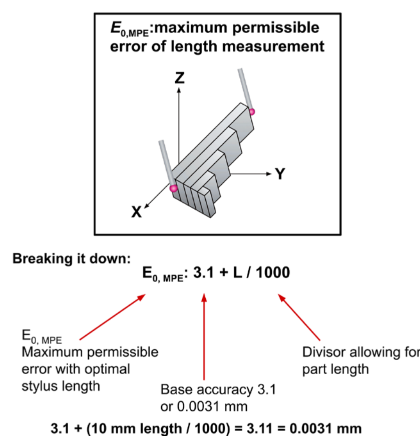
METROLOGY DECISION RISK

“Path to GOOD DECISIONS” series

Higher Risk of Inspectors/Metrologists Accepting Non-Conforming Parts!

The risk of rejecting parts that conform to specification requirements, and the higher risk of accepting parts that do not conform to specification requirements, is increasing. This risk is influenced by feature tolerances getting tighter and the level of confidence (or lack of confidence) the metrologist has in the full measurement process. This article highlights the key areas of concern and offers guidance to increase confidence and reduce the risk. Mechanical drawings that state compliance to the ASME Y14.5-2018 “Dimensioning and Tolerancing” includes compliance to ASME Y14.5.1-2019 “Mathematical Definition of Dimensioning and Tolerancing Principles.” This would also apply to earlier versions of the Y14.5 and Y14.5.1 standards.

Common Misconception of Maximum Permissible Error on a CMM



A major problem throughout all industries is individuals commonly are under the misconception that the stated 3-dimensional “maximum permissible error” (per ISO 10360-2) of the coordinate measuring machine (CMM), often stated as a baseline error plus some length dependent factor (e.g. $E_{0,\,MPE}$: 3.1µm + L/1000mm), equates to the measurement uncertainty when measuring features on a given manufactured part. Everyone needs to understand that this can be far from the true task/feature-based uncertainty required to make accept/reject decisions, which is influenced by many other key factors. Metrologists, inspectors, supplier engineers and anyone charged with the responsibility of ensuring manufactured parts truly conform to specification requirements must have this foundational knowledge.

Key Factors Influencing Measurement Confidence

- Measurement equipment being used ($E_{0,\,MPE}$), plus stylus/probe configuration including multi-probe orientations.
- Measuring procedure, which includes the feature-based point sampling used to measure the feature(s).
- Repeatability and reproducibility of the measurements, which would highlight interactions between the workpiece and setup.
- Environmental factors such as temperature and humidity of the environment measurements are taken.

- Software algorithms to ensure mathematically correct results especially with simultaneous Profile and Position callouts. Incorrect algorithms can produce repeatably and reproducibly incorrect results. Mechanical drawing stating compliance to the ASME Y14.5-2018 / ASME Y14.5.1-2019 Standards require use of specific algorithms (e.g.: minimum zone and simultaneous fitting algorithms), and/or knowledge and quantification of the associated uncertainties if other algorithms are used.
- Part dependent "Form" errors including surface texture, which is the highest level of unknown error until the features have been thoroughly tested/sampled with high point densities.
- A key factor out of the metrologists control is the specification requirement(s) defined by the designer. Quality Starts in Design, which means if the specification requirements (per ASME Y14.5/Y14.5.1) do not optimally reflect the true functional intent of the part, then everyone in manufacturing and metrology are dealing with design uncertainties that can be larger than the measurement error by an order of magnitude.

Understand how "Form" effects of all the surfaces

The expanded uncertainty should be a quantitative statement about our ignorance of the true value of the measurand. To accomplish this, we would need to understand the "Form" effects of all the surfaces or features associated with the specification requirements. For companies using a significant amount of GD&T, there can be multiple Profile of a Surface and Position callouts all related to a single Primary Datum, or no datum at all, which means (per ASME Y14.5) that all these specifications must be checked and analyzed "simultaneously" to ensure compliance. All these requirements control size, form, orientation, and location simultaneously, which must include many other uncertainty factors not even considered in the accuracy statement on a CMM. If we only use the $E_{0,\,MPE}$ (3D Maximum Permissible Error) values as the input to the expanded uncertainty then we increase the risk of accepting parts that might not conform to the specification requirements.

In my personal experience, the CMM $E_{0,\,MPE}$ accuracy statement, is one of the least significant error contributors to the task/feature specific uncertainty budget, especially for looser toleranced features. Be aware that CMM's use precision artifacts such as gage blocks and step gages, with exceptionally low form error, when characterizing to determine the $E_{0,\,MPE}$ values. Manufactured parts normally have much larger form deviations so the feature-based point sampling must be significantly larger to even determine the true form variation.

Metrology Decision Risk – Path to GOOD DECISIONS

To aid individuals in establishing a beginning understanding of the differences in 1) Tolerance to Uncertainty Ratios, 2) GR&R's, and 3) Uncertainty Budgets, four posters were jointly developed by PQI/AIS/IIGDT to try and help individuals with good metrology decisions related to understanding the impact of Measurement Uncertainty (UNC Budget). These posters are being made available to the world to help positive direction to reduce future risk. We also developed a "3-day Metrology Bootcamp and Uncertainty course" to aid individuals in establishing a positive foundation to improve these key skill sets (visit: Metrology Boot Camp).

Comparison

Tolerance to Uncertainty Ratio

Base Accuracy	3.1
Length Divisor	1000
Total Tolerance	0.02
Feature Size	10
Calculated Error	0.0031
% of Tol. (~TUR)	15.55%

GR&R

Pooled Standard Deviation	0.00090
Sigma Multiplier	4
R&R Value	0.00359
Total Tolerance	0.0200
% of Tol. (~TUR)	18.0%

Uncertainty Budget

GR&R Data	13.56%
Resolution	2.13%
CTE	1.58%
UNDE	0.16%
Accuracy Statement	66.02%
Surface Roughness Rz	15.06%
Form Deviations	1.51%
Combined Standard Uncertainty	0.00187
Expanded Uncertainty (K=2)	0.00375
% of Tol. (TUR)	37.48%

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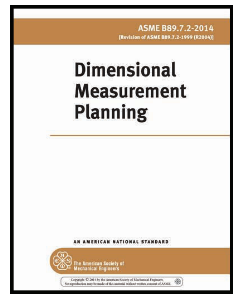
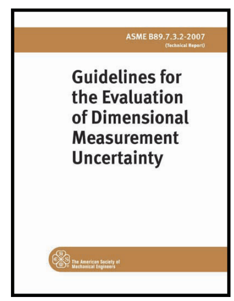
Industry Standards:

In addition, standards have been developed to aid industry with insight on how to determine and manage measurement uncertainty. In 1998, the American Society of Mechanical Engineers established the ASME B89.7 committee for Measurement Uncertainty, with the "Mission" to support U.S. manufacturing industry in a smooth, economical transition to the requirement of using measurement uncertainty. The outcome of this effort was the release of a full series of B89.7 documents. The following two are examples:

- ASME B89.7.2-2014 (R2019) "Dimensional Measurement Planning"
  - The intent of this Standard is to facilitate agreement between suppliers and customers by specifying a standard method for assessing the dimensional acceptability of workpieces. Components of the method are the preparation of an adequate dimensional measurement plan and use of the plan in making measurements. The major input to the method is dimensional specifications developed, for example, in compliance with ASME Y14.5 standards on Dimensioning and Tolerancing.



- ASME B89.7.3.2-2007 (R2021) "Guidelines for the Evaluation of Dimensional Measurement Uncertainty"
  - The primary purpose of this Technical Report is to provide introductory guidelines for assessing dimensional measurement uncertainty in a manner that is less complex than presented in the Guide to the Expression of Uncertainty in Measurement (GUM).



Download the free supporting poster:

Metrology Decision Risk - Path to Good Decisions
https://iigdt.com/metrology-decision-risk/pdf/The Path to Good Decisions Poster Series.pdf

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Metrology Matters is a project of these organizations to provide basic metrology fundamentals to manufacturing.