2.6 LIMIT GAUGES

Gauging, done in manufacturing processes, refers to the method by which it is determined quickly whether or not the dimensions of the checking parts in production, are within their specified limits. It is done with the help of some tools called gauges. A gauge does not reveal the actual size of dimension.

A clear distinction between measuring instruments and gauges is not always observed. Some tools that are called gauges are used largely for measuring or layout work. Even some are used principally for gauging give definite measurement.

High carbon and alloy steels have been the principal material used for many years. Objections to steel gauges are that they are subjected to some distortion because of the heat-treating operations and that their surface hardness is limited. These objections are largely overcome by the use of chrome plating or cemented carbides as the surface material. Some gauges are made entirely of cemented carbides or they have cemented carbides inserted at certain wear points.

2.6.1 GAUGES AND THEIR CLASSIFICATIONS

Gauges are the tools which are used for checking the size, shape and relative positions of various parts but not provided with graduated adjustable members. Gauges are, therefore, understood to be single-size fixed-type measuring tools.

Classifications of Gauges

(a) Based on the standard and limit

(i) Standard gauges

(ii) Limit gauges or “go” and “not go” gauges

(b) Based on the consistency in manufacturing and inspection

(i) Working gauges

(ii) Inspection gauges

(iii) Reference or master gauges

(c) Depending on the elements to be checked

(i) Gauges for checking holes

(ii) Gauges for checking shafts

(iii) Gauges for checking tapers

(iv) Gauges for checking threads

(v) Gauges for checking forms

(d) According to the shape or purpose for which each is used

(i) Plug

(ii) Ring

(iii) Snap

(iv) Taper

(v) Thread

(vi) Form

(vii) Thickness

(viii) Indicating

(ix) Air-operated

2.6.1.1 Standard Gauges

Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. A standard gauge should mate with some snugness.

2.6.1.2 Limit Gauges

These are also called „go‟ and „no go‟ gauges. These are made to the limit sizes of the work to be measured. One of the sides or ends of the gauge is made to correspond to maximum and the other end to the minimum permissible size. The function of limit gauges is to determine whether the actual dimensions of the work are within or outside the specified limits. A limit gauge may be either double end or progressive. A double end gauge has the „go‟ member at one end and „no go‟ member at the other end. The „go‟ member must pass into or over an acceptable piece but the „no go‟ member should not. The progressive gauge has „no go‟ members next to each other and is applied to a workpiece with one movement. Some gauges are fixed for only one set of limits and are said to be solid gauges. Others are adjustable for various ranges.

2.6.2 WORKING GAUGES, INSPECTION GAUGES AND REFERENCE GAUGES

To promote consistency in manufacturing and inspection, gauges may be classified as working, inspection, and reference or master gauges:

Working Gauges

Working gauges are those used at the bench or machine in gauging the work as it being made.

Inspection Gauges

These gauges are used by the inspection personnel to inspect manufactured parts when finished.

Reference Gauges

These are also called master gauges. These are used only for checking the size or condition of other gauges and represent as exactly as possible the physical dimensions of the product.

2.6.3 GAUGES FOR CHECKING ELEMENTS

Hole Gauge

It is used to check the dimensions of the hole present in the element.

Shaft Gauge

It is used to check the dimensions of the shaft.

Taper Gauge

It is used to check the dimensions of the tapers.

Thread Gauge

It is used to check the threading of the element.

Form Gauge

It is used to check the forms of the elements.

2.6.4 GAUGES COMMONLY USED IN PRODUCTION WORK

Some of the important gauges which are commonly used in production work have been discussed as follows:

2.6.4.1 Plug Gauges

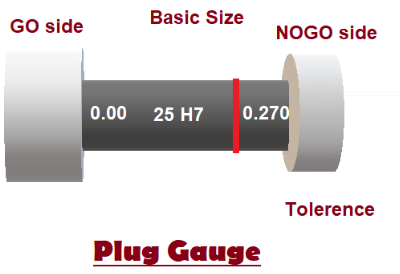

Fig. 2.52 Plug Gauges

[source: https://gaugehow.com/lesson/go-and-nogo-gauge/]

These gauges are used for checking holes of many different shapes and sizes. There are plug gauges for straight cylindrical holes, tapered, threaded square and splined holes. At one end, it has a plug minimum limit size, the „go‟ end and; at the other end a plug of maximum limit, the „no go‟ end. These ends are detachable from the handle so that they may be renewed separately when worn in a progressive limit plug gauge. The „go‟ and „no go‟ section of the gauge are on the same end of the handle. Large holes are gauged with annular plug gauges, which are shell-constructed for light weight, and flat plug gauges, made in the form of diametrical sections of cylinders.

2.6.4.2 Ring Gauges

Ring gauges are used to test external diameters. They allow shafts to be checked more accurately since they embrace the whole of their surface. Ring gauges, however, are expressive manufacture and, therefore, find limited use. Moreover, ring gauges are not suitable for measuring journals in the middle sections of shafts. A common type of standard ring gauge is shown in Figure. In a limit ring gauge, the „go‟ and „no go‟ ends are identified by an annular groove on the periphery. About 35 mm all gauges are flanged to reduce weight and facilitate handling.

Fig. 2.53 Ring Gauges

[source: https://www.thomasnet.com/articles/instruments-controls/all-about-ring-gauges/]

2.6.4.3 Taper plug Gauges

The most satisfactory method of testing a taper is to use taper gauges. They are also used to gauge the diameter of the taper at some point. Taper gauges are made in both the plug and ring styles and, in general, follow the same standard construction as plug and ring gauges.

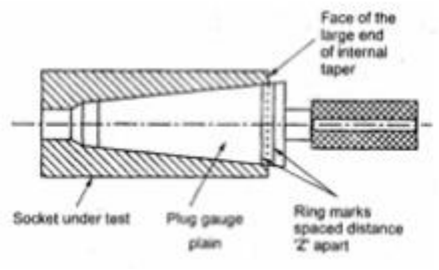

Fig. 2.54 Taper Gauges

[source: https://www.brainkart.com/article/Taper-plug-gauges-and-Ring-gauges_5823/]

When checking a taper hole, the taper plug gauge is inserted into the hole and a slight pressure is exerted against it. If it does not rock in the hole, it indicates that the taper angle is correct. The same procedure is followed in a ring gauge for testing tapered spindle. The taper diameter is tested for the size by noting how far the gauge enters the tapered hole or the tapered spindle enters the gauge. A mark on the gauge shows the correct diameter for the large end of the taper.

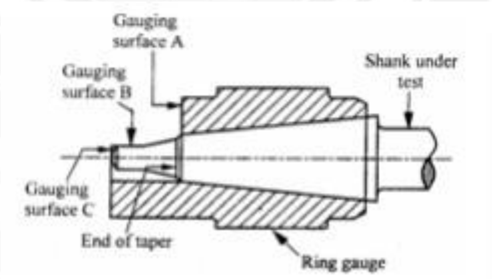

Fig. 2.55 Taper ring plug Gauges

[source: https://www.brainkart.com/article/Taper-plug-gauges-and-Ring-gauges_5823/]

To test the correctness of the taper two or three chalk or pencil lines are drawn on the gauge about equidistant along a generatrix of the cone. Then the gauge is inserted into the hole and slightly turned. If the lines do not rub off evenly, the taper is incorrect and

the setting in the machine must be adjusted until the lines are rubbed equally all along its length. Instead of making lines on the gauge, a thin coat of paint (red led, carbon black, Purssian blue, etc.) can be applied. This has two check lines „go" and „no go" each at a certain distance from the end of the face. The go portion corresponds to the minimum and „no go" to the maximum dimension.

2.6.4.4 Snap Gauges

These gauges are used for checking external dimensions. Shafts are mainly checked by snap gauges. They may be solid and progressive or adjustable or double ended.

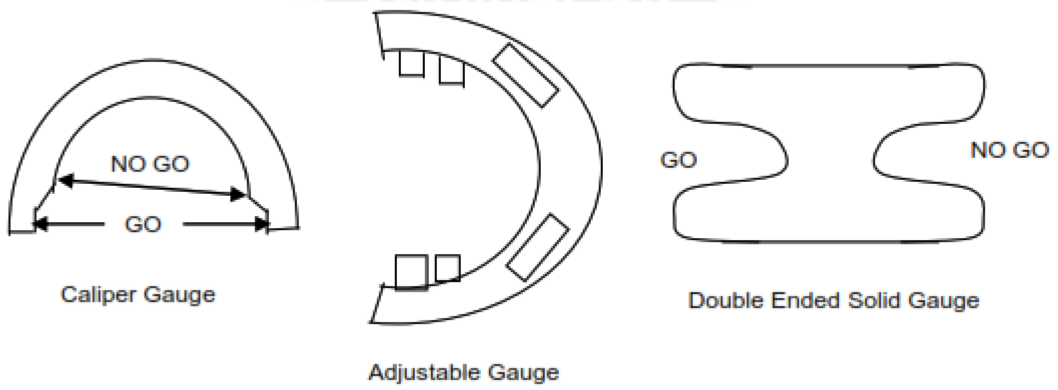

Fig. 2.56 Taper ring plug Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

(a) Solid or non-adjustable caliper or snap gauge with „go" and „no go" each is used for large sizes.

(b) Adjustable caliper or snap gauge used for larger sizes. This is made with two fixed anvils and two adjustable anvils, one for „go" and another for the „no go". The housing of these gauges has two recesses to receive measuring anvils secured with two screws. The anvils are set for a specific size, within an available range of adjustment of 3 to 8 mm. The adjustable gauges can be used for measuring series of shafts of different sizes provided the diameters are within the available range of the gauge.

(iii) Double-ended solid snap gauge with „go" and „no go" ends are used for smaller sizes.

2.6.4.5 Thread Gauges

Thread gauges are used to check the pitch diameter of the thread. For checking internal threads (nut, bushes, etc.), plug thread gauges are used, while for checking external threads (screws, bolts, etc.), ring thread gauges are used. Single-piece thread gauges serve for measuring small diameters. For large diameters the gauges are made with removable plugs machined with a tang. Standard gauges are made single-piece.

Standard plug gauges may be made of various kinds:

(a) Plug gauge with only threaded portion.

(b) Threaded portion on one end and plain cylindrical plug on opposite end to give correct "core" diameter.

(c) Thread gauge with core and full diameters.

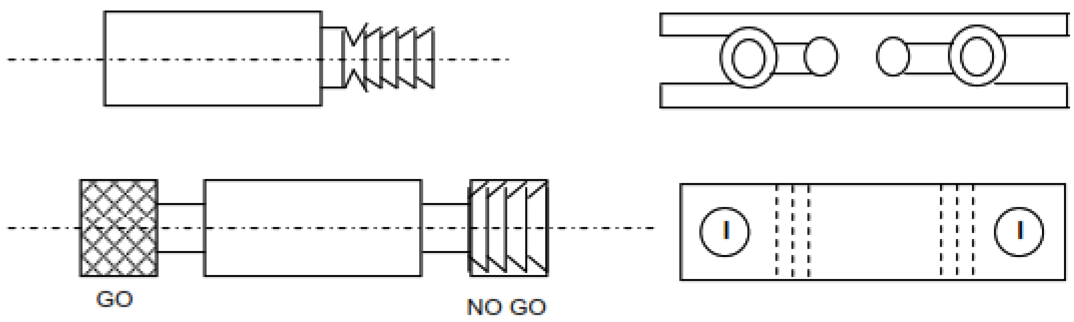

Fig. 2.57 Thread Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

Limit plug gauges have a long-thread section on the „go" and a short-threaded section on the „no go" end to correspond to the minimum and maximum limits respectively.

Roller rings gauges, similarly have „go" and „no go" ends. They may also be solid and adjustable.

Roller Snap gauges are often used in production practice for measuring external threads. They comprise a body, two pairs „go" rollers and two pairs „no go" rollers.

Taper thread gauges are used for checking taper threads. The taper-ring thread gauge are made in two varieties – rigid (non-adjustable) and adjustable. The "go" non-adjustable ring gauges are full threaded while the „no go‟ have truncated thread profile.

2.6.4.6 Form Gauges

Form gauges may be used to check the contour of a profile of workpiece for

conformance to certain shape or form specifications.

Template Gauge

It is made from sheet steel. It is also called profile gauge. A profile gauge may contain two outlines that represent the limits within which a profile must lie a

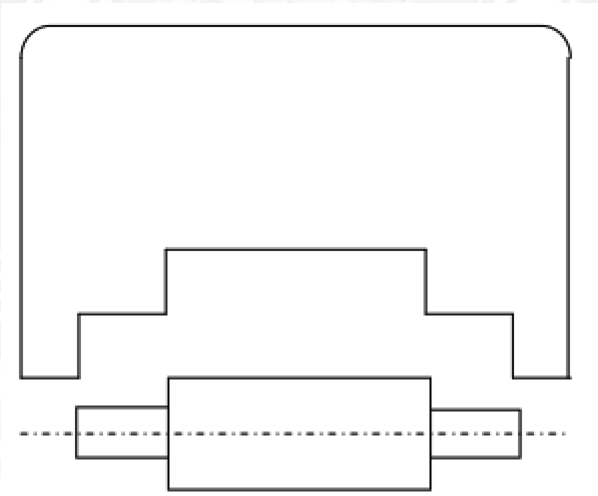

Fig. 2.58 Template Gauge

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

2.6.4.7 Screw Pitch Gauges

Screw pitch gauges serve as an everyday tool used in picking out a required screw and for checking the pitch of the screw threads. They consist of a number of flat blades which are cut out to a given pitch and pivoted in a holder as shown in Figure 4.8. Each blade is stamped with the pitch or number of threads per inch and the holder bears an identifying number designing the thread it is intended for. The sets are made for metric threads with an angle 60°, for English threads with an angle of 55°. A set for measuring metric threads with 30 blades has pitches from 0.4 to 0.6 mm and for English threads with 16 blades has 4 to 28 threads per inch.

In checking a thread for its pitch, the closest corresponding gauge blade is selected and applied upon the thread to be tested. Several blades may have to be tried until the correct is found.

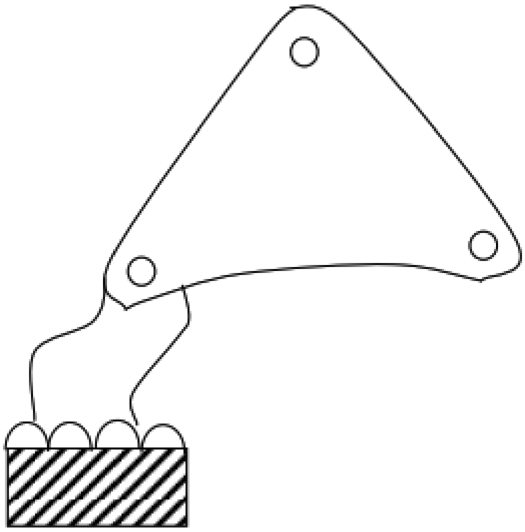

Fig. 2.59 Screw Pitch Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

2.6.4.8 Radius and Fillet Gauges

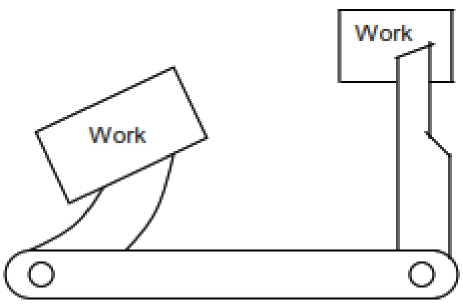

Fig. 2.60 Radius and Fillet Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

The function of these gauges is to check the radius of curvature of convex and concave surfaces over a range from 1 to 25 mm. The gauges are made in sets of thin plates curved to different radius at the ends as shown in Figure 4.9. Each set consists of 16 convex and 16 concave blades.

2.6.4.9 Feller Gauges

Feller gauges are used for checking clearances between mating surfaces. They are made in form of a set of steel, precision machined blade 0.03 to 1.0 mm thick and 100 mm long. The blades are provided in a holder as shown in Figure 4.10. Each blade has an indication of its thickness. The Indian standard establishes seven sets of feller gauges: Nos 1, 2, 3, 4, 5, 6, 7, which differ by the number of blades in them and by the range of thickness. Thin blades differ in thickness by 0.01 mm in the 0.03 to 1 mm set, and by 0.05 mm in the 0.1 to 1.0 mm set.

To find the size of the clearance, one or two blades are inserted and tried for a fit between the contacting surfaces until blades of suitable thickness are found.

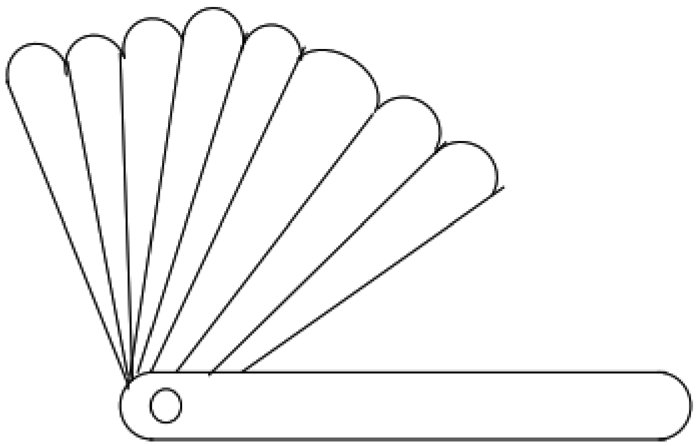

Fig. 2.61 Feller Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

2.6.4.10 Plate and Wire Gauges

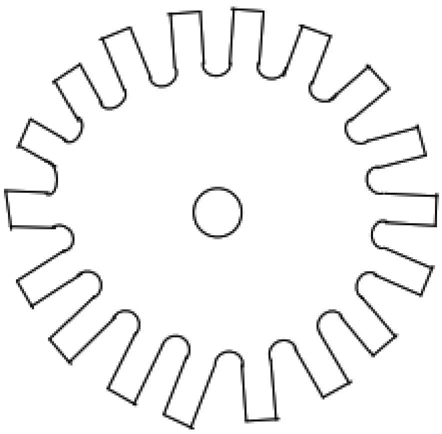

Fig. 2.62 Plate Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

The thickness of a sheet metal is checked by means of plate gauges and wire diameters by wire gauges. The plate gauge is shown in Figure. It is used to check the thickness of plates from 0.25 to 5.0 mm, and the wire gauge, is used to check the diameters of wire from 0.1 to 10 mm.

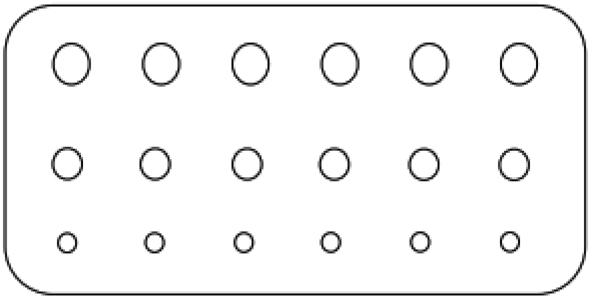

Fig. 2.63 Wire Gauges

[source: http://www.ignou.ac.in/upload/Unit-4-62.pdf]

2.6.4.11 Indicating Gauges

Indicating gauges employ a means to magnify how much a dimension deviates, plus or minus, from a given standard to which the gauge has been set. They are intended for measuring errors in geometrical form and size, and for testing surfaces for their true position with respect to one another. Beside this, indicating gauges can be adapted for checking the run out of toothed wheels, pulleys, spindles and various other revolving parts of machines. Indicating gauges can be of a dial or lever type, the former being the most widely used.

2.6.4.12 Air Gauges

Pneumatic or air gauges are used primarily to determine the inside characteristics of a hole by means of compressed air. There are two types of air gauges according to operation: a flow type and a pressure type gauge. The flow type operates on the principle of varying air velocities at constant pressure and the pressure type operates on the principle of air escaping through an orifice.

2.6.5 GAUGE DESIGN TERMINOLOGY

The following are the commonly used terms in the system of limits and fits.

Basic size

This is the size in relation to which all limits of size are derived. Basic or nominal size is defined as the size based on which the dimensional deviations are given. This is, in general, the same for both components.

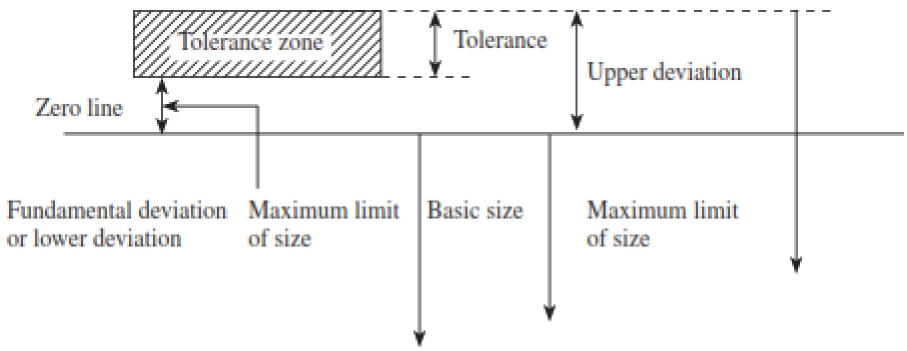

Fig. 2.64 Relationship between fundamental, upper, and lower deviations

[source: “Engineering Metrology & Measurements”, N.V. Raghavendra., page-62]

Limits of size

These are the maximum and minimum permissible sizes acceptable for a specific dimension. The operator is expected to manufacture the component within these limits. The maximum limit of size is the greater of the two limits of size, whereas the minimum limit of size is the smaller of the two.

Tolerance

This is the total permissible variation in the size of a dimension, that is, the difference between the maximum and minimum limits of size. It is always positive.

Allowance

It is the intentional difference between the LLH and HLS. An allowance may be either positive or negative.

$$\text{Allowance} = \text{LLH} - \text{HLS}$$

Grade

This is an indication of the tolerance magnitude; the lower the grade, the finer the tolerance.

Deviation

It is the algebraic difference between a size and its corresponding basic size. It may be positive, negative, or zero.

Upper deviation

It is the algebraic difference between the maximum limit of size and its corresponding basic size. This is designated as ‘ES’ for a hole and as ‘es’ for a shaft.

Lower deviation

It is the algebraic difference between the minimum limit of size and its corresponding basic size. This is designated as ‘EI’ for a hole and as ‘ei’ for a shaft.

Actual deviation

It is the algebraic difference between the actual size and its corresponding basic size.

Fundamental deviation

It is the minimum difference between the size of a component and its basic size. This is identical to the upper deviation for shafts and lower deviation for holes. It is the closest deviation to the basic size. The fundamental deviation for holes are designated by capital letters, that is, A, B, C, …, H, …, ZC, whereas those for shafts are designated by small letters, that is, a, b, c…, h…, zc. The relationship between fundamental, upper, and lower deviations is schematically represented in Figure.

Zero line

This line is also known as the line of zero deviation. The convention is to draw the zero line horizontally with positive deviations represented above and negative deviations indicated below. The zero line represents the basic size in the graphical representation.

Shaft and hole

These terms are used to designate all the external and internal features of any shape and not necessarily cylindrical.

Fit

It is the relationship that exists between two mating parts, a hole and a shaft, with respect to their dimensional difference before assembly.

Maximum metal condition

This is the maximum limit of an external feature; for example, a shaft manufactured to its high limits will contain the maximum amount of metal. It is also the minimum limit of an internal feature; for example, a component that has a hole bored in it to its lower limit of size will have the minimum amount of metal removed and remain in its maximum metal condition, (i.e., this condition corresponds to either the largest shaft or the smallest hole). This is also referred to as the GO limit.

Least metal condition

This is the minimum limit of an external feature; for example, a shaft will contain minimum amount of material, when manufactured to its low limits. It is also the maximum limit of an internal feature; for example, a component will have the maximum amount of metal removed when a hole is bored in it to its higher limit of size, this condition corresponds to either the smallest shaft or the largest hole. This is also referred to as the NO GO limit.

Tolerance zone

The tolerance that is bound by the two limits of size of the component is called the tolerance zone. It refers to the relationship of tolerance to basic size.

International tolerance grade (IT)

Tolerance grades are an indication of the degree of accuracy of the manufacture. Standard tolerance grades are designated by the letter IT followed by a number, for example, IT7. These are a set of tolerances that varies according to the basic size and provides a uniform level of accuracy within the grade.

Tolerance class

It is designated by the letter(s) representing the fundamental deviation followed by the number representing the standard tolerance grade. When the tolerance grade is associated with letter(s) representing a fundamental deviation to form a tolerance class, the letters IT are omitted and the class is represented as H8, f7, etc.

Tolerance symbols

These are used to specify the tolerance and fits for mating components. For example, in 40 H8f7, the number 40 indicates the basic size in millimetres; capital letter

H indicates the fundamental deviation for the hole; and lower-case letter f indicates the shaft. The numbers following the letters indicate corresponding IT grades.

2.6.6 Taylor's Principle

In 1905, William Taylor developed a concept relating to the gauging of components, which has been widely used since then. Since World War II, the term Taylor's principle has generally been applied to the principle of limit gauging and extensively used in the design of limit gauges. Prior to 1905, simple GO gauges were used. The components were carefully manufactured to fit the gauges. Since NOT GO gauges were not used, these components were without tolerance on their dimensions.

The theory proposed by Taylor, which is extensively used in the design of limit gauges, not only defines the function, but also defines the form of most limit gauges.

Taylor's principle states that the GO gauge is designed to check maximum metal conditions, that is, LLH and HLS. It should also simultaneously check as many related dimensions, such as roundness, size, and location, as possible.

The NOT GO gauge is designed to check minimum metal conditions, that is, HLH and LLS. It should check only one dimension at a time. Thus, a separate NOT GO gauge is required for each individual dimension.

During inspection, the GO side of the gauge should enter the hole or just pass over the shaft under the weight of the gauge without using undue force. The NOT GO side should not enter or pass.

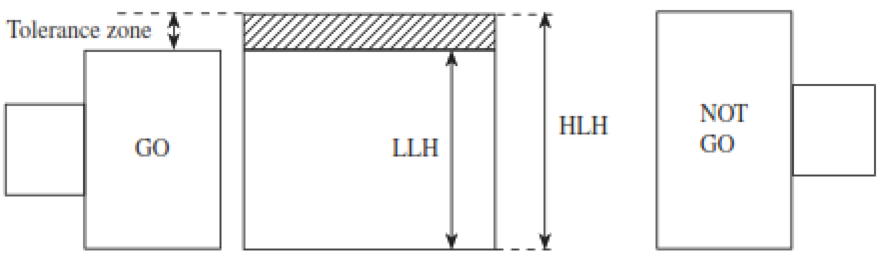

Fig. 2.65 GO and NOT GO limits of plug gauge

[source: "Engineering Metrology & Measurements", N.V. Raghavendra., page-66]

The basic or nominal size of the GO side of the gauge conforms to the LLH or HLS, since it is designed to check maximum metal conditions. In contrast, the basic or nominal size of the NOT GO gauge corresponds to HLH or LLS, as it is designed to check minimum metal conditions.

It can be seen that the size of the GO plug gauge corresponds to the LLH and the NOT GO plug gauge to the HLH. Conversely, it can be observed that the GO snap gauge represents the HLS, whereas the NOT GO snap gauge represents the LLS.

It is pertinent to discuss here that since the GO plug is used to check more than one dimension of the hole simultaneously, the GO plug gauge must have a full circular section and must be of full length of the hole so that straightness of the hole can also be checked.

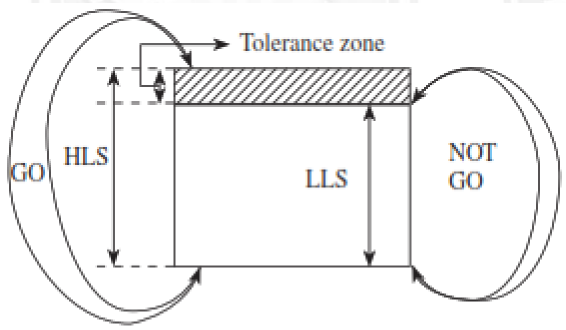

Fig. 2.66 GO and NOT GO limits of snap gauge

[source: “Engineering Metrology & Measurements”, N.V. Raghavendra., page-67]

During inspection, it can be ensured that if there is any lack of straightness or roundness of the hole a full entry of the GO plug gauge will not be allowed. Thus, it not only controls the diameter in any given cross-section but also ensures better bore alignment. However, it should be mentioned here that the GO plug gauge cannot check the degree of ovality.

The short GO plug gauge, if used in inspection, will pass through all the curves and is hence not possible to identify defective parts. Therefore, in order to get good results, this condition has to be fulfilled during the inspection of the parts. The length of the plug should normally be more than 1.5 times the diameter of the hole to be checked. Compared to GO plug gauges, the NOT GO plug gauges are relatively shorter.

2.6.7 Important Points for Gauge Design

The following points must be kept in mind while designing gauges:

1. The form of GO gauges should be a replica of the form of the opposed (mating) parts.

2. GO gauges enable several related dimensions to be checked simultaneously and hence are termed complex gauges.

3. During inspection, GO gauges must always be put into conditions of maximum impassability.

4. NOT GO gauges check a single element of feature at a time.

5. In inspection, NOT GO gauges must always be put into conditions of maximum possibility.