Introduction to Metrology



Metrology-Science of Measurement

- What do we usually measure
 - Time
 - Space
 - Flow
 - Mass/weight/force
- In this topic we will measure
 - Geometry
 - Quality
 - Surface finish



Topics

- Errors in Measurement
- Light Waves as a Standard of Length
- Linear Measurement
- Angular Measurement & Circular Division
- Limits & Limit Gauges, Fits and Tolerances
- Thermal Issues
- Coordinate Metrology
- Probability & Statistics
- Error Budgeting
- Measuring Machine Tools
- Gear & Screw Inspection
- Surface Texture & Roundness
- \$tatistical Quality Control.

Measurement Issues

- What is quality?
- What do I need to measure?
- How do I quantify it?
- Where are my quality problems?
- How accurate
- Does the measurement need to be?
- Is the measurement?
- How fast do I need to measure?.



Machine and Control System Design

- Structural
- Kinematic / semi-kinematic design
- Abbe Principle or options
- Elastic averaging and fluid film
- Direct displacement transducers
- Metrology frames
- Servo-drives and control
- Drives
- Carriages
- Thermal drift
- <u>– Error compensation.</u>

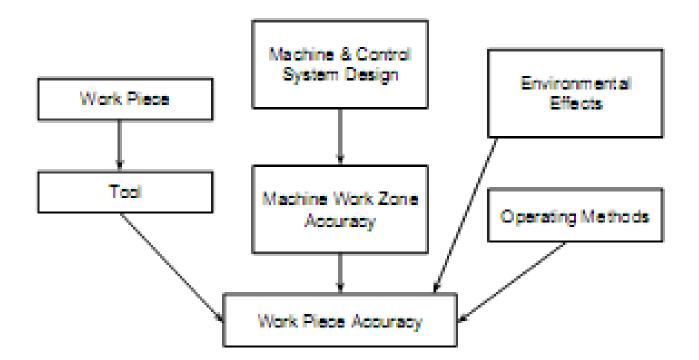


- Environment
- Temperature
- External vibrations
- ♦ seismic
- airborne
- Humidity
- Pressure
- Particle size
- Machine Work Zone Accuracy
- Displacement (1D)
- Planar (2D)
- Volumetric (3D)



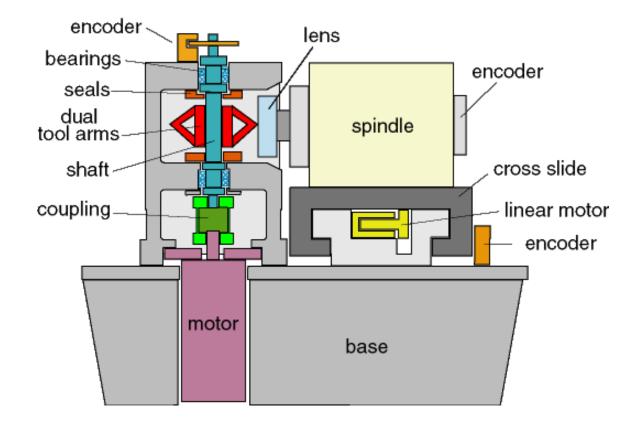
- Spindle error motions.

- ✤ Tool
- Geometry (wear)
- Stiffness
- Built Up Edge effects
- Speeds
- Feeds
- Workpiece
- stiffness
- Weight
- Datum preparation
- Clamping
- Stress condition
- $\overline{1}$ Thermal properties
- Limpurities.





An Diamond Turning Machine





Definitions

- Accuracy
- a quantitative measure of the degree of conformance to recognized national or international standards of measurement
- Repeatability
- a measure of the ability of a machine to sequentially position a tool with respect to a work piece or produce a part within small range under similar conditions.
- Resolution
- is the least increment of a measuring device; the least significant bit on a digital machine.

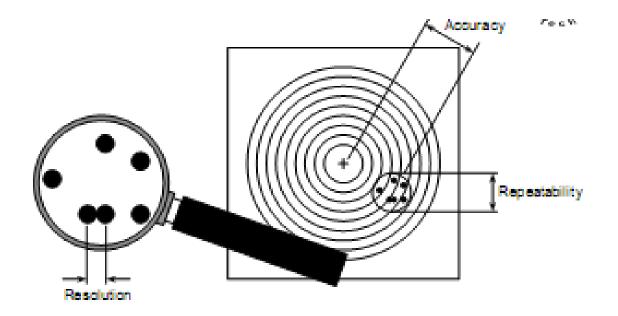


Definitions

- Accuracy
- a quantitative measure of the degree of conformance to recognized national or international standards of measurement
- Repeatability
- a measure of the ability of a machine to sequentially position a tool with respect to a work piece or produce a part within small range under similar conditions.
- Resolution
- is the least increment of a measuring device; the least significant bit on a digital machine.

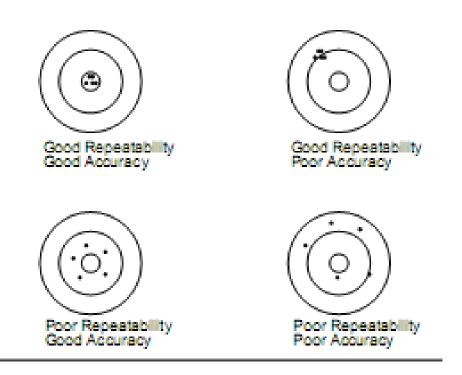


Basic Terms in Metrology





Repeatability and Accuracy





Establishing Machine Capabilities

- Cut part
- Inspect part for dimensional accuracy
- Infer from data overall machine accuracy
- Advantages
- machine can be optimized for a particular part
- simple purchase and acceptance specifications
- Disadvantages
- machine accuracy masked by other error sources (e.g., inspection errors, process errors, etc...)
- individual sources of error are not identified
- the accuracy data cannot be extended to other part geometries.



Establishing.....

- Apply machine tool metrology principles
- Parametric accuracy testing
- straightness
- squareness
- positioning spindle motion ...
- No load tool path accuracy testing (contouring accuracy).



Parametric Accuracy Testing

- Advantages
- machine can be specified according to individual parameter
- test results can be used to correct or compensate for error sources
- test results can be used to predict tool path error contribution in the inaccuracy of a given part geometry
- test results can be merged with process error information to establish an overall manufacturing error budget for a component
- periodic re-testing can be used for process validation and predictive maintenance
- Disadvantages
- test procedures can be time consuming
- testing requires test equipment
- higher level of skill required
- -___the accuracy of a particular work piece geometry is not determined.



Standard-ANSI B5.54

- Provides procedures for machine tool testing
- Facilitates machine tool performance comparisons by:
- unifying terminology
- classifying machine tools
- addressing the treatment of environmental effects
- describing tests and methods of tests
- ✤ The B5.54 standard also
- addresses most issues faced by the majority of machine tool builders and users
- coordinates terminology with ISO and other national standards
- provides a fair and uniform set of measures by which to evaluate machine tools for performance
- The standard does not
- place limits on 100% testing of any individual machine
- replace more complete tests that may be suitable for special applications.



Other Stds.

- ✤ ANSI/ASME B89.3.1-1972
- Measurement of Out-of-Roundness
- ✤ ANSI/ASME B89.6.2-1973
- Temperature and Humidity Environment for Dimensional

Measurement

- ✤ ANSI/ASME B46.1-1978
- Surface Texture
- ✤ ANSI/ASME B89.3.4M-1985

Axes of motion

Determinism

The basic idea is that automatic machine tools obey cause and effect relationships that are within our ability to understand and control and that there is

nothing random or probabilistic about their behavior.

- (J. Bryan)
- "Random" implies
- the causes of the error cannot be determined
- nothing can be done about the causes of the variations
- the best one can do is try to statistically assess the range of variatio
- Machine tools have apparent non-repeatable errors rather than random errors
- Statistics
- a statistical approach to quantifying non-repeatable errors us a tool
 enabling us to address variables that are too numerous or expensive to
 sort them out using common sense and good metrology.

