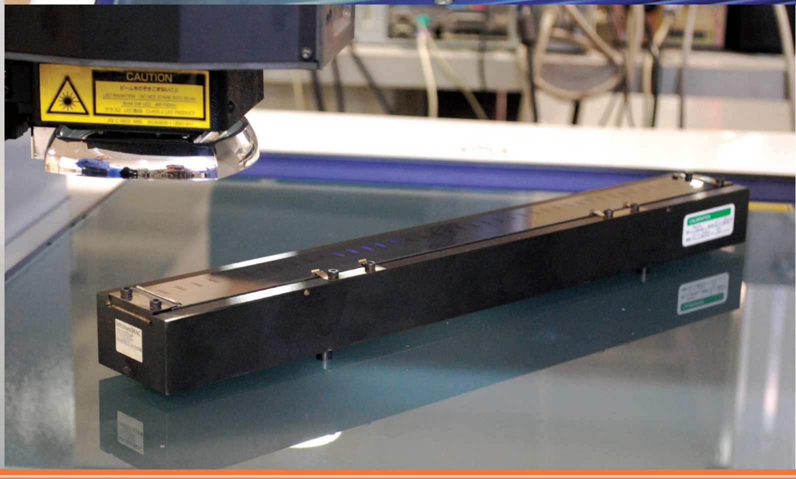

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About this Technical Paper

ISO 10360-7:2011 is the first international standard to address the calibration and testing of non-contacting coordinate measuring machines (CMMs) equipped with any type of imaging probing system, such as video or vision measuring instruments. This technical paper provides an overview of this new standard along with some insight into the options available in the standard. In particular, this paper explains how the tests in this standard can be used for the most modern three-dimensional measuring systems while still providing testing methods to meet the needs of older systems. Recommendations are also made regarding the use of the tests in this standard for the calibration of both old and new vision based CMMs. This paper was initially presented at the 2012 NCSL International Workshop and Symposium (www.ncsli.org).

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Developments in the International Standardization of Testing Methods for CMMs with Imaging Probing Systems

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Abstract

The first international standard to address the calibration and testing of certain types of non-contacting measuring instruments was published in 2011. This important new standard addresses the need for common testing methods and specifications for coordinate measuring machines (CMMs) equipped with any type of imaging probing system, such as video or vision systems. The standard, ISO 10360-7:2011, was developed by a working group within the ISO technical committee 213. This paper provides an overview of this new standard along with some insight into the options available in the standard. In particular, it will be shown how the tests in this standard can be used for the most modern three-dimensional measuring systems while still providing testing methods to meet the needs of older systems. Recommendations will also be made regarding the use of the tests in this standard for the calibration of both old and new vision based CMMs.

Learning Objectives

- Identify the new ISO 10360-7 and recognize how the new standard fits within the ISO 10360 series of standards.
- Interpret and apply the test methods in ISO 10360-7.
- Compare the new test methods to prior methods and derive modern specifications and calibration methods for older equipment.

1 Introduction

An important new international standard for the dimensional metrology community was published in June 2011. To address the need for common testing methods and specifications for certain types of non-contact measuring instruments, the working group on coordinate measuring machines (CMMs) within the ISO technical committee 213 developed the new ISO 10360-7:2011, Geometrical product specifications (GPS) – Acceptance and reverification tests for coordinate measuring machines (CMM) – Part 7: CMMs equipped with imaging probing systems [1]. This paper provides an overview of this new standard and provides some insight into the options written into the standard. This author was the task force leader for the development of this standard, but the content of this paper should not be considered as any type of official interpretation of the standard.

2 ISO 10360 Series of Standards

Performance testing standards for CMMs began in 1985 with the publication of ASME/ANSI B89.1.12 [2], and this was soon followed by related standards published by various groups and standards bodies around the world. The historical evolution of CMM testing standards is shown in Figure 1.

The first international standard for CMM testing, ISO 10360-2, was published in 1994 [3]. The solidification and harmonization of CMM testing concepts around the world lead to the publication of a new version of ISO 10360-2 in 2009 [4]. This latest version contains many mature ideas that go beyond any prior national or international CMM test standards.

Until the publication of ISO 10360-7, all the CMM testing standards (such as those shown in Figure 1), only applied to CMMs with contacting probing systems. The goal of ISO 10360-7 was to extend the contacting probing testing ideas to a certain class of CMMs with non-contacting probes. ISO 10360-7 was developed from ISO 10360-2:2009 and contains many of the same concepts and much of the same language.

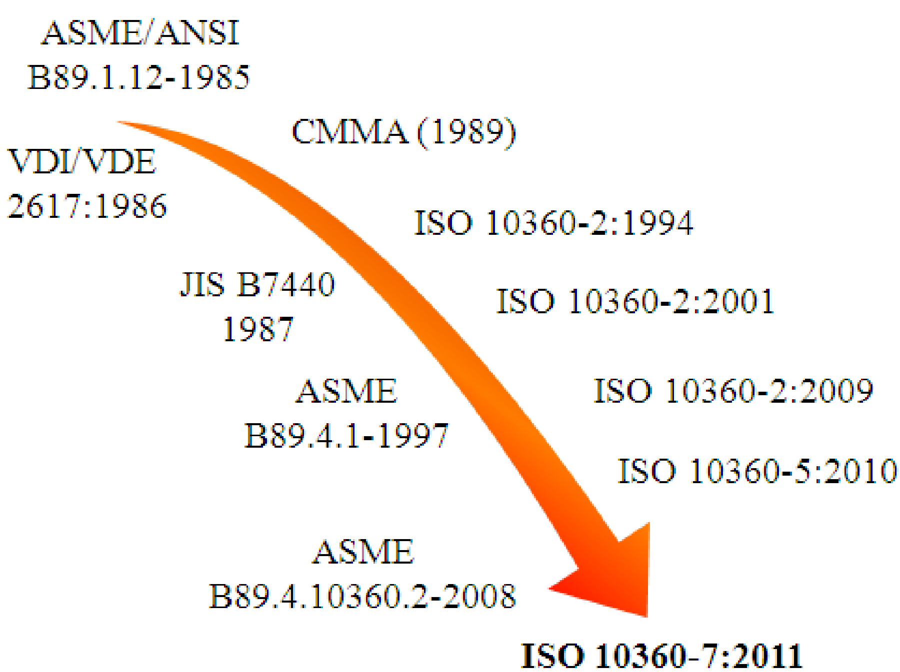
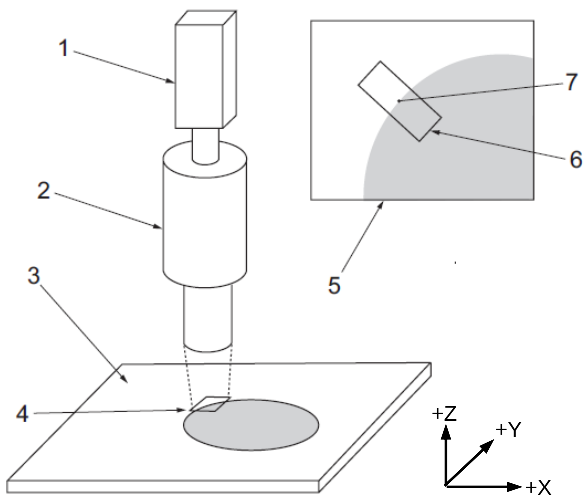


Figure 1. The evolution of national and international standards for testing CMMs.

3 Scope of ISO 10360-7:2011

There are many types of CMMs with non-contact probing systems. ISO 10360-7 only applies to Cartesian CMMs using any type of imaging probing system and operating in the discrete point probing mode. In the metrology market, the largest class of these instruments is the vision or video measuring instrument. An example of an imaging probing system is shown in Figure 2, where the two-dimensional image is nominally parallel to the XY plane of the CMM.

The scope of 10360-7 was specifically chosen based on the market size of CMMs equipped with imaging probing systems plus the lack of existing standardized testing methods. Other types of non-contacting probing systems are being addressed in other parts of the ISO 10360 series of standards, for example see [5].



Key
1 device for capturing an image of the measured object
2 various optical elements of the imaging probing system
3 measured object
4 field of view (object)
5 field of view (image)
6 measuring window
7 measured point

Figure 2. Example imaging probing system

4 Length Tests in ISO 10360-7

ISO 10360-7 offers two alternative methods and specifications for length tests: the composite approach and the component approach.

4.1 Composite Approach

The composite approach adapts the exact same length testing approach as used for contacting probe CMMs in ISO 10360-2:2009. In 10360-2, the E_0 test involves measuring a step gage (or similar artifact) along seven measurement lines in the volume of the CMM, with the four spatial diagonals being required, and the other three lines usually being parallel to the machine axes. Along each measurement line, five different lengths are measured three times each, for a total of 105 measurement values. The 105 E_0 values are compared to $E_{0,\mathrm{MPE}}$, the maximum permissible error (MPE) of the CMM under test, to determine conformance. To allow for consistency with contacting probe CMMs, the composite approach in 10360-7 applies this same testing method to CMMs equipped with imaging probing systems.

4.2 Bidirectional versus Unidirectional

In comparison to 10360-2, 10360-7 does allow one key difference in regards to the type of artifact being used for the testing. For the E_0 test in 10360-2, the test artifact must be measured in a bidirectional manner, i.e. the two points that are used in the measurement of a length must be in opposing directions. See Figure 3. In 10360-7, both bidirectional and unidirectional measurements are allowed. The notation in 10360-7 is therefore slightly different than 10360-2; E_B and E_U are used to indicate bidirectional or unidirectional testing to the corresponding $E_{B,MPE}$ or $E_{U,MPE}$ specifications. The choice of specification is at the discretion of the CMM manufacturer, and 10360-7 does not recommend one approach over the other.

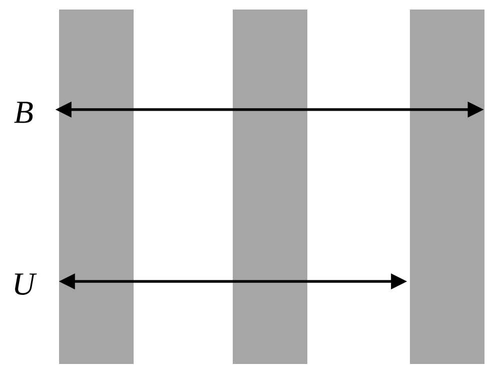


Figure 3. Many artifacts, e.g. a linescale, allow both unidirectional measurements (U) and bidirectional measurements (B). The artifact must be calibrated for the desired use.

4.3 Component Approach

The component approach is based on common industrial testing methods for imaging probe CMMs and includes three separate tests. The first test is a modification of the 10360-2 E_0 test applied to the XY plane, E_{UXY} or E_{BXY}, and is tested along four measurement lines parallel to the XY plane with a linescale or similar artifact (see Figure 4). The second test involves length measurements parallel to the Z axis, E_{UZ} or E_{BZ}, and is tested along one measurement line with gage blocks or similar artifacts (see Figure 5).

4.4 Z-axis Motion Relative to X and Y Axes

A major goal of 10360-7 was to ensure that imaging probe CMMs have three-dimensional specifications. Even when these instruments are used for two-dimensional measurements, it is common for the instrument to move in all three dimensions. As shown in Figure 6, when a measurement involves projecting measured features into a common plane, such as is needed to measure the distance between the two bores shown in the figure, the Z axis is typically moved up or down. The error motion of the Z axis relative to the XY plane is often over-looked and can result in large errors in what are usually considered to be just two-dimensional measurements. This error motion is typically dominated by the Z-axis squareness error (to the X and Y axes) and therefore 10360-7 has a Z-axis squareness test, E_{SQ}. An example E_{SQ} test using a square is shown in Figure 7.

The measurement of a mechanical square for testing E_{SQ} may require the use of an indicator, or indicating gauge head, as shown in Figure 7. This approach has some drawbacks and was carefully considered in the development of the 10360-7 standard. The standard also allows for alternative testing approaches of E_{SQ}.

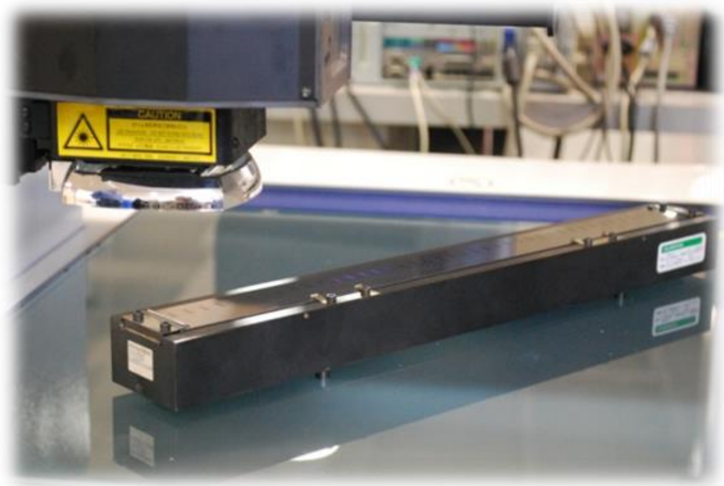


Figure 4. Example testing of E_{UXY} along one of two required planar face diagonals. The default for the other two positions is parallel to the axes.

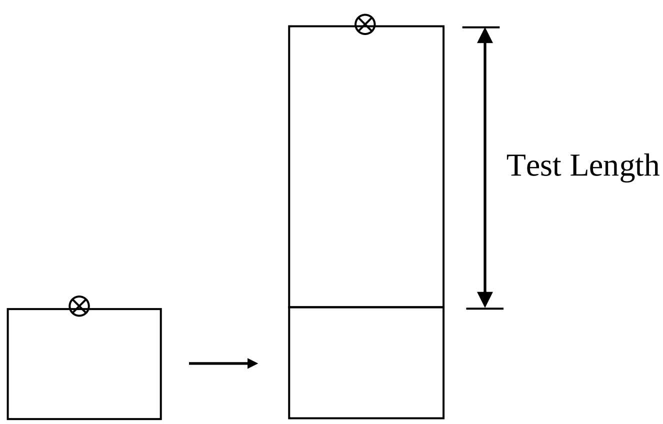


Figure 5. Example test of E_{UZ} using one gage block stacked onto another one which is used as the reference point.

4.5 Composite versus Component Approach

ISO 10360-7 offers two approaches to length testing and does not recommend one approach over the other. The composite approach may be more useful when comparing the performance of imaging probe CMMs to contacting probe CMMs. The component approach may be more useful when comparing new imaging probe CMMs to prior products (which used similar specifications). The component approach may also be more useful when the measurement application is primarily two-dimensional; however, both approaches address the three-dimensional nature of the CMM. In addition, the MPE values associated with the two approaches cannot necessarily be directly compared.

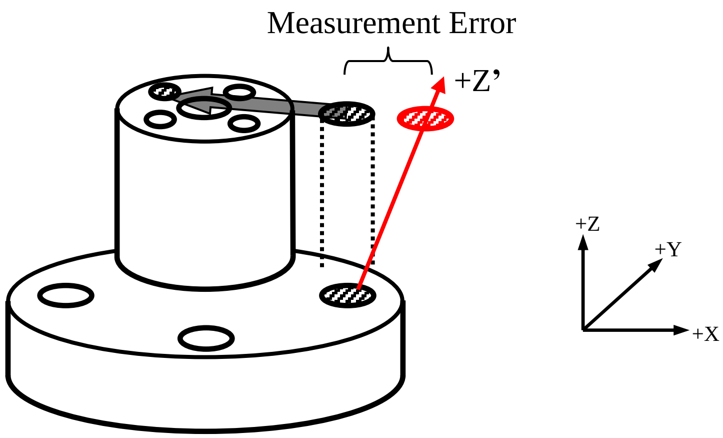


Figure 6. Measurement error associated with a squareness error in the XZ-plane. The Z' axis represents a possible error motion in an actual Z-axis, which results in measurement errors in two-dimensional measurements, as shown.

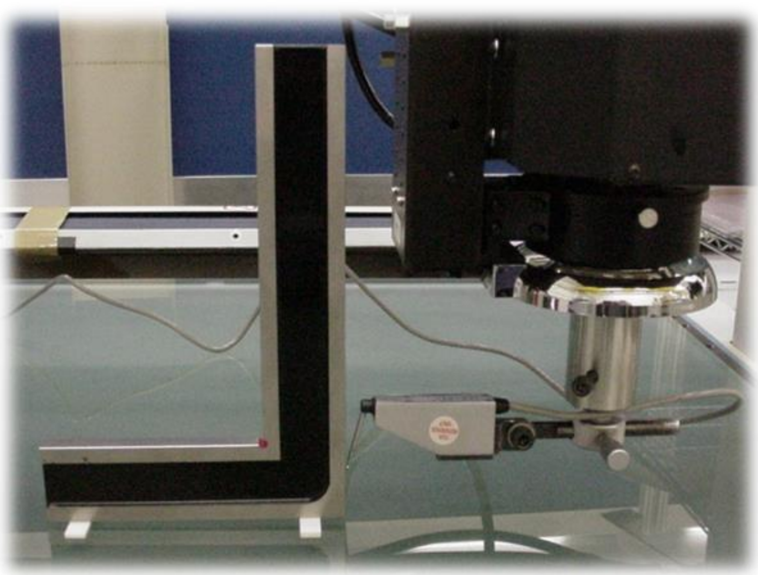
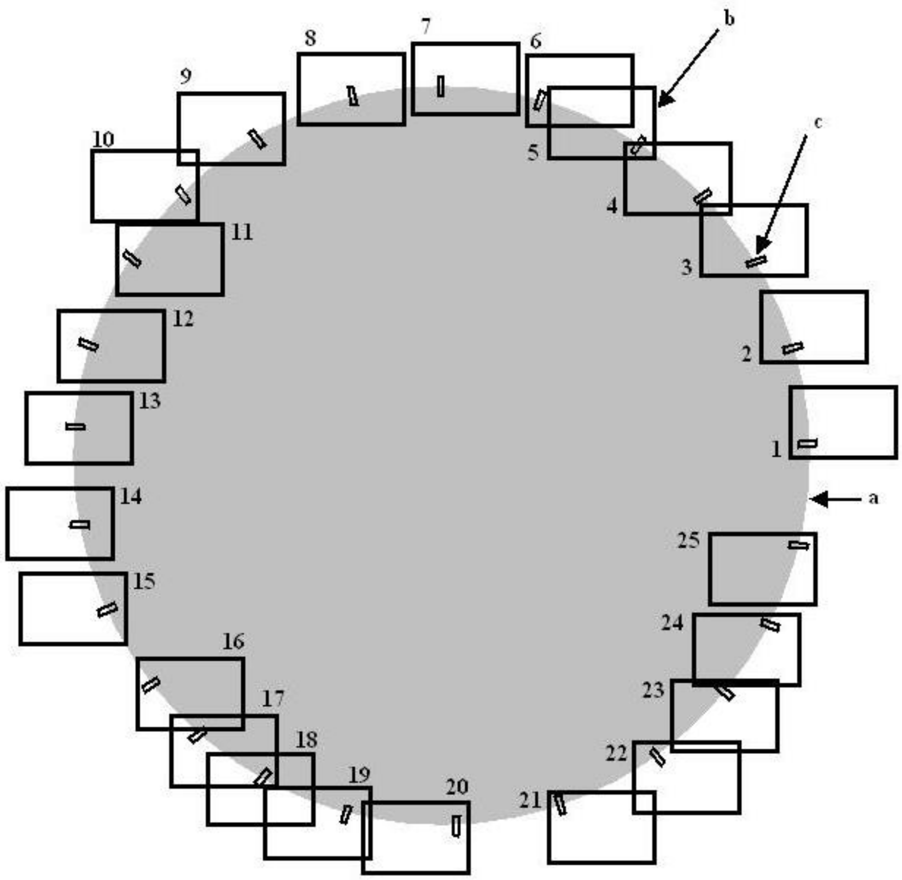


Figure 7. Example test of E_{SQ} with a square.

5 Probing Tests in ISO 10360-7

In addition to length tests, ISO 10360-7 also includes a so-called probing performance test, P_{F2D}, which is based on other probing tests within the ISO 10360 series [6]. For P_{F2D} a test circle is measured using 25 points in a manner such that the CMM moves between all consecutive points and that the measuring windows are distributed across the entire field of view. From the 25 points, a single circle is calculated and the form (maximum minus minimum radial distance) is reported as the P_{F2D} measured value. An example of an allowable measuring pattern for P_{F2D} is shown in Figure 8. The test circle for use in the P_{F2D} test must be calibrated for the form of the circle (i.e. the circle roundness).



a Test circle
b Field of view
c Measuring window

Figure 8. Example of an allowable test pattern for measuring P_{F2D}. Note the distribution of the 25 measuring windows across the field of view.

6 Testing Field of View Separately

ISO 10360-7 offers two optional tests associated with the measuring performance of the field of view separate from the rest of the CMM. The length test, E_{UV} or E_{BV}, and the probing test, P_{FV2D}, are similar to the tests described above but are done with no motion of the CMM. The test for E_{UV} or E_{BV} is similar to E_{UXY} and E_{BXY} respectively but requires the four measurement lines to be within the field of view. Similarly, the test for P_{FV2D} is identical to that of P_{F2D} but uses a smaller circle that can be completely contained within the field of view. The specification of an MPE associated with these field of view only tests is at the discretion of the imaging probe CMM manufacturer.

10360-7 does not provide any recommendation concerning the application of these optional specifications. E_{UV}, E_{BV}, or P_{FV2D} will be more applicable to some imaging probe CMMs than others, and some manufacturers may find these specifications useful to highlight features of their particular instruments.

7 Specifications to ISO 10360-7:2011

A summary of the MPE specifications to ISO 10360-7:2011 that would be expected from the imaging probe CMM manufacturers includes:

For the composite approach:
- $E_{B,MPE}$ or $E_{U,MPE}$
- $P_{F2D,MPE}$

For the component approach:
- $E_{BXY,MPE}$ or $E_{UXY,MPE}$
- $E_{BZ,MPE}$ or $E_{UZ,MPE}$
- $E_{SQ,MPE}$
- $P_{F2D,MPE}$

For both approaches, the following are optional:
- $E_{BV,MPE}$ or $E_{UV,MPE}$
- $P_{FV2D,MPE}$

8 Options in ISO 10360-7:2011

Unlike most of the current test methods in the ISO 10360 series, 10360-7 offers a number of options. These options include the composite versus component approach, the use of either bidirectional or unidirectional artifacts, and the optional field of view only specifications. These options allow for greater acceptance of the new standard in industry, but there is some risk that too many options will lead to incomparable specifications. In the introduction clause of 10360-7, it is mentioned that the differences between 10360-7 and 10360-2 may be eliminated in future revisions of either standard.

9 Historical Specifications Compared to ISO 10360 Standards

It may be possible for older imaging probe CMMs to be tested following the latest ISO 10360 standards. Table 1 shows common historically listed manufacturer specifications in comparison with the latest ISO 10360 standards.

Table 1. Comparison of historical specifications to the ISO 10360 series of standards.

Test	Historical Specifications	New Specifications	
		Parameters	ISO Standard
Length parallel to X or Y axis	E_{1XY} or U_{1XY}	$E_{UXY,MPE}$ or $E_{BXY,MPE}$	ISO 10360-7
Length diagonals in XY plane	E_{2XY} or U_{2XY}		
Length parallel to Z axis	E_{1Z} or U_{1Z}	$E_{UZ,MPE}$	ISO 10360-7
Squareness of Z to XY	Internal squareness specification	$E_{SQ,MPE}$	ISO 10360-7
Volumetric (composite)	Nothing	$E_{U,MPE}$ or $E_{B,MPE}$ $R_{U,MPE}$ or $R_{B,MPE}$	ISO 10360-7
Probe test, vision probe	Nothing	$P_{F2D,MPE}$	ISO 10360-7
Volumetric with touch probe (multi-sensor CMM)	Not used	$E_{0,MPE}$	ISO 10360-2
Probe test, touch probe (multi-sensor CMM)	Not used	$P_{FTU,MPE}$	ISO 10360-5

10 Summary

The test methods in the new ISO 10360-7:2011 were presented and some of key options discussed. It is expected that this standard will have a positive impact on the imaging probe CMM market and will significantly benefit users of this technology by bringing about a better understanding of measurement performance.

References

1. ISO 10360-7:2011, Geometrical product specifications (GPS) – Acceptance test and reverification test for coordinate measuring machines (CMMs) – Part 7: CMMs equipped with imaging probing systems. ISO: Geneva; 2011.
2. ASME B89.1.12-1985, Methods for performance evaluation of coordinate measuring machine. American Society of Mechanical Engineers: New York; 1985.

3. ISO 10360-2:1994, Coordinate metrology – Performance assessment of coordinate measuring machine. ISO: Geneva; 1994.
4. ISO 10360-2:2009, Geometrical product specifications (GPS) – Acceptance test and reverification test for coordinate measuring machines (CMMs) – Part 2: CMMs used for measuring linear dimensions. ISO: Geneva; 2009.
5. ISO/DIS 10360-8, Geometrical product specifications (GPS) – Acceptance test and reverification test for coordinate measuring machines (CMMs) – Part 8: CMMs with optical distance sensors. ISO: Geneva; 2011.
6. ISO 10360-5:2010, Geometrical product specifications (GPS) – Acceptance test and reverification test for coordinate measuring machines (CMMs) – Part 5: CMMs using single and multiple stylus contacting probing systems. ISO: Geneva; 2010.