Measurement and Industrial Instrumentation

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Linear & Angular Measurement

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Linear measurement applies to measurement of lengths, diameters, heights, and thickness including external and internal measurements.

The line measuring instruments have series of accurately spaced lines marked on them, e.g. scale. The dimension to be measured is aligned with the graduations of the scale.

Linear measuring instruments are designed either for line instruments or the measurement is taken between two end surfaces as in micrometers, slip gauges etc.
A length may be measured as the distance between two lines or as the distance between two parallel faces.

So, the instruments for direct measurement of linear dimensions fall into two categories.

- Line standards
- End standards.
When the length is measured as the distance between centers of two engraved lines, it is called line standard. Both material standards yard and meter are line standards. The most common example of line measurements is the rule with divisions shown as lines marked on it.
Characteristics of Line Standards

- Scales can be accurately engraved but the engraved lines themselves possess thickness and it is not possible to take measurements with high accuracy.
- A scale is a quick and easy to use over a wide range.
- The scale markings are not subjected to wear. However, the leading ends are subjected to wear and this may lead to undersize measurements.
- Scales are subjected to parallax error.
- Also, the assistance of magnifying glass or microscope is required if sufficient accuracy is to be achieved.
When length is expressed as the distance between two flat parallel faces, it is known as end standard. Examples: Measurement by slip gauges, end bars, ends of micrometer anvils, Vernier calipers etc. The end faces are hardened, lapped flat and parallel to a very high degree of accuracy.
Characteristics of End Standards

- These standards are highly accurate and used for measurement of close tolerances in precision engineering as well as in standard laboratories, tool rooms, inspection departments etc.

- They require more time for measurements and measure only one dimension at a time.

- They are subjected to wear on their measuring faces.

- Group of slips can be "wrung" together to build up a given size; faulty wringing and careless use may lead to inaccurate results.

- They are not subjected to parallax effect as their use depends on feel.
Vernier Calipers

- **jaws for measuring inner dimensions**
- **screw clamp**
- **vernier scale**
- **main scale**
- **jaws** (for measuring outer dimensions)
- **stem for measuring depths**
- **Main Scale:** The main scale is similar to that on a ruler, graduated in mm and cm on one side; inches on the other side.

- **Vernier Scale:** The Vernier scale is a sliding scale. It slides parallel to the main scale and enables readings to be made to a fraction of a division on the main scale.

- **Screw:** The Vernier scale can be fixed at any position on the main scale with the help of a screw.

- **Outside Jaws:** used to measure external diameter or width of an object.

- **Inside Jaws:** used to measure internal diameter of an object.

- **Depth Probe:** used to measure depths of an object or a hole.
Types of Vernier Calipers

- Type A
- Type B
- Type C
**Type A Vernier Calipers:** The first one is with jaws on both sides for external and internal measurements and it has a needle for depth measurement.
Types of Vernier Calipers

**Type B Vernier Calipers:** The second type, there are no separate jaws for internal and external measurements. One set of jaws are available for both internal and external measurements. The measuring faces of the jaws in this type of Vernier caliper are suitable for taking both internal and external measurements.
Type C Vernier Calipers: And the third type of Vernier caliper is also similar to the second one and it will have knife edges for marking purpose.
A micro meter is a precision instrument used to measure a job, generally within an accuracy of 0.01mm.
**Micrometer**

**C-Frame:** It is a rigid part that has both holding points for a job or object to be measured. Its size depends on micrometer measuring range so size of C frame increases as range expands to bigger.

**Anvil:** It is a small stationary cylindrical part of micrometer located in far end of C frame and acts as one holding point for measuring objects.

**Spindle:** A cylindrical long part which is mounted through all other parts sleeve, lock nut and thimble. It is moveable part and has a connection with ratchet as we rotate the ratchet clockwise or counter clockwise the spindle slides out or inward to adjust it with compare to measuring object size.

**Anvil Face and Spindle Face:** Faces of both anvil and spindle which are opposite to each other are the measuring points of micrometer and hold the measuring object collectively.
Lock nut: As we know the mechanism of micrometer based on precision ground threads of spindle so the lock nut works as stationary nut for this mechanism, so rotation of this mechanism into lock nut controls the spindle movement.

Sleeve: It’s a barrel type cylindrical part which mounted on spindle and is main scale of micrometer because main scale is engraved on the sleeve.

Thimble: Thimble is also mounted on spindle and a scale is engraved around it perimeter of thimble. Scale of thimble is to show the measurement value in fraction.

Ratchet: It’s a knurled thumb gripe to rotate the spindle into desired direction for measuring process, provided with ratchet action to avoid over tightening of micrometer across the measuring object and also ensures equal pressure force of each measurement.
Slip gauges or gauge blocks are universally accepted end standard of length in industry. These were introduced by Johansson, a Swedish engineer, and are also called as Johansson gauges.

Slip gauges are rectangular blocks of high grade steel with exceptionally close tolerances. These blocks are suitably hardened throughout to ensure maximum resistance to wear.

They are then stabilized by heating and cooling successively in stages so that hardening stresses are removed, after being hardened they are carefully finished by high grade lapping to a high degree of finish, flatness and accuracy.
For successful use of slip gauges their working faces are made truly flat and parallel. A slip gauge is shown in figure 1.

Slip gauges are also made from tungsten carbide which is extremely hard and wear resistant.

Any two slips when perfectly clean may be wrung together. The dimensions are permanently marked on one of the measuring faces of gauge blocks.
Slip Gauges
Slip Gauges

Gauges blocks are used for:

- Primarily used for inspection.
- Direct precise measurement, where the accuracy of the work piece demands it.
- For checking accuracy of Vernier callipers, micrometers, and such other measuring instruments.
- Setting up a comparator to a specific dimension.
- For measuring angle of work piece and also for angular setting in conjunction with a sine bar.
- To check gap between parallel locations such as in gap gauges or between two mating parts.
Dial indicators are small indicating devices using mechanical means such as gears and pinions or levers for magnification system.

They are basically used for making and checking linear measurements.

Dial indicators are very sensitive and versatile instruments.

They require little skill in their use than other precision instruments, such as micrometer vernier callipers, gauges etc.

A dial indicator by itself is not of much unless it is properly mounted and set before using for inspection purposes.
Dial Indicator
By mounting a dial indicator on any suitable base and with various attachments, it can be used for variety of purposes as follows.

- Determining errors in geometrical forms, e.g., ovality out of roundness, taper etc.
- Determining positional errors of surfaces, e.g., in squareness, parallelism, alignment etc.
- Taking accurate measurements of deformation (extension compression) in tension and compression testing of material.
- Comparing two heights or distances between narrow limits (comparator).
Uses of Dial Indicator

The **practical applications** of the use of dial indicator are:

- To check alignment of lathe centers by using a suitable accurate bar between centers.
- To check trueness of milling machine arbors.
- To check parallelism of the shaper ram with table surface or like.
Other Devices

- Height Gauge
Other Devices
Other Devices

Depth Gauge
Other Devices

- Gear Tooth Vernier Calipers
& Many more
Angular Measurement

- Bevel Protractor
- Sine bar & Sine Center
- Angle Gauge
- Angle Plate
- Spirit Level
- Clinometer
- Autocollimators
Bevel Protractor
Bevel Protractor

- It is probably the simplest instrument for measuring the angle between two faces of component.
- It consists of a base plate attached to the main body, and an adjustable blade which is attached to a circular plate containing Vernier scale.
- The adjustable blade is capable of rotating freely about the center of the main scale engraved on the body of the instrument and can be locked in any position. It is capable of measurement from 0 to 360 degree.
- The Vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus the least count of the instrument is 5'. This instrument is most commonly used in workshops for angular measurements till more precision is required.
The sine principle uses the ratio of the length of two sides of a right triangle in deriving a given angle.

The sine of an angle is the side opposite the angle divided by the hypotenuse.
A sine bar is made up of a hardened steel beam having a flat upper surface.

The bar is mounted on two cylindrical rollers. These rollers are located in cylindrical grooves specially provided for the purpose. The axes of the two rollers are parallel to each other.

They are also parallel to the upper flat surface at an equal distance from it.

The sine bar in itself is not a complete measuring instrument. Another datum such as a surface plate is needed, as well as other auxiliary equipment, notably slip gauges, and indicating device to make measurements. Sine bars used in conjunction with slip gauges constitute a very good device for the precise measurement of angles.
Sine bars are used either to measure angles very accurately or for locating any work to a given angle within very close limits.

- The accuracy attainable with this instrument is quite high and the errors in angular measurement are less than 2 seconds for angle up to 45.

  here, $l =$ distance between centers of ground cylinder (typically 5” or 10”)

  $h =$ height of the gauge blocks

  $\theta =$ the angle of the plane

  $\theta = \arcsin\left(\frac{h}{l}\right)$
Measuring known angles or locating any work to a given angle

- For this purpose the surface plate is assumed to be having a perfectly flat surface, so that its surface could be treated as horizontal.

- One of the cylinders or rollers of sine bar is placed on the surface plate and other roller is placed on the slip gauges of height $h$.

- Let the sine bar be set at an angle $\theta$. Then $\sin \theta = \frac{h}{l}$, where $l$ is the distance between the center of the rollers.
Use of Sine Bar

Checking Of Unknown Angles

- In such a case first find the angle approximately with the help of a bevel protector.
- Let the angle be $\theta$. Then the sine bar is set at an angle $\theta$ and clamped to an angle plate.
- Next, the work is placed on sine bar and clamped to angle plate as shown in Fig. And a dial indicator is set at one end of the work and moved to the other, and deviation is noted.
- Again slip gauges are so adjusted (according to this deviation) that dial indicator reads zero across work surface.
Checking of unknown angles of heavy component

- In such cases where components are heavy and can’t be mounted on the sine bar, then sine bar is mounted on the component as shown in Fig.

- The height over the rollers can then be measured by a vernier height gauge
Sine center provides convenient means for measuring angles of conical workpiece, which are held between centers as shown in figure.

One of the rollers is pivoted about its axis, thereby allowing the sine bar to be set to an angle by lifting the other roller.

The base of the sine center has high degree of flatness and slip gauges are wrung and placed on it in order to set the sine bar to the required angle.
Sine Center
Factors Affecting Accuracy of Sine Bar

Accuracy of Sine bar depends on:

- Equality of size rollers.
- Centre distance of rollers (must known).
- Parallelism of roller axes to each other.
- Parallelism of roller axes to upper surface of bar.
- Flatness of upper surface of bar.
- Equality of distance from roller centers to upper surface.
Angle gauges, which are made of high grade wear resistant steel work similar to slip gauges. While the slip gauges can be built up to give linear dimensions, angle gauges can be built up to give the required angle.

The gauges come in a standard set of angle blocks that could be wrung together in a suitable combination to build an angle.

C.E. Johansson who developed the slip gauges is also credited with the invention of angle gauge blocks.

However, the first set of combination of angle gauges was devised by Dr. G.A. Tomlinson of the National Physical Laboratory in the United Kingdom. He developed a set in the year 1939, which provided the highest number of angle combinations. His set of ten blocks could be used to set any angle between 0 and 1800 in increments of 5’.
Angle Gauges
Adding and Subtracting Angle Gauge Blocks

Illustration shows the way in which two gauge blocks could be used in combination to generate two different angles. If a 5 degree angle block is used along with a 30 degree angle block as shown on the left, the resulting angle is 35 degree. If the 5 degree angle block is reversed and combined with the 30 degree angle block as shown on the right, the resulting angle is 25 degree.
Spirit Level, Clinometer, Autocollimator & Angle Plate

Self Study
Thank You