Measurement and Industrial Instrumentation

ME 3225

Credit: 3.00

Measurement

Presented By

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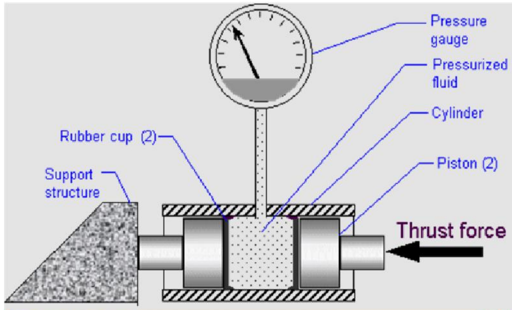
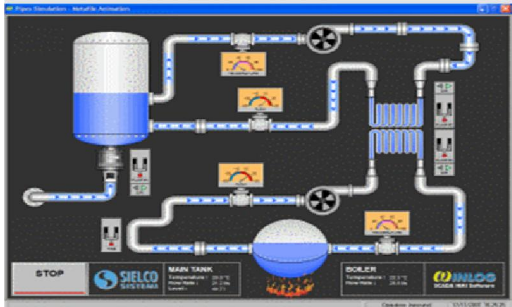
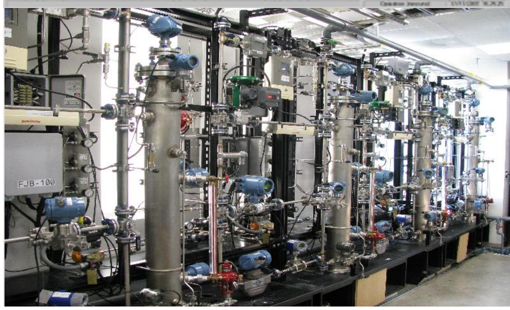




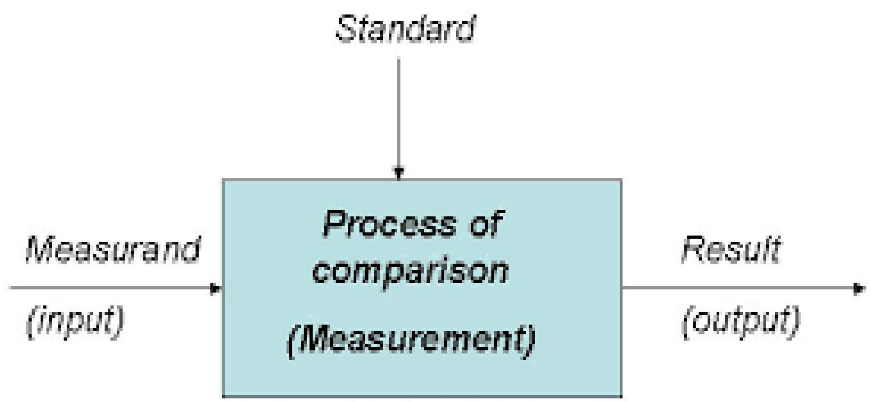


Measurement

- **Measurement** is the act, or the result of a quantitative comparison between a predetermined standard and an unknown magnitude.
- The physical quantity or the characteristic condition which is the object of measurement in an instrumentation system is variously termed as "**measurand**", "measurement variable", "instrumentation variable", or "process variable".

Basic Requirements For A Meaningful Measurement

- The standard used for comparison purposes must be accurately defined and should be commonly accepted.
- The apparatus used and the method adopted must be provable.



Fundamental Measuring Process

Instrument & Instrumentation

- An Instrument may be defined as a device for determining the value or magnitude of a quantity or variable.
- The technology of using instruments to measure and control the physical and chemical properties of materials is called Instrumentation.
- When instruments are used for the measurement and control of industrial manufacturing, conversion or treatment process, the term “process instrumentation” is used.
- When the measuring and controlling instruments are combined so that measurements provide impulses for remote automatic action, the result is called a “control system”.

Why Measurements?

- Measurements play a very significant role in every branch of scientific research and engineering process which include the following:
  - Control system
  - Process instrumentation
  - To acquire data or information
- In the case of process industries and industrial manufacturing
  - To improve the quality of the product
  - To improve the efficiency of production
  - To maintain the proper operation
- Importance of Measurement is simply and eloquently expressed in the following statement of famous physicist Lord Kelvin: "*I often say that when you can measure what you are speaking about and can express it in numbers, you know something about it; when you cannot express in it numbers your knowledge is of meager and unsatisfactory kind*"

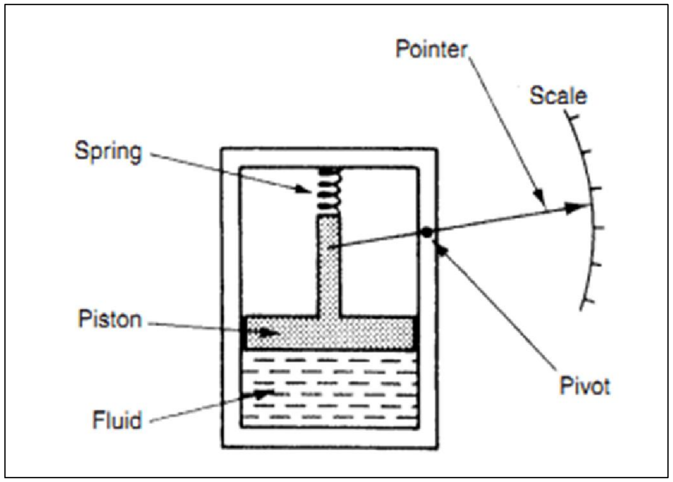
Methods of Measurement

- **Direct Methods**: In these methods, the unknown quantity (called the measurand) is directly compared against a standard.
- **Indirect Methods**: Measurements by direct methods are not always possible, feasible and practicable. In engineering applications measurement systems are used which require need of indirect method for measurement purposes.
  - Absolute/Fundamental method
  - Comparative method
  - Transposition method
  - Coincidence method
  - Deflection method
  - Complementary method
  - Contact method
  - Contactless method etc.

Types of Instruments

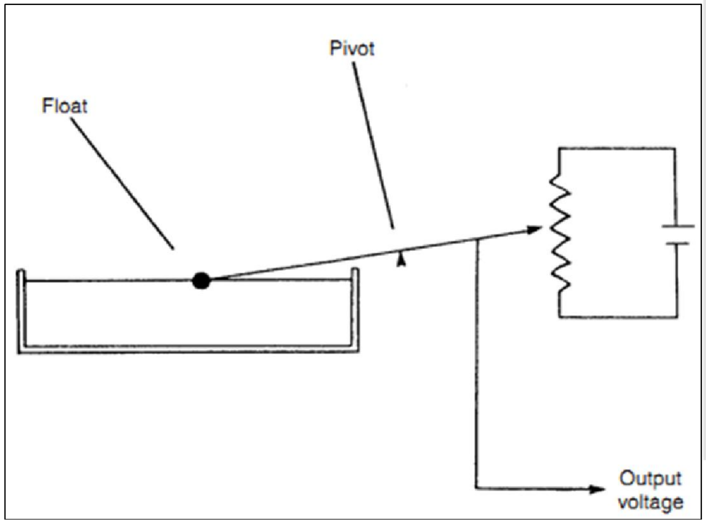
- Instruments are divided as active or passive instrument.
- In Passive Instruments the instrument output is entirely produced by the quantity being measured.
- In Active Instruments the quantity being measured simply modulates the magnitude of some external power source.
- ”Active” means is that some component inside requires power, either a battery or an external voltage source for working.
- “Passive” just means that no components inside need to be powered.

Understanding Active and Passive Instruments



Passive Instrument:
Pressure Measuring Device

Active Instrument:
Float-type Petrol Tank Level Indicator



Understanding Active and Passive Instruments

- An example of a passive instrument is the pressure-measuring device shown in Figure. The pressure of the fluid is translated into a movement of a pointer against a scale. The energy expended in moving the pointer is derived entirely from the change in pressure measured: there are no other energy inputs to the system.
- An example of an active instrument is a float-type petrol tank level indicator as sketched in Figure. Here, the change in petrol level moves a potentiometer arm, and the output signal consists of a proportion of the external voltage source applied across the two ends of the potentiometer. The energy in the output signal comes from the external power source.

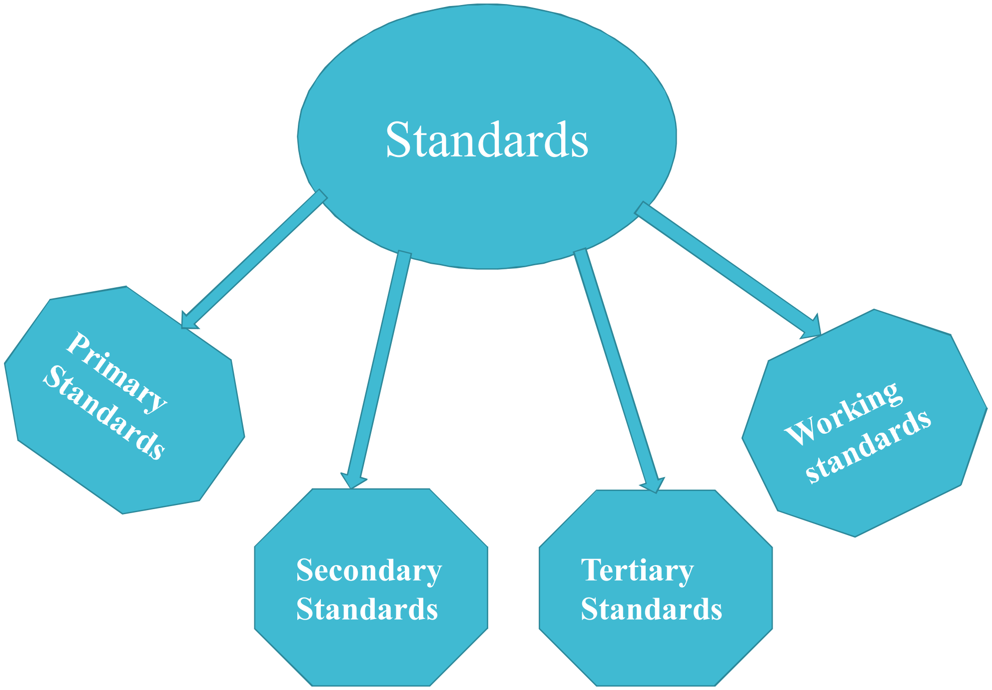
Difference between Active and Passive Instruments

S.No.	Passive Instruments	S.No.	Active Instruments
1.	The output is produced entirely by the quantity being measured.	1.	The quantity to be measured activates some external power input source, which inturn produces the output.
2.	Additional energy input source not required.	2.	Additional external energy input source is .equired.
3.	The resolution is less.	3.	The resolution is high.
4.	The resolution can not be easily adjusted.	4.	The resolution can be adjusted by adjusting the magnitude of the external energy input.
5.	Simple to design.	5.	Complicated to design.
6	Cheaper hence economical.	6.	Due to complex design and higher number of elements, it is costlier.
7.	Examples are pressure gauge, voltmeter, ammeter.	7.	Examples are liquid level indicator, flow indicator.

Standard

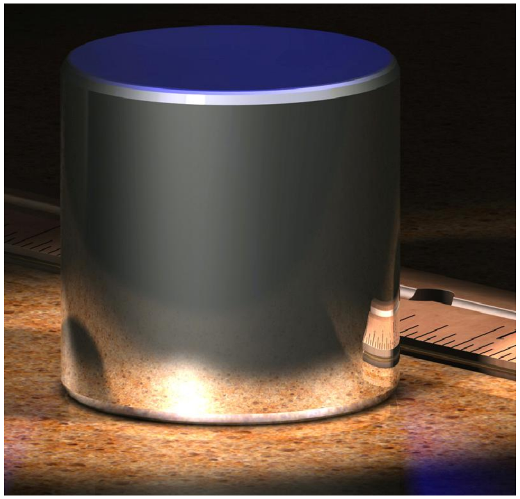
- In metrology, a **standard** is an object, system, or experiment that bears a defined relationship to a unit of measurement of a physical quantity.
- Standards are the fundamental reference for a system of weights and measures, against which all other measuring devices are compared.
- **Examples of Standard Bodies**:
  - International Organization for Standardization (ISO)
  - International Electrotechnical Commission (IEC)
  - American National Standards Institute (ANSI)
  - Standards Council of Canada (SCC)
  - British Standards (BS)

Subdivision of Standard



Primary Standard

- For precise definition of the unit, there shall be one, and only one material standard, which is to be preserved under most careful conditions. It is called as primary standard.
- International yard and International meter are the examples of primary standards.
- Primary standard is used only at rare intervals (say after 10 to 20 years) solely for comparison with secondary standards.
- It has no direct application to a measuring problem encountered in engineering.



Secondary Standards

- Secondary standards are made as nearly as possible exactly similar to primary standards as regards design, material and length.
- They are compared with primary standards after long intervals and the records of deviation are noted.
- These standards are kept at number of places for safe custody.
- They are used for occasional comparison with tertiary standards whenever required.

Tertiary Standards

- The primary and secondary standards are applicable only as ultimate control.
- Tertiary standards are the first standard to be used for reference purposes in laboratories and workshops.
- They are made as true copy of the secondary standards.
- They are used for comparison at intervals with working standards.

Working Standards

- Working standards are used more frequently in laboratories and workshops.
- They are usually made of low grade of material as compared to primary, secondary and tertiary standards, for the sake of economy.
- They are derived from fundamental standards.

Errors in Measurement

- **Measurement Error** is the difference between a measured value of a quantity and its true value.
- In statistics, an error is not a "mistake". Variability is an inherent part of the results of measurements and of the measurement process.
- It is not possible to completely eliminate error in a measurement.
- Measurement errors can be divided into two components:
  - *Systematic Error and*
  - *Random Error*

Systematic Error

- Systematic error is predictable and typically constant or proportional to the true value.
- If the cause of the systematic error can be identified, then it usually can be eliminated.
- Systematic errors are caused by imperfect calibration of measurement instruments or imperfect methods of observation
- Incorrect zeroing of an instrument leading to a zero error is an example of systematic error in instrumentation.

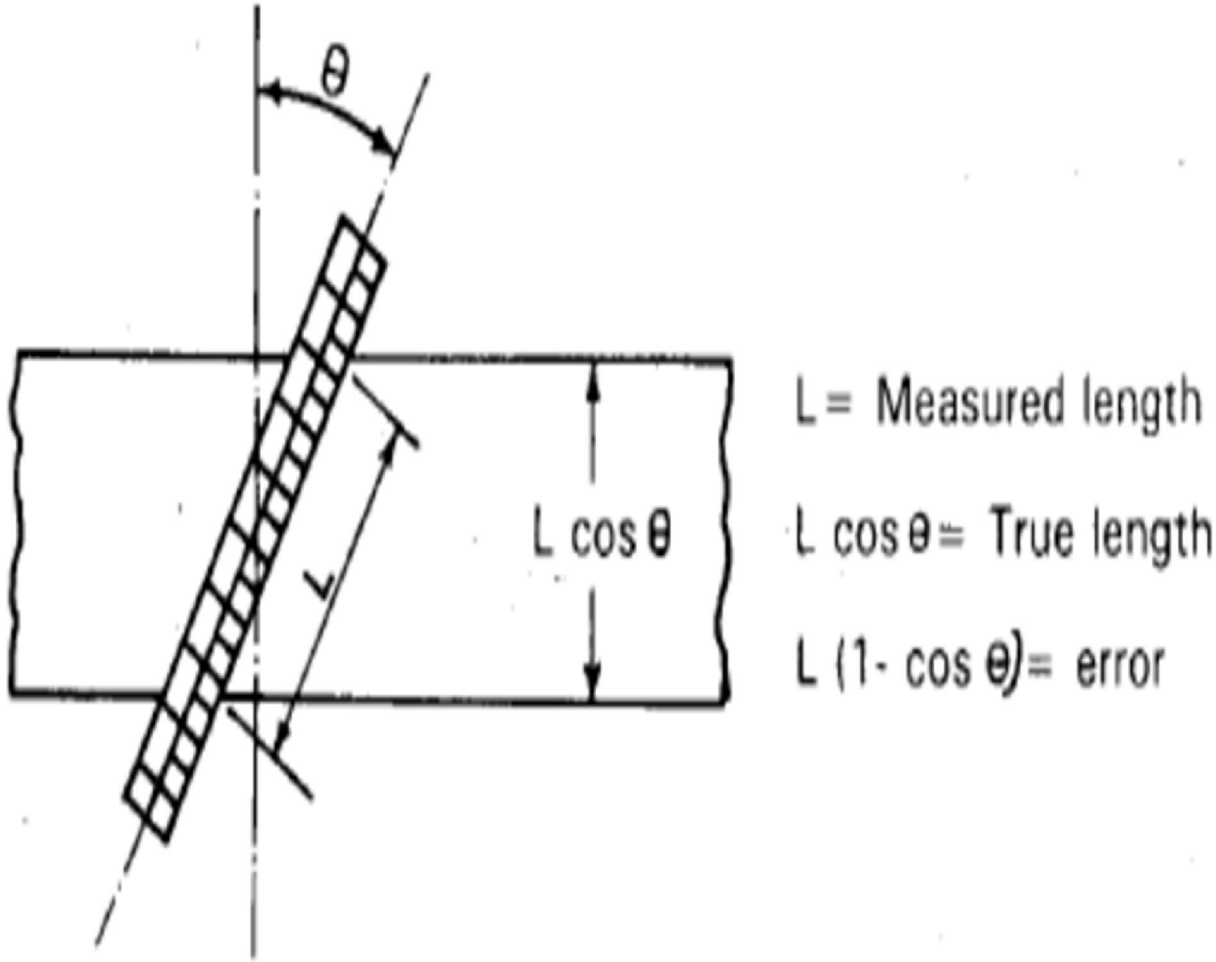
Random Error

- Random error is always present in a measurement.
- It is caused by inherently unpredictable fluctuations in the readings of a measurement apparatus or in the experimenter's interpretation of the instrumental reading.
- Random errors show up as different results for ostensibly the same repeated measurement.
- They can be estimated by comparing multiple measurements, and reduced by averaging multiple measurements.

Effect of Alignment: Abbe's Alignment Principle

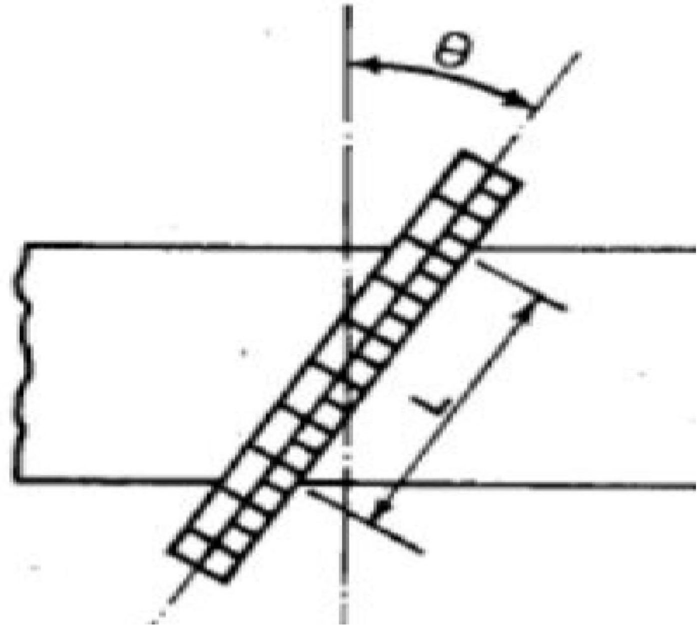
- It states that "the axis or line of measurement should coincide with the axis of measuring instrument or line of the measuring scale."
- If while measuring the length of a work piece the measuring scale is inclined to the true line of the dimension being measured there will be an error in the measurement. The length recorded will be more than the true length. This error is called "**Cosine error**". In many cases the angle θ is very small and the error will be negligible.

Abbe’s alignment principle

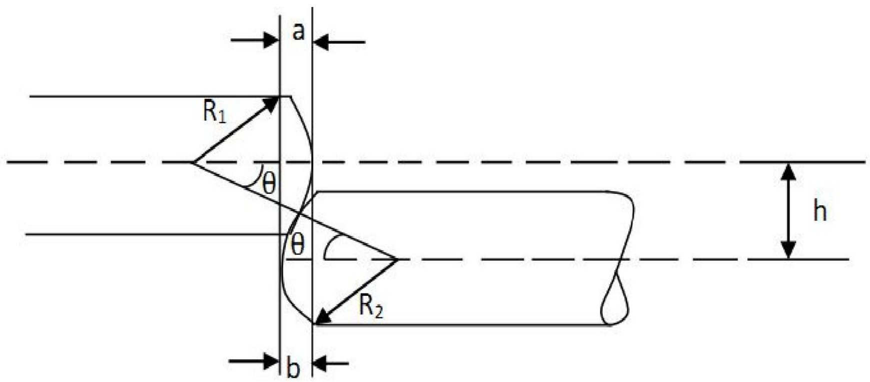


Problem

- A person measuring width of a flat bar. To measure this , he is using a ruler or scale and the scale is at slope of 0.58, with respect to the direction of width. His scale reading is 45 mm. Is there any error? If, then which type of error is this and how much the error?



Alignment of Spherical End Gauges



Now, $a = R_1 - R_1 \cos\theta$

$$= R_1(1 - \cos\theta)$$

$$= R_1\left(1 - \sqrt{1 - \sin^2\theta}\right)$$

$$= R_1\left[1 - \sqrt{1 - \frac{h^2}{(R_1+R_2)^2}}\right]$$

$$= R_1\left[1 - \left(1 - \frac{h^2}{2(R_1+R_2)^2}\right)\right] \text{.....(Approximately)}$$

$$= R_1\left[1 - 1 + \frac{h^2}{2(R_1+R_2)^2}\right]$$

Alignment of Spherical End Gauges

$$= \frac{R_1 h^2}{2(R_1+R_2)^2}$$

Similarly, $b = \dfrac{R_2 h^2}{2(R_1+R_2)^2}$

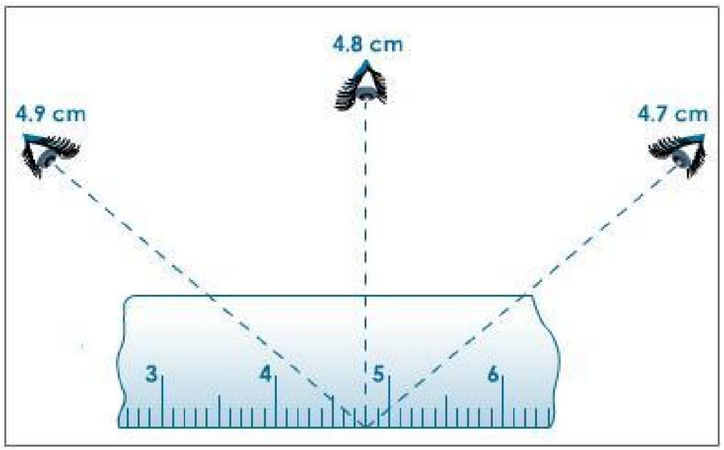
So, $(a+b) = \dfrac{(R_1+R_2)h^2}{2(R_1+R_2)^2} = \dfrac{h^2}{2(R_1+R_2)}$

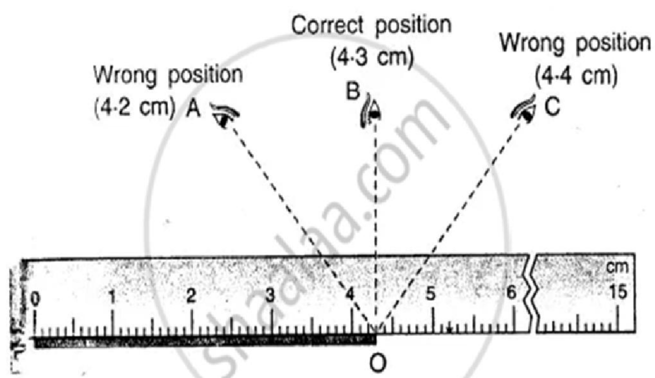
Question: Show that error for alignment of spherical end gauges is

$$\frac{h^2}{2(R_1+R_2)}$$

Parallax Error

- A very common error that may occur in an instrument while taking the readings is parallax error.
- Parallax error occurs when:
- The line of vision is not directly in line with the measuring scale. The scale and the pointer are separated from each other (not in the same plane).





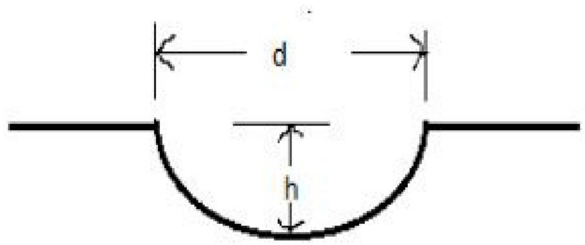
Measuring the length of a a rod PQ with a metre ruler

Problem

- The radius of curvature (R) of a concave surface is determined by noting two dimensions d and h such that,

$$R = \frac{d^2}{8h} + \frac{h}{2}$$

If error in measurement of d is ± 1% and in measuring h is ±0.5%, determine the total error in measurement of R if d= 50mm and h=5 mm.



Problem

Solution:

$$R = \frac{d^2}{8h} + \frac{h}{2}$$

$$\frac{\partial R}{\partial d} = \frac{2d}{8h} + 0 = \frac{d}{4h}$$

$$\frac{\partial R}{\partial h} = \frac{d^2\,(-1\times h^{-2})}{8} + \frac{1}{2} = \frac{-d^2}{8h^2} + \frac{1}{2}$$

$$\delta R = \frac{d}{4h} \times \delta d + \left(\frac{-d^2}{8h^2} + \frac{1}{2}\right) \times \delta h$$

$$= \frac{d}{4h}\left(\pm\frac{d}{100}\right) + \left(\frac{-d^2}{8h^2} + \frac{1}{2}\right)\left(\pm\frac{h}{200}\right)$$

$$= \pm\frac{d^2}{400h} + \left(\frac{d^2}{1600h} - \frac{h}{400}\right)$$

$$= \pm\left(\frac{d^2}{400h} - \frac{d^2}{1600h} + \frac{h}{400}\right)$$

$$= \pm\left(\frac{50\times 50}{400\times 5} - \frac{50\times 50}{1600\times 5} + \frac{5}{400}\right)$$

$$= \pm(1.25 - 0.31 + 0.01)$$

$$= \pm 0.95\ \%\ \text{(Ans.)}$$

Other Errors

- Effect of temperature
- Effect of support
- Contact Pressure
- Error due to presence of Dust
- Error due to vibration
- Error due to poor contact
- Error due to wear in gauge

See: Book: ***Practical Engineering Metrology*** by K W B Sharp

Engineering Metrology by R. K. Jain

& Internet

Thank You

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