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

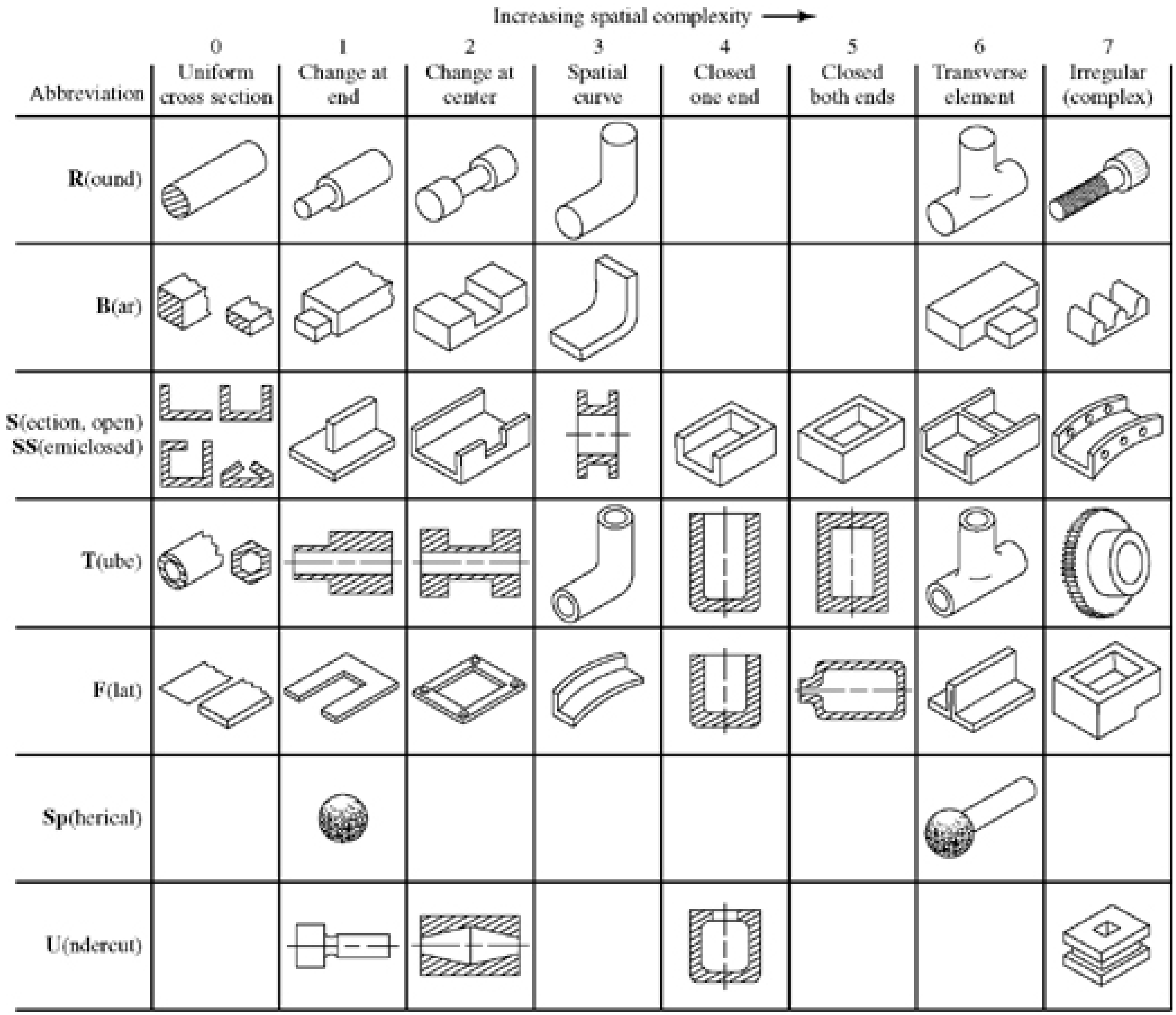


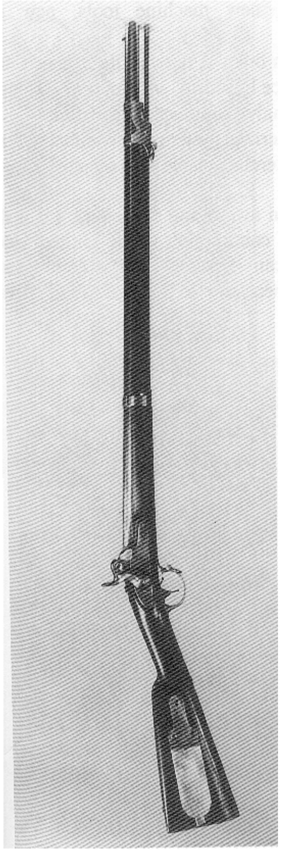
figure 3.1

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.



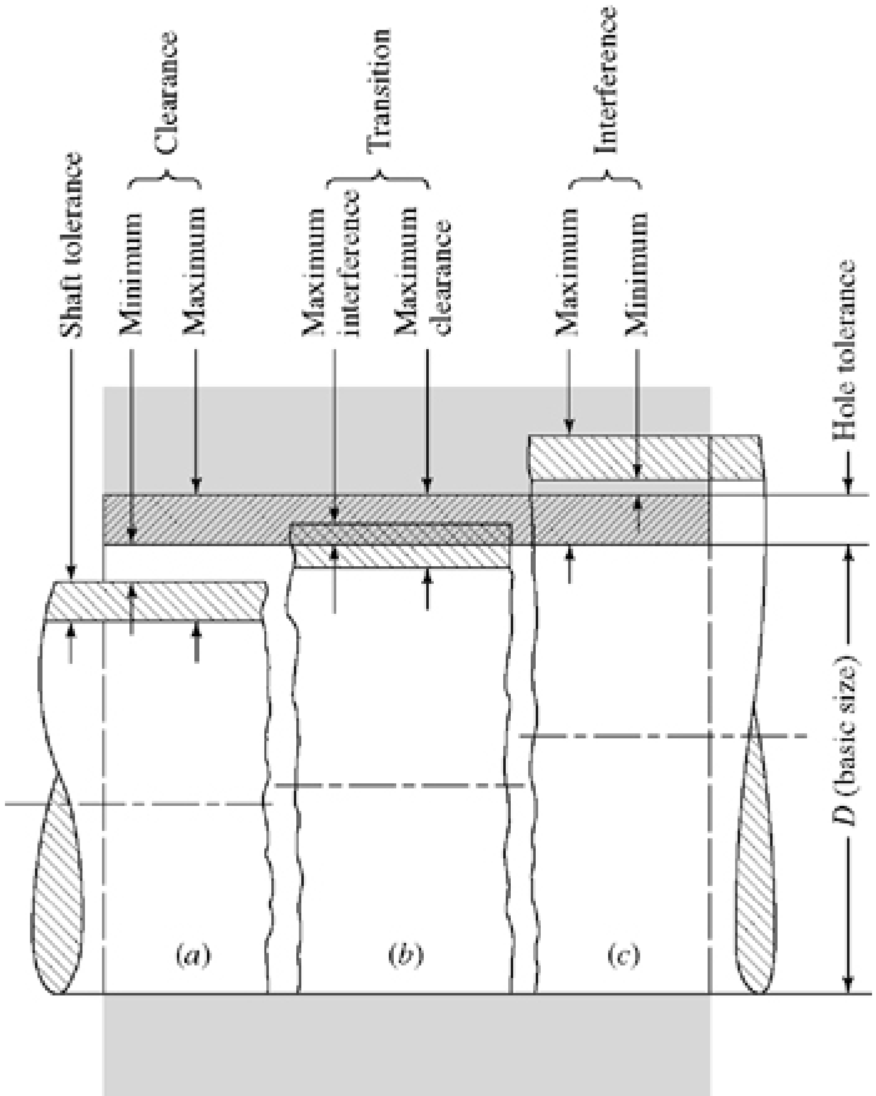
Rifles with interchangeable parts (1850, Robbins & Lawrence)

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

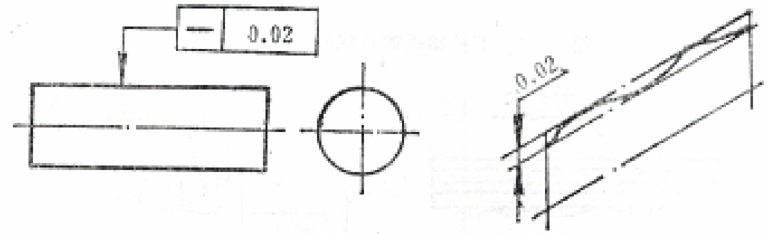


- – **Tolerance (Tolerance Zone) is the allowable variation of dimension.**
- – **Clearance fit allows sliding or rotation.**
- – **Transition fit provides accurate location**
- – **Interference fit provides rigidity and alignment.**

figure 3.4

Form and Profile Tolerances

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



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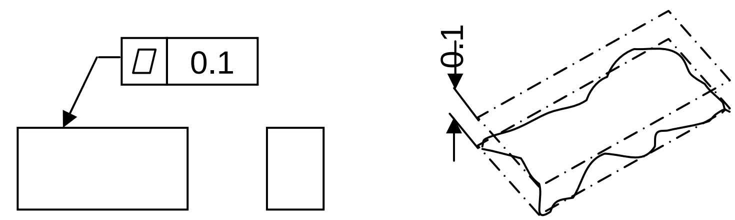

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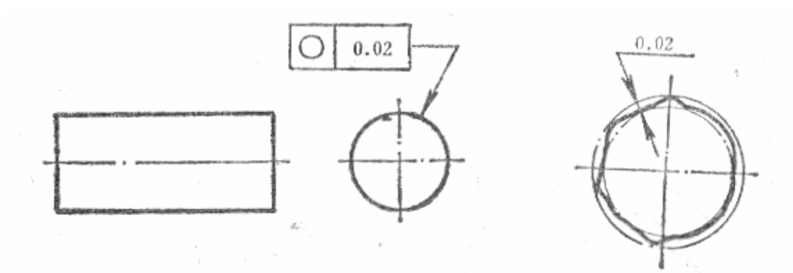

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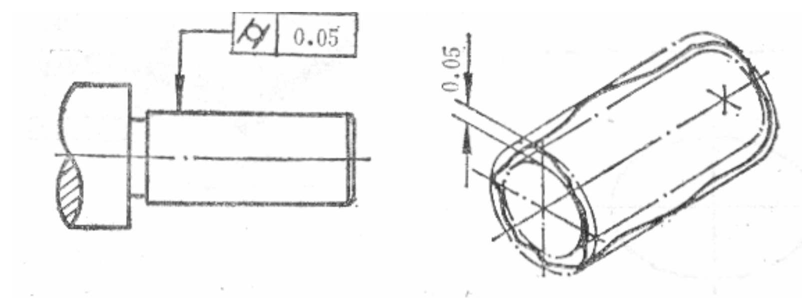

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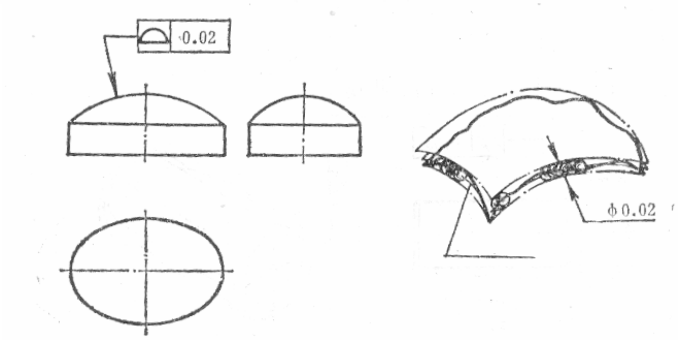

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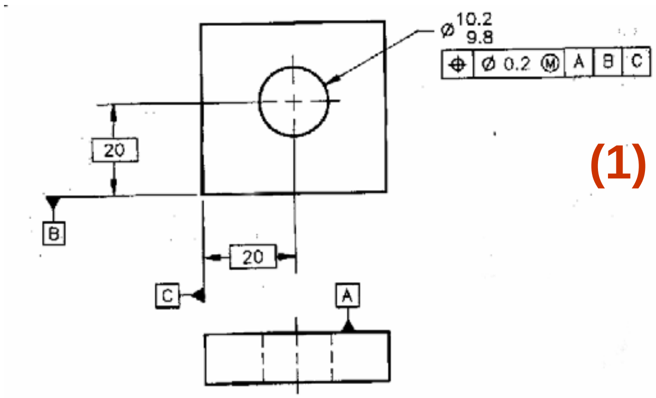
Location Tolerances

1. Position tolerance
2. Concentricity
3. Symmetry



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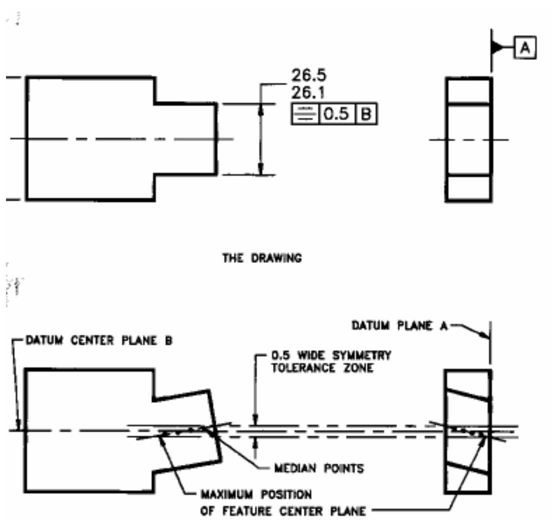

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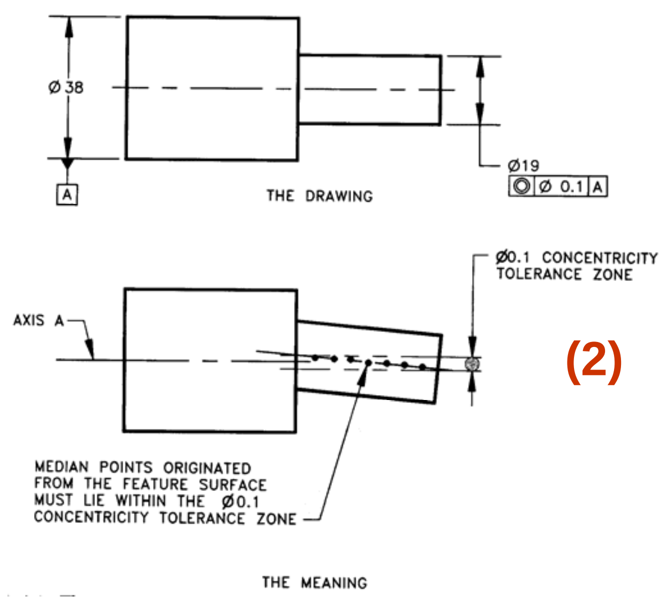
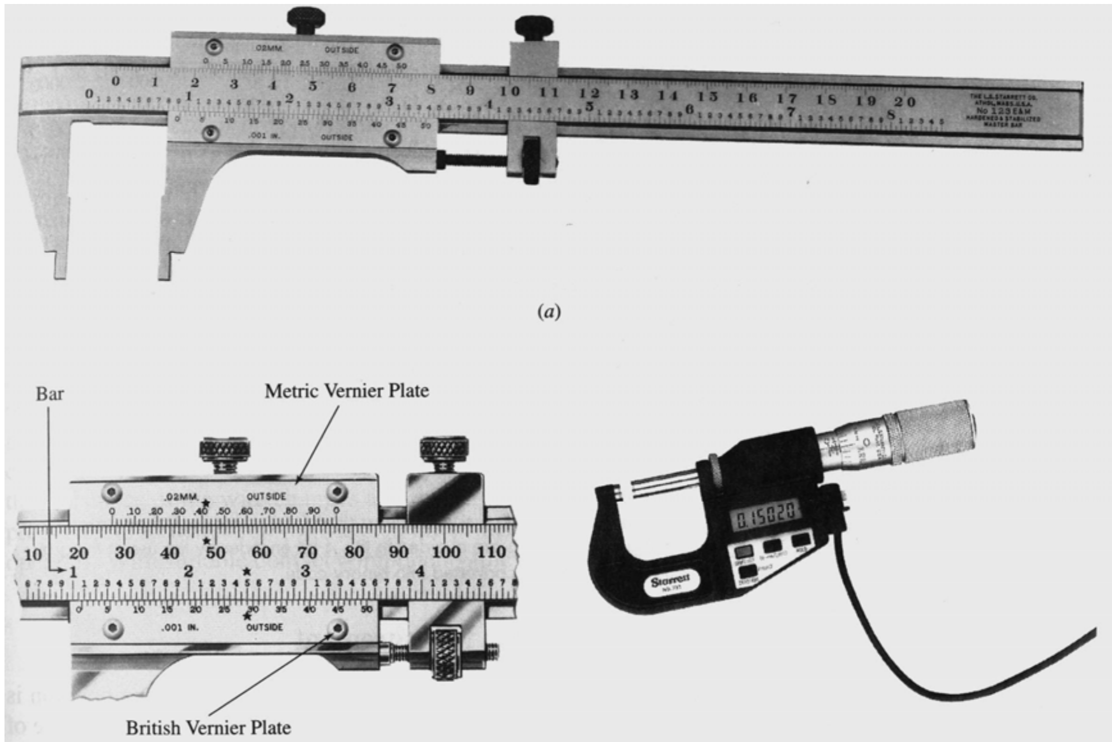


(2)

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.

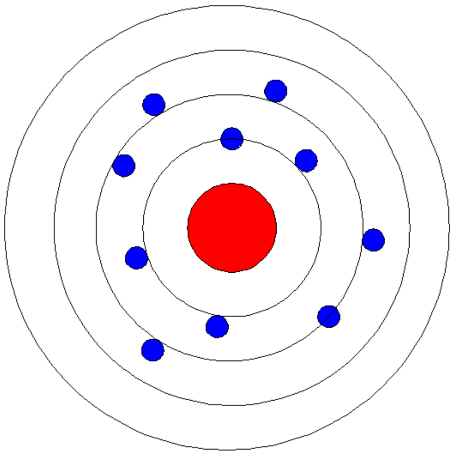
Engineering Metrology



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

Principles of Variation

- Variations (Randomness) is given by nature.



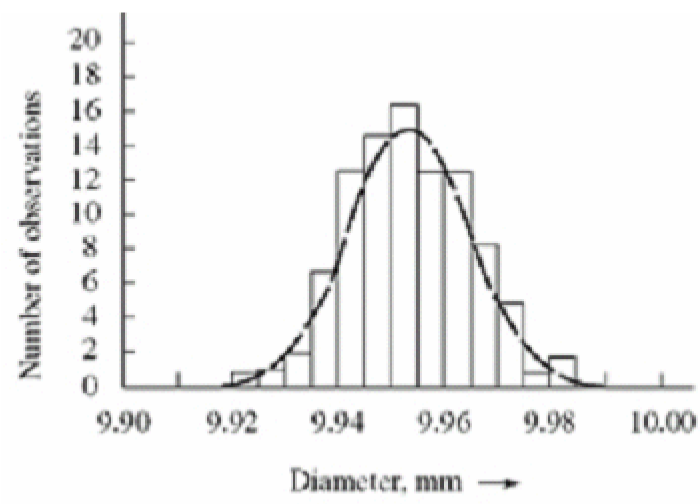
Need parameters to describe randomness

Average ------→Mean

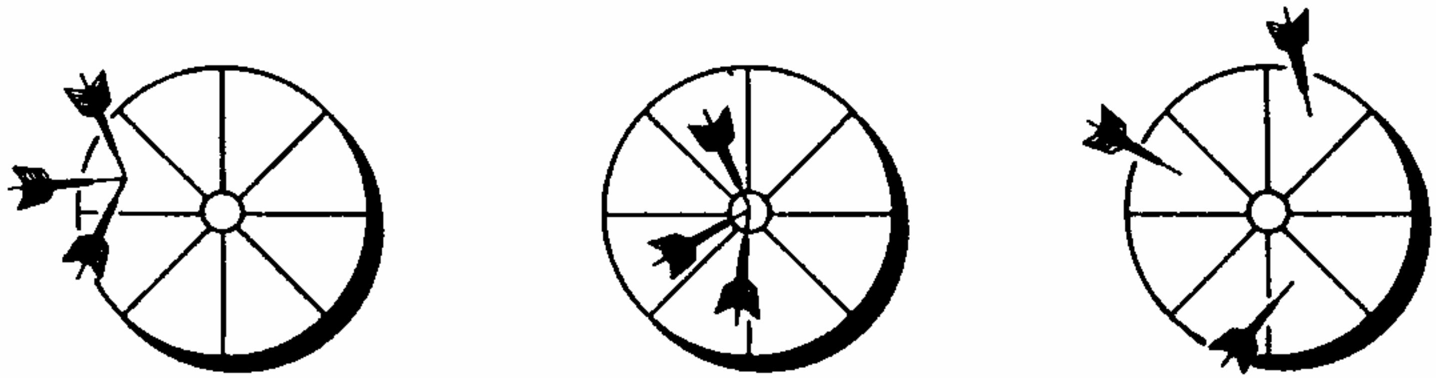
Variation -----→ Standard deviation

Statistically, for observations $x_1, x_2, \ldots, x_n$

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$



Random Error vs. Systematic Error



(*a*) High repeatability gives low precision error but gives no direct indication of accuracy

(*b*) High accuracy means low precision and bias errors

(*c*) Bias and precision errors lead to poor accuracy

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

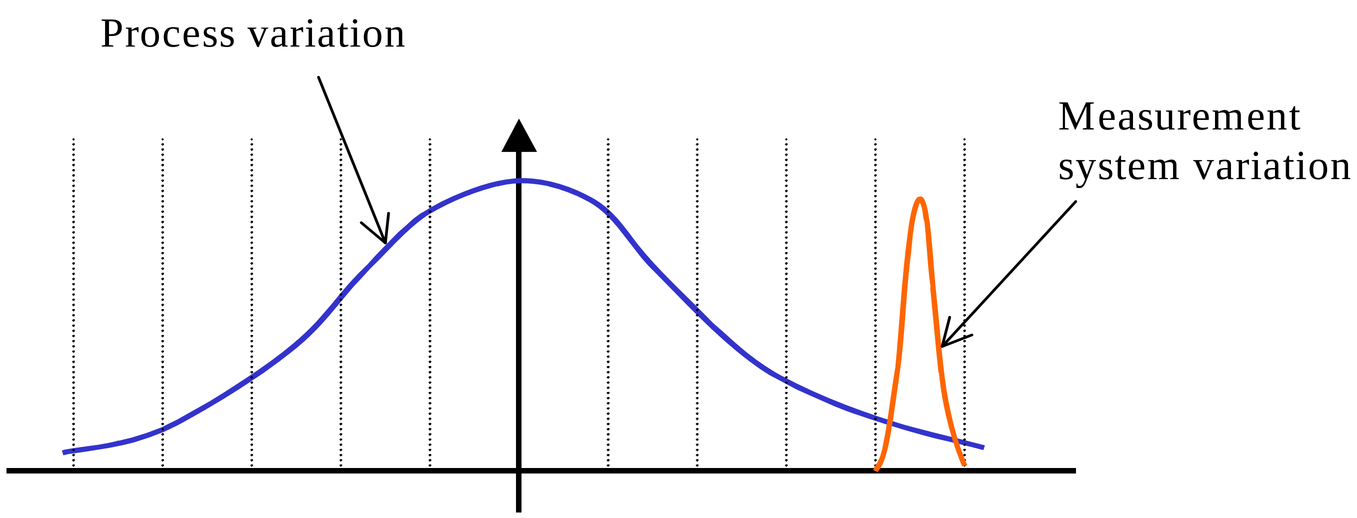
- When checking a dimension of a part being produced in large quantity, the variation of the readings can come from the following sources:
  - Product error – variation of parts being produced, $\sigma_{p.}$
  - Gage error – variation associated with the measurement device and method, σ_g
    - Repeatability error – variation associated with measurement device itself, σ_e
    - Reproducibility error – variation associated with measurement operators, methods, etc., σ_o

$$
\begin{aligned}
\text{Total measurement variation} &= \sigma_p^2 + \sigma_g^2 \\
&= \sigma_p^2 + \sigma_e^2 + \sigma_o^2
\end{aligned}
$$

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.,

$$\sigma_g / \sigma_p < 30\%$$

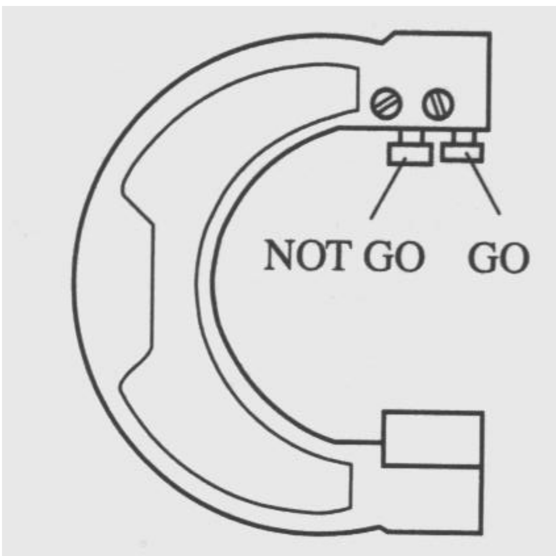


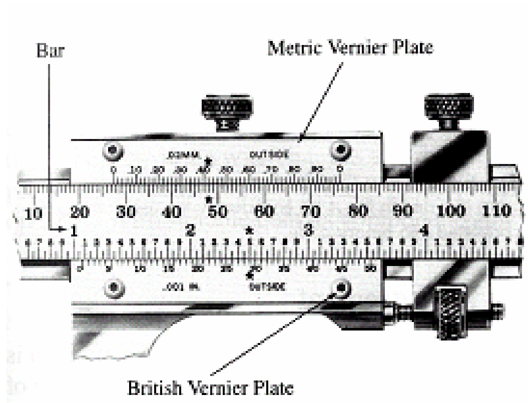
Attributes of Measurement Devices

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

Measurement Devices

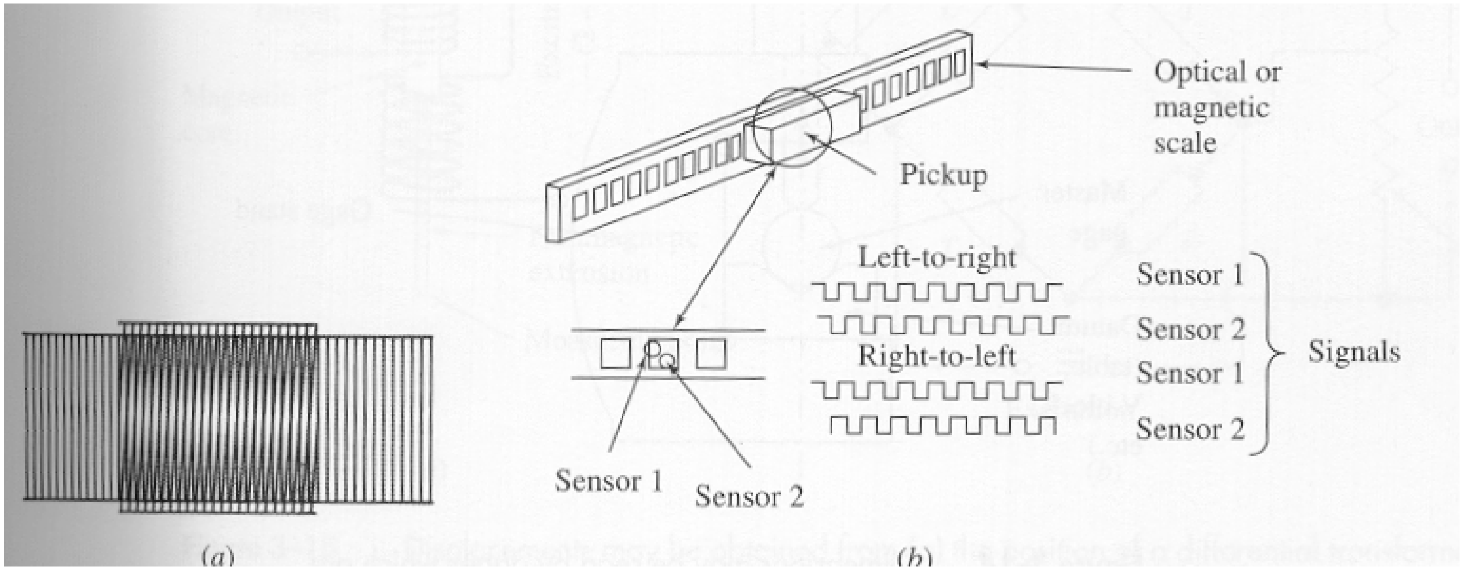
- Gages in a broader sense: an instrument that measures some variable.
- Gages in a narrower sense: gage blocks, plug gages, ring gages, thread plugs
- Graduated measuring devices

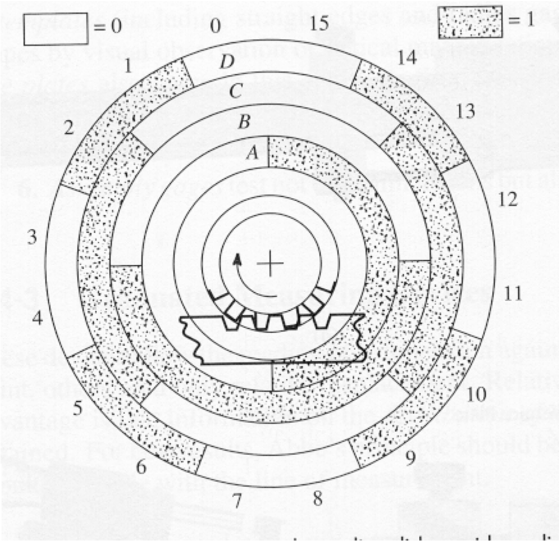




Dial indicator

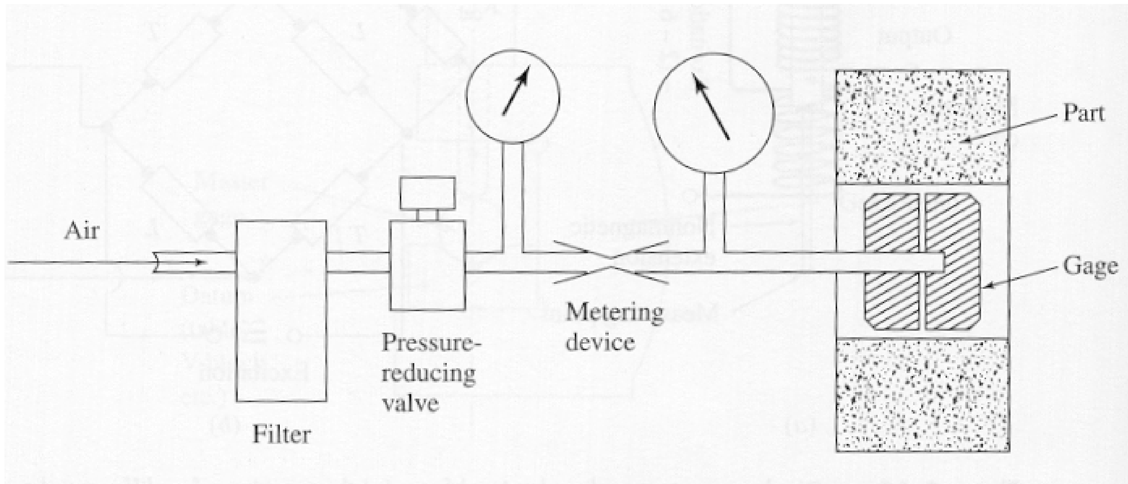
Optical Devices





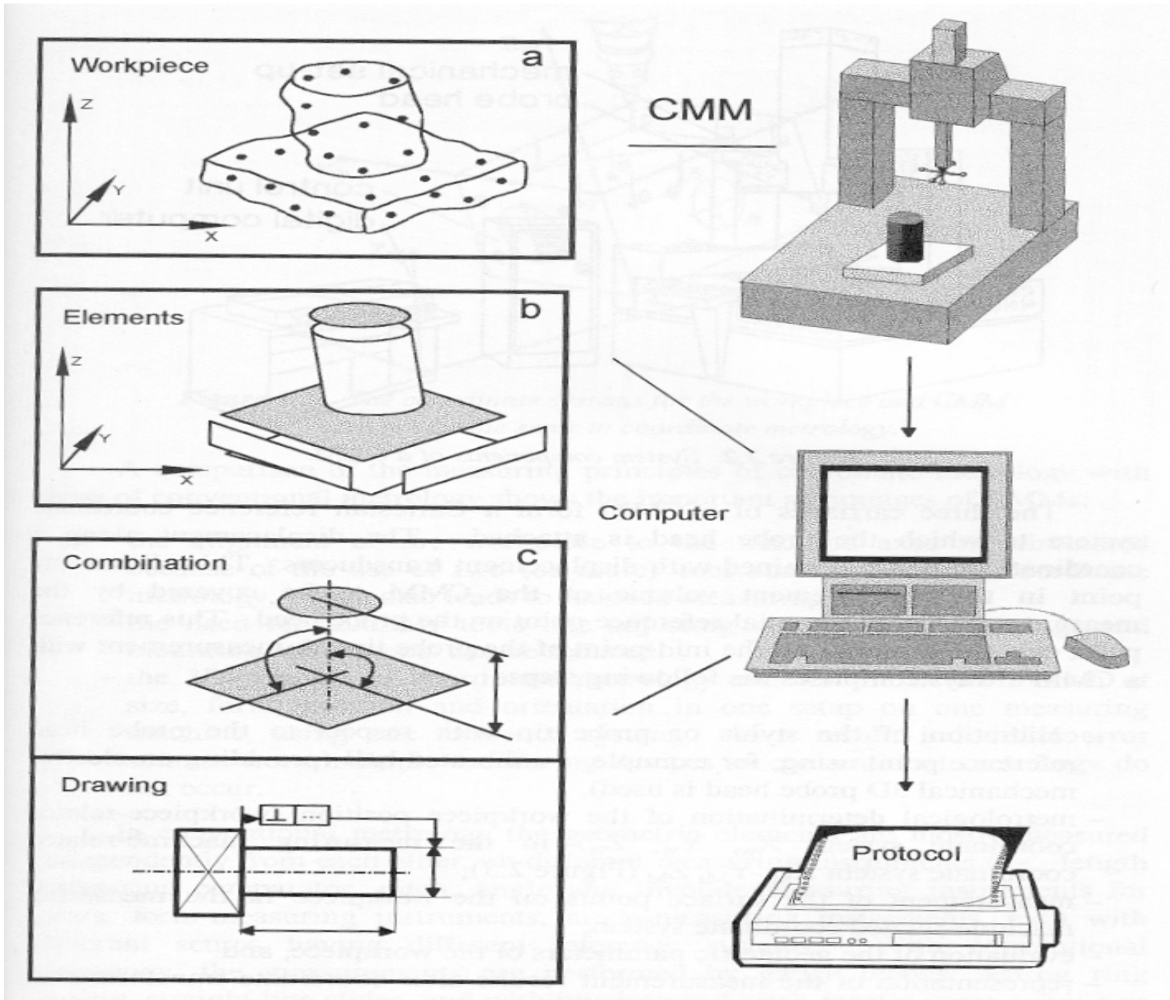
Linear encoder
Angular encoder

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)

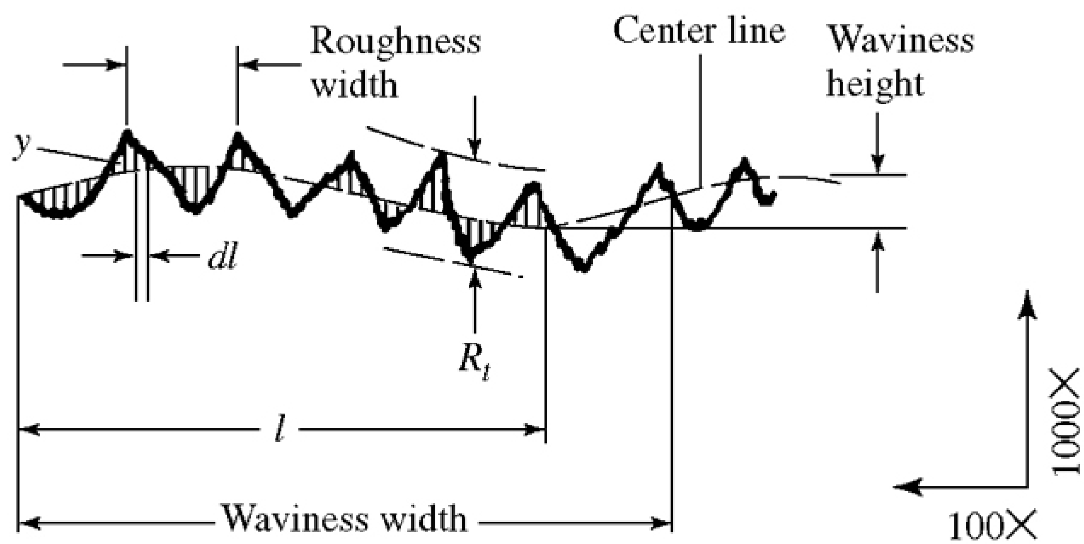


Gantry Type CMM

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

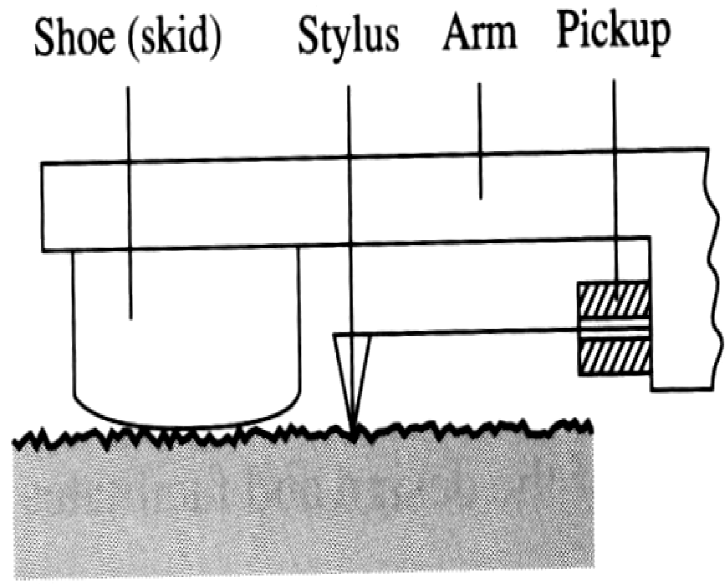


Figure 3–25 Surface features are revealed by drawing a stylus, attached to a pickup, across the surface.