TA 202A

Lecture 12

Measurement and Metrology

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Metrology

- Metrology is the science of measurement
- Dimensional metrology is that branch of Metrology which deals with measurement of "dimensions" of a part or workpiece (lengths, angles, etc.)
- Dimensional measurements at the required level of accuracy are the essential link between the designers' intent and a delivered product.

Dimensional Metrology Needs

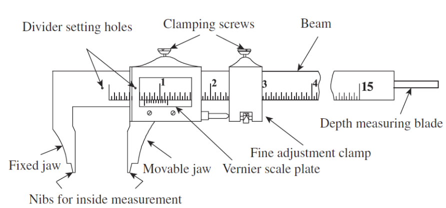
- Linear measurements
- Angular measurements
- Geometric form measurements
  - Roundness
  - Straightness
  - Cylindricity
  - Flatness, etc.
- Geometric relationships
  - Parallel, perpendicular, etc.
  - Concentric, runout, etc.
- Controlled surface texture

Types of Measurement and Instruments Used

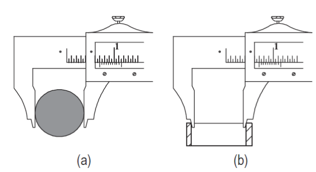
Measurement	Instrument	Sensitivity μm	Sensitivity μin.
Linear	Steel rule	0.5 mm	1/64 in.
	Vernier caliper	25	1000
	Micrometer, with vernier	2.5	100
	Diffraction grating	1	40
Angle	Bevel protractor, with vernier	5 min	
	Sine bar		
Comparative length	Dial indicator	1	40
	Electronic gage	0.1	4
	Gage blocks	0.05	2
Straightness	Autocollimator	2.5	100
	Transit	0.2 mm/m	0.002 in./ft
	Laser beam	2.5	100
Flatness	Interferometry	0.03	1
Roundness	Dial indicator Circular tracing	0.03	1
Profile	Radius or fillet gage		
	Dial indicator	1	40
	Optical comparator	125	5000
	Coordinate measuring machines	0.25	10
GO-NOT GO	Plug gage		
	Ring gage		
	Snap gage		
Microscopes	Toolmaker's	2.5	100
	Light section	1	40
	Scanning electron	0.001	0.04
	Laser scan	0.1	5

Linear-Measuring Instruments

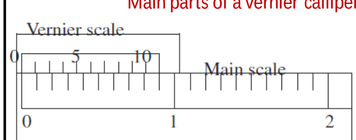
Vernier calliper



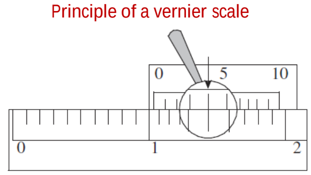
Main parts of a vernier calliper



Measurement of dimensions (a) Outside dimension (b) Inside dimension



Principle of a vernier scale



Fourth division of vernier coinciding with a division on the main scale

Calculation of least count: The minimum length or thickness that can be measured with a vernier scale is called the *least count.*

N VSD = $(N-1)$ MSD

1 VSD = $(N-1)/N$ MSD

Least count = 1 MSD – 1 VSD

Therefore, Least count = 1 MSD – $(N - 1)/N$ MSD

Least count = $[1- (N - 1)/N]$ MSD

Least count = 1 MSD/N

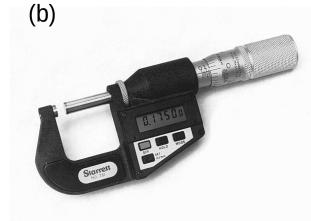
Total reading = MSR + (VC × LC)

MSR: Main scale reading
LC: Least count
VC :Vernier coinciding division

Analog and Digital Micrometers

(a)

(b)



(a) A micrometer being used to measure the diameter of round rods.

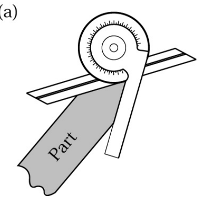
(b) Vernier on the sleeve and thimble of a micrometer.

(c) These dimensions are read in a manner similar to that described Vernier Caliper.

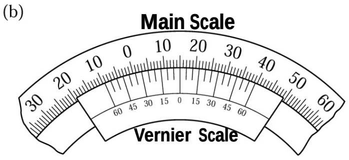
1. A digital micrometer with a range of 0-1 in. (0-25 mm) and a resolution of 0.00005 in. (0.001 mm = 1μm).
2. Note how much easier it is to read dimensions on this instrument than on the analog micrometer shown in (a).
3. However, such instruments should be handled carefully.

Angle-Measuring Instruments

(a)



(b)

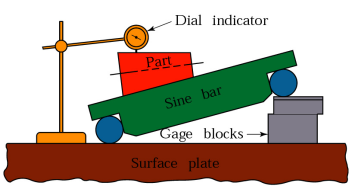


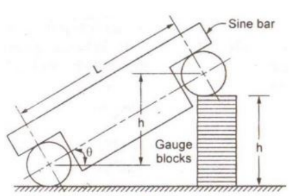
(a) Schematic illustration of a bevel protractor for measuring angles

(b) Vernier for angular measurement, indicating 14° 30´

Sine bar:

Setup showing the use of a sine bar for precision measurement of workpiece angles.





$$\sin\theta = \frac{h}{L}$$

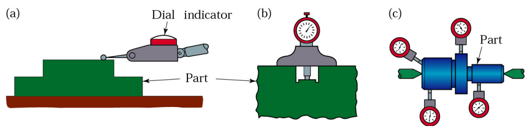
For error in angle measurement, differentiating h with respect to θ, we have

$$\frac{d\theta}{dh} = \frac{\sec\theta}{L}$$

Gage Block Will Give The Height And Center To Center Distance Is Known In Advance.

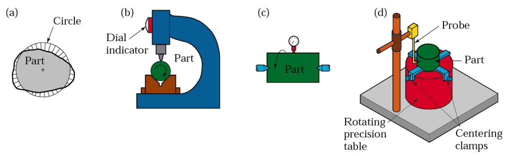
Therefore, the error in angle measurement **dθ**, due to an error **dh** in height **h** is proportional to **secθ**.

Use of Dial Indicators



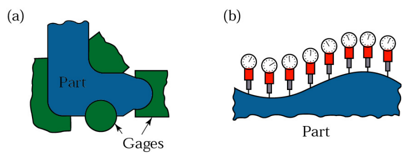
Different applications of a Dial Indicator (a) Multi dimensions measurement, (b) Depth Measurement, (c) Roundness measurement

Measuring Roundness

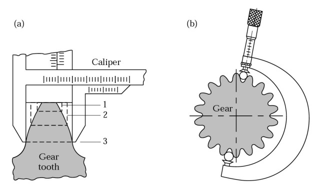


(a) Schematic illustration of "out of roundness" (exaggerated). Measuring roundness using
(b) V-block and dial indicator,
(c) part supported on centers and rotated
(d) circular tracing, with part being rotated on a vertical axis.

Measuring Profiles



Measuring profiles with (a) radius gages and (b) dial indicators



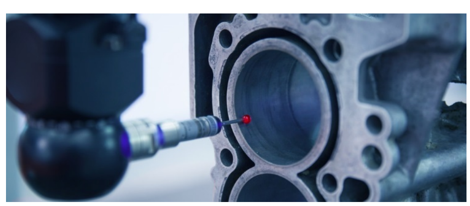
Measuring gear tooth profiles with (a) gear-tooth caliper and (b) Ball and micrometer

Coordinate Measuring Machine (CMM)

- To measure the actual size of workpiece, comparison with desired shape and evaluation of metrological information, such as
  - Size
  - Form
  - Location
  - Position
- Actual size is obtained by probing the surface at discrete measuring points. Every point is expressed in terms of its x,y,z coordinates
- Probes may be mechanical, optical, laser, or white light, among others

Components of CMM

- Mechanical Setup with 3 axes movement & the displacement transducer
- Probe head to probe the workpiece in a spatial direction
- Control Unit
- Computer with software to calculate & represent the results



Measurement of Cutting Forces

Different types of transducers used in dynamometers for measuring machining forces.

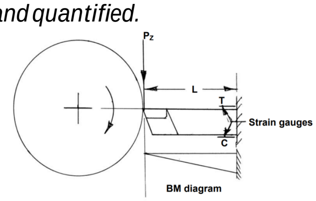
Measurement of cutting forces is based on three basic principles :

(a) measurement of elastic deflection of a body subjected to the cutting force

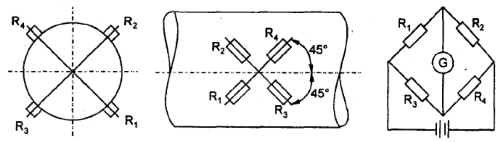
(b) measurement of elastic deformation, i.e. strain induced by the force

(c) measurement of pressure developed in a medium by the force.

The type of the transducer depends upon how that deflection, strain or pressure is detected and quantified.



Measuring cutting forces by strain gauges



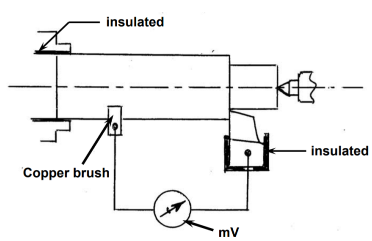
Measuring cutting force by monitoring elastic strain caused by the force

The cutting forces are suitably measured by using the change in strain caused by the force.

$$\varepsilon = \frac{\sigma}{E} = \frac{M/Z}{E} = \frac{P_Z.l}{Z.E} = k_1 P_Z$$

Measurement of Cutting Temperatures

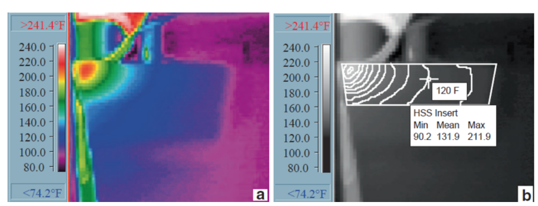
Thermocouple Method



Tool-work thermocouple technique of measuring cutting temperature

- When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, here is a continuous current which flows in the thermoelectric circuit- **Seebeck Effect**.
- The tool and the job constitute the two dissimilar metals and the cutting zone functions as the hot junction

Radiation Method



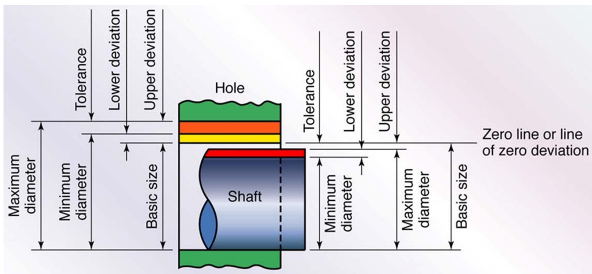
(a) Infrared thermal image and (b) processed image with 10 °F isotherms for dry cut of Al6061-T6 with HSS at 28 m/min, 0.058 mm/rev

- Cameras and films sensitive to infrared radiation can be used to determine the temperature distribution in the cutting zone.
- A furnace of known temperature is usually photographed simultaneously with the cutting operation to allow calibration.

Introduction to Tolerances

It is impossible to manufacture a part or component to an exact size or geometry, hence acceptable degree of variation must be applied.

- Tolerances are used to control the amount of variation inherent in all manufactured parts.
- One of the great advantages of using tolerances is that it allows for interchangeable parts, thus permitting the replacement of individual parts.



Bilateral Tolerances

20 ± 0.5 $\quad 20^{+0.5}_{-0.5}$ $\quad \begin{matrix}20.05\\19.95\end{matrix}$

Unilateral Tolerances

$20^{+0.5}_{0}$ $\quad \begin{matrix}20.05\\20.00\end{matrix}$

In unilateral tolerance, variation can be only in one direction. That is either Negative or Positive.

Shaft: A term used by convention to designate all external features of a part, including those which are not cylindrical.

Hole: A term used by convention to designate all internal features of a part, including those which are not cylindrical.

Basic Size: the nominal diameter of the shaft (or bolt) and the hole. This is, in general, the same for both components.

Actual Size: the measured size of the finished part after machining.

Zero Line: It is a straight line corresponding to the basic size. The deviations are measured from this line. The positive and negative deviations are shown above and below the zero line respectively.

Limits of Size: The term limits of size referred to the two extreme permissible sizes for a dimension of a part (hole or shaft), between which the actual size should lie.

Maximum Limit of Size: The greater of the two limits of size of a part(Hole or shaft).

Minimum Limit of Size: The smaller of the two limits of size of a part(Hole or shaft).

Allowance: It is defined as an intentional difference between the maximum material limits of mating parts. Allowance is the minimum clearance (positive allowance), or maximum interference (negative allowance) between mating parts.

Tolerance: It is the difference between the upper limit and lower limit of a dimension.

Tolerance Zone: It is the zone between the maximum and minimum limit size.

Deviation: The Algebraic Difference Between Size (Actual, Maximum etc.) and The Corresponding Basic Size.

Lower Deviation: The algebraic difference between the minimum limit of size and the corresponding basic size.

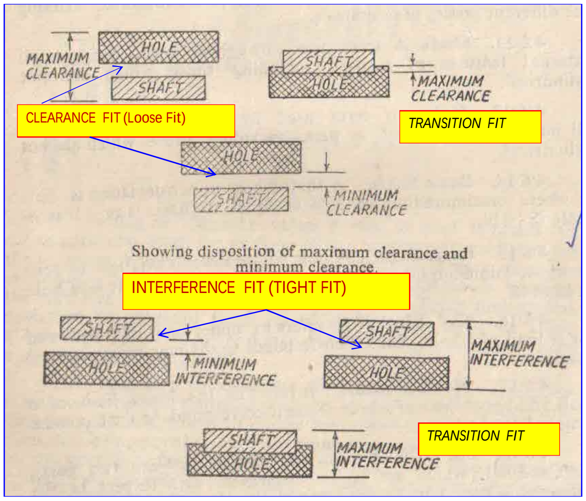
- It is a positive quantity when the minimum limit of size is greater than the basic size and a negative quantity when the minimum limit of size is less than the basic size.
- It is designated by *EI* for a hole and *ei* for a shaft.

Upper Deviation: Thealgebraic difference between the maximum limit of size and the corresponding basic size.

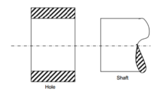
- It is a positive quantity when the maximum limit of size is greater than the basic size and a negative quantity when the maximum limit of size is less than the basic size.
- It is designated by ES for a hole and es for a shaft.

Types of Fit

A fit may be defined as the degree of tightness and looseness between two mating parts.

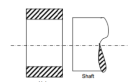


- Clearance fit



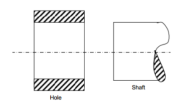
  - Clearance = Hole - Shaft
  - Hole - Shaft > 0
  - Hole > Shaft

- Interference fit



  - Interference = (- Clearance)
  - Hole - Shaft < 0
  - Hole < Shaft

- Transition fit



Clearance Fit (Loose Fit)

Clearance fit occurs when two toleranced mating parts will always leave a space or clearance when assembled.

- In clearance fit, an air space or clearance exists between the shaft and hole
- Such fits give loose joint.
- A clearance fit has positive allowance, i.e. there is minimum positive clearance between high limit of the shaft and low limit of the hole.
- Allows rotation or sliding between the mating parts.

Interference Fit

Interference fit occurs when two toleranced mating parts will always interfere when assembled.

- A negative difference between diameter of the hole and the shaft is called interference.
- In such cases, the diameter of the shaft is always larger than the hole diameter.
- It used for components where motion, power has to be transmitted.
- Interference exists between the high limit of hole and low limit of the shaft.

Transition Fit

Transition fit occurs when two toleranced mating parts will sometimes be an interference fit and sometimes be a clearance fit when assembled.

- It may result in either clearance fit or interference fit depending on the actual value of the individual tolerances of the mating components.
- Transition fits are a compromise between clearance and interference fits.
- They are used for applications where accurate location is important but either a small amount of clearance or interference is permissible.

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Recap of this Topic

- Introduction to Metrology
- Different types of Measurement Instruments
- Introduction to Limit, Fit and Tolerances