Geometric Attributes

- Group Technology: A tool for DFM
- Dimensional Tolerances
- Shape and Location Deviations; Geometric Dimensioning and Tolerancing (ASME/ISO standards)
- Engineering Metrology
  - Accuracy vs. Precision
  - Variation (errors) in measurements
  - Characteristics of Measuring Instruments
- Surface Characterization
Dimensioning and Tolerancing

- Shape of Manufactured Parts
- Group Technology
- Dimensional Tolerances
- Geometrical Dimensioning and Tolerancing
Shape

- Function dictates part shape.
- Shape should make manufacturing easy.
# Shape Classification

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Uniform cross section</th>
<th>Change at end</th>
<th>Change at center</th>
<th>Spatial curve</th>
<th>Closed one end</th>
<th>Closed both ends</th>
<th>Transverse element</th>
<th>Irregular (complex)</th>
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Group Technology

• Group Technology (GT)
  – Ensures economics in design and manufacturing through classification of families of parts according to their commonalities in design features and manufacturing processes and sequences.
Need for Dimensional Tolerances

The goal is to ensure functionality and interchangeability.

Rifles with interchangeable parts (1850, Robbins & Lawrence)

Select and fit assembly - Early assembly line. Flywheels and magnetos being assembled at Ford’s Highland Park, Michigan plant in 1913.
Goals of Dimensional Tolerancing

- Dimensional control required – exact dimensions are not possible nor necessary.
- Maximum and minimum limits of dimensions (length and angle)
  - Set tolerance close enough to ensure functionality and interchangeability.
  - Set tolerance as wide as possible to reduce manufacturing cost.
Tolerance Zone and Types of Fit

- Tolerance (Tolerance Zone) is the allowable variation of dimension.
- Clearance fit allows sliding or rotation.
- Transition fit provides accurate location.
- Interference fit provides rigidity and alignment.
Form and Profile Tolerances

1. Straightness
2. Flatness
3. Circularity
4. Cyclindricity
5. Profile of a Surface
Location Tolerances

1. Position tolerance
2. Concentricity
3. Symmetry
Summary

- **Shape affects function and manufacture.**
- **Group technology offers cost and time savings.**
- **Dimensions and tolerances – Key attributes in engr. drawings.**
- **Maintaining Specified tolerance – function of assemblies and interchangeability.**
- **GD&T – communicates intent of design, facilitates production & QC.**
Engineering Metrology

- Principles of Variation
- Attributes of Measurement Devices
- Measurement Devices
- Surface Topology
Principles of Variation

• Variations (Randomness) is given by nature.

Need parameters to describe randomness

Average \( \rightarrow \) Mean

Variation \( \rightarrow \) Standard deviation

Statistically, for observations \( x_1, x_2, \ldots, x_n \)

\[
\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}
\]

\[
\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}}
\]
Random Error vs. Systematic Error

Systematic error is likely caused by assignable factors such as temperature, humidity, …
Random error is cause by unknown sources, but often related to human errors.
Source of Variation in A Measurement System

• When checking a dimension of a part being produced in large quantity, the variation of the readings can come from the following sources:
  – Product error – variation of parts being produced, $\sigma_p$.
  – Gage error – variation associated with the measurement device and method, $\sigma_g$.
    • Repeatability error – variation associated with measurement device itself, $\sigma_e$.
    • Reproducibility error – variation associated with measurement operators, methods, etc., $\sigma_o$.

  Total measurement variation $= \sigma_p^2 + \sigma_g^2$
  $\quad \quad \quad \quad \quad \quad \quad \quad = \sigma_p^2 + \sigma_e^2 + \sigma_o^2$
Capability of A Measurement Device

• Rules of thumb
  – The precision of a measurement device should be 10 times better than the precision of the dimension to be measured.

  – The gage error should be 30% or less of the product error, i.e.,
    \[ \frac{\sigma_g}{\sigma_p} < 30\% \]
Attributes of Measurement Devices

- Sensitivity of a gage
- Linearity
- Repeatability
- Stability
- Speed of response
- Feasibility of automation
Measurement Devices

- Gages in a broader sense: an instrument that measures some variable.
- Gages in a narrower sense: gage blocks, plug gages, ring gages, thread plugs
- Graduated measuring devices

Dial indicator
Optical Devices

Linear encoder
Angular encoder
Pneumatic Gages

- Measure the back pressure generated when air emerging from the orifice of the gage head impinges upon the surface of the part.
- Within a narrow dimensional range, pressure change is proportional to the size of the gap between gage head and workpiece surface.
- Can measure both flat and cylindrical surfaces.
- Widely used on shop floors.
- Need frequent calibration.
Coordinate Measurement Machines (CMM)
Gantry Type CMM

Gantry configuration with dual linear motor drives, laser scales, and on-line compensation.

Sheffield Measurement
Surface Characterization

- $R_t$ is the maximum roughness height
- $R_a$ is the arithmetical average
- $R_q$ is the Root mean square
- Skewness
Surface Characterization (Profilometry)

- Basic measurement is to drag a stylus across the surface and measure the deflection.

Figure 3-25: Surface features are revealed by drawing a stylus, attached to a pickup, across the surface.