

Metrology Qualifying Exam Syllabus

last updated Fall 2023

The metrology is based on contents from the courses (i) Engineering Metrology and (ii) Machine Tool Metrology. Students must obtain 70% or above on the exam to pass.

The selected topics from the course Machine Tool Metrology contain:

Understand / Explain / Describe

- realms of manufacturing production
- machine tools in general
 - functional point
 - sub-system components and how they affect positioning repeatability and accuracy,
- physical determinism
 - generally
 - in the context of machine tool carriage motion
- reference coordinate systems
 - six degrees of freedom of a carriage positioning stage (machine tool “axis”).
 - rigid body assumption for moving components.
 - physical relationships of reference coordinate systems.
- eleven areas of machine tool performance parametric evaluation.
- instrumentation that is useful for measuring each of the eleven areas of machine tool performance.
- machine tool metrology applications
- instrumentation of systemic operation.
- international standards
 - Requirements, uses, and purposes.
 - ISO 230 and other standards (test codes) for parametric evaluation of machine tools

- measurand parameters defined by documentary standards for machine tools.
- difference between standards-based measurements and model-based measurements
- mathematically model parametric evaluations of machine tools.
- produce an error model for an arbitrary stacked carriage machine tool using rotation matrices and translation vectors.
- produce an error model for an arbitrary stacked carriage machine tool using rotation matrices and translation vectors and via homogeneous transformation matrices (HTMs)
- uncertainty analyses of the general error model of a machine tool
- specified parametric equation-based measurands.

The selected topics from the course Engineering Metrology contain:

- The SI – base units, unit definitions
- Vocabulary – definition of uncertainty, traceability, measurand, and related terms.
- Uncertainty evaluation – type A and B evaluations, LPU, contributors to uncertainty for dimensional metrology, calculation examples
- Decision rules, an agreement between measurements, use of EN
- Probability and statistics fundamentals, confidence intervals, hypothesis testing, ANOVA, ...
- Reversals
- Coordinate data fitting, algorithms, 1-, 2-, and ∞ - norms
- Errors of motion (some duplicate with machine tool metrology)
- Abbe offsets and errors
- GR&R studies
- Optical metrology – CSI, Confocal, Focus Variation techniques
- Tactile surface metrology – skidded, skidless
- Surface metrology basics – parameters, cutoffs, etc.

- Optical Form measurement – Fizeau, role of reference and/or null, CGH
- Displacement interferometry
- Documentary Standards – Y14.5, B46, instrument standards (use of MPEs)
- Thermal effects – ISO 1, calculation and correction of thermal effects
- Basics of GD&T – size, role of datums, envelope principle (Rule #1)