Mitutoyo

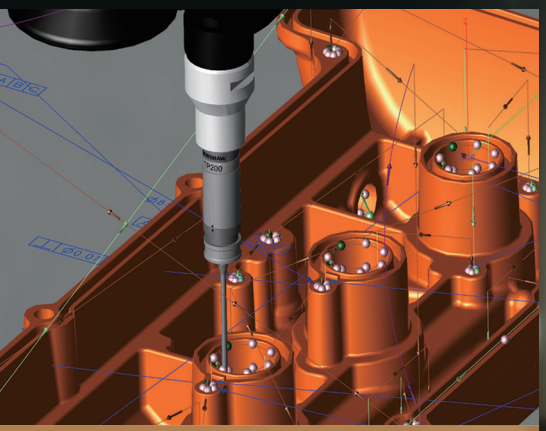
Mitutoyo
Institute of Metrology

CMM-GD&T MEASUREMENT PLANNING

AN EDUCATIONAL PRESENTATION FROM THE LEADING MANUFACTURER OF METROLOGY INSTRUMENTS

EDUCATION

ASME Y14.5



ASME B89.7.2-2014
[Revision of ASME B89.7.2-1999 (R2004)]

Dimensional Measurement Planning

ISO 1101

EDU-14001A-H

Mitutoyo Institute of Metrology

The Mitutoyo Institute of Metrology provides educational courses and on-demand resources across a wide variety of measurement related topics including basic inspection techniques, principles of dimensional metrology, calibration methods, and GD&T. Visit **www.mitutoyo.com/education** for details on the educational opportunities available from Mitutoyo America Corporation.

About this Presentation

This presentation has been delivered at a number of national and international events, and based on the positive response received, Mitutoyo America Corporation wanted to make it more widely available. Many users of coordinate measuring machines (CMMs) struggle with the measurement of workpieces toleranced in accordance with ASME Y14.5 (GD&T). There is no measurement method dictated by ASME Y14.5, as this standard is for defining product requirements and is not a measurement compliance standard. Users of CMMs must consider a number of business and technical factors when planning a measurement method. This presentation introduces the topic of measurement planning and highlights the American national standard on Dimensional Measurement Planning, ASME B89.7.2. This presentation recommends organizations develop best practices for CMM use, and some examples and topics for consideration are discussed.

Whatever your challenges are, Mitutoyo supports you from start to finish.

Mitutoyo is not only a manufacturer of top-quality measuring products but one that also offers qualified support for the lifetime of the equipment, backed by comprehensive services that ensure your staff can make the very best use of the investment.

Apart from the basics of calibration and repair, Mitutoyo offers product and metrology training, as well as IT support for the sophisticated software used in modern measuring technology. We can also design, build, test and deliver measuring solutions and even, if deemed cost-effective, take your critical measurement challenges in-house on a sub-contract basis.

Mitutoyo Institute of Metrology

Mitutoyo America Corporation
Education
965 Corporate Boulevard
Aurora, Illinois 60502
Phone: 888-648-8869 option 6
Fax: 630-978-6471

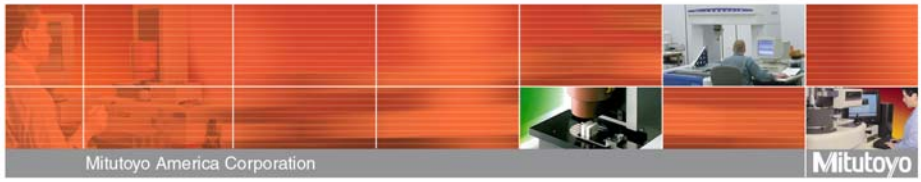
Find additional product literature and our product catalog

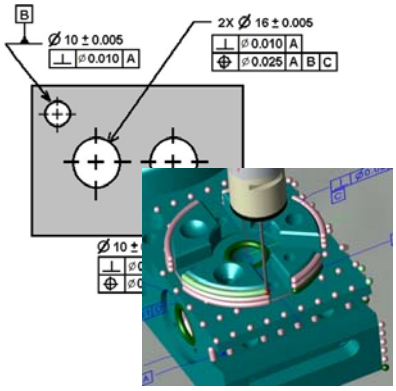
www.mitutoyo.com

Mitutoyo

Mitutoyo America Corporation
www.mitutoyo.com
One Number to Serve You Better
1-888-MITUTOYO (1-888-648-8869)

M³ Solution Centers:
Aurora, Illinois (Headquarters)
Boston, Massachusetts
Huntersville, North Carolina
Mason, Ohio
Plymouth, Michigan
City of Industry, California
Birmingham, Alabama
Renton, Washington
Houston, Texas



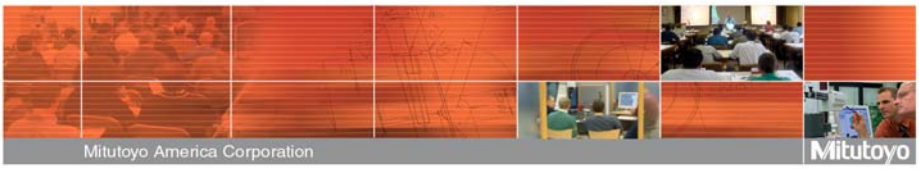


Introduction to CMM-GD&T Measurement Planning

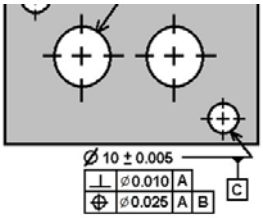
Mitutoyo

Learning Objectives of this Presentation

- Identify roadblocks to success in the implementation of modern measuring equipment for the measurement of geometrical tolerances (GD&T).
- Apply techniques for the development of optimal measurement plans and their deployment across an organization.
- Identify differences between US and international tolerancing standards and analyze the impact.



It would be so nice if the engineering design simply told us how to measure?



Engineering Design

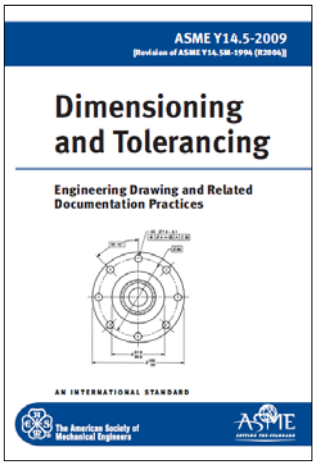
Measurement Method

A design captures product requirements - a measurement method must then be developed that meets business needs.

Mitutoyo

ASME Y14.5-2009

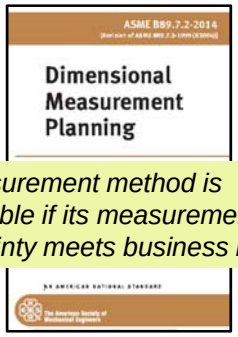
- ASME Y14.5-2009 states:
  - *"…establishes uniform practices…for use on engineering drawings…"*
  - *"This document is not intended as a gaging standard."*
  - *"It is neither the intent nor within the scope of this Standard to define measurement methods."*
- Defines tolerance zones only.
- Developing measurement methods can be challenging at times.



Mitutoyo

Measurement Planning

- Measurements can never "conform" to ASME Y14.5.
- But measurement methods are influenced by ASME Y14.5.
- ASME B89.7.2-2014 Dimensional Measurement Planning.



"a measurement method is acceptable if its measurement uncertainty meets business needs"

- Must consider business needs:
  - Cost of measurements.
  - Purpose of the measurement.
  - Impact of pass and fail errors.
  - Legal/liability issues.
  - Organizational policies.
  - Customer requirements.

Mitutoyo

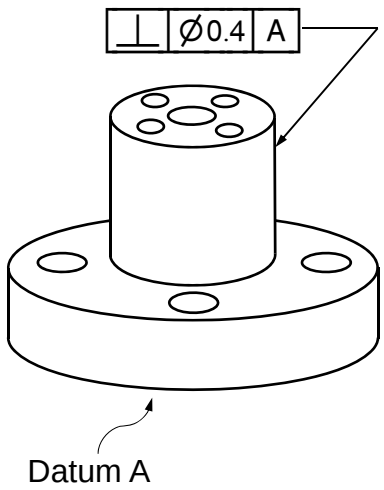
The Inspector who said "So What?"

A radical and controversial case study in determining if measurement uncertainty meets business needs

Mitutoyo

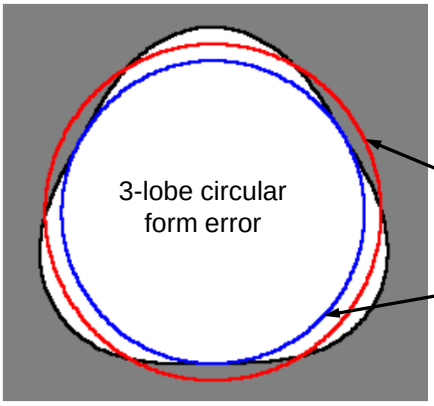
The inspector who said “so what”

- Real example from audit of contract inspection lab.
- Measure: perpendicularity of cylinder axis.
- Measured on a CMM. The usual advanced concerns:
  - Number of points.
  - Software algorithms.
  - CMM/probe configuration.
  - Datums and part coordinate system.



Mitutoyo

Power = Responsibility



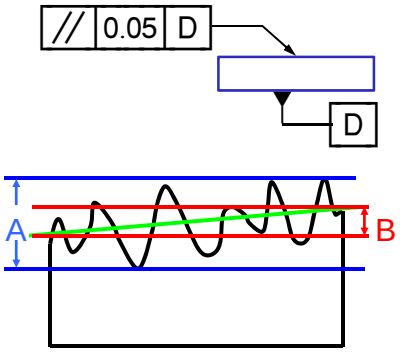
- Modern measuring instruments offer options, particularly in software.
- Typical circle fitting:
  - Least squares
  - Minimum zone
  - Maximum inscribed
  - Minimum circumscribed

Different experts may argue one method or another is “correct”.

Mitutoyo

What is the Software Doing?

- Modern software provides many tools to support GD&T measurement challenges. The user must understand their software.
- "Methods Divergence" is a term used to describe how equally valid methods may give very different results.

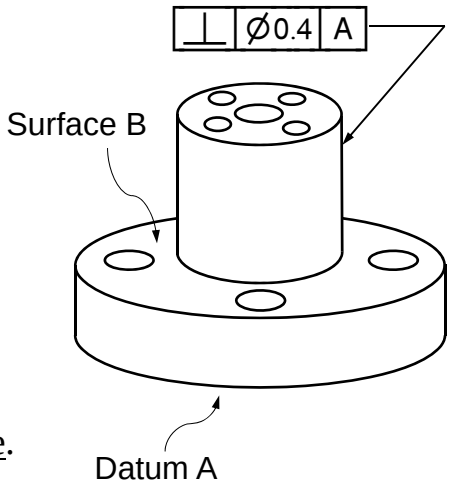


In 1988, a GIDEP Alert shut down CMM use for GD&T in some industries. The key example was parallelism not including the form error (reporting B, not A, shown above).
(GIDEP is Government-Industry Data Exchange Program)

Mitutoyo

The inspector who said "so what"

- Inspector used Surface B as datum instead of A.
- He measured the *wrong* surface and then said "so what" when questioned.
- If A and B are parallel *enough*, then is this ok?
- With the large 0.4 mm tolerance, the difference was negligible, <u>in this case</u>.

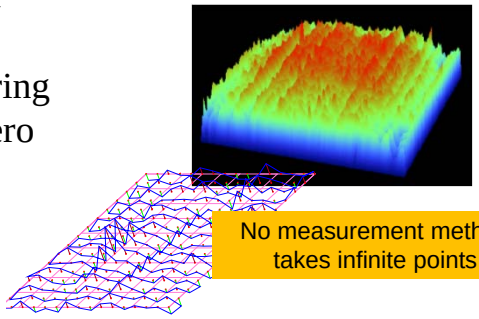


Mitutoyo

Measurement Planning

- Do we always measure at exactly 20°C (68°F)?
- Do we always measure infinite points on part surfaces?
- Do we use measuring equipment with zero error and perfect repeatability?

- All measurements involve balancing costs versus accuracy.



No measurement method takes infinite points

Mitutoyo

Comparing Measurement Uncertainty

"Right" – using Datum A

Component	Standard Uncertainty (µm)
Machine	3.5
Repeatability (probing, form, finish, fixturing)	12.0
Scale	1.2
Thermal	10.5
Datum	2.2
Expanded Uncertainty	25.0 µm
Tolerance	0.4 mm
TUR	16.0 to 1

"Wrong" – using Surface B

Component	Standard Uncertainty (µm)
Machine	3.5
Repeatability (probing, form, finish, fixturing)	54.0
Scale	1.2
Thermal	10.5
Datum	2.2
Expanded Uncertainty	60.0 µm
Tolerance	0.4 mm
TUR	6.7 to 1

- a measurement method is acceptable if the measurement uncertainty meets business needs

Both methods are acceptable

Mitutoyo

Measurement Quality

- You don't necessarily have to do a formal uncertainty analysis – you just need to recognize and manage the important sources of variation (error).

Source of Uncertainty		Management Technique
Instrument accuracy	→	Recalibration
Measurement process variation	→	Gage repeatability (or Gage R&R)
Methods divergence	→	Understand and assess impact or establish best practices

Industry doesn't have deep experience with managing methods divergence issues

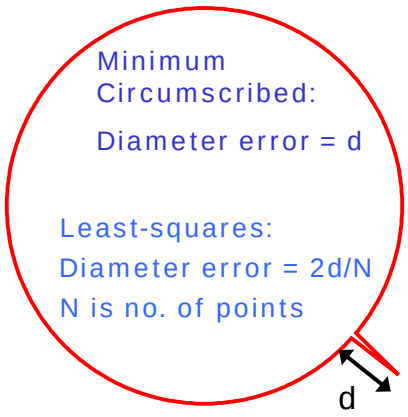
Mitutoyo

Do the ~~right~~ best thing?

- There is no "correct" measurement method.
- There is always error in each measurement.
- Decisions associated with measurement uncertainty must be managed and balanced with other factors (e.g. cost, productivity, risk) to find the best solution.
- Sometimes the "wrong" thing is really the "best" thing to do based on overall cost.
- See ASME B89.7.2 for more information.

Mitutoyo

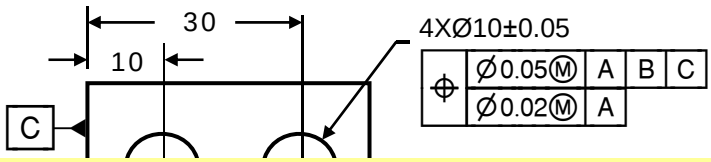
Wrong is best – our love affair with the least squares algorithm



- Easy to implement in software.
- Historically developed for handling imperfect measurement data.
- Most repeatable results.
- Averages out errors, like shown here for diameter influenced by “dirt”.

Mitutoyo

What is the Purpose of Your Measurement?



- Inspect/sort good from bad:
  - Careful attention to GD&T and measurement technique.
- Manufacturing process control:
  - Need to address what is important to manufacturing, which may be different than the design.
  - May want to decompose the GD&T tolerances into the important components to manage.

Mitutoyo

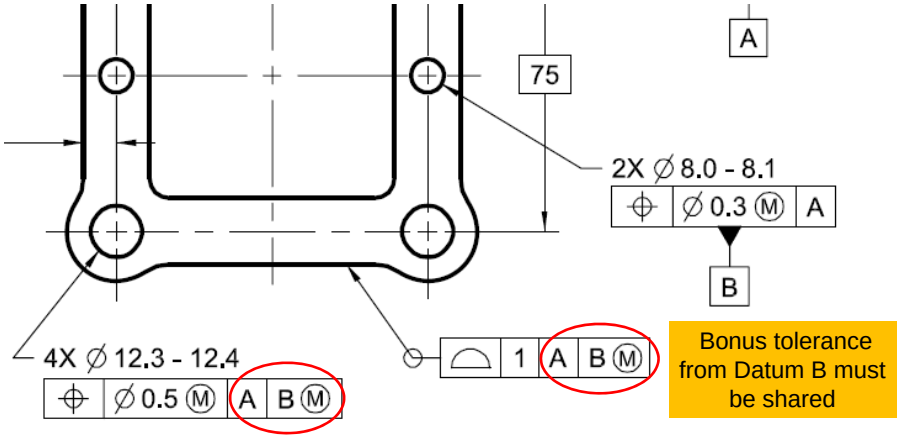
Is the Drawing even "Correct"?

- In theory, tolerances are supposed to be independent of measurement methods.
- But many drawing tolerances were developed based on data from measurements.
- In some cases, the drawing simply attempts to capture the functional manufacturing and measurement process.

Which came first – a functional part or the drawing?

Mitutoyo

And sometimes measurement is a real challenge…



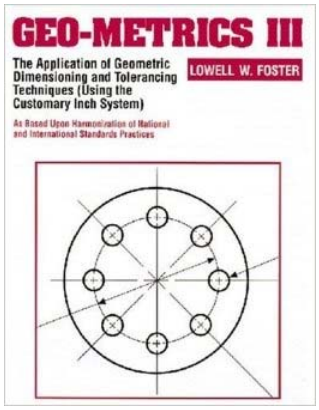
Bonus tolerance from Datum B must be shared

Patterns, simultaneous requirement, and Ⓜ on datums can create measurement challenges.

Mitutoyo

ASME Y14.5 versus ISO 1101

- There are two GD&T standards in use.
- In Lowell Foster's 1994 book GEO-METRICS III, he said there is 90 to 95% agreement between ASME and ISO.
- Example issue – same symbol, different meaning:



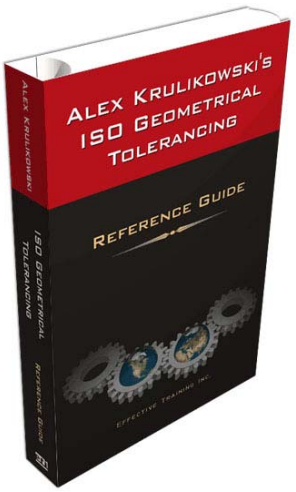
◎	Ø0.02	B

For concentricity, ISO controls axis but ASME controls opposed median points

Mitutoyo

ASME Y14.5-2009

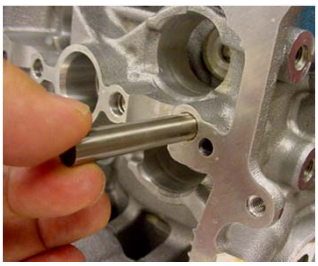
- In Alex Krulikowski's 2010 book ISO Geometrical Tolerancing, he says about 65% of the possible tolerances are either specified or interpreted differently between ASME and ISO.
- Though so much "looks the same", the difference in fundamental design principles continues to grow every year.



Mitutoyo

ASME vs. ISO for Size Tolerance

- In ASME Y14.5, a size tolerance controls the actual mating size and the local size.
- In ISO 1101, a size tolerance controls only a 2-point size, unless indicated otherwise.
  - To control the mating size in ISO, use the envelope symbol Ⓔ



Mitutoyo

Independency versus Simultaneous

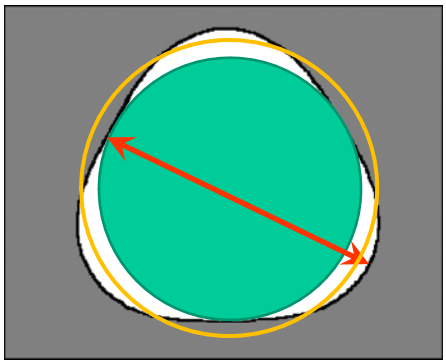
- ISO default is the Independency Principle, whereby specifications shall be fulfilled independently of other specifications.
- ASME default is Rule #1 and “Simultaneous Requirements” whereby many tolerance controls are linked together.

Both ISO and ASME support the principles of Independency, Envelope, and Simultaneous, but the defaults are the opposite between ISO and ASME and therefore the meaning of an engineering specification or drawing can be very different.

Mitutoyo

Impact of ISO-ASME Differences?

- The differences between ISO and ASME are real, but does it matter to you?
- Depends on:
  - Tightness of tolerances.
  - Magnitude of form error.
  - Measurement tools.
- Usually not a problem, until it gets suddenly ugly.



Need to establish rules and have a good way of deploying them

Mitutoyo

Possible GD&T Inspection Rules (CMMs)

- Never use ASME ◎
- Ignore Ⓜ on datums.
- Always report form, even if no tolerance.
- CNC measure datums.
- Report coordinate values in addition to ⌖
- Least Squares for axis
- Min Zone for form

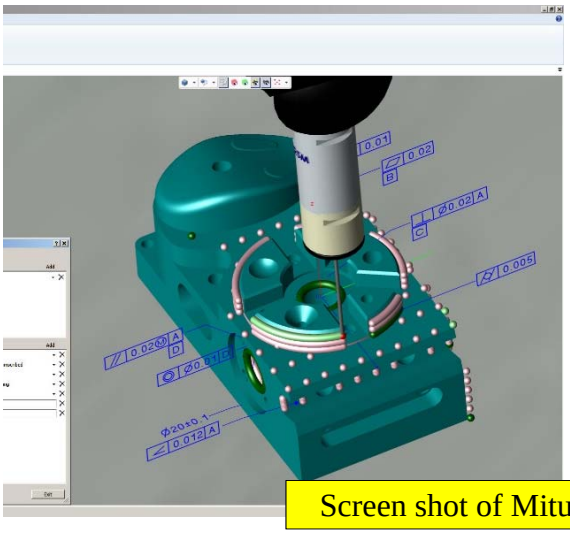
- Size – one average value.
- Cylinder – 3 circles: top, middle, and bottom. Report diameter of each.

Tolerance	Points/circle
> 0.010”	4
< 0.010”	8
< 0.002”	16
< 0.0005”	24

This is just an example

Mitutoyo

Rules-based CMM Programming



- From CAD model to measuring program in a few seconds
- Focus energy on establishing best practice rules, not on writing programs
- Eliminate variation coming from use of different methods.

Screen shot of Mitutoyo MiCAT Planner

Mitutoyo

Measurement Planning Software

Actions		
Measure	=	True
Fitting method	=	Maximum inscribed
Automatic tool selection	=	True
Sampling method	=	Contact scanning
Sampling pattern	=	Circles
Number of circles	=	7
Edge offset	=	1.000
Circular movement	=	True
Sampling interval	=	By number of points
Scan points per circle	=	100
High speed scan	=	True
Scan speed high	=	50.00
Filter type	=	Gaussian
Scan ru		
Scan run out angle	=	5.000000
Scan run in length	=	1.000

Screen shot of “rules editor” in new Mitutoyo MiCAT Planner software

Summary

- Be aware of GD&T meaning, standards, and your measuring software tools.
- Define best practice rules for your organization.
- Don’t fall for the “right” trap. The “wrong” method might save your organization a lot of money.
- If form error is small, then less problems.
- If tolerances are tight, then be careful.
- New software tools make deploying best practices across organizations much easier.

Mitutoyo

Thank You

Mitutoyo
Institute of Metrology

Mitutoyo
CALIBRATION
LABORATORY

Visit our On-Demand Educational resources at:
www.mitutoyo.com/education

Mitutoyo