brown & sharpe

World Headquarters

Precision Park, 200 Frenchtown Road
North Kingstown, RI 02852-1700
Tel: (800) 766-4673
(401) 886-2000
Fax: (800) 933-2937
(401) 886-2762
Internet: www.brownandsharpe.com

Brown & Sharpe DEA SpA

Strada del Portone, 113
10095 Grugliasco (TO), Italy
Tel: 011 4025111
Fax: 011 7803254

Brown & Sharpe GmbH

Siegmund-Hiepe-Straße 2-12
D-35578 Wetzlar, Germany
Tel: 06441 207 0
Fax: 06441207 122

Brown & Sharpe Qianshao

11 Luoyang Road
Qingdao 266045, P.R. China
Tel: 86 532 486 2324/2534
Fax: 86 532 485 6427

Brown & Sharpe - USA

North Kingstown, RI
Tel: (800) 766-4673 Fax: (800) 933-2937

Elgin, IL
Tel: (847) 931-0100 Fax: (847) 931-1979

Wixom, MI
Tel: (248) 449-9400 Fax: (248) 449-7438

Charlotte, NC
Tel: (704) 525-0182 Fax: (704) 525-3154

Cincinnati, OH
Tel: (513) 942-0800 Fax: (513) 942-0804

Nashville, TN
Tel: (615) 331-0800 Fax: (615) 331-0875

Irvine, CA
Tel: (800) 955-5200 Fax: (949) 727-0167

Brown & Sharpe - Mexico

Garza Garcia, Mexico
Tel: 8 338 6272 Fax: 8 338 7968

Brown & Sharpe -South America

Sao Paolo, SP Brasil
Tel: (011) 5505-0215 Fax: (011) 5505-5677

Brown & Sharpe - Europe

Ludwigsburg, Germany
Tel: 07 141 8747 0 Fax: 07 141 8747 88

Wetzlar, Germany
Tel: 06441 207 0 Fax: 06441 207 122

Telford, United Kingdom
Tel: 01952 681300 Fax: 01952 681310

Swindon, United Kingdom
Tel: 01793 877633 Fax: 01793 877636

Vilnius, Lithuania
Tel: 02 771 848 Fax: 02 775 963

Grugliasco, Italy
Tel: 011 4025111 Fax: 011 7803254

Milan, Italy
Tel: 02 93549608 Fax: 02 93549609

Pistoia, Italy
Tel: 0573 364664 Fax: 0573 364663

Bari, Italy
Tel: 080 4670496 Fax: 080 4670495

Courtaboeuf Cedex, France
Tel: 01 69 291200 Fax: 01 69 290032

Blagnac, France
Tel: 05 61 71 37 74 Fax: 05 61 71 38 97

Lyon, France
Tel: 04 72 57 90 24 Fax: 04 72 57 90 27

Barcelona, Spain
Tel: 93 5946920 Fax: 93 5946921

Brown & Sharpe - Asia Pacific

Minato-ku, Tokyo, Japan
Tel: 81 3 5440 3500 Fax: 81 3 5440 5295

Qingdao, China
Tel: 86 532 486 2324/2534
Fax: 86 532 485 6427

Beijing, China
Tel: 10 65186561 Fax: 10 65186557

Hong Kong, China
Tel: 2 881 8007 Fax: 2 894 8064

Shanghai, China
Tel: 21 6353 5159 Fax: 21 6353 7231

Guangzhou, China
Tel/Fax: 20 8551 1851 3407
Mobile: 139 0846 2504

Chongqing, China
Mobile: 130 0167 7570/139 0642 9120

Performance Standard - 03/01

Form No. 80-80398

brown & sharpe™

understanding the ISO 10360-2 performance standard®

BRIDGE MEASURING MACHINES

Introduction

Process control and quality assurance in modern manufacturing depends more and more on Coordinate Measuring Machines (CMMs). Over the last 20 years CMMs have widely replaced the traditional inspection methods with gages and fixtures. Because of their flexibility CMMs can reduce investment costs while increasing inspection throughput.

In addition to standard geometrical features, precision CMMs equipped with highly accurate analog scanning technology can inspect special tight tolerance features such as gear and CAM profiles, roundness, and cylindricity. In the past inspection of this type would require single purpose, dedicated measuring devices.

High product quality does not only depend solely on the quality of the machine tools used for manufacturing. High product quality relies on the accuracy and repeatability of the instruments used for controlling the manufacturing process. For example, a low cost, low performance machining center in combination with a high precision CMM may still assure quality since only acceptable parts will pass inspection. Further a high quality machining center in combination with a low cost, low accuracy measuring device can not assure high quality product as a percentage of “out of tolerance” parts will inevitably pass inspection.

The selection of a suitable CMM therefore is a critical decision in a company’s quality control standards. This important selection is further complicated by the long life expectancy of CMMs compared to machine tools and by the wide array of CMM performance standards used in whole or part by various CMM manufacturers.

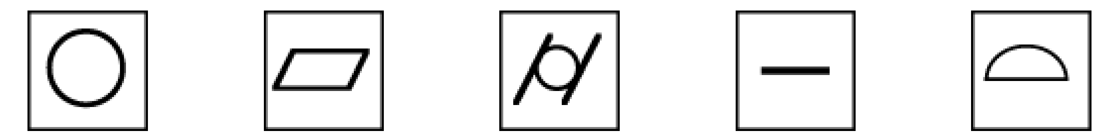
This brief guide focuses on the ISO 10360-2 performance standard utilized by Brown & Sharpe. The ISO 10360-2 is a comprehensive easy to understand standard that may be applied to real inspection applications to insure that an acceptable level of measurement uncertainty is considered for a given process. Specifically this guide includes:

- **Overview of the ISO standard with an explanation of the test method.**
- **Discussion of the volumetric length measuring and volumetric probing uncertainties.**
- **Determining a measurement uncertainty to tolerance ratio.**
- **Analysis of the required CMM uncertainty and application examples.**

3. Form Tolerances

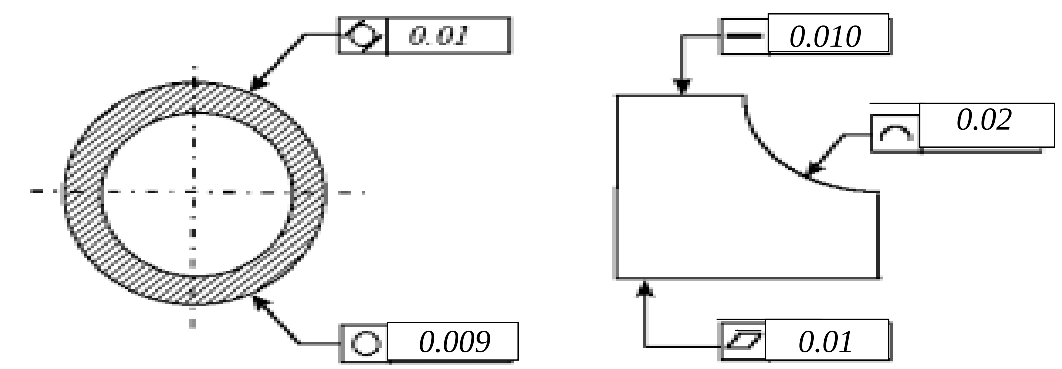
Refer to your part drawing and locate the tightest form tolerances. These include call outs for roundness, flatness, straightness, cylinder and profile form.

Example: Consider a Global Image 9158 with Analog probe, ISO R= 1.7 µm for the following application.



Roundness Flatness Cylinder form Straightness Profile form

Drawing Tolerances



Determine the Tightest Tolerance: 0.009mm Roundness call-out

Determine the required Machine Measurement Uncertainty (based on a ratio of uncertainty to tolerance of 1:5)

Uncertainty to tolerance Ratio x (tolerance)
0.20 x (±9 µm) = 1.8 µm

Check the selected machine uncertainty at this length:

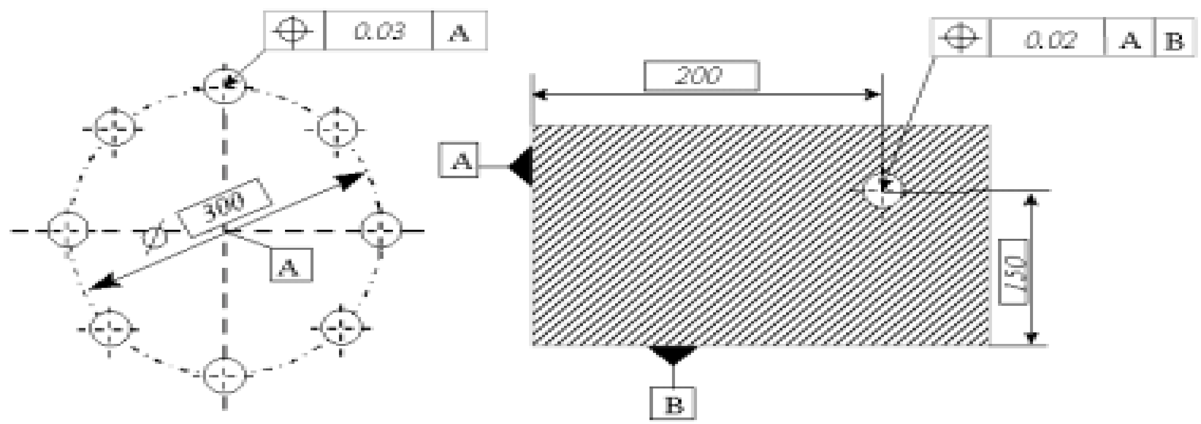
R (for Global Image 9158 with Analog Probe) = 1.7 µm

Since 1.7 µm >1.8 µm ; This machine is acceptable for this application!

2. Position Tolerances

Refer to your part drawing and locate the tightest position tolerance. Since position tolerances usually define a tolerance diameter only the radius is used to determine the deviation from the nominal center. Again, note that because of the length dependency of volumetric uncertainty, a larger tolerance on a feature with a long distance to the datum may present more difficulty than a very tight tolerance with a short datum.

Example: Consider a Global Image 9158, ISO E = 1.9 + 3L/1000, for the following application.



NOTE: A Position tolerance of 20µm (circular) is equivalent to a tolerance of ± 10µm for the measurement!

For the 300 mm Circle Pattern	For the hole position
± 0.030mm or ± 30µm @ a length of 150mm **30 µm** /300mm = 0.1**µm**/mm	± 0.020mm or ± 20µm @ a length of 200mm **20 µm** /200mm = 0.1**µm**/mm
Since 0.1µm/mm < 0.2 µm/mm, the hole position presents the tighter tolerance.	

Determine the required Machine Measurement Uncertainity (based on a ratio of uncertainty to tolerance of 1:5)

Uncertainty to tolerance Ratio x (tolerance)
0.20 x (± 20µm / 2) = 2.0 µm

Check the selected machine uncertainty at this length:
E (for Global Image 9158) = 1.9 + 3 (200mm)/1000 =2.10 µm

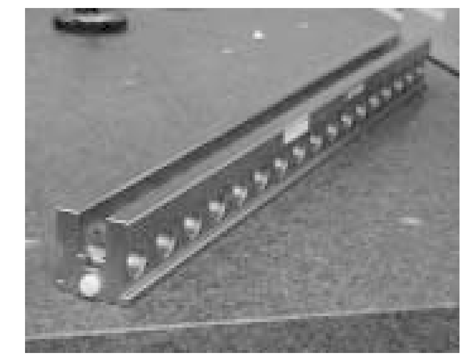
Since 2.10 µm > 2.0 µm; A higher accuracy machine is required for this application!
Consider the Global Reference.

Overview of ISO 10360-2

ISO is an international organization that defines standards. The goal of the ISO 10360-2 standard is to define the performance verification of the CMM and its associated probe.

At the heart of the standard is the reliance on certified artifacts that by definition reproduce known values of a determined quantity. The artifacts utilized by the standard may include a series of gage blocks, step gauges and a precision sphere.

Series of Gage Blocks



Koba Step Gauge

Precision Sphere

It is important to note that for length measurements it is recommended that the longest standard be at least 66% of the longest measuring volume diagonal and that the shortest be no longer than 30mm.

There are two general uncertainties associated with the ISO standard; the first is the volumetric length measurement uncertainty (E) and the second is the volumetric probing uncertainty (R).

The Volumetric Length Measuring Uncertainty (E)

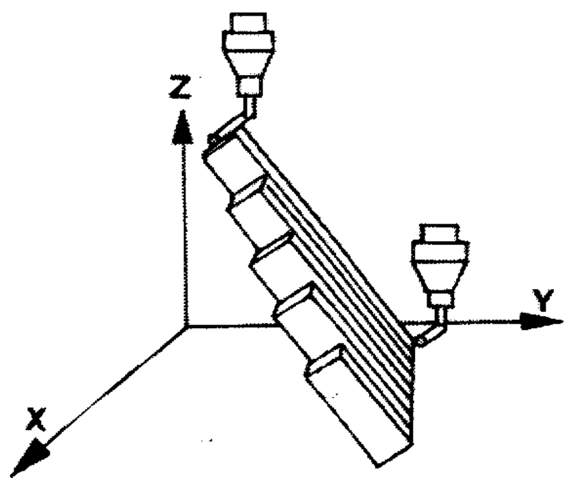
General Procedure

To verify the CMMs volumetric length measuring uncertainty a series of gage blocks or a step gauge is utilized.

The user selects 7 different locations (position and direction) within the machines measuring volume for the test. For each location five(5) material standards (lengths) are measured, three times each, for a total of 105 measurements.

7 different Locations x 5 different lengths x 3 repetitions = 105 Measurements

All 105 measurement results (100%) must be within the stated tolerance specified by the manufacturer.



Note:

The uncertainty of the artifacts must be considered. In general the artifact used should not have a length uncertainty (F) of greater than 20% of the CMM manufacturer's stated volumetric length uncertainty (E).

If; F < 0.2 x E , than the E stated by the manufacturer applies. F > 0.2 x E, than $E = E_{manufacturer} + F$ applies.

Determine the Tightest Tolerance:

For the Diameter	**For the distance**
± 0.030mm or ± 30 µm @ a length of 300mm 30 **µm**/300mm = 0.1 **µm**/mm	± 0.020mm or ± 20 µm @ a length of 50mm 20 **µm**/50mm = 0.4 **µm**/mm
Since 0.1µm/mm < 0.4 µm/mm, the diameter is presents the tighter tolerance.	

Determine the required Machine Measurement Uncertainty (based on a ratio of uncertainty to tolerance of 1:5)
Uncertainty to tolerance Ratio x (tolerance)
0.20 x (± 30 µm) = 6.0 µm

***Check the selected machine uncertainty at this length*:**

E (for Global Status 9158) = 3.0 + 4 (300mm)/1000 = 4.2mm

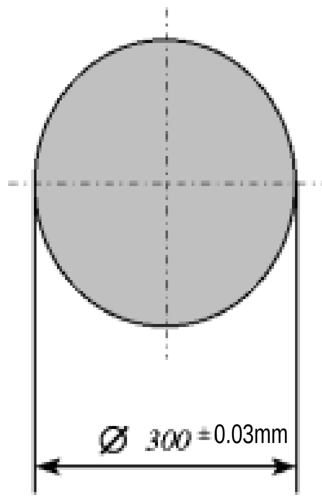
Since 4.2 µm< 6.0 µm; This machine is acceptable for the application!

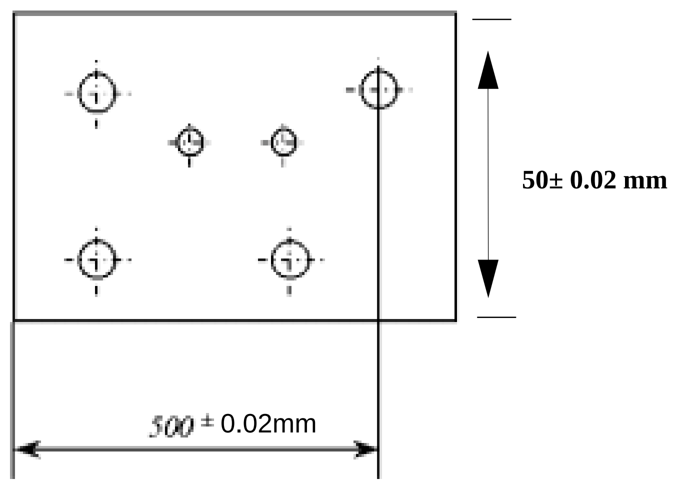
1. <u>Diameter and Distance Tolerances</u>

Refer to your part drawing and locate the diameter for distances with the tightest tolerance. Note that because of the length dependency of volumetric uncertainty, a larger tolerance on a very long feature may present more difficulty than a very tight tolerance on a small feature.

Next calculate the required machine volumetric length measurement uncertainty by applying the appropriate ratio of uncertainty to tolerance.

Example: Consider a Global Status 9158, ISO E = 3.0 + 4L/1000, for the following application.





The Volumetric Length Measuring Uncertainty (Continued)

<u>Results</u>

The volumetric length measuring uncertainty (E) is expressed as an equation of a line in micrometers (mm).

E = ± (A + L/K)

where: ***A = Systemic or constant machine uncertainty in*** **mm**
L = Length of measurement in mm.
K = Length constant or slope of line.

Example:

Given a machine E specification of 3.0 + L/250. For a 200mm length measurement, anywhere in the machine volume, the associated uncertainty is:

E = ± 3.0 + (200/250) = ± 3.0 + 0.8 = ± 3.8 mm

Sample output:

Machine Data
Machine Name: Global C1
Machine Type: Bridge
Controller Type: Common
Machine Serial No: 12345

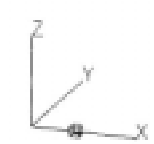
Parameters
Positioning Ve.: 100
Contact Vel: 1.4
Acceleration: 100
Probe/Retract: 2

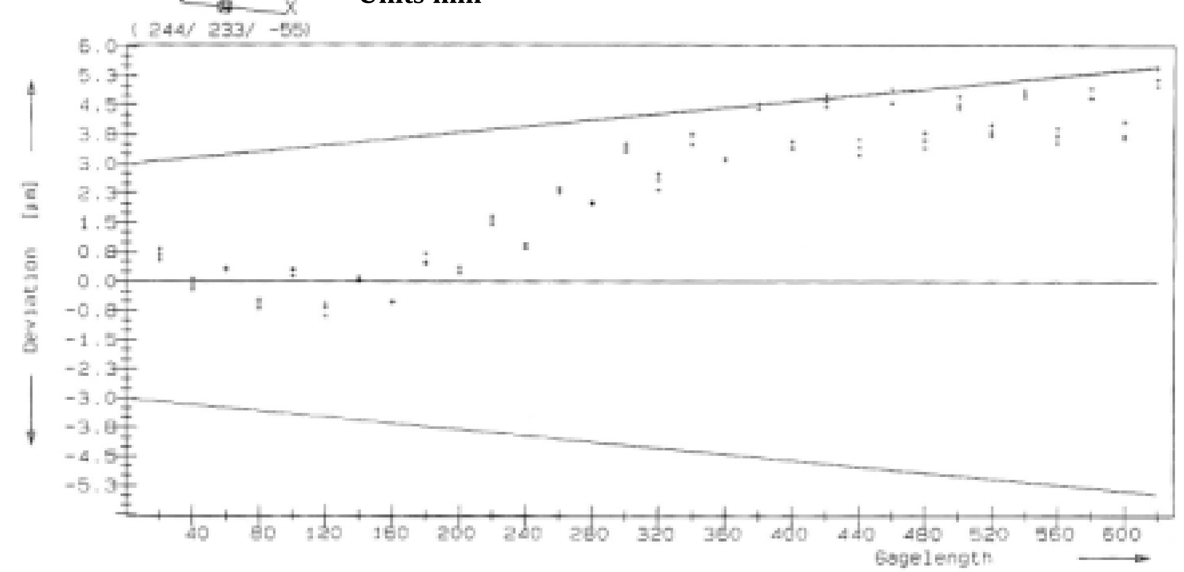
Software
Operating System: Windows NT
App. Software: XactQuindos
Program Version: 1.0
Operator: J Dove

ISO 10360-2 3D Diagonal (+X, -Y, -Z to -x, +Y, +Z)

General
Date/Time: 30-Dec-99 12:00:00 AM
Units mm

Specifications Drw: 62-95001
Specification: 1.9 + 3L /1000
Probe Diameter: 4

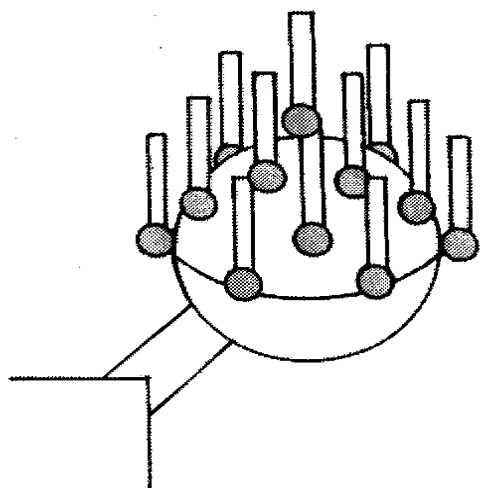




The Volumetric Probing Uncertainty (R)

To verify the CMMs volumetric probing uncertainty a precision sphere is utilized. The sphere is required to be between 10mm and 50mm in diameter with certification for form and diameter.

The test consists of measuring 25 equally spaced points on the sphere hemisphere as illustrated below.



R is computed by adding the absolute values of the minimum and maximum deviation from the radial form. This result is typically reported in micrometers (mm). All 25 probings (100%) must be used in the calculation.

Analysis of the Required CMM Uncertainty

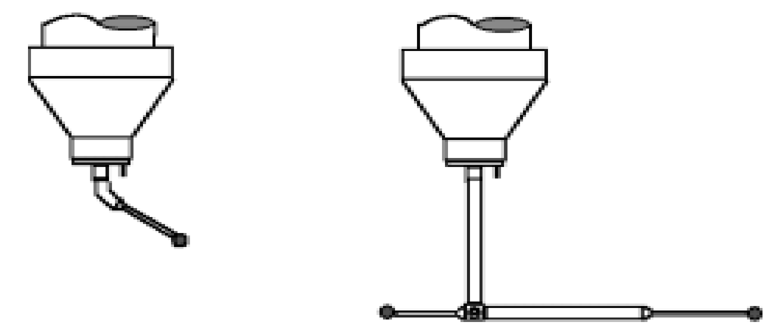
In nearly all applications, CMMs are used to inspect three general groups of features:

1. **Diameter and Distance Tolerances**
2. **Position Tolerances**
3. **Form Tolerances**

For each of these groups a determination of the acceptability of a given machine based on its ISO performance specification may be made. Examples follow for each case.

The Ratio of Machine Uncertainty to Tolerance

From your drawing tolerances the theoretically required ISO specifications “E” and “R” may be determined for a given application. However it is important to note that the manufacturer’s verified specifications may differ from actual workpiece measurements because of the use of probe extensions, long or thin probes, probe or stylus changes, environmental conditions, fixturing, etc.



<u>E and R as specified</u>

- probe pin
- fixed directly in probe head
- no extensions
- no rotation of probe head

<u>E and R (Working condition):</u>

- combination of several probe pins
- use of extensions
- rotation of probe head (Renishaw)
- probe change

Because of these differences it is generally accepted practice to apply a ratio of uncertainty to tolerance when calculating a required CMM specification. This ratio may vary widely depending on the factors described above, the complexity of the measurement task and the process itself. Typical ratios may range from 1:3 to 1:20 with 1:5 and 1:10 being most common.

Note:

In order to maintain a 1:5 ratio of CMM uncertainty to part tolerance the CMM data sheet specification should be 5 times more accurate than the tolerance being inspected.