UNIT 6 ANGULAR MEASURING DEVICES

Structure

6.1 INTRODUCTION

There are a wide variety of geometric features that are measured in angular units. These varieties include angular separation of bounding planes, angular spacing conditions related to circle, digression from a basic direction etc. Because of these diverse geometrical forms, different types of methods and equipment are available to measure angles in common angular units of degree, minute and second. Several factors come into picture in selection of suitable angular measuring instruments. These factors may be the size and general shape of the part, the location and angular accessibilities of the feature to be measured, expected range of angle variations, the required sensitivity and accuracy of measurement etc. Because of the different systems and techniques in angular measuring instruments, it is difficult to categorize them completely. As in linear measurement, they can be categorized in two groups. The first one is line standard instrument. It includes divided scales like protractors, bevel gauges. The second category of angular measuring instruments is called face standard instruments. Sine bars and angle gauges falls in this category. In this unit, we will discuss both types of angular measuring devices and the techniques used in determining the angle. In addition to that, we will have an overview of angle comparators (autocollimators).

Objectives

After studying this unit, you should be able to

- familiarise yourself with various types of angular measuring devices, and
- choose a suitable angular measuring device according to the precision required.

6.2 LINE STANDARD ANGULAR MEASURING DEVICES

Line standard gives direct angular measurement from the engraved scales in the instruments. They are not very precise. Hence they are not used when high precision is required. However, they can be used in initial estimation of the angles in measurement. We will discuss some of the line standard angular measuring devices in the following sub-sections.

6.2.1 Protractors

It is the simplest instrument for measuring angles between two faces. It consists of two arms and an engraved circular scale. The two arms can be set along the faces between which the angle is to be measured. The body of the instrument is extended to form one of the arms, and this is known as the *stock*. It is the fixed part of the protractor and should be perfectly straight. The other arm is in the form of a *blade* that rotates in a *turret* mounted on the body. One of the bodies of the turret carries the divided scale and the other member carries a vernier or index. The ordinary protractor measures angles only in degrees and used for non-precision works. By using angular vernier scale along with it, precision up to 5′ can be achieved. Figure 6.1 shows the diagram of a protractor.

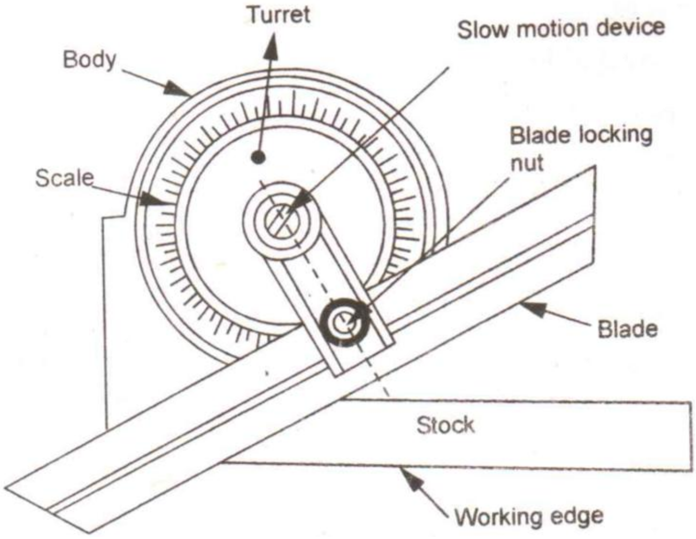


Figure 6.1 : Protractor

6.2.2 Universal Bevel Protractors

It is an angular measuring instrument capable of measuring angles to within 5 min. The name universal refers to the capacity of the instrument to be adaptable to a great variety of work configurations and angular interrelations. It consists of a *base* to which a vernier scale is attached. A *protractor dial* is mounted on the circular section of the base. The protractor *dial* is graduated in degrees with every tenth degree numbered. The *sliding blade* is fitted into this dial; it may be extended to either direction and set at any angle to the base. The blade and the dial are rotated as a unit. Fine adjustment are obtained with a small knurled headed pinion that, when turned, engages with a gear attached to the blade mount. The protractor dial may be locked in any position by means of the dial clamp nut.

Measurement in a universal bevel protractor is made either by embracing the two bounding elements of the angle or by extraneous referencing, for example, the part and the instrument resting on a surface plate.

The vernier protractor is used to measure an obtuse angle, or an angle greater than 90° but less than 180°. An *acute angle attachment* is fastened to the vernier protractor to measure angles of less than 90°. The main scale is divided into two arcs of 180°. Each arc is divided into two quadrants of 90° and has graduation from 0° to 90° to the left and right of the zero line, with every tenth degree numbered.

The vernier scale is divided into 12 spaces on each side of its zero (total 24). The spacing in the vernier scale is made in such a way that least count of it corresponds to $^{1}/_{12}{}^{th}$ of a degree, which is equal to 5′.

If the zero on the vernier scale coincides with a line on the main scale, the number of vernier graduations beyond the zero should be multiplied by 5 and added to the number of full degrees indicated on the protractor dial. Figure 6.2 shows a diagram of a bevel protractor.

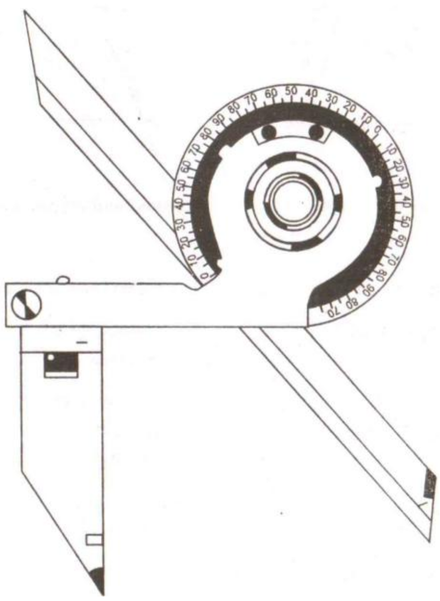


Figure 6.2 : Universal Bevel Protractor

SAQ 1

(a) What are the various line standard angular measuring devices?

(b) Name the parts of a universal bevel protractor and state the functions of each.

6.3 FACE STANDARD ANGULAR MEASURING DEVICES

Face standard angular measuring devices include angle gauges and sine bars. The measurements are done with respect to two faces of the measuring instruments. Precision obtained in such instruments is more than the precision obtained in line standard angular measuring devices. Some commonly used face standard angular measuring devices are discussed in the following sub-sections.

6.3.1 Sine Bar

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.

Unlike bevel protractors sine bars make indirect measurements. The operation of a sine bar is based on known trigonometric relationship between the sides and the angle of a right angle triangle. Here, dimension of two sides determine the size of the third side and of the two acute angles. 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°. Generally, right-angled triangle is obtained by using a horizontal and precise flat plate on which gage blocks are stacked in the direction normal to the plane of the plate.

Sine block itself is not a measuring instrument. It acts as an important link in the angle measuring process. The actual measurement consists in comparing the plane of the part's top element to the plane of supporting surface plate. Mechanical or electronic height gauges are essentially used in the process.

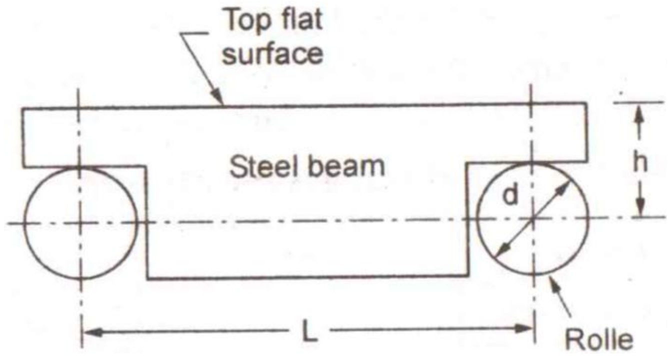


Figure 6.3 : Sine Bar

Figure 6.3 shows the schematic diagram of a sine bar. It is specified by the distance between the two centres of two rollers. The high degree of accuracy and precision available for length measurement in the form of slip and block gauges may be utilized for measurement of angle using the relationship as shown in Figure 6.4, where we have,

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

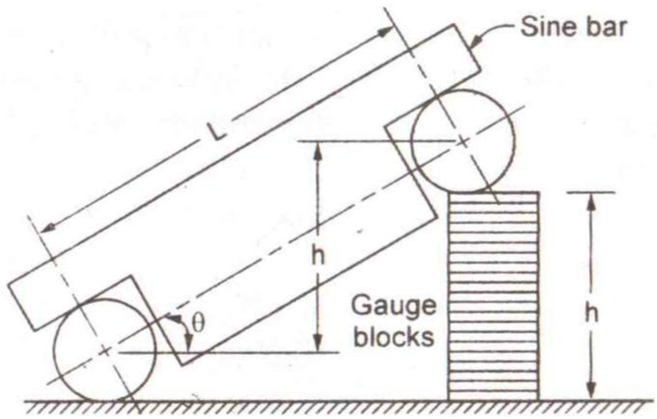


Figure 6.4 : Use of Sine Bar for Angle Measurement

Apparently, the accuracy of angle measurement depends upon the accuracy with which length *L*, of the sine bar and height *h* under the roller is known. Since the gage blocks incorporate a very high degree of accuracy, the reliability of angle measurement by means of sine bar depends essentially on the accuracy of the sine bar itself.

Now, differentiating *h* with respect to θ, we have

$$\cos \theta = \frac{1}{L} \cdot \frac{dh}{d\theta}$$

$$\Rightarrow \frac{d\theta}{dh} = \frac{1}{L \cos \theta} = \frac{\sec \theta}{L}$$

Therefore, the error in angle measurement $d\theta$, due to an error, dh in height h is proportional to sec θ. Now sec θ increases very rapidly for angle greater than 45°. Therefore, sine bars should not be used for measurement of angles greater than 45° and if at all they have to be used, sine bars should measure the complement of the angle rather than the angle itself.

SAQ 2

(a) Why is sine bar not preferred for measuring angle more than 45°?

(b) Calculate the gauge block buildup required to set a 10 cm sine bar to an angle of 30°.

6.4 MEASUREMENT OF INCLINES

Inclination of a surface generally represents its deviation from the horizontal or vertical planes. Gravitational principle can be used in construction of measurements of such inclinations. Spirit levels and clinometer are the instruments of this category. We will discuss these instruments in brief in the following sub-sections.

6.4.1 Spirit Level

Spirit level is one of the most commonly used instruments for inspecting the horizontal position of surfaces and for evaluating the direction and magnitude of minor deviation from that nominal condition. It essentially consists of a close glass tube of accurate form. It is called as the vial. It is filled almost entirely with a liquid, leaving a small space for the formation of an air or gas bubble. Generally, low viscosity fluids, such as ether, alcohol or benzol, are preferred for filling the vial. The liquid due to its greater specific weight tends to fill the lower portion of the closed space. Upper side of the vial is graduated in linear units. Inclination of a surface can be known from the deviation of the bubble from its position when the spirit level is kept in a horizontal plane. Temperature variations in the ambient condition cause both liquid and vial to expand or contract. Therefore, selection of proper liquid and material for the spirit level is very important for accurate result. To reduce the effect of heat transfer in handling spirit levels are made of a relatively stable casting and are equipped with thermally insulated handles. Figure 6.5 shows a schematic diagram of a spirit level.

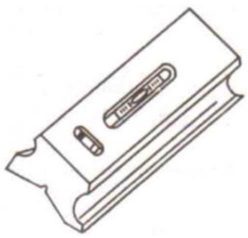


Figure 6.5 : Spirit Level

Sensitivity of the vial used in spirit level is commonly expressed in the following two ways.

Each graduation line representing a specific slope is defined by a tangent relationship, e.g. 0.01 cm per meter.

An angular value is assigned to the vial length covered by the distance of two adjacent graduation lines, i.e. the distance moved by the bubble from the zero will correspond the angle directly.

6.4.2 Clinometer

A clinometer is a special case of application of spirit level for measuring, in the vertical plane, the incline of a surface in relation to the basic horizontal plane, over an extended range. The main functional element of a clinometer is the sensitive vial mounted on a rotatable disc, which carries a graduated ring with its horizontal axis supported in the housing of the instrument. The bubble of the vial is in its centre position, when the clinometer is placed on a horizontal surface and the scale of the rotatable disc is at zero position. If the clinometer is placed on an incline surface, the bubble deviates from the centre. It can be brought to the centre by rotating the disc. The rotation of the disc can be read on the scale. It represents the deviation of the surface over which the clinometer is placed from the horizontal plane. Figure 6.6 shows a diagram of a clinometer.

A number of commercially available clinometers with various designs are available. They differ in their sensitivity and measuring accuracy. Sensitivity and measuring accuracy of modern clinometers can be compared with any other high precision measuring instruments. For shop uses, clinometers with 10′ graduations are available.

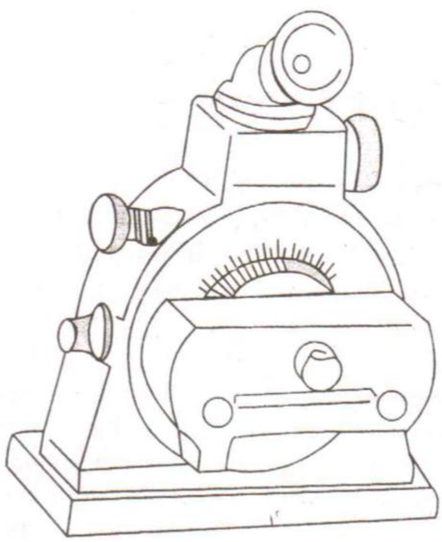


Figure 6.6 : Clinometer

Applications

Two categories of measurement are possible with clinometer. Care must be taken to keep the axis of the rotatable disc parallel to the hinge line of the incline. The two categories of measurement are :

(i) Measurement of an incline place with respect to a horizontal plane. As discussed earlier, this is done by placing the instrument on the surface to be measured and rotating graduated disc to produce zero inclination on the bubble. The scale value of the disc position will be equal to the angle of incline.

(ii) Measurement of the relative position of two mutually inclined surfaces. This is done by placing the clinometer on each of the surface in turn, and taking the readings with respect to the horizontal. The difference of both the readings will indicate the angular value of the relative incline.

SAQ 3

(a) How the inclination is estimated with the help of a spirit level?

(b) Describe the principle, working and uses of a clinometer.

6.5 ANGLE COMPARATORS

Angle comparators are the metrological instruments used for finding the difference between two nearly equal angles. The principle used in angle comparators is same as that of linear comparators. In practice, they are frequently used in calculating the difference between the angle of working standard gauges or instruments. It is also used in measuring angle of a number of angle gauges wrung together, or the angle between two faces of a standard polygon.

The most widely used angle comparators are Autocollimators. They are designed to measure small angles by comparison. They are quite accurate and can read up to 0.1 seconds, and may be used for distance up to 30 meters. We will discuss the principle and the working of an autocollimator in the following section.

6.5.1 Autocollimators

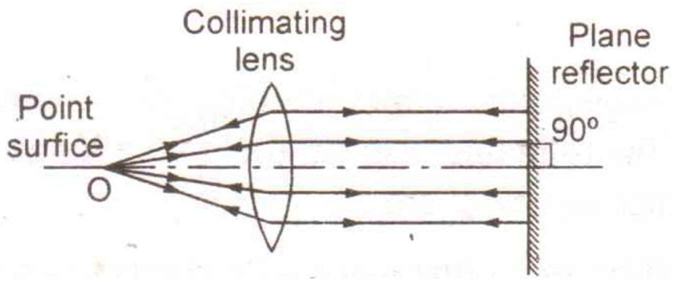
Principle

The two main principles used in an autocollimator are

(a) the projection and the refraction of a parallel beam of light by a lens, and

(b) the change in direction of a reflected angle on a plane reflecting surface with change in angle of incidence.

To understand this, let us imagine a converging lens with a point source of light *O* at its principle focus, as shown in Figure 6.7(a). When a beam of light strikes a flat reflecting surface, a part of the beam is absorbed and the other part is reflected back. If the angle of incidence is zero, i.e. incident rays fall perpendicular to the reflecting surface, the reflected rays retrace original path. When the reflecting plane is tilted at certain angle, the total angle through which the light is deflected is twice the angle through which the mirror is tilted. Thus, alternately, if the incident rays are not at right angle to the reflecting surface they can be brought to the focal plane of the light sources by tilting the reflecting plane at an angle half the angle of reflection as shown in Figure 6.7(b).



(a) Reflector is at 90° with the Direction of Rays

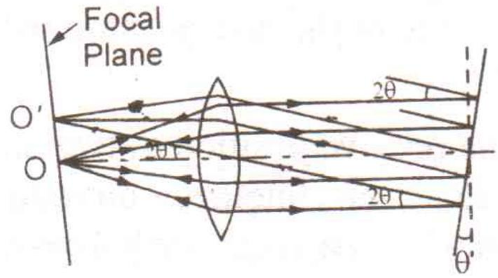


Figure 6.7(b) : Reflector is not at Right Angles to the Direction of the Rays

Now, from the diagram, $OO' = 2\theta \times f = x$, where f is the focal length of the lens.

Thus, by measuring the linear distance x, the inclination of the reflecting surface θ can be determined. The position of the final image does not depend upon the distance of the reflector from the lens. If, however, the reflector is moved too long, the reflected ray will then completely miss the lens and no image will be formed.

Working

In actual practice, the work surface whose inclination is to be obtained forms the reflecting surface and the displacement x is measured by a precision microscope which is calibrated directly to the values of inclination θ.

The optical system of an autocollimator is shown in Figure 6.8. The target wires are illuminated by the electric bulb and act as a source of light since it is not convenient to visualize the reflected image of a point and then to measure the displacement x precisely. The image of the illuminated wire after being reflected from the surface being measured is formed in the same plane as the wire itself. The eyepiece system containing the micrometer microscope mechanism has a pair of setting lines which may be used to measure the displacement of the image by setting to the original cross lines and then moving over to those of the image.

Generally, a calibration is supplied with the instrument. Thus, the angle of inclination of the reflecting surface per division of the micrometer scale can be directly read.

Autocollimators are quite accurate and can read up to 0.1 seconds, and may be used for distance up to 30 meters.

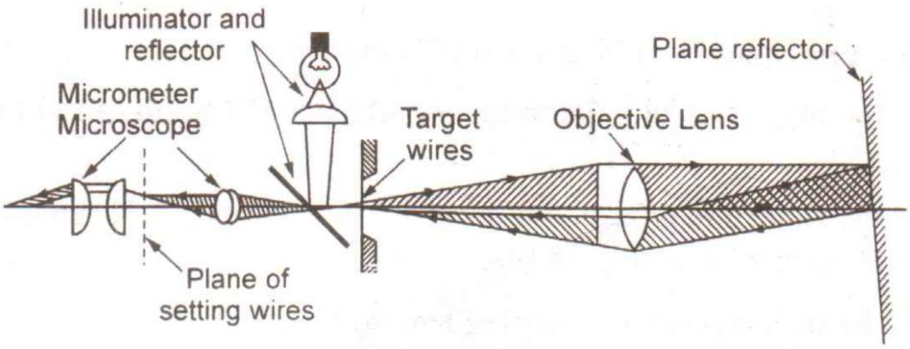


Figure 6.8 : Optical System of an Autocollimator

SAQ 4

Describe the principle and working of an autocollimator.

6.6 SUMMARY

In this unit, principles and techniques of angular measuring devices have been discussed. The unit begins with description of line standard angular measuring devices like protractor and bevel protractor. Next, face standards angular measuring devices, viz. slip gauges and sine bars are discussed. Instruments used for measurement of inclinations, viz. spirit level inclinometers are discussed in the next section. The unit finishes with the discussion of the principle and working of angle comparator, viz. autocollimators.

6.7 KEY WORDS

Protractor : It is the simplest angle-measuring device and can give reading up to 5′.

Clinometer : It is a device for measuring angle between two faces. It uses the principle of spirit level.

Sine Bar : It is an indirect angle-measuring instrument which gives measurement up to 2″.

Angle Gauges : It is a precision angular measuring device that can give accuracy up to 3″.

Vial : The closed glass tube of accurate size in a spirit level, which is used for storing the liquid, is called the vial. It is graduated in linear scale and the bubble moves inside it.

Autocollimator : It is an angle comparator based on the principle of reflection of light. Least measurement given by autocollimator is up to 1′.

6.8 ANSWERS TO SAQs

SAQ 1

(a) See preceding text for answer.

(b) See preceding text for answer.

SAQ 2

(a) See preceding text for answer.

(b) Buildup = 10 sin 30°

= 10 × 0.5

= 5 cm

SAQ 3

(a) See preceding text for answer.

(b) See preceding text for answer.

SAQ 4

See preceding text for answer.