UNIT-2

Measurement and machine tool

Introduction & Definition

Definition of Measurement [RGPV June 11, 14 Dec 11]

Measurement is defined as the process of obtaining a quantitative comparison between a predefined standard & an unknown magnitude.
Example- consider the measurement of length of bar. We make use of a scale/steel ruler (i.e a standard)

Two basic methods are commonly employed for measurement.

Direct comparison

In this method, measurement is made directly by comparing the unknown magnitude with a standard & the result is expressed by a number. The simplest example for this would be, length measurement using a meter scale.

Drawbacks of Direct comparison methods

•The main drawback of this method is, the method is not always accurate and reliable.
• Also, human senses are not equipped to make direct comparison of all quantities with equal facility all the times.
• Also, measurement by direct methods is not always possible, feasible and practicable.

Example: Measurement of temperature, Measurement of weight.

- One can experience or feel the hotness or coldness of a body with respect to a particular environment. But may not be able to exactly predict or say the temperature. Further, these measurements in most cases involve human factors. Hence this method in general is not preferred and employed for very accurate measurements.

Indirect comparison

Most of the measurement systems use indirect method of measurement.

- In this method a chain of devices which is together called as *measuring system* is employed. The chain of devices transforms the sensed signal into a more convenient form & indicates this transformed signal either on an indicator or a recorder or fed to a controller i.e. it makes use of a transuding device/element which convert the basic form of input into an analogous form, which it then processes and presents as a known function of input.
- For example, to measure strain in a machine member, a component senses the strain, another component transforms the sensed signal into an electrical quantity which is then processed suitably before being fed to a meter or recorder.

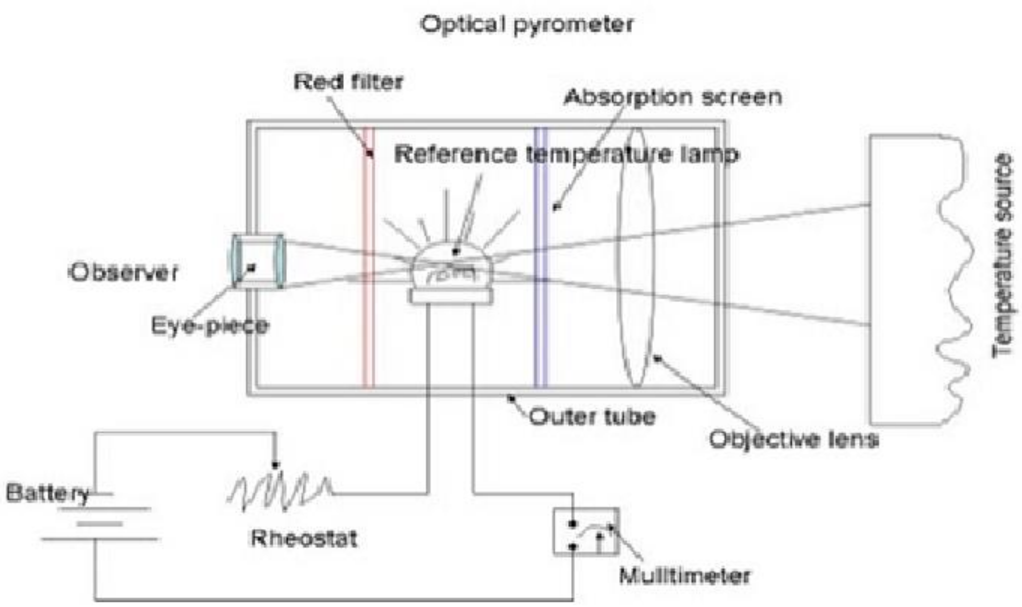
Further, human senses are not equipped to detect quantities like pressure, force or strain. But can feel or sense and cannot predict the exact magnitude of such quantities. Hence, we require a system that detects/sense, converts and finally presents the output in the form of a displacement of a pointer over a scale a , a change in resistance or raise in liquid level with respect to a graduated stem.

DEFINITIONS

1. **Measurement** - The determination of an unknown dimension. This requires that known standards be used directly or indirectly for comparison.
2. **Basic Dimension** - The target dimension for a part. This typically has an associated tolerance.
3. **Tolerance** - The allowable variation in a basic dimension before a part is considered unacceptable
4. **Dimension** - A size of a feature, either measured, or specified.
5. **Dimensional Metrology** - The use of instruments to determine object sizes shapes, form, etc.
6. **Limits** - These typically define a dimensional range that a measurement can be expected to fall within.
7. **Accuracy** - The expected ability for a system to discriminate between two settings. It is comparison of desired results with undesired results.
8. **Precision** - Implies a high degree of accuracy. It is the measure of the dispersion of the results.
9. **Repeatability** - Imperfections in mechanical systems can mean that during a Mechanical cycle, process does not stop at the same location, or move through the same spot each time. The variation range is referred to as repeatability.
10. **Standards** - a known set of dimensions, or ideals to compare others against.

- Standards are the basis for all modern accuracy. As new methods are found to make more accurate standards, the level of accuracy possible in copies of the standard increase, and so on.
- A well known metric standard is the metric 1m rod.
- Many standards are available for measuring, and many techniques are available for comparison.

11. **Standard Sizes** - a component, or a dimension that is chosen from a table of standard sizes/forms.



Measurement of temperature

Mercury Thermometer

Mercury Thermometer consists of a bulb containing mercury attached to a glass tube of narrow diameter capillary. Volume of mercury in the tube is much less than the volume in the bulb. Volume of mercury changes slightly with temperature; A small change in volume drives the narrow mercury column a relatively long way up the tube. The space above the mercury may be filled with nitrogen or it may be at less than atmospheric pressure, a partial vacuum.

PRESSURE MEASUREMENT- [RGPV June 10,14]

Types of Pressure Measurement Devices

1. Mechanical instruments.
2. Electro-mechanical instruments.
3. Electronic instruments.

Mechanical-type Instruments

1. Manometer gauges
2. Pressure gauges

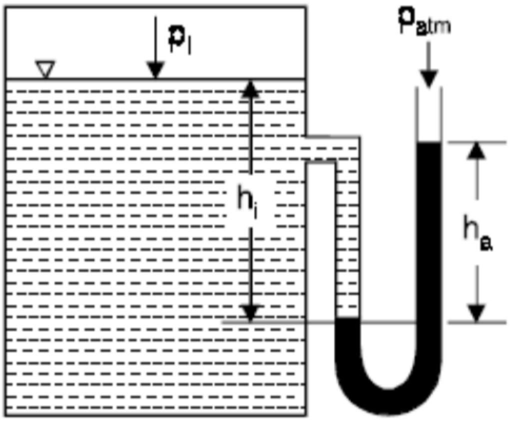
Liquid manometers

Low pressures are generally determined by manometers which employ liquid columns. It is difficult and costly to construct manometers to measure high pressures, as otherwise the liquid column will become unwieldy and temperature corrections will also be difficult. Their use is, therefore, restricted to low pressures only, and for such purposes they are quite accurate. The liquids commonly employed for manometers are mercury and water. Mercury is used for high and water for low pressures. For this purpose a liquid is suitable if it has a low viscosity, so that it can adjust itself quickly and also a low co-efficient of thermal expansion, so that density changes with temperature are minimum.

U-tube manometer :

A U-tube manometer is in the form of U-tube and is made of glass. When no pressure is applied, the height of the liquid in the two legs is the same. The pressure is then applied to one leg, whilst the other is open to the atmosphere. Under this pressure the liquid will sink in this leg and will rise in the other. As the other leg is open to the air, therefore, the pressure on this side is known, and is barometric. Now the pressure applied to the first leg can be calculated. This is explained with reference to Fig. 2.15. This consists of a water manometer.

Considering equilibrium condition, we have



$$Pa_{tm} + W_a h_a = P_i + W_i h_i$$

$$\therefore P_i = Patm + W_a h_a - W_i h_i$$

Where

P_{atm}. = Atmospheric pressure,
P_i = Pressure over water surface in the container,
h_a = Height of liquid in U-tube manometer,
h_i = Difference between water surface and lower surface of the liquid in manometer,
W_a = Specific weight of liquid,
W_i = Specific weight of water.

The U-tube manometer shown in Fig. 2.16 is of the simplest form. However, readings have to be taken at two different places. Moreover, the deflection of the two columns may not be the same. To avoid this difficulty cistern or well type manometer is used.

Bourdon tube type pressure gauge

Bourdon type tube pressure gauge is used for measuring high as well as low pressures. A simple form of this gauge is shown in Fig. 2.23. In this case the pressure element consists of a metal tube of approximately elliptical cross-section. This tube is bent in the form of a segment of a circle and responds to pressure changes. When one end of the tube which is attached to the gauge case, is connected to the source of pressure, the internal pressure causes the tube to expand, whereby circumferential stress i.e., hoop tension is set up. The free end of the tube moves and is in turn connected by suitable levers to a rack, which engages with a small pinion mounted on the same spindle as the pointer. Thus the pressure applied to the tube causes the rack and pinion to move. The pressure is indicated by the pointer over a dial which can be graduated in a suitable scale.

The Bourdon tubes are generally made of bronze or nickel steel. The former is generally used for low pressures and the latter for high pressures. Depending upon the purpose for which they are required Bourdon tube gauges are made indifferent forms, some of them are :

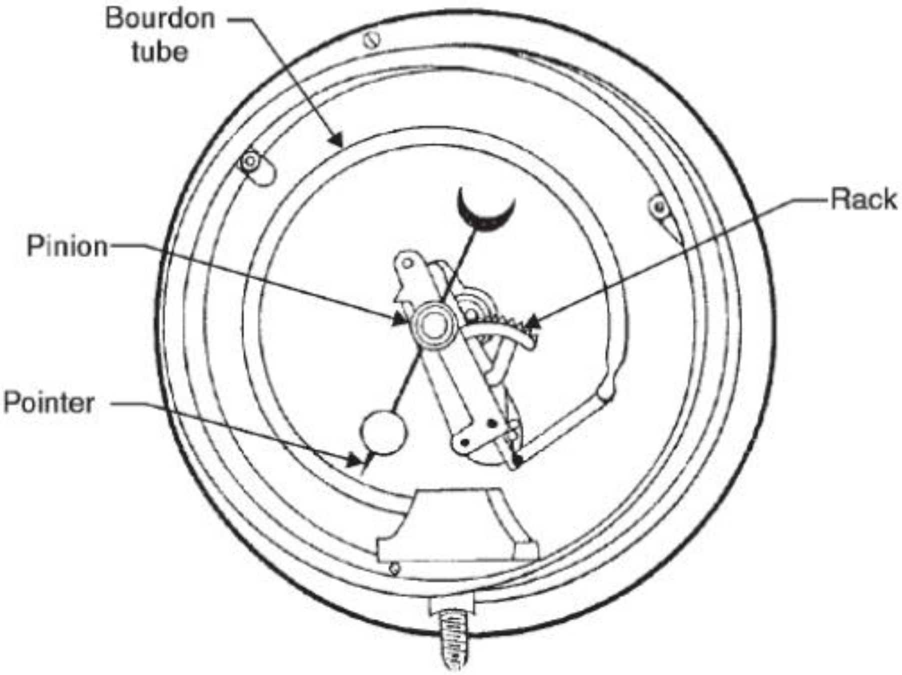


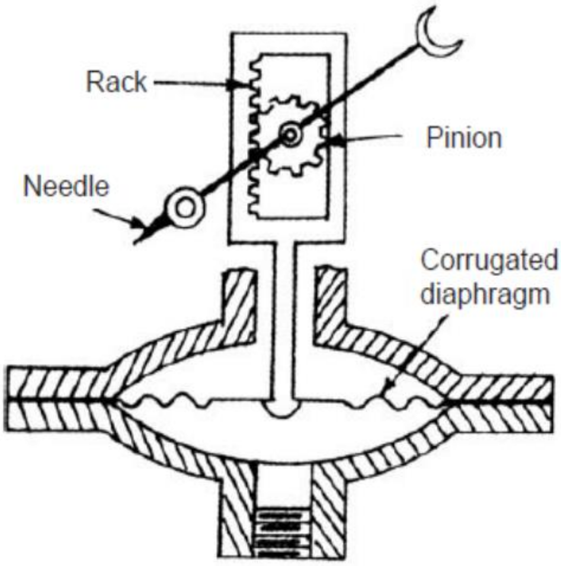
Fig. 2.23. Burdon tube pressure gauge.

(i) **Compound Bourdon tube** ...... used for measuring pressures both above and below atmospheric.

(ii) **Double Bourdon tube** ...... used where vibrations are encountered.

2. Diaphragm gauge :

This type of gauge employs a metallic disc or diaphragm instead of a bent tube. This disc or diaphragm is used for actuating the indicating device. Refer Fig. When pressure is applied on the lower side of the diaphragm, it is deflected upward. This movement of the diaphragm is transmitted to a rack and pinion. The latter is attached to the spindle of needle moving on a graduated dial. The dial can again be graduated in a suitable scale.



3.Vacuum gauge

Bourdon gauges discussed earlier can be used to measure vacuum instead of pressure. Slight changes in the design are required for this purpose. Thus, in this case, the tube is bent inward instead of outward as in pressure gauge. Vacuum gauges are graduated in millimetres of mercury below atmospheric pressure. In such cases, therefore, absolute pressure in millimetres of mercury is the difference between barometer reading and vacuum gauge reading. Vacuum gauges are used to measure the vacuum in the condensers etc. If there is leakage, the vacuum will drop. The pressure gauge installation require the following considerations :

(i) Flexible copper tubing and compression fittings are recommended for most installations.

(ii) The installation of a gauge cock and tee in the line close to the gauge is recomm- ended because it permits the gauge to be removed for testing or replacement without having to shut down the system.
(iii) Pulsating pressures in the gauge line are not required.
(iv) The gauge and its connecting line is filled with an inert liquid and as such liquid seals are provided. Trapped air at any point of gauge lines may cause serious errors in pressure reading.

TARQUE AND FLOW MEASUREMENT-

Dynamometer is a brake but in addition it has a device to measure the frictional resistance. Knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine.

Types of Dynamometers

Following are the two types of dynamometers, used for measuring the Torque and brake power of an engine.
1. Absorption dynamometers, and
2. Transmission dynamometers.
In the absorption **dynamometers,** the entire energy or power produced by the engine is absorbed by the friction resistances of the brake and is transformed into heat, during the process of measurement. But in the **transmission dynamometers,** the energy is not wasted in friction but is used for doing work. The energy or power produced by the engine is transmitted through the dynamometer to some other machines where the power developed is suitably measured.

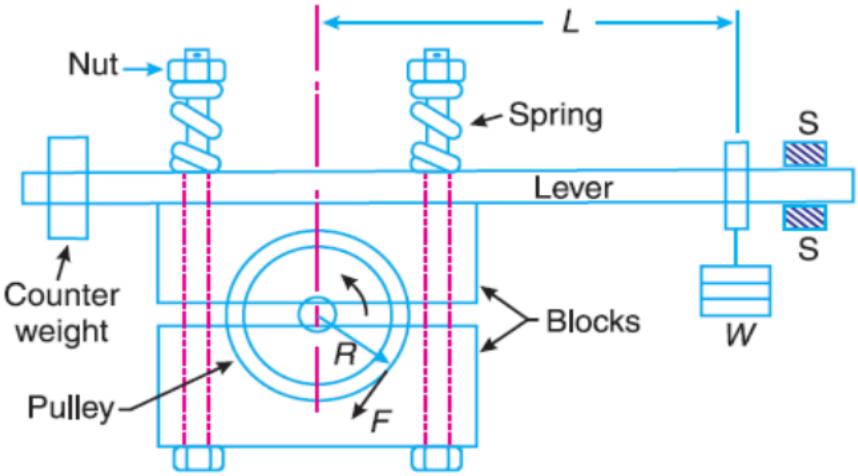
Classification of Absorption Dynamometers

The following two types of absorption dynamometers are important from the subject point of
view :

1. Prony brake dynamometer, and **2.** Rope brake dynamometer.

Prony Brake Dynamometer

A simplest form of an absorption type dynamometer is a prony brake dynamometer, as shown in Fig. It consists of two wooden blocks placed around a pulley fixed to the shaft of an engine whose power is required to be measured. The blocks are clamped by means of two bolts and nuts, as shown in Fig. 19.31. A helical spring is provided between the nut and the upper block to adjust the pressure on the pulley to control its speed. The upper block has a long lever attached to it and carries a weight W at its outer end. A counter weight is placed at the other end of the lever which balances the brake when unloaded. Two stops S, S are provided to limit the motion of the lever.



When the brake is to be put in operation, the long end of the lever is loaded with suitable weights *W* and the nuts are tightened until the engine shaft runs at a constant speed and the lever is in horizontal position. Under these conditions, the moment due to the weight *W* must balance the moment of the frictional resistance between the blocks and the pulley.
Let
W = Weight at the outer end of the lever in Newton's,
L = Horizontal distance of the weight W
from the centre of the pulley in metres,
F = Frictional resistance between the blocks
and the pulley in Newton's,
R = Radius of the pulley in metres, and
N = Speed of the shaft in r.p.m.
We know that the moment of the frictional resistance
or torque on the shaft,

$$\mathbf{T = W.L = F.R\ N\text{-}m}$$

Rope Brake Dynamometer

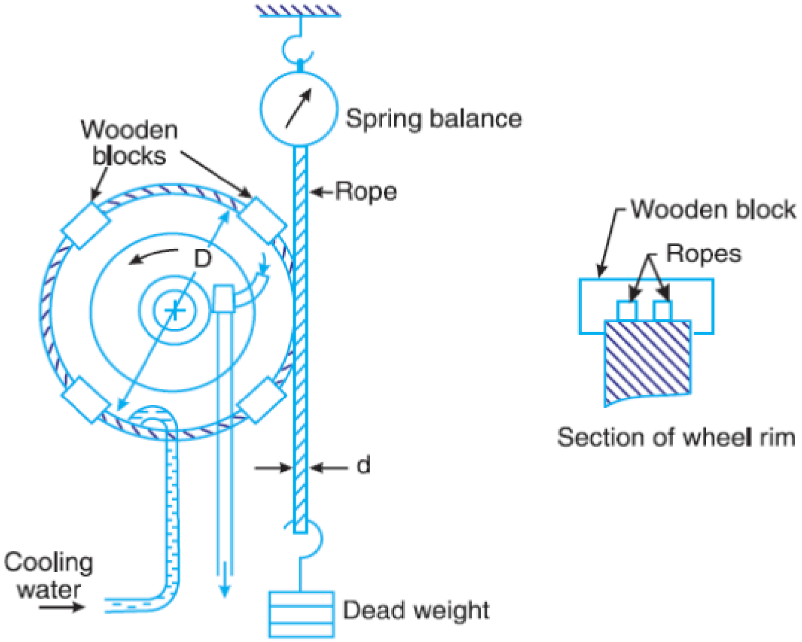
It is another form of absorption type dynamometer which is most commonly used for measuring the brake power of the engine. It consists of one, two or more ropes wound around the flywheel or rim of a pulley fixed rigidly to the shaft of an engine. The upper end of the ropes is attached to a spring balance while the lower end of the ropes is kept in position by applying a dead weight as shown in Fig.
In order to prevent the slipping of the rope over the flywheel, wooden blocks are placed at intervals around the circumference of the flywheel. In the operation of the brake, the

engine is made to run at a constant speed. The frictional torque, due to the rope, must be equal to the torque being transmitted by the engine.

Let

W = Dead load in Newton's,
S = Spring balance reading in Newton's,
D = Diameter of the wheel in metres,
d = diameter of rope in metres, and
N = Speed of the engine shaft in r.p.m.

$$\therefore \text{Net load on the brake} = (W - S) \text{ N}$$



We know that distance moved in one revolution
$= \pi(D + d)$ m

4 Work done per revolution $= (W - S)\,\pi\,(D + d)$ N-m

and work done per minute $= (W - S)\,\pi\,(D + d)\,N$ N-m

4 Brake power of the engine,

$$\text{B.P} = \text{Work done per min} / 60 \quad \text{watts}$$

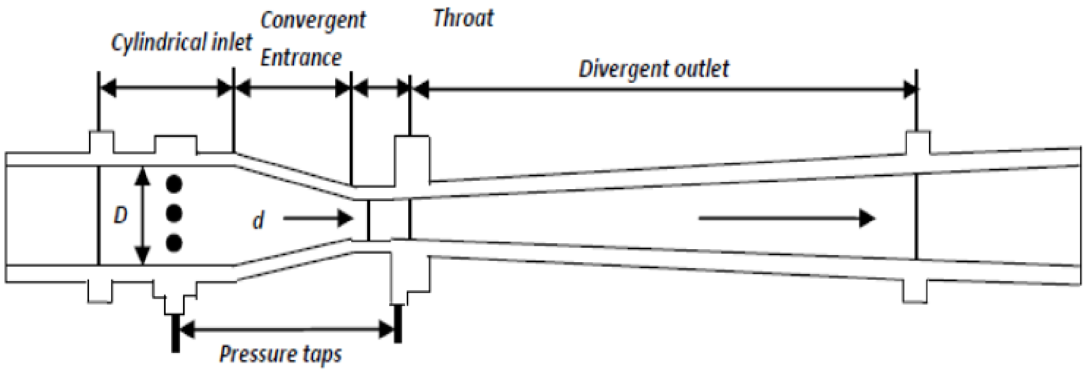
$$= (W - S) \square (D + d)\, N/60 \ \text{watts}$$

Flow Measurement

Venturi meter

Venturi meter is commonly used flow meters for measuring mass/volumetric flow rate or velocity of the flowing fluid. These flow meters are also known as variable head meters. They are categorized as *full-bore meter* as measurement of the fluid takes place when it flows through a conduit or channel.

The venturi meter has a converging conical inlet, a cylindrical throat and a diverging recovery cone. It has no projections into the fluid, no sharp corners and no sudden changes in contour. The following figure shows the venturi meter with uniform cylindrical section before converging entrance, a throat and divergent outlet. The converging inlet section decreases the area of the fluid stream, causing the velocity to increase and the pressure to decrease. The low pressure is measured in the centre of the cylindrical throat as the pressure will be at its lowest value, where neither the pressure nor the velocity will be changing. As the fluid enters the diverging section the pressure is largely recovered lowering the velocity of the fluid. The major disadvantages of this type of flow detection are the high initial costs for installation and difficulty in installation and inspection.



The *Venturi effect* is the reduction in fluid pressure that results when a fluid flows through a constricted section of pipe. The fluid velocity must increase through the constriction to satisfy the equation of continuity, while its pressure must decrease due to conservation of energy: the gain in kinetic energy is balanced by a drop in pressure or a pressure gradient force. An equation for the drop in pressure due to Venturi effect may be derived from a combination of Bernoulli's principle and the equation of continuity. The equation for venturi meter is obtained by applying Bernoulli equation and equation of continuity assuming an incompressible flow of fluids through manometer tubes. If $V1$ and $V2$ are the average upstream and downstream velocities and ρ is the density of the fluid, then using Bernoulli's equation we get,

$$\alpha_2 V_2^2 - \alpha_1 V_1^2 = \frac{2g\,(P_a - P_b)}{\rho} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where 〈*1* and 〈*2* are kinetic energy correction factors at two pressure tap positions.
Assuming density of fluid to be constant, the equation of continuity can be written as:

$$V_1 = \left(\frac{D_2}{D_1}\right)^2 V_2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where *D1* and *D2* are diameter of pipe and throat in meters respectively. Eliminating *V1* from equation (1) and equation (2) we get,

$$V_2 = \frac{1}{\sqrt{\alpha_2 - \alpha_1 \beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where *β* is the ratio of the diameter of throat to that of diameter of pipe.
If we assume a small friction lose between two pressure taps, the above equation (3) can be corrected by introducing empirical factor *Cv* and written as,

$$V_2 = \frac{C_V}{\sqrt{1 - \beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The small effect of the kinetic energy factors *α1* and *α2* are also taken into account in the definition of *Cv*.
Volumetric flow rate *Qa* can be calculated as:

$$Q_a = V_2 S_2 = \frac{C_V S_2}{\sqrt{1 - \beta^4}} \sqrt{\frac{2(P_1 - P_2)}{\rho}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, *S2* is the cross sectional area of throat in m2. Substituting *(P1 – P2) = ρgH* in above equation (5) we get,

$$Q_a = V_2 S_2 = \frac{C_V S_2}{\sqrt{1 - \beta^4}} \sqrt{2g\Delta H} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where Δ*H* is the manometric height difference * (specific gravity of manometric fluid – specific gravity of manometric fluid of water).

FORCE , STRAIN AND VELOCITY MEASUREMENT -

Force Measurement

Methods of measurement of a force

(1) Force may be measured by mechanical balancing using simple elements such as the lever

a. A platform balance is an example – of course mass is the measured quantity since acceleration is equal to the local acceleration due to gravity

(2) Simplest method is to use a transducer that transforms force to displacement

a. Example: Spring element
b. Spring element may be an actual spring or an elastic member that undergoes a strain
(3) Force measurement by converting it to hydraulic pressure in a piston cylinder device

a. The pressure itself is measured using a pressure transducer

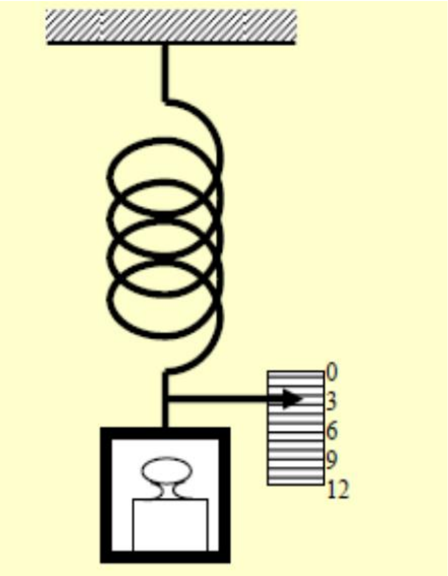
(4) Force measurement using a piezoelectric transducer

SPRING BALANCE

A spring balance is an example where a force may be converted to a displacement based on the spring constant. For a spring element (it need not actually be a spring in the form of a coil of wire) the relationship between force F and displacement x is linear and given by

$$F = K x$$

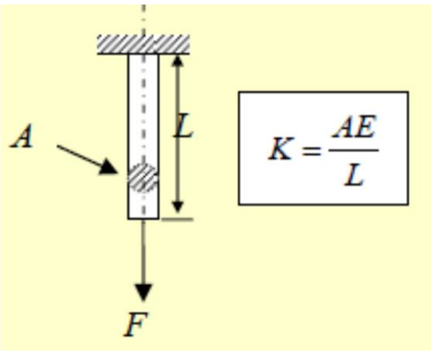
Where K is the spring constant. Simplest device of this type is in fact the spring balance whose schematic is shown in Figure



The spring is fixed at one end and at the other end hangs a pan. The object to be weighed is placed in the pan and the position of the needle along the graduated scale gives the weight of the object. For a coiled spring like the one shown in the illustration, the spring constant is given by

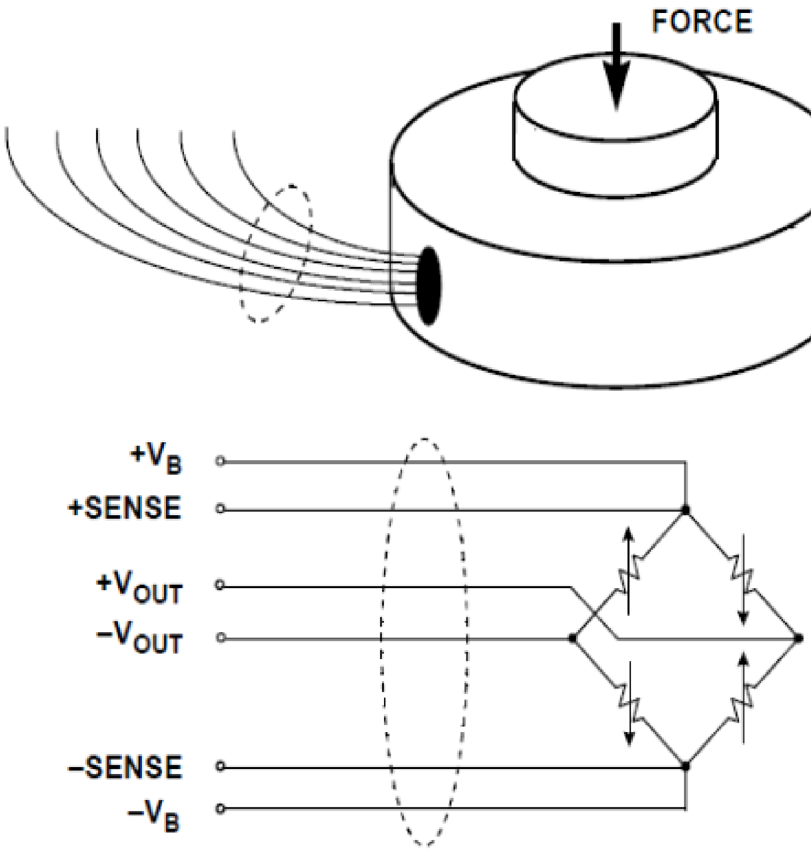
$$K = \frac{E_s D_w^4}{8 D_m^3 N}$$

In this equation *Es* is the shear modulus of the material of the spring, *Dw* is the diameter of the wire from which the spring is wound, *Dm* is the mean diameter of the coil and *N* is the number of coils in the spring. An elastic element may be used to convert a force to a displacement. Any elastic material follows Hooke’s law within its elastic limit and hence is a potential spring element. Several examples are given in Figure 49 along with appropriate expressions for the applicable spring constants. Spring constants involve *E*, the Young’s modulus of the material of the element, the geometric parameters indicated in the figure. In case of an element that undergoes bending the moment of inertia of the cross section is the appropriate geometric parameter. The expressions for spring constant are easily derived and are available in any book on strength of materials.



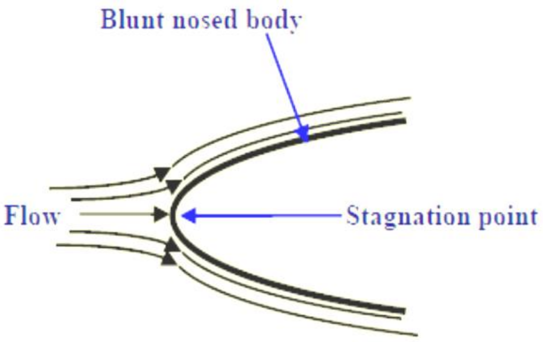
LEAD LOAD CELL

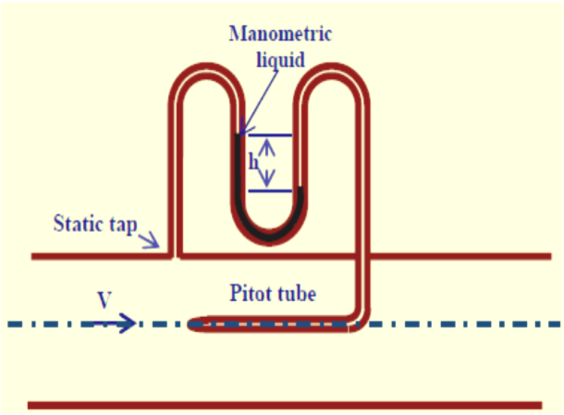
Pressures in liquids and gases are measured electrically by a variety of pressure transducers. A variety of mechanical converters (including diaphragms, capsules, bellows, manometer tubes, and Bourdon tubes) are used to measure pressure by measuring an associated length, distance, or displacement and to measure pressure changes by the motion produced. The output of this mechanical interface is then applied to an electrical converter such as a strain gage or piezoelectric transducer. Unlike strain gages, piezoelectric pressure transducers are typically used for high-frequency pressure measurements (such as sonar applications or crystal microphones).



Pitot and Pitot static tube

The basic principle of the Pitot and Pitot static tube is that the pressure of a flowing fluid will increase when it is brought to rest at a stagnation point of the probe. Figure 81 shows the streamlines in the vicinity of a blunt nosed body. We assume that, if the flow is that of a gas, like air, the velocity of the fluid is much smaller than the speed of sound in air such that density changes may be ignored. Basically the fluid behaves as an incompressible fluid. The stagnation point is located as shown. Streamlines bend past the body as shown. The pressure at the stagnation point is the stagnation pressure.





If viscous effects are negligible the difference between the stagnation pressure and the static pressure is related to the dynamic pressure which is related to the square of the velocity. Thus the velocity information is converted to a pressure difference that may be measured by a pressure measuring device such as a manometer. The basic arrangement for measuring fluid velocity using a Pitot tube is shown in Figure 98. The Pitot tube consists of bent tube of small diameter (small compared to the diameter or size of the duct) with a rounded nose. The flow is axi-symmetric and in the vicinity of the nose is like the flow depicted in Figure. The Pitot tube is connected to one limb of a U tube manometer. The other limb of the manometer is connected to a tap made on the tube walls indicated. The tube tap and the nose of the Pitot tube are roughly in the same plane. It is assumed that the wall tap senses the static pressure p of the fluid while the Pitot tube senses the stagnation pressure po of the fluid. From Bernoulli principle we have (for low speed flow, fluid velocity much less than sonic velocity in the fluid)

$$(p_o - p) = \frac{1}{2}\rho V^2$$

With ρm as the density of the manometer liquid the pressure difference is given by

$$p_o - p = (\rho_m - \rho) g h$$

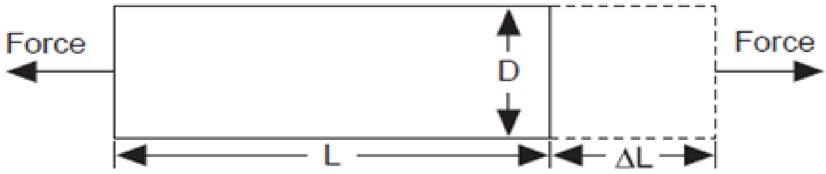
By above two relations we get...

$$V = \sqrt{2\frac{(\rho_m - \rho)}{\rho} g h}$$

Strain Measurement

Definition of strain

Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length, as shown in Figure below.



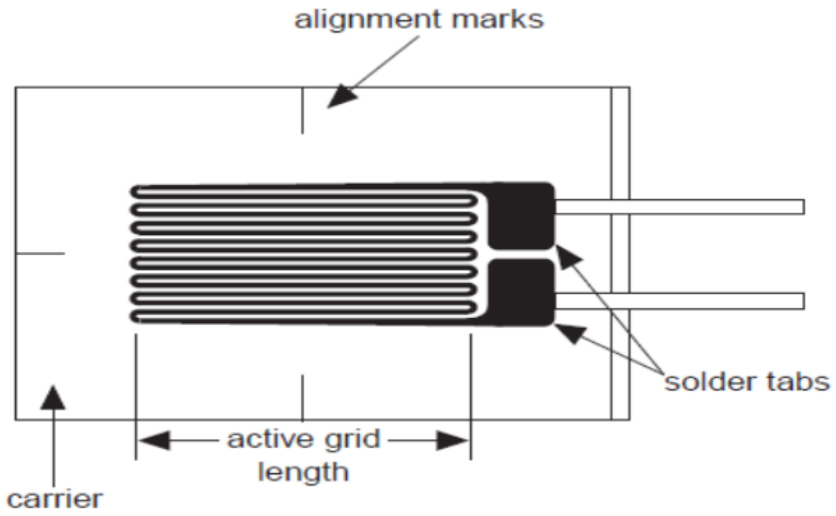
$$\varepsilon = \frac{\Delta L}{L}$$

Definition of Strain

Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as micro strain (me), which is e ´ 10^{-6}. When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction

Strain Gauge

While there are several methods of measuring strain, the most common is with a strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. For example, the piezoresistive strain gauge is a semiconductor device whose resistance varies nonlinearly with strain. The most widely used gauge, however, is the bonded metallic strain gauge. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction. The cross sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gauge, which responds with a linear change in electrical resistance. Strain gauges are available commercially with nominal resistance values from 30 to 3000 W, with 120, 350, and 1000 W being the most common values.



It is very important that the strain gauge be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, though the adhesive and strain gauge backing, to the foil itself. Manufacturers of strain gauges are the best source of information on proper mounting of strain gauges. A fundamental parameter of the strain gauge is its sensitivity to strain, expressed quantitatively as the gauge factor (GF). Gauge factor is defined as the ratio of fractional change in electrical resistance to the fractional change in
length (strain):

$$GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$$

The Gauge Factor for metallic strain gauges is typically around 2.

Error and uncertainty analysis - [RGPV Dec 12]

Types of error

Generally the errors incurred in any measurement can be considered to be of two distinct types, those which should not occur and can be eliminated by careful work and attention to detail, and those which are inherent in the measuring process.

1. Calamitous or Catastrophic Errors

These are errors of large magnitude having two fundamental causes:
(a) Misreading an instrument. A micrometer is misread as 6•28 mm or 5•78 mm instead of the correct reading of 5•28 mm.

(b) Arithmetic errors. These are usually errors of addition. A simple check is to make the calculation twice using different methods, e.g. add a column of figures twice, first upwards then downwards, to ensure that the two results coincide.

In most cases such errors give a result so different from that expected that it is obvious when an error has occurred, and the measurement is repeated and the error detected. This may not always be so, however, and such errors can only be avoided

2. Alignment Errors

This type of error occurs when the measuring instrument is misaligned relative to the work piece. It usually results in the measured dimension **M** being related to the actual dimension **D** by one of the trigonometrical ratios. Hence such errors are known as trigonometrical or cosine errors. A simple example is shown in Fig. 1.1, where a dial gauge is inclined at angle **θ** to the required line of measurement.

3. Errors Due to Ambient Conditions

Most measurements are affected to a greater or lesser extent by the environment in which they are carried out. The most important condition is the temperature, both of the work piece and of its surroundings. The international standard temperature of measurement is **20**°C (68°F) and the ambient temperature should be maintained at this level. However carefully this is controlled, it is to no avail if the temperature of the work piece is allowed to vary. Handling a gauge changes its temperature, so it should be handled as little as possible, and having been handled, allowed stabilizing. Where measurements are being made to a high order of accuracy a time of **20** minutes per **25** mm length of gauge is recommended. During a measurement it is best if all of the components used are left standing on a cast iron surface plate rather than a plastic or wooden bench top. The cast iron, being a good conductor, acts as a heat sink and dissipates temperature differentials more rapidly.

There are two situations to be considered when the effects of temperature are to be discussed:

(a) **Direct measurement**. Consider a gauge block being measured directly by interferometry. Here the effect of using a non-standard temperature produces a proportional error:

Error = l α (t -- ts)

(b) Comparative measurement. If we consider two gauges whose expansion coefficients are respectively **α1** and **α2**, then the error due to a non-standard temperature will be

(a) **Error = l (α1 - α 2)(t - ts)**

4. Errors Due to Elastic Deformation

Any elastic body subject to a load will undergo elastic deformation. The magnitude of the deformation will depend upon the magnitude of the load, the area of contact and the mechanical properties of the materials in contact. It is therefore necessary to ensure that the measuring loads are the same in comparative measurement.

In most instruments used in fine measurement, comparators, bench micrometers, etc., the measuring pressure is reasonably constant, and it follows that the greatest difficulty is due to different types of contact when first setting an instrument to a gauge and then taking a reading on the work under test.

Scale Errors

If the scale against which a measurement made is in error, then obviously that measurement will be in error. This can only be overcome by calibrating the instrument scale against known standards of length over its whole length.

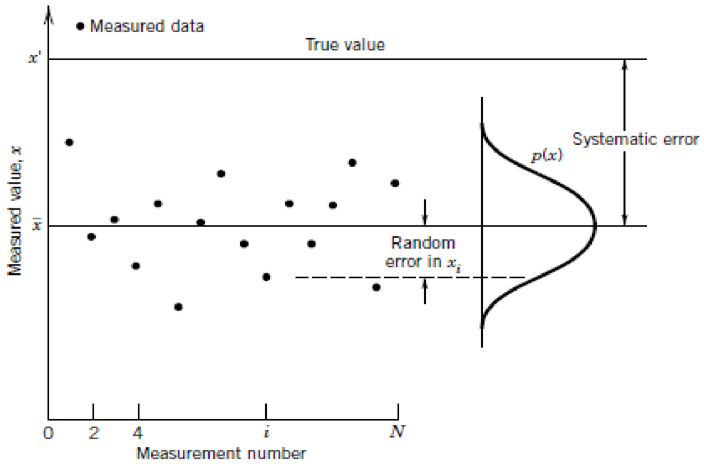
In comparative measurements the effects of scale errors are reduced by using as short a length of scale as possible, by choosing a setting master whose size is as close to that of the gauge being checked as is conveniently possible.

Measuring Errors

The different types of error discussed above are cumulative, and in some cases a further amount must be added to allow for sensitivity of touch or feel. This will depend upon the type of instrument being used, and in general the effect is eliminated with comparators.

Uncertainty Analysis

Errors are a property of the measurement. Measurement is the process of assigning a value to a physical variable based on a sampling from the population of that variable. Error causes a difference between the value assigned by measurement and the true value of the population of the variable. Measurement errors are introduced from various elements, for example, the individual instrument calibrations, the data set finite statistics, and the approach used. But because we do not know the true value and we only know the measured values, we do not know the exact values of errors. Instead, we draw from what we do know about the measurement to estimate a range of probable error. This estimate is an assigned value called the uncertainty. The uncertainty describes an interval about the measured value within which we suspect that the true value must fall with a stated probability. Uncertainty analysis is the process of identifying, quantifying, and combining the errors. Uncertainty is a property of the result. The outcome of a measurement is a result, and the uncertainty quantifies the quality of that result. Uncertainty analysis provides a powerful design tool for evaluating different measurement systems and methods, designing a test plan, and reporting uncertainty. This chapter presents a systematic approach for identifying, quantifying, and combining the estimates of the errors in a measurement. While the chapter stresses the methodology of analyses, we emphasize the concomitant need for an equal application of critical thinking and professional judgment in applying the analyses. The quality of an uncertainty analysis depends on the engineer’s knowledge of the test, the measured variables, the equipment, and the measurement procedures (1). Errors are effects, and uncertainties are numbers. While errors are the effects that cause a measured value to differ from the true value, the uncertainty is an assigned numerical value that quantifies the probable range of these errors.



Distribution of errors on repeated measurements.

Certain assumptions are implicit in an uncertainty analysis:

1. The test objectives are known and the measurement itself is a clearly defined process.
2. Any known corrections for systematic error have been applied to the data set, in which case the systematic uncertainty assigned is the uncertainty of the correction.
3. Except where stated otherwise, we assume a normal distribution of errors and reporting of uncertainties.
4. Unless stated otherwise, the errors are assumed to be independent (uncorrelated) of each other. But some errors are correlated, .
5. The engineer has some ‘‘experience’’ with the system components.

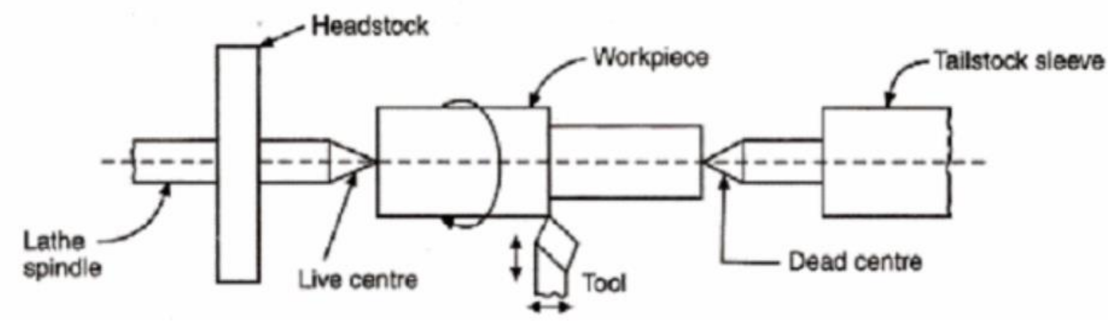
LATHE MACHINE - [RGPV June 11,13,14 Dec 12,13]

working principle of lathe

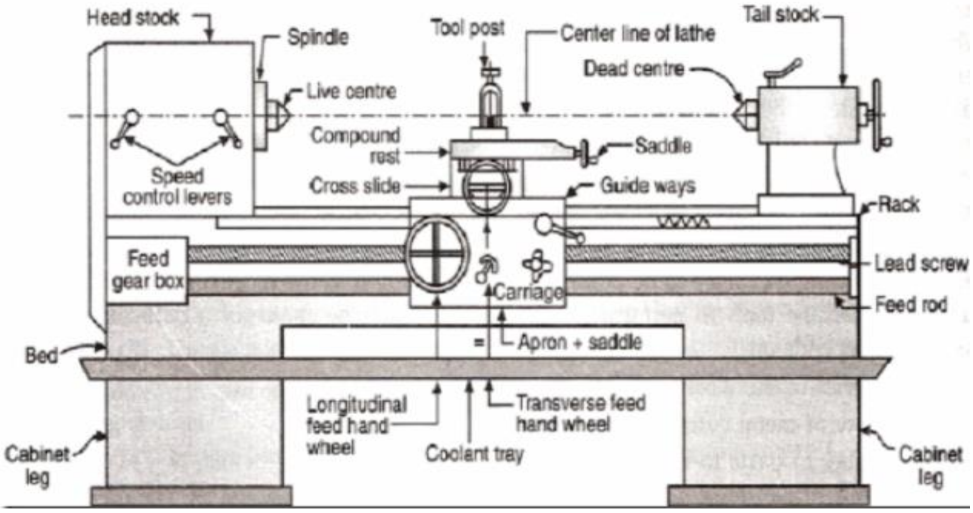
The lathe machine works on the principle that, a cutting tool can remove material when it is moved against a rotating work piece. This is accomplished by rotating the work piece between two rigid and strong supports, while the cutting tool is fed against it. the principle of operation is shown in figure

When the tool is moved against the rotating work piece, the excess material is removed from the work piece in the form of fine chips. the type of surface produced depends on the Movement of the tool with respect to the axis of rotation of the workpiece.

- When the tool moves parallel to the axis of rotation of the work piece, a cylindrical surface is produced.
- When the tool moves perpendicular to the axis of rotation of the work piece, a flat surface is produced.
- When the tool moves at an angle to the axis of rotation of the work piece, a tapered surface can be produced.



parts of a lathe:



1. Bed: the bed is a heavy, rugged casting in which are mounted the working parts of the lathe. it carries the headstock and tail stock for supporting the work piece and provides a base for the movement of carriage assembly which carries the tool.

2. Legs: the legs carry the entire load of machine and are firmly secured to floor by foundation bolts.

3. Headstock: the headstock is clamped on the left hand side of the bed and it serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

4. Gear box: the quick-change gear-box is placed below the headstock and contains a number of different sized gears.

5. Carriage: the carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation. the main parts of carriage are:

a). the saddle is an h-shaped casting mounted on the top of lathe ways. it provides support to cross-slide, compound rest and tool post.

b). the cross slide is mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

c). the compound rest is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

d). the tool post is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

e). the apron is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented she carriage along the lathe bed.

6. Tailstock: the tailstock is a movable casting located opposite the headstock on the ways of the bed. The tailstock can slide along the bed to accommodate different lengths of work piece between the centres. A tailstock clamp is provided to lock the tailstock at any desired position. The tailstock spindle has an internal taper to hold the dead centre and the tapered shank tools such as reamers and drills.

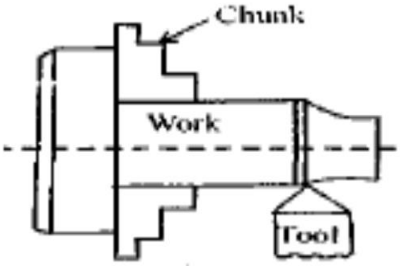
lathe operations:

the operations performed on a lathe machine are:

1. Plain turning or cylindrical turning.
2. facing
3. knurling
4. drilling
5. threading
6. taper turning
7. parting

plain turning:

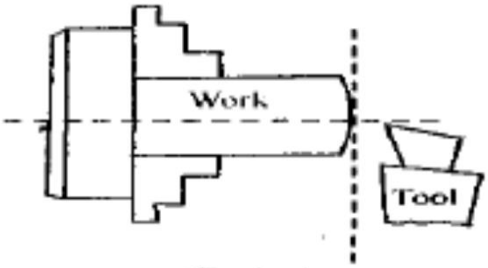
It is the operation of removing excess amount of material from the work piece to produce a cylinder work piece. in this operation, shown in fig., the work is held either in the chuck or between centres, the cutting tool is fed against the revolving work piece and is then moved parallel to the lathe axis so as to produce a cylindrical surface.



(Plain turning)

facing:

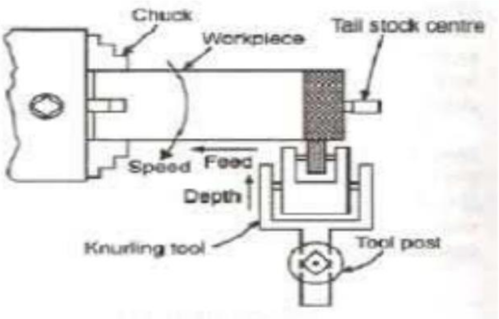
It is the operation for generating a flat surface at the end of the work piece. In this operation, as shown in fig., the work piece is held in the chuck and the facing tool is fed from the centre of the work piece towards the outer surface or from the outer surface to the centre, with the help of a cross-slide. facing is also carried out to reduce or cut the work piece to the required length.



(Facing)

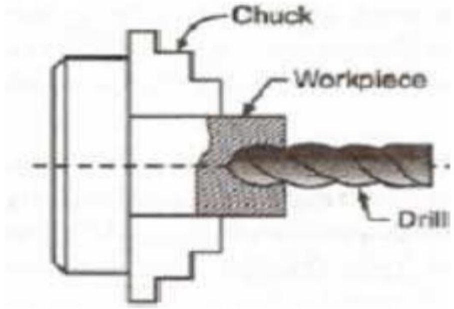
knurling

It is the process carried out on a lathe, where a visually-attractive diamond shaped pattern is cut or rolled on the surface of metallic parts. In this operation, as shown in fig., the work piece is held rigidly between two centres, the knurling tool is pressed against the rotating work piece and pressure is slowly increased until the tool produces a pattern on the work piece. The surface on the work piece formed by knurling is used for applications where grip is required to hold the part.



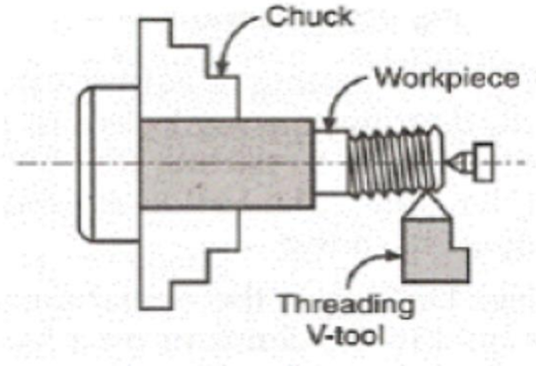
drilling

It is the operation of producing a cylindrical hole in a work piece with the help of a drill. In this operation, as shown in fig., the work piece is held in the tapered hole of the tail stock sleeve and is fed into the rotating work piece, by rotating the tail stock hand wheel.



thread cutting

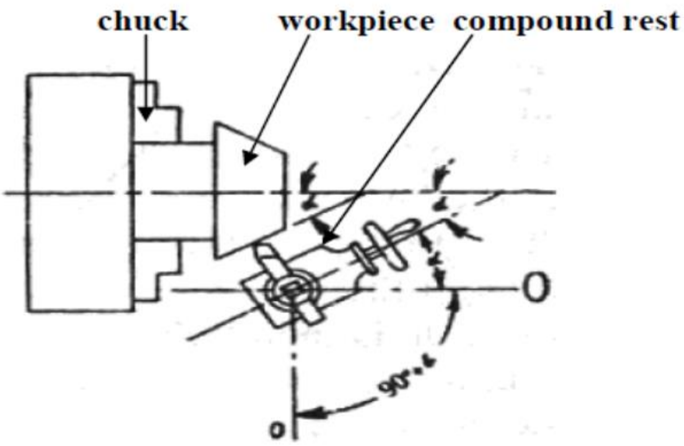
It is a operation for cutting screw threads on metallic parts. In this operation, as shown in fig., the work piece is held in between the two centres, the cutting tool is mounted on the tool post and the carriage is connected to the lead screw with the help of a split nut. The rotation of the lead screw gives the required motion to the carriage relative to the rotation of the work piece. The depth of cut is selected and the tool is made to move parallel to the axis of rotation of the work piece by means of automatic arrangement. By disengaging split nut or half nut, the carriages brought back to its initial position to start another cut.



taper turning

it is the operation of producing a conical surfaces on the work pieces. a taper can be produced by any one of the following methods.

i. by swivelling the compound rest
ii. by off-setting the tailstock
iii. by using a taper turning attachment
iv. by form tool method

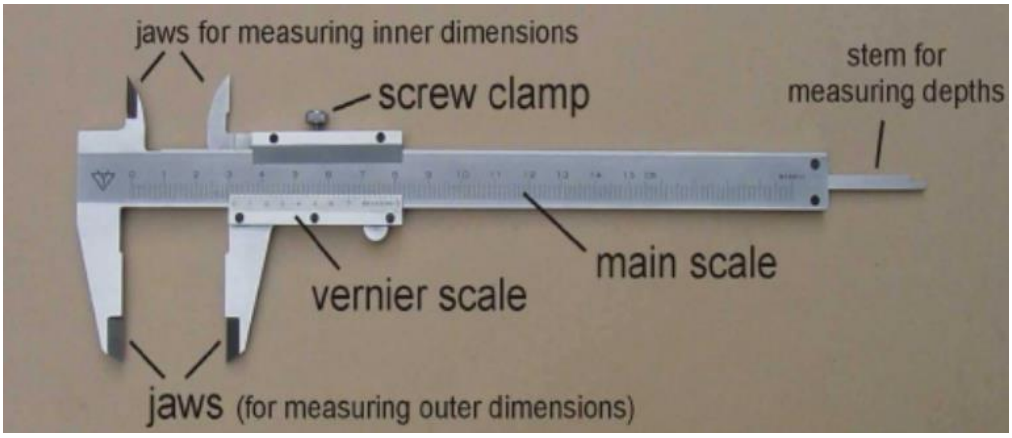


Vernier callipers and Micrometer - [RGPV June 12,13,14]

The precision of length measurements may be increased by using a device that uses a sliding vernier scale. Two such instruments that are based on a vernier scale which you will use in the laboratory to measure lengths of objects are the vernier callipers and the micrometer screw gauge. These instruments have a main scale (in millimetres) and a sliding or rotating vernier scale.

The vernier:

A Typical vernier callipers is shown in figure. To use this kind of device we need to follow the
steps below:
1- To measure outer dimensions of an object, the object is placed between the jaws, which are then moved together until they secure the object.
2- The first significant figures are read immediately to the left of the "zero" of the vernier scale.
3- The remaining digits are taken from the vernier scale and placed after the decimal point of the main reading. This remaining reading corresponds to the division that lines up with any main scale division. Only one division on the vernier scale coincides with one on the main scale. See figures



Reading on the vernier callipers

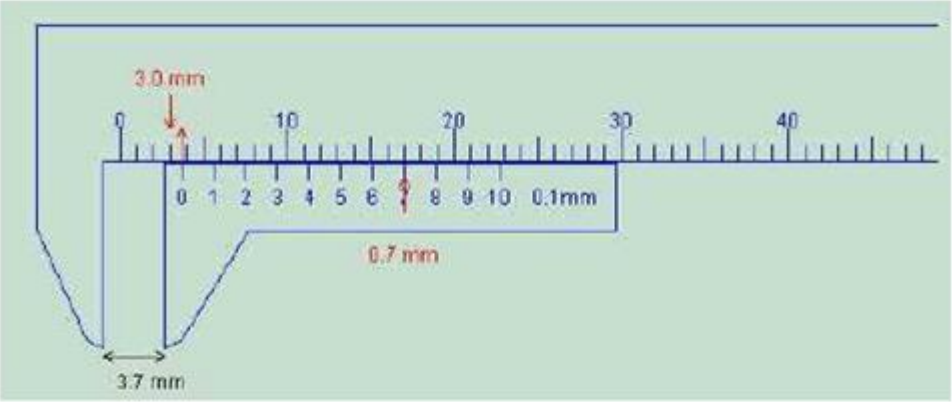


Figure : The reading here is 3.7 mm.

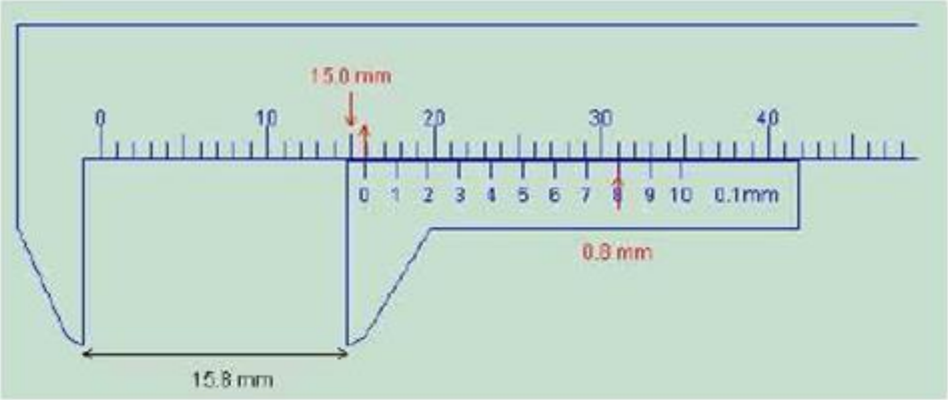
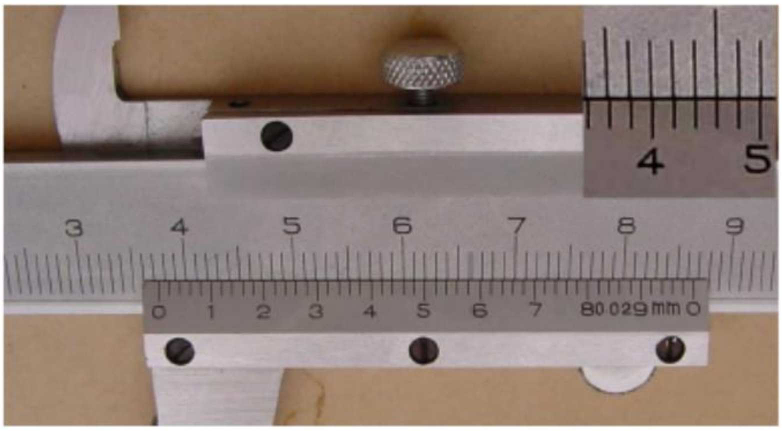


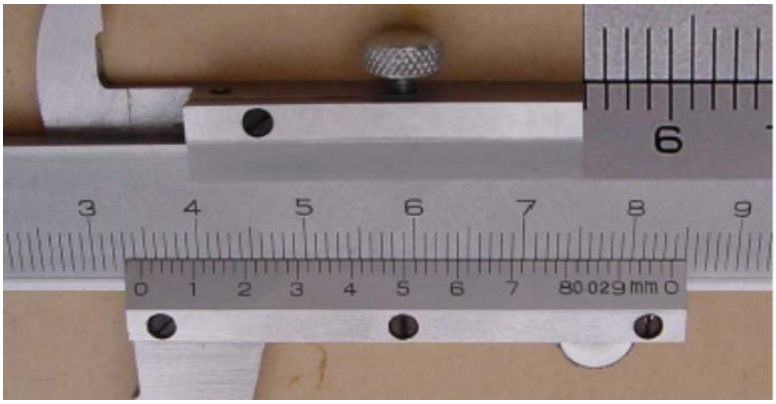
Figure : The reading here is 15.8 mm.

Some examples:

Note that the important region of the vernier scale is enlarged in the upper right hand corner of each figure.



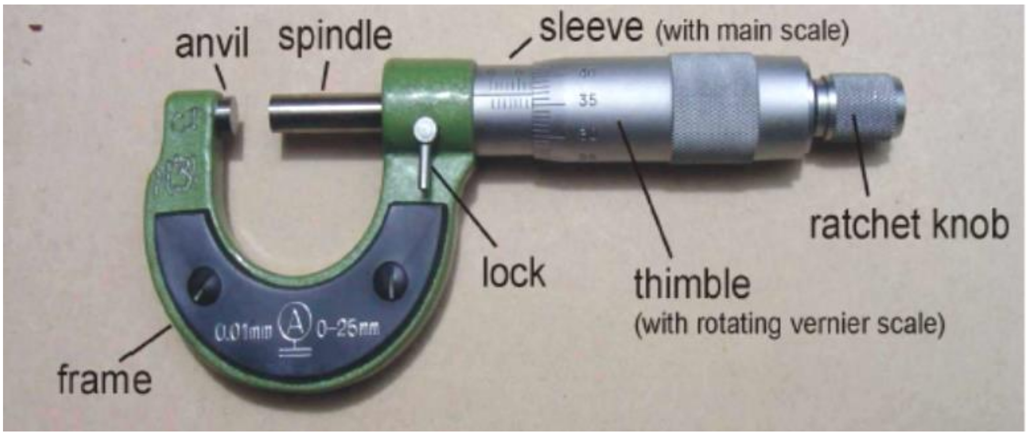
In above figure, the first significant figures are taken as the main scale reading to the left of theVernier zero, i.e. 37 mm. The remaining two digits are taken from the vernier scale reading that lines up with any main scale reading, i.e. 46 on the vernier scale. Thus the reading is 37.46 mm.



In figure 5 above, the first significant figures are taken as the main scale reading to the left of the vernier zero, i.e. 34 mm. The remaining two digits are taken from the vernier scale reading that lines up with any main scale reading, i.e. 60 on the vernier scale. Note that the zero must be included because the scale can differentiate between fiftieths of a millimetre. Therefore the reading is 34.60 mm.

micrometer screw gauge

The micrometer screw gauge is used to measure even smaller dimensions than the vernier callipers. The micrometer screw gauge also uses an auxiliary scale (measuring hundredths of a millimetre) which is marked on a rotary thimble. Basically it is a screw with an accurately constant pitch (the amount by which the thimble moves forward or backward for one complete revolution). The rotating thimble is subdivided into 50 equal divisions. The thimble passes through a frame that carries a millimetre scale graduated to 0.5 mm. The jaws can be adjusted by rotating the thimble using the small ratchet knob. The thimble must be rotated through two revolutions to open the jaws by 1 mm.



To use this kind of device we need to follow the steps below:

1- Place the object to be measured between the jaws and the thimble is rotated using the ratchet until the object is secured.

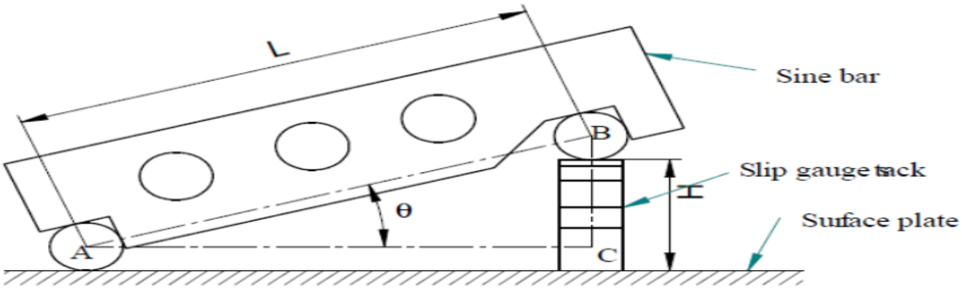
2- The first significant figure is taken from the last graduation showing on the sleeve directly to the left of the revolving thimble. Note that an additional half scale division (0.5 mm) must be included if the mark below the main scale is visible between the thimble and the main scale division on the sleeve.

3- The remaining two significant figures (hundredths of a millimetre) are taken directly from the thimble opposite the main scale. See the examples below.

In figure 11 the last graduation visible to the left of the thimble is 7 mm and the thimble lines up with the main scale at 38 hundredths of a millimeter (0.38 mm); therefore the reading is 7.38 mm.

Sine Bar and Combination set - [RGPV June 10,13, Dec 13]

Sine bars are made from high carbon, high chromium, corrosion resistant steel which can be hardened, ground & stabilized. Two cylinders of equal diameters are attached at the ends as shown in fig. The distance between the axes can be 100, 200 & 300 mm. The Sine bar is designated basically for the precise setting out of angles and is generally used in conjunction with slip gauges & surface plate. The principle of operation relies upon the application of Trigonometry.

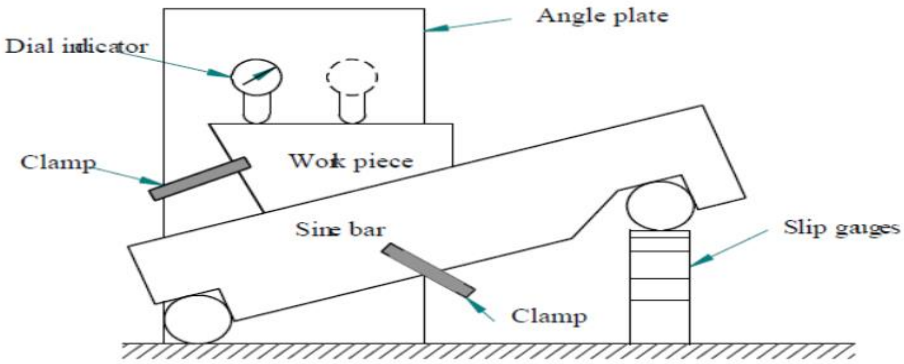


In the above fig, the standard length AB (L) can be used & by varying the slip gauge stack (H), any desired angle q can be obtained as,

$$\theta=\sin^{-1}(H/L)$$

Sine Bar

For checking unknown angles of a component, a dial indicator is moved along the surface of work and any deviation is noted. The slip gauges are then adjusted such that the dial reads zero as it moves from one end to the other.



Limitations of Sine bars:

The accuracy of sine bars is limited by measurement of centre distance between the two precision rollers & hence it cannot be used as a primary standard for angle measurements. Sine principle is fairly reliable at angles less than 15o, but becomes inaccurate as the angle increases.

For angles exceeding 45°, sine bars are not suitable for the following reasons:

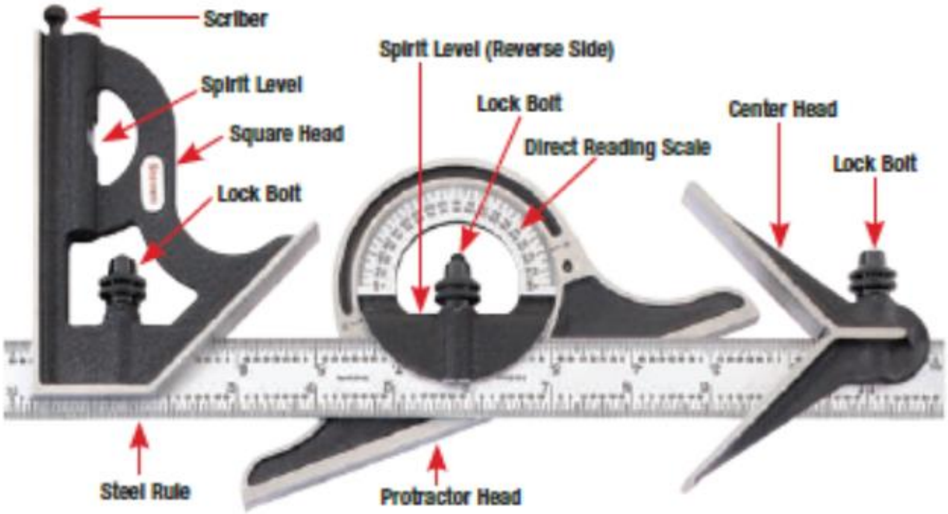
1. The sine bar is physically clumsy to hold in position.
2. The body of the sine bar obstructs the gauge block stack, even if relieved.
3. Slight errors of the sine bar cause large angular errors.
4. Long gauge stacks are not nearly as accurate as shorter gauge blocks.
5. A difference in deformation occurs at the point of roller contact supporting the surface and to the gauge blocks, because at higher angles, the load is shifted more towards the fulcrum roller.

Combination set

Description and Components

The combination square includes a hardened steel graduated rule and movable combination square and mitre head with spirit level and scriber. The square head has a precision ground 90° square face and a 45° mitre face. It is a highly versatile layout tool for scribing right angles and parallel lines, and a measuring tool that can be used as a tri-square, mitre, depth gage, height gage, and level. The Centre Head is an available attachment that provides an easy means of accurately locating the centre of cylindrical or square work.

The Protractor Head is another available attachment. It has revolving turrets with direct-reading double graduations, a full 0 to 180° in opposite directions. This permits accurate and quick direct reading of angles above or below the blade. Complete Sets are available including the rule and all three heads in a fitted case.

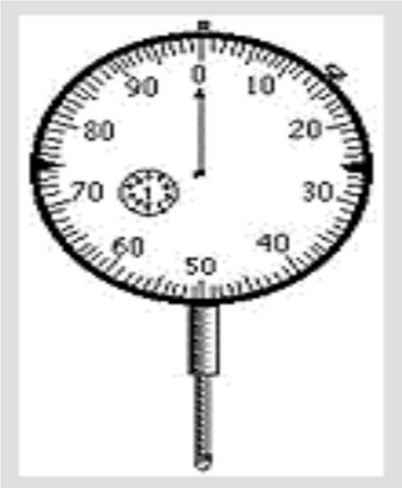


Dial gauge and Milling machine - [RGPV June 10]

Dial Indicators are instruments used to accurately measure a small distance. The measurement results are displayed in a magnified way by means of a dial. They may be used to check the variation in tolerance during the inspection process of a machined part, measure the deflection of a beam or ring under laboratory conditions, as well as many other situations where a small measurement needs to be registered or indicated.

Applications

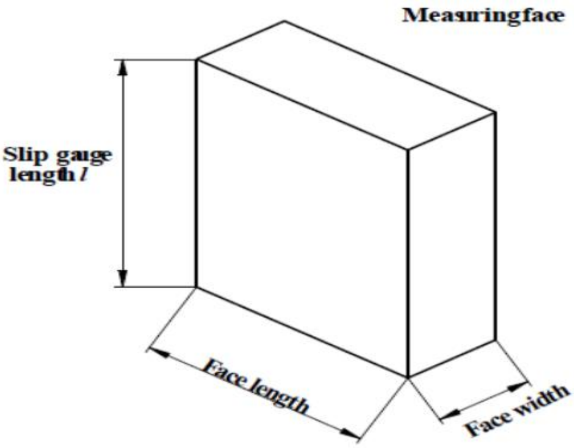
- In a quality environment to check for consistency and accuracy in the manufacturing process.
- On the *workshop floor* to initially set up or calibrate a machine, prior to a production run.
- By toolmakers (moldmakers) in the process of manufacturing precision tooling.
- In metal engineering workshops, where a typical application is the cantering of a lathe's work piece in a four jaw chuck. The DTI is used to indicate the *run out* (the misalignment between the work piece's axis of rotational symmetry and the axis of rotation of the spindle) of the work piece, with the ultimate aim of reducing it to a suitably small range using small chuck jaw adjustments.
- In areas other than manufacturing where accurate measurements need to be recorded, eg:- physics.



The dial indicator typically consist of a graduated dial and needle to record the minor increments, with a smaller embedded clock face and needle to record the number of needle rotations on the main dial. They may be graduated to record measurements of between 0.001" down to 0.00005" for more accurate usage. The dial face can be rotated to any position, this is used to orient the face towards the user as well as *set* the zero point, there will also be some means of incorporating limit indicators (the two metallic tabs visible in the right image, at 90 and 10 respectively), these limit tabs may be rotated around the dial face to any required position. The dial indicators are normally set up in a fixture (possibly a magnetic base) which would secure the dial indicator and allow its adjustment to read zero at the optimal size of a sample part.

SLIP GAUGES

Slip gauges are rectangular blocks of steel having cross section of 30 mm face length & 10 mm face width as shown in fig.



Slip gauges are blocks of steel that have been hardened and stabilized by heat treatment. They are ground and lapped to size to very high standards of accuracy and surface finish. A gauge block (also known Johansson gauge, slip gauge, or Jo block) is a precision length measuring standard consisting of a ground and lapped metal or ceramic block. Slip gauges were invented in 1896 by Swedish machinist Carl Edward Johansson.

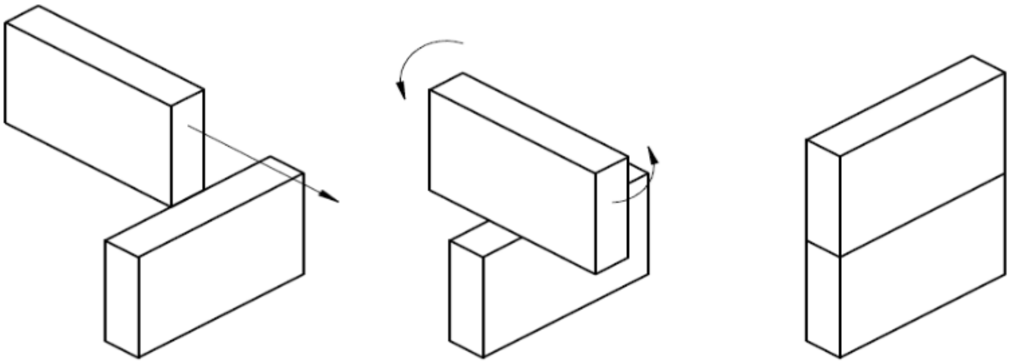
Protector Slips:

In addition, some sets also contain protector slips that are 2.50mm thick and are made from a hard, wear resistant material such as tungsten carbide. These are added to the ends of the slip gauge stack to protect the other gauge blocks from wear. Allowance must be made of the thickness of the protector slips when they are used.

Wringing of Slip Gauges:

Slip gauges are wrung together to give a stack of the required dimension. In order to achieve the maximum accuracy the following precautions must be taken.

- Use the minimum number of blocks.
- Wipe the measuring faces clean using soft clean chamois leather.
- Wring the individual blocks together by first pressing at right angles, sliding & then twisting.



Milling machine

Milling machine is a machine tool in which metal is removed by means of a rotating cutter with multiple number of teeth (or multipoint). Each teeth has cutting edge which removes metal from work piece. The feed and depth of cut to the job is provided by feeding the job to the cutter, longitudinally, transversely or vertically.

• Up Milling and Down Milling

When cutter rotates against the direction of feed of job then it is called Up or Conventional milling.

When cutter rotates in the same direction as feed of job then it is called Down milling/Climb milling.

- **Common operations performed on Milling Machine**

Plain milling, Face milling, Angular milling, Gear milling, Form milling, Milling slots, Keyways etc.

- **Principal parts of Milling machine are shown in Fig.**

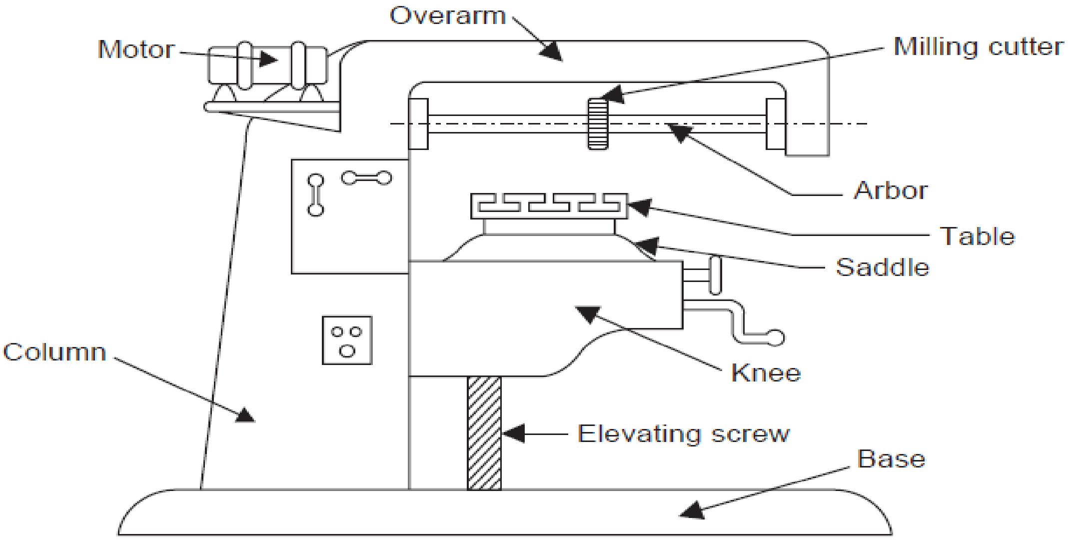


Fig. Milling Machine.

Shaper and Drilling machine - [RGPV June 10,11]

Introduction

Shaper is a reciprocating type machine tool which is primarily intended to produce flat surfaces. The surfaces may be horizontal, vertical on inclined. This machine involves the use of a single point cutting tool similar to a tool used in lathe machine. Tool is held in the tool post mounted at the end of ram. Workpiece is held in a vice or clamed directly on table. The ram reciprocates in to and fro direction and cutting of material takes place during forward stroke while the return stroke is idle. Return stroke time is less as compared to forward stroke and this is obtained by a quick return mechanism. Feed is provided by moving job relative to tool in a direction perpendicular to the movement of ram. Depth of cut is adjusted by moving tool downward towards the work piece.

Principal parts of a Shaper machine are shown in Fig.

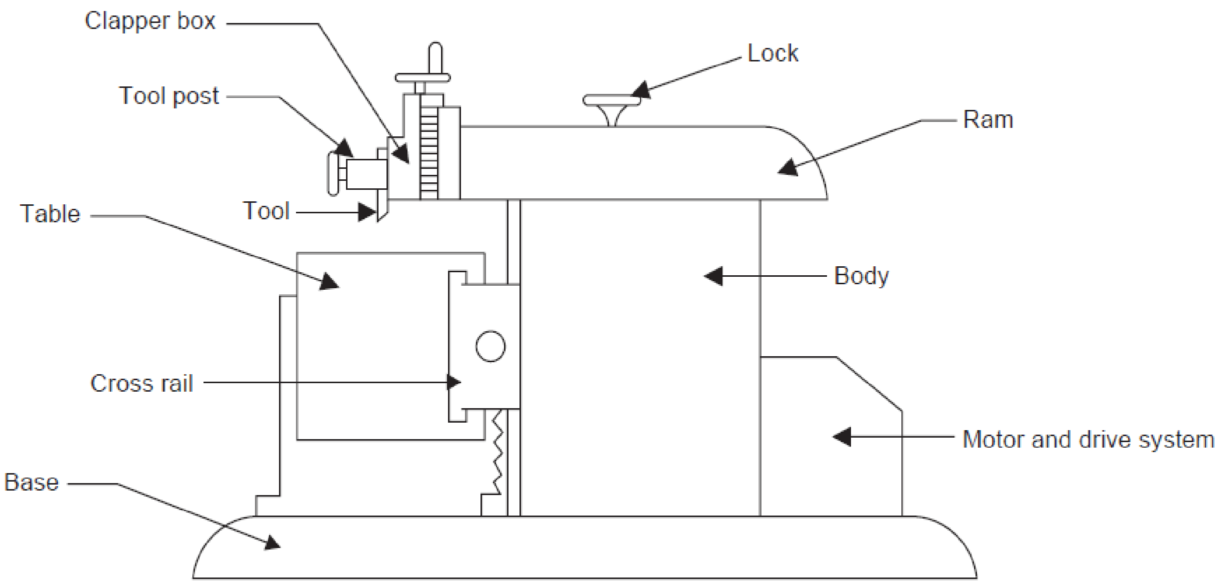


Fig. Shaper Machine.

Drilling Machine

Drilling machine is used to produce or generate a round hole in the work piece. The tool used for drilling holes is called Drill. The Drill is placed in the chuck of the machine which rotates about its axis. The linear motion is given to the drill towards the work piece. A tap is a tool used for making internal threads. The taps are provided with cutting edges and three or four flutes cut across it, so that when it is screwed into a hole, it cuts an internal thread. These are made in sets of three. First use taper tap, then medium tap and then bottoming or plug tap. These are made of high carbon steel or high speed steel and hardened and tempered.

Drill machine operation

The common operations performed on drilling machine are drilling, boring, reaming, tapping, counter boring etc.

Principal parts of the drilling machine are shown in Fig.

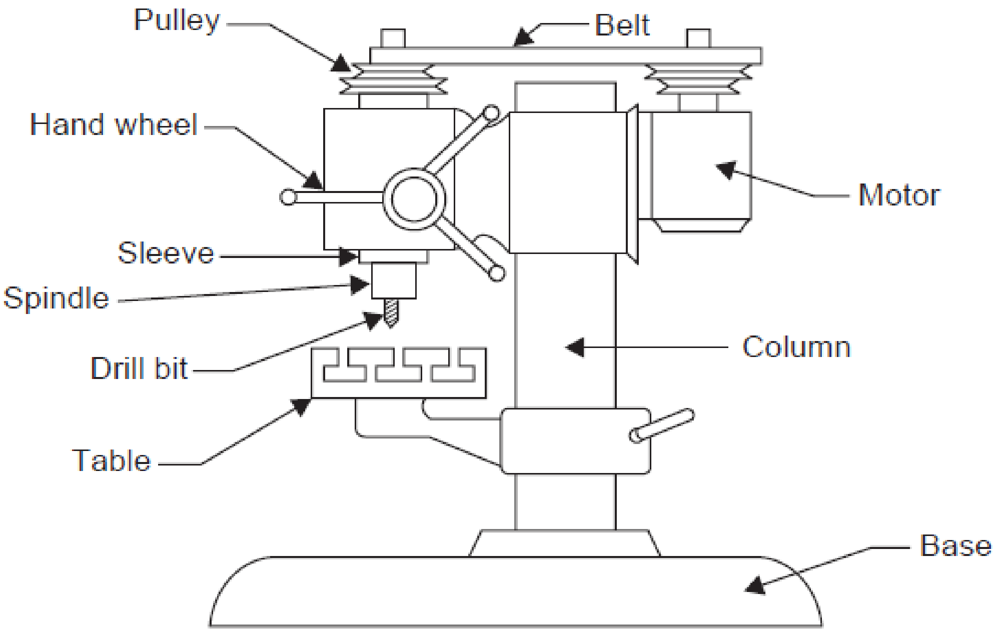


Fig. Drilling Machine.

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THANK YOU