Necessity of Interchangeability in engineering field

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of mass production**
- **outline the meaning of the term,'interchangeability'**
- **state the necessity for the limit system**
- **name the different standards of system of limits and fits.**

Mass production

Mass production means production of a unit, component or part in large numbers.

Advantages of mass production

Time for the manufacture of components is reduced.

The cost of a piece is reduced.

Spare parts can be quickly made available.

Disadvantages of mass production

Special purpose machines are necessary.

Jigs and fixtures are needed.

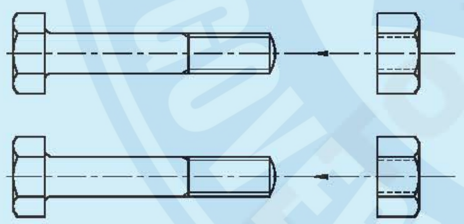
Gauges are to be used instead of conventional precision instruments.

Initial expenditure will be very high.

Selective assembly

The figures illustrate the difference between a selective assembly and a non-selective assembly. It will be seen in (Fig 1) that each nut fits only one bolt. Such an assembly is slow and costly, and maintenance is difficult because spares must be individually manufactured.

Fig 1

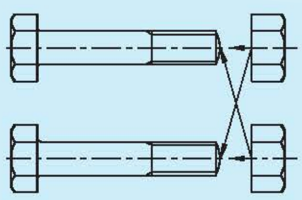


SELECTIVE ASSEMBLY

Non-selective assembly

Any nut fits any bolt of the same size and thread type. Such an assembly is rapid, and costs are reduced. Maintenance is simpler because spares are easily available. (Fig 2)

Fig 2



NON-SELECTIVE ASSEMBLY INTERCHANGEAB ILITY

Non-selective assembly provides interchangeability between the components.

In modern engineering production, i.e. mass production, there is no room for selective assembly. However, under some special circumstances, selective assembly is still justified.

Interchangeability: When components are mass-produced, unless they are interchangeable, the purpose of mass production is not fulfilled. By interchangeability, we mean that identical components, manufactured by different personnel under different environments, can be assembled and replaced without any further rectification during the assembly stage, without affecting the functioning of the component when assembled.

Necessity of the limit system: If components are to be interchangeable, they need to be manufactured to the same size which is not possible, when they are mass-produced. Hence, it becomes necessary to permit the operator to deviate by a small margin from the exact size which he is not able to maintain for all the components. At the same time, the deviated size should not affect the quality of the assembly. This sort of dimensioning is known as limit dimensioning.

A system of limits is to be followed as a standard for the limit dimensioning of components.

Various standard systems of limits and fits are followed by different countries based on the ISO (International Standards Organisation) specifications.

The system of limits and fits followed in our country is stipulated by the BIS. (Bureau of Indian Standards)

Other systems of limits and fits

International Standards Organisation (ISO)

British Standard System (BSS)

German Standard (DIN)

The indian standard system of limits & fits - terminology

Objectives: At the end of this lesson you shall be able to
- **state the terms under the BIS system of limits and fits**
- **define each term under the BIS system of limits and fits**.

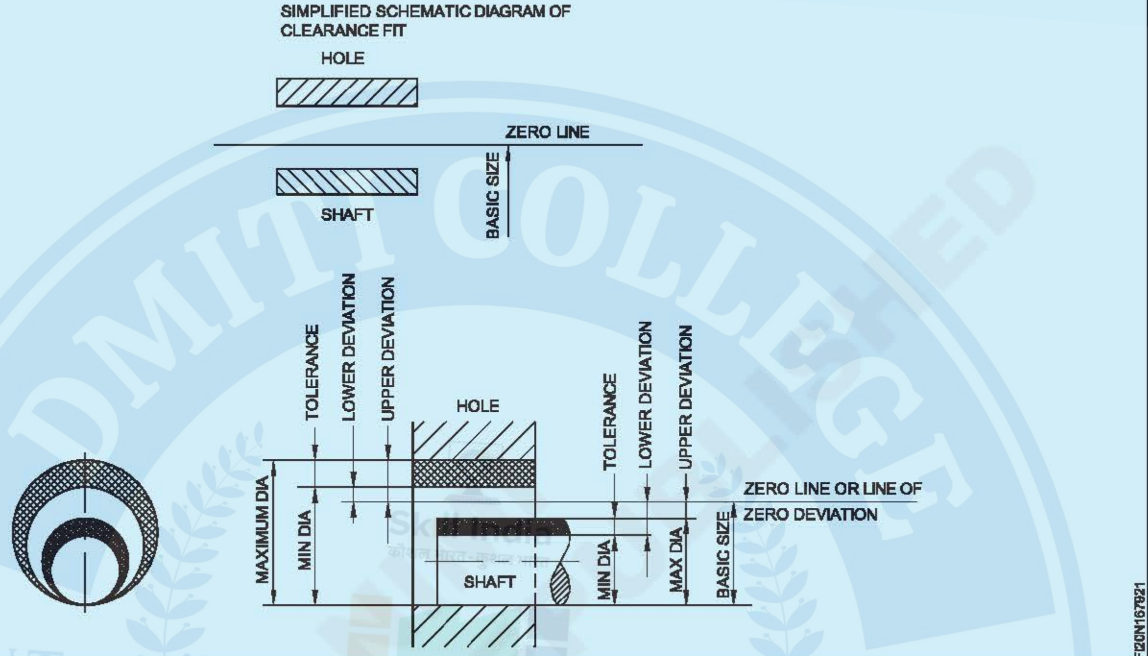
Size

It is a number expressed in a particular unit in the measurement of length.

Basic size

It is the size based on which the dimensional deviations are given. (Fig 1)

Fig 1



Actual size

It is the size of the component by actual measurement after it is manufactured. It should lie between the two limits of size if the component is to be accepted.

Limits of size

These are the extreme permissible sizes within which the operator is expected to make the component. (Fig 2) (Maximum and minimum limits)

Maximum limit of size

It is the greater of the two limit sizes.(Fig 2) (Table 1)

Minimum limit of size

It is the smaller of the two limits of size. (Fig 2) (Table 1)

Hole

In the BIS system of limits & fits, all internal features of a component including those which are not cylindrical are designated as ` hole'. (Fig 3)

Shaft

In the BIS system of limits & fits, all external features of a component including those which are not cylindrical are designated as shaft. (Fig 3)

Fig 2

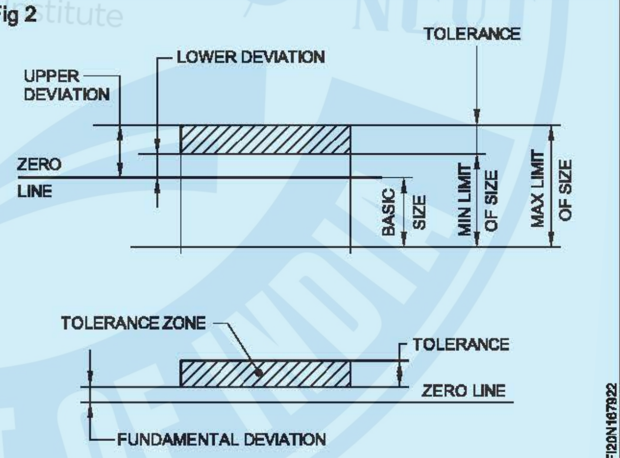


Fig 3

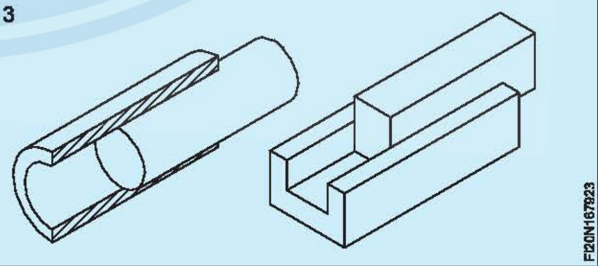


Table 1 (Examples)

SL. NO.	SIZE OF COMPONENT	UPPER DEVIATION	LOWER DEVIATION	MAX-LIMIT OF SIZE	MIN-LIMIT OF SIZE
1	+ .008 20 - .005	+ 0.008	- 0.005	20.008	19.995
2	+ .028 20 + .007	+ 0.028	+ 0.007	20.028	20.007
3	- .012 20 - .021	- 0.012	- 0.021	19.988	19.979

Deviation

It is the algebraic difference between a size, to its corresponding basic size. It may be positive, negative or zero. (Fig 2)

Upper deviation

It is the algebraic difference between the maximum limit of size and its corresponding basic size. (Fig 2) (Table 1)

Lower deviation

It is the algebraic difference between the minimum limit of size and its corresponding basic size.(Fig 2) (Table 1)

Upper deviation is the deviation which gives the maximum limit of size. Lower deviation is the deviation which gives the minimum limit of size.

Actual deviation

It is the algebraic difference between the actual size and its corresponding basic size. (Fig 2)

Tolerance

It is the difference between the maximum limit of size and the minimum limit of size. It is always positive and is expressed only as a number without a sign. (Fig 2)

Zero line

In graphical representation of the above terms, the zero line represents the basic size. This line is also called as the line of zero deviation. (Figs 1 and 2)

Fundamental deviation

There are 25 fundamental deviations in the BIS system represented by letter symbols (capital letters for holes and small letters for shafts), i.e for holes - ABCD....Z excluding I,L,O,Q & W. (Fig 4)

In addition to the above, four sets of letters JS, ZA, ZB & ZC are included. For fine mechanisms CD, EF and FG are added. (Ref. IS:919 Part II - 1979)

For shafts, the same 25 letter symbols but in small letters are used. (Fig 5)

The position of tolerance zone with respect to the zero line is shown in Figs 6 and 7.

The fundamental deviations are for achieving the different classes of fits. (Figs 8 and 9)

Fig 4

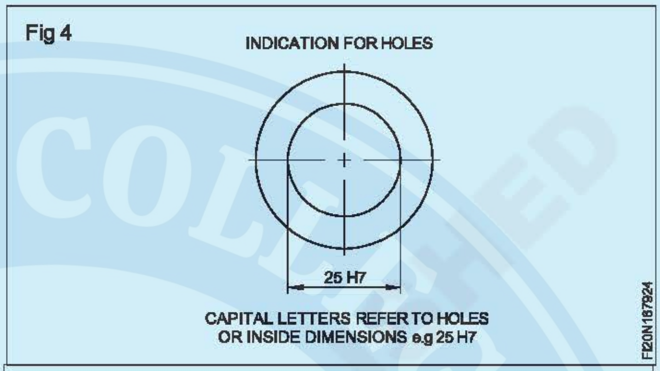


Fig 5

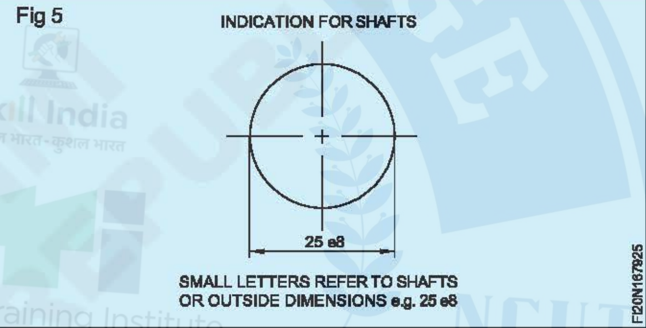


Fig 6

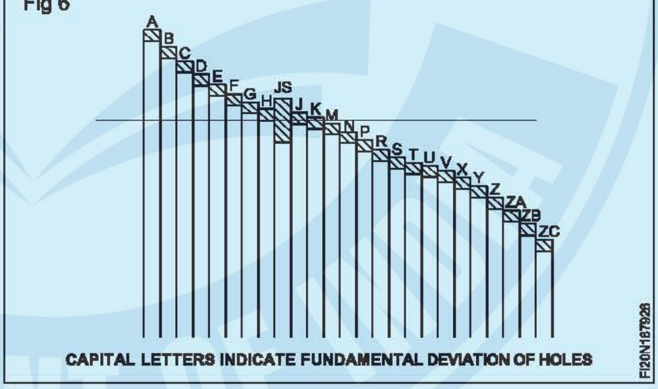
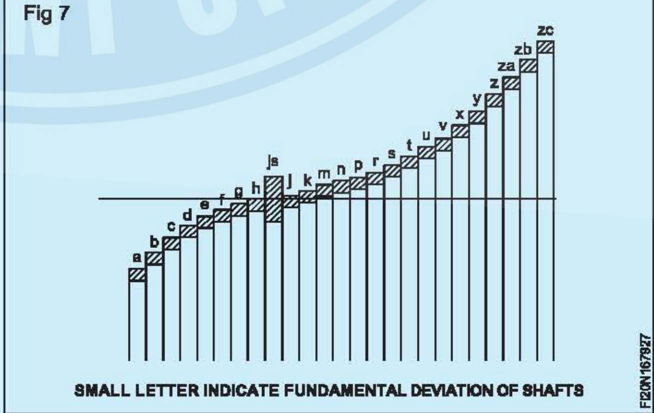
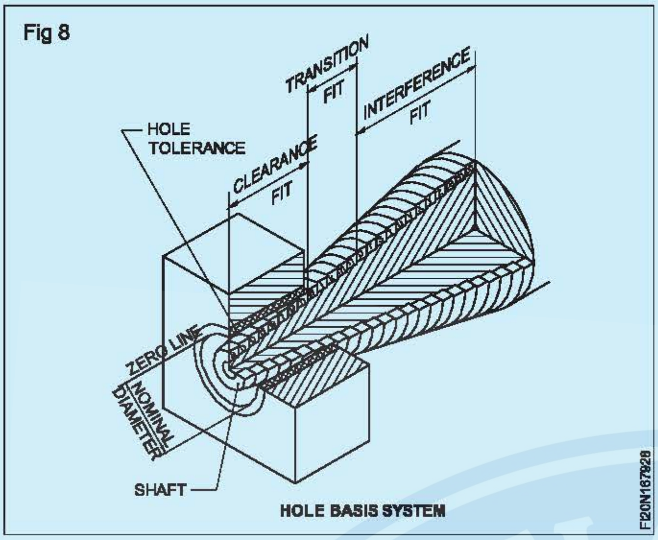
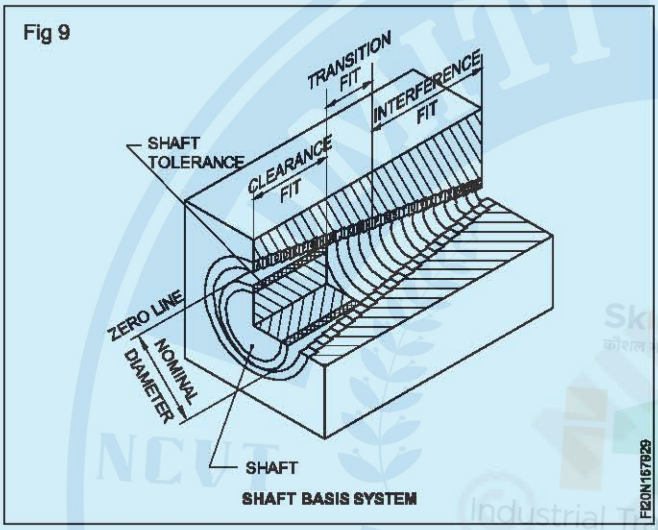


Fig 7

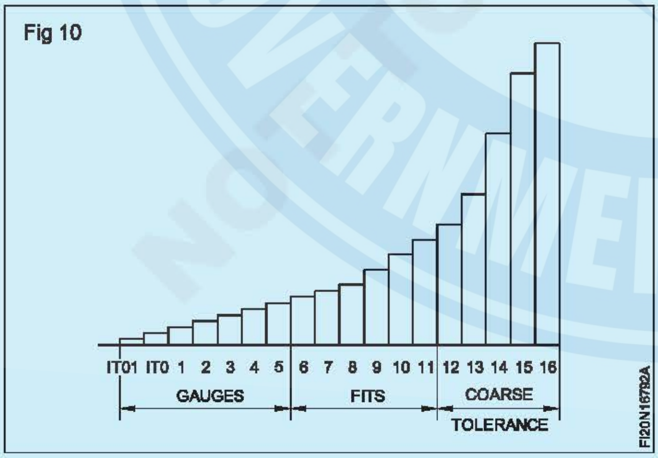






Fundamental tolerance

This is also called as 'grade of tolerance'. In the Indian Standard System, there are 18 grades of tolerances represented by number symbols, both for hole and shaft, denoted as IT01, IT0, IT1....to IT16. (Fig 10) A high number gives a large tolerance zone.



The grade of tolerance refers to the accuracy of manufacture.

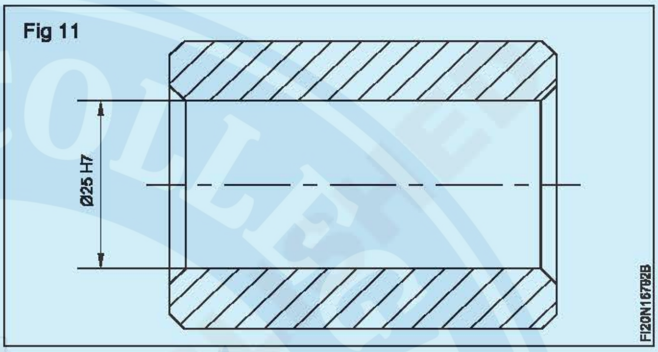
In a standard chart, the upper and lower deviations for each combination of fundamental deviation and fundamental tolerance are indicated for sizes ranging up to 500 mm. (Refer to IS 919)

Toleranced size

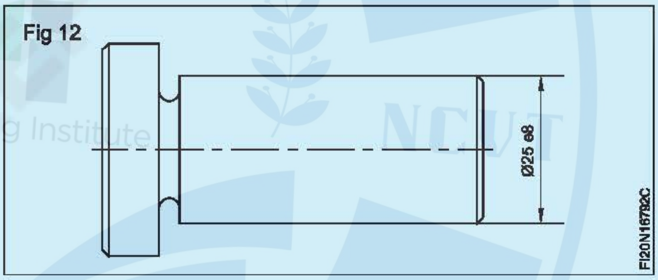
This includes the basic size, the fundamental deviation and the grade of tolerance.

Example

25 H7 - toleranc size of a hole whose basic size is 25. The fundamental deviation is represented by the letter symbol H and the grade of tolerance is represented by the number symbol 7. (Fig 11)



25 e8 - is the toleranced size of a shaft whose basic size is 25. The fundamental deviation is represented by the letter symbol e and the grade of tolerance is represented by the number 8. (Fig 12)



A very wide range of selection can be made by the combination of the 25 fundamental deviations and 18 grades of tolerances.

Example

In figure 13, a hole is shown as 25 ± 0.2 which means that 25 mm is the basic dimension and ± 0.2 is the deviation.

As pointed out earlier, the permissible variation from the basic dimension is called 'DEVIATION'.

The deviation is mostly given on the drawing with the dimensions.

In the example 25 ± 0.2, ± 0.2 is the deviation of the hole of 25 mm diameter. (Fig 13) This means that the hole is of acceptable size if its dimension is between

25 + 0.2 = 25.2 mm

or 25 - 0.2 = 24.8 mm.

25.2 mm is known as the maximum limit. (Fig 14)

24.8 mm is known as the minimum limit. (Fig 15)

Fig 13

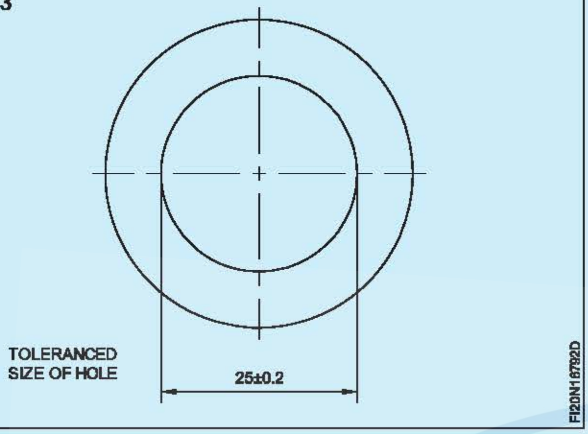
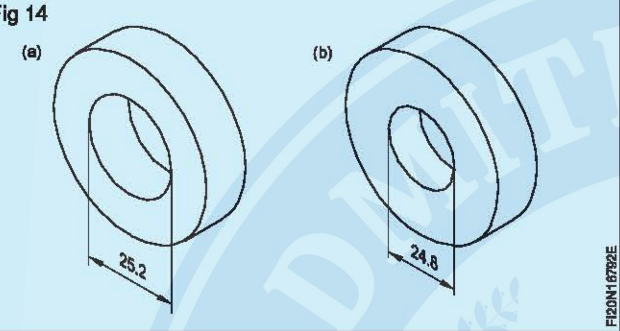
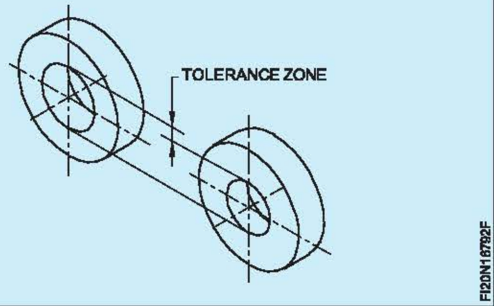


Fig 14



The difference between the maximum and minimum limits is the TOLERANCE. Tolerance here is 0.4 mm. (Fig 16)

Fig 15



All dimensions of the hole within the tolerance zone are of acceptable size as in Fig 17.

Fig 16

As per IS 696, while dimensioning the components as a drawing convention, the deviations are expressed as tolerances.

Fits and their classification as per the Indian Standard

Objectives: At the end of this lesson you shall be able to
- **define 'Fit' as per the Indian Standard**
- **list out the terms used in limits and fits as per the Indian Standard**
- **state examples for each class of fit**
- **interpret the graphical representation of different classes of fits.**

Fit

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

Expression of a fit

A fit is expressed by writing the basic size of the fit first, (the basic size which is common to both the hole and the shaft,) followed by the symbol for the hole, and by the symbol for the shaft.

Example

30 H7/g6 or 30 H7 - g6 or $30 \frac{H7}{g6}$

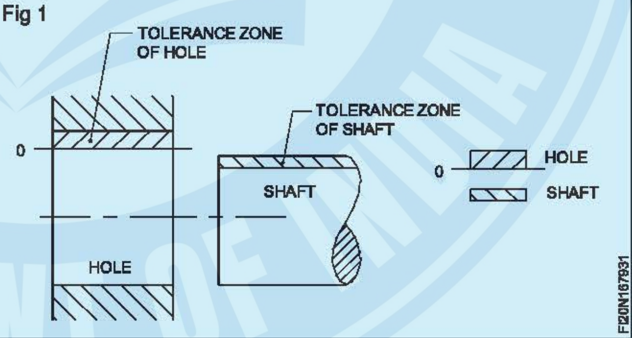
Clearance

In a fit the clearance is the difference between the size of the hole and the size of the shaft which is always positive.

Clearance fit

It is a fit which always provides clearance. Here the tolerance zone of the hole will be above the tolerance zone of the shaft. (Fig 1)

Fig 1



Example 20 H7/g6

With the fit given, we can find the deviations from the chart.

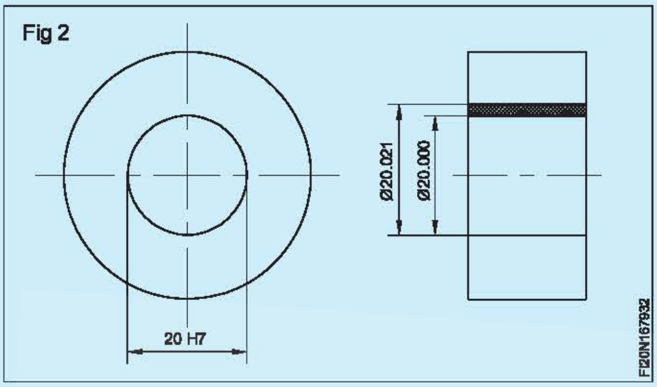
For a hole 20 H7 we find in the table + 21.

These numbers indicate the deviations in microns.

(1 micrometre = 0.001 mm)

The limits of the hole are 20 + 0.021 = 20.021 mm and 20 + 0 = 20.000mm. (Fig.2)

Fig 2



For a shaft 20 g6 we find in the table – 7

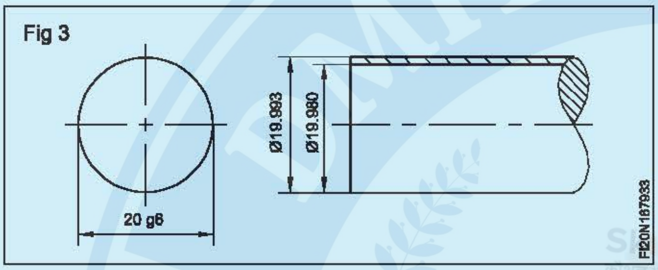
– 20.

So the limits of the shaft are

20 – 0.007 =19.993 mm

and 20 – 0.020 =19.980mm.(Fig .3)

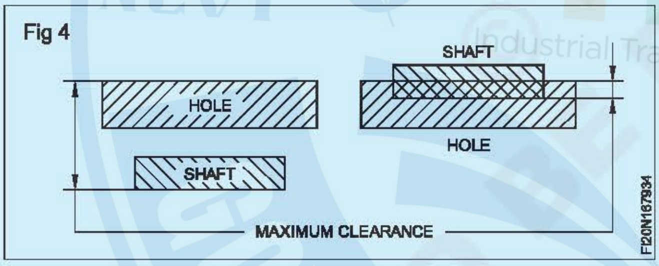
Fig 3



Maximum clearance

In a clearance fit or transition fit, it is the difference between the maximum hole and minimum shaft. (Fig 4)

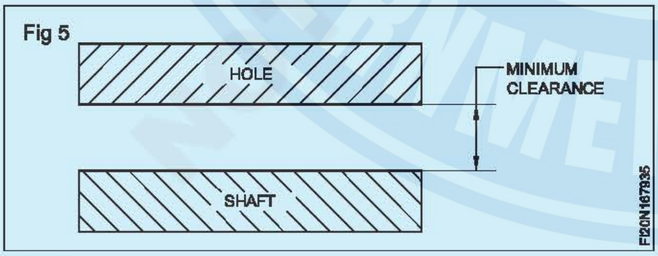
Fig 4



Minimum Clearance

In a clearance fit, it is the difference between the minimum hole and the maximum shaft. (Fig 5)

Fig 5



The minimum clearance is 20.000 - 19.993 = 0.007mm. (Fig 6)

The maximum clearance is 20.021 - 19.980 = 0.041 mm. (Fig 7)

There is always a clearance between the hole and the shaft. This is the clearance fit.

Fig 6

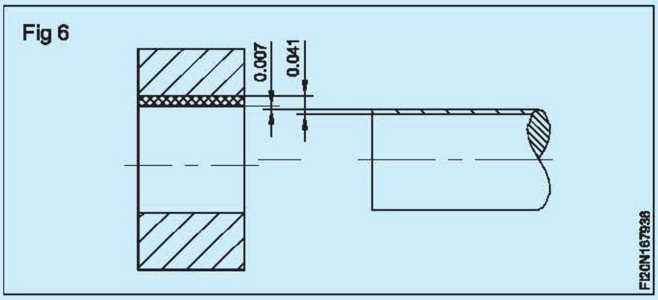
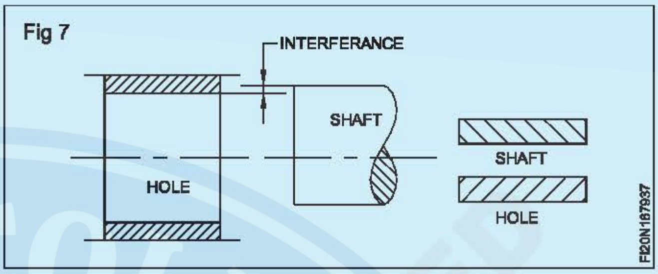


Fig 7



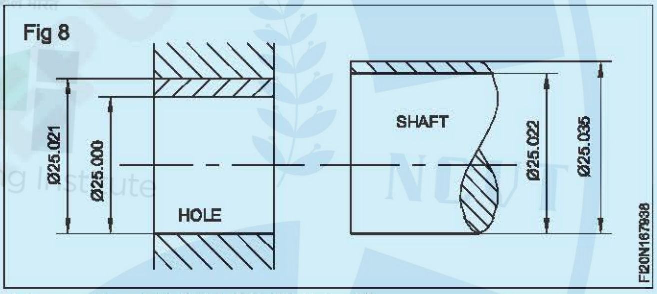
Interference

It is the difference between the size of the hole and the shaft before assembly, and this is negative. In this case, the shaft is always larger than the hole size.

Interference Fit

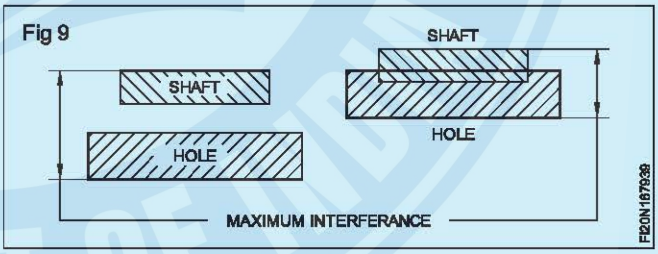
It is a fit which always provides interference. Here the tolerance zone of the hole will be below the tolerance zone of the shaft. (Fig 8)

Fig 8



Example: Fit 25 H7/p6 (Fig 9)

Fig 9



The limits of hole are 25.000 and 25.021 mm and the limits of the shaft 25.022 and 25.035 mm. The shaft is always bigger than the hole. This is an interference fit.

Maximum interference

In an interference fit or transition fit, it is the algebraic difference between the minimum hole and the maximum shaft. (Fig 10)

Minimum interference

In an interference fit, it is the algebraic difference between the maximum hole and the minimum shaft. (Fig 11)

Fig 10

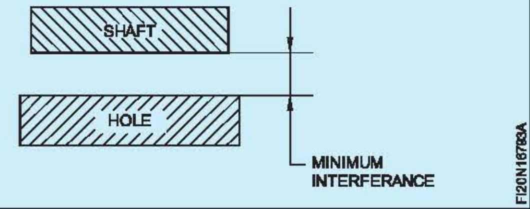
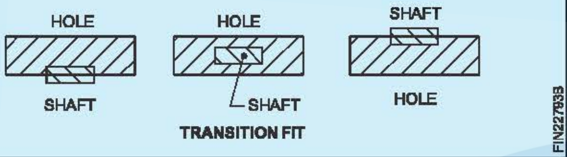


Fig 11



In the example shown in figure 9

The maximum interference is = 25.035 – 25.000

= **0.035**

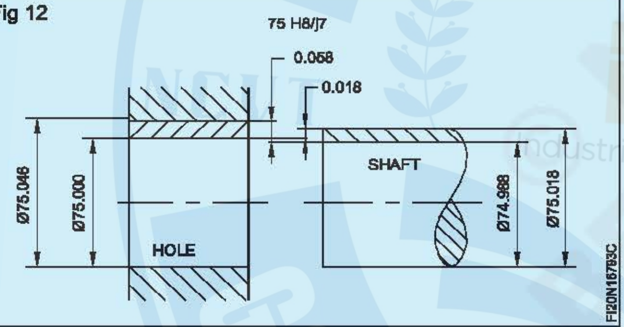
The minimum interference is = 25.022 – 25.021

= 0.001

Transition fit

It is a fit which may sometimes provide clearance, and sometimes interference. When this class of fit is represented graphically, the tolerance zones of the hole and shaft will overlap each other. (Fig 12)

Fig 12

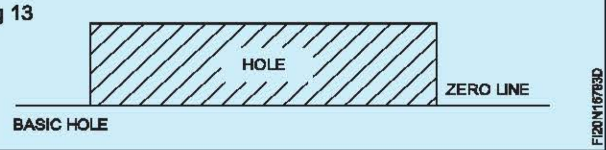


Example Fit 75 H8/j7 (Fig 13)

The limits of the hole are 75.000 and 75.046 mm and those of the shaft are 75.018 and 74.988 mm.

Maximum Clearance = 75.046 - 74.988 = 0.058 mm.

Fig 13



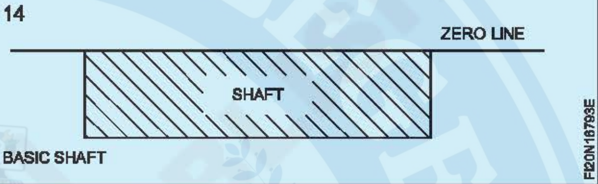
If the hole is 75.000 and the shaft 75.018 mm, the shaft is 0.018 mm, bigger than the hole. This results in interference. This is a transition fit because it can result in a clearance fit or an interference fit.

Hole basis system

In a standard system of limits and fits, where the size of the hole is kept constant and the size of the shaft is varied to get the different class of fits, then it is known as the hole basis system.

The fundamental deviation symbol `H' is chosen for the holes, when the hole basis system is followed. This is because the lower deviation of the hole `H' is zero. It is known as `basic hole'. (Fig 14)

Fig 14



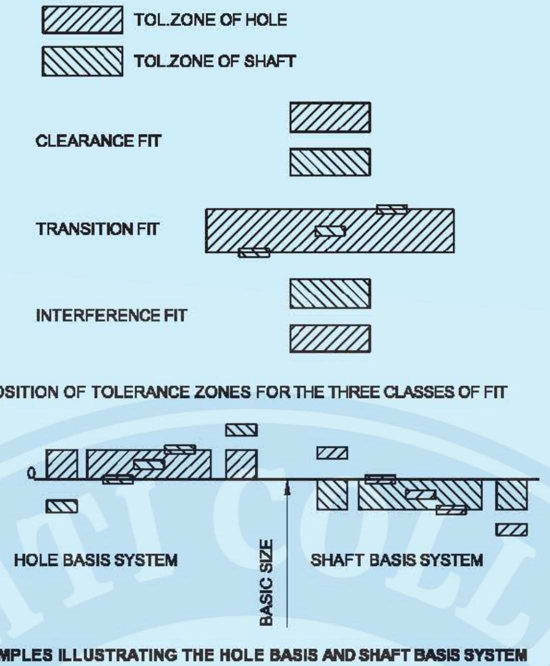
Shaft basis system

In a standard system of limits and fits, where the size of the shaft is kept constant and the variations are given to the hole for obtaining different class of fits, then it is known as shaft basis. The fundamental deviation symbol `h' is chosen for the shaft when the shaft basis is followed. This is because the upper deviation of the shaft `h' is zero. It is known as `basic shaft'. (Fig 15)

The hole basis system is followed mostly. This is because, depending upon the class of fit, it will be always easier to alter the size of the shaft because it is external, but it is difficult to do minor alterations to a hole. Moreover the hole can be produced by using standard tooling's.

The three classes of fits, both under hole basis and shaft basis, are illustrated in (Fig 15).

Fig 15



The BIS system of limits and fits- reading the standard chart

Objective: At the end of this lesson you shall be able to
- **refer to the standard limit system chart and determine the limits of sizes.**

The standard chart covers sizes upto 500 mm (I.S. 919 of 1963) for both holes and shafts. It specifies the upper and lower deviations for a certain range of sizes for all combinations of the 25 fundamental deviations, and 18 fundamental tolerances.

The upper deviation of the hole is denoted as ES and the lower deviation of the hole is denoted as E I. The upper deviation of the shaft is denoted as **es** and the lower deviation of the shaft is denoted as **ei.**

> **"ES is expanded as ECART SUPERIEUR and "EI" as ECART INFERIEUR.**

Determining the limits from the chart

Note whether it is an internal measurement or an external measurement.

Note the basic size.

Note the combination of the fundamental deviation and the grade of tolerance.

Then refer to the chart and note the upper and lower deviations which are given in microns, with the sign. Accordingly add or subtract from the basic size and determine the limits of size of the components.

Example

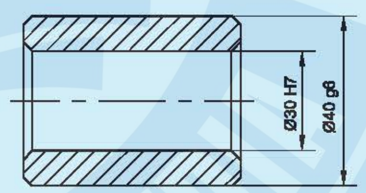
30 H7 (Fig 1)

It is an internal measurement. So we must refer to the chart for 'holes'.

The basic size is 30 mm. So see the range 30 to 40.

Look for ES, and EI values in microns for H7 combination

Fig 1



for 30 mm basic size.

It is given as

Therefore, the maximum limit of the hole is 30 + 0.025 = 30.025mm.

The minimum limit of the hole is 30 + 0.000 = 30.000mm.

Refer to the chart and note the values of 40 g6.

The table for tolerance zones and limits as per IS 2709 is attached.

British standard limits and fits BS 4500: 1969

International Tolerance Grades (IT)

The specific tolerance for a particular IT grade is calculated via the following formula:

$$T = 10^{0.2 \times (ITG - 1)} . (0.45 \times \sqrt[3]{D} + 0.001 \times D)$$

T is the tolerance in micrometres [μ m]

D is the geometric mean dimension in millimeters [mm]

ITG is the IT Grade, a positive integer.

NOMINAL (BASIC) SIZES (INCHES)		INTERNATIONAL TOLERANCE GRADES OVER UP TO INCL.									
OVER	UP TO INCL	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13
0	0.12	0.12	0.15	0.25	0.4	0.6	1.0	1.6	2.5	4	6
0.12	0.24	0.15	0.20	0.3	0.5	0.7	1.2	1.8	3.0	5	7
0.24	0.40	0.15	0.25	0.4	0.6	0.9	1.4	2.2	3.5	6	9
0.40	0.71	0.2	0.3	0.4	0.7	1.0	1.6	2.8	4.0	7	10
0.71	1.19	0.25	0.4	0.5	0.8	1.2	2.0	3.5	5.0	8	12
1.19	1.97	0.3	0.4	0.6	1.0	1.6	2.5	4.0	6	10	16
1.97	3.15	0.3	0.5	0.7	1.2	1.8	3.0	4.5	7	12	18
3.15	4.73	0.4	0.6	0.9	1.4	2.2	3.5	5	9	14	22
4.73	7.09	0.5	0.7	1.0	1.6	2.5	4.0	6	10	16	25
7.09	9.85	0.6	0.8	1.2	1.8	2.8	4.5	7	12	18	28
9.85	12.41	0.6	0.9	1.2	2.0	3.0	5.0	8	12	20	30
12.41	15.75	0.7	1.0	1.4	2.2	3.5	6	9	14	22	35
15.75	19.69	0.8	1.0	1.63	2.5	4	6	10	16	25	40
19.69	30.09	0.9	1.2	2.0	3	5	8	12	20	30	50
30.09	41.49	1.0	1.6	2.5	4	6	10	16	25	40	60
41.49	56.19	1.2	2.0	3	5	8	12	20	30	50	80
56.19	76.39	1.6	2.5	4	6	10	16	25	40	60	100
76.39	100.9	2.0	3	5	8	12	20	30	50	80	125
100.9	131.9	2.5	4	6	10	16	25	40	60	100	160
131.9	171.9	3	5	8	12	20	30	50	80	125	200
171.9	200	4	6	10	16	25	40	60	100	160	250

Tolerances in Thousandths of an Inch (0.001)

Table 1 for Tolerance Zones & Limits (Dimensions in μm)

NOMINAL SIZE RANGE mm	s6	r6	p6	n6	k6	js6	h6	h7	h9	h11	g6	f7	e8	d9	c11	b11	a11	S7
From 1 up to 3	+20 +14	+16 +10	+12 +6	+10 +4	+6 0	+3 -3	0 -6	0 -10	0 -25	0 -60	-2 -8	-6 -16	-14 -28	-20 -45	-60 -120	-140 -200	-270 -330	-14 -24
Over 3 up to 6	+27 +19	+23 +15	+20 +12	+16 +8	+9 +1	+4 -4	0 -8	0 -12	0 -30	0 -75	-4 -12	-10 -22	-20 -38	-30 -60	-70 -145	-140 -215	-270 -345	-15 -27
Over 6 up to 10	+32 +23	+28 +19	+24 +15	+19 +10	+10 +1	+4.5 -4.5	0 -9	0 -15	0 -36	0 -90	-5 -14	-13 -28	-25 -47	-40 -76	-80 -170	-150 -240	-280 -370	-17 -32
Over 10 up to 14	+39	+34	+29	+23	+12	+5.5	0	0	0	0	-6	-16	-32	-50	-95	-150	-290	-21
Over 14 up to 18	+28	+23	+18	+12	+1	-5.5	-11	-18	-43	-110	-17	-34	-59	-93	-205	-260	-400	-39
Over 18 up to 24	+48	+41	+35	+28	+15	+6.5	0	0	0	0	-7	-20	-40	-65	-110	-160	-300	-27
Over 24 up to 30	+35	+28	+22	+15	+2	-6.5	-13	-21	-52	-130	-20	-41	-73	-117	-240	-290	-430	-48
Over 30 up to 40	+59	+50	+42	+33	+18	+8	0	0	0	0	-9	-25	-50	-80	-120 -280	-170 -330	-310 -470	-34
Over 40 up to 50	+43	+34	+26	+17	+2	-8	-16	-25	-62	-160	-25	-50	-89	-142	-130 -290	-180 -340	-320 -480	-59
Over 50 up to 65	+72 +53	+60 +41	+51	+39	+21	+9.5	0	0	0	0	-10	-30	-60	-100	-140 -330	-190 -380	-340 -530	-42 -72
Over 65 up to 80	+78 +59	+62 +43	+32	+20	+2	-9.5	-19	-30	-74	-190	-29	-60	-106	-174	-150 -340	-200 -390	-360 -550	-48 -78
Over 80 up to 100	+93 +71	+73 +51	+59	+45	+25	+11	0	0	0	0	-12	-36	-72	-120	-170 -390	-220 -440	-380 -600	-58 -93
Over 100 up to 120	+101 +79	+76 +54	+37	+23	+3	-11	-22	-35	-87	-220	-34	-71	-126	-207	-180 -400	-240 -460	-410 -630	-66 -101
Over 120 up to 140	+117 +92	+88 +63													-200 -450	-260 -510	-460 -710	-77 -117
Over 140 up to 160	+125 +100	+90 +65	+68 +43	+52 +27	+28 +3	+12.5 -12.5	0 -25	0 -40	0 -100	0 -250	-14 -39	-43 -83	-85 -148	-145 -245	-210 -460	-280 -530	-520 -770	-85 -125
Over 160 up to 180	+133 +108	+93 +68													-230 -480	-310 -560	-580 -830	-93 -133
Over 180 up to 200	+151 +122	+106 +77													-240 -530	-340 -630	-660 -950	-105 -151
Over 200 up to 225	+159 +130	+109 +80	+79 +50	+60 +31	+33 +4	+14.5 -14.5	0 -29	0 -46	0 -115	0 -290	-15 -44	-50 -96	-100 -172	-170 -285	-260 -550	-380 -670	-740 -1030	-113 -159
Over 225 up to 250	+169 +140	+113 +84													-280 -570	-420 -710	-820 -1110	-123 -169
Over 250 up to 280	+190 +158	+126 +94	+88	+66	+36	+16	0	0	0	0	-17	-56	-110	-190	-300 -620	-480 -800	-920 -1240	-138 -190
Over 280 up to 315	+202 +170	+130 +98	+56	+34	+4	-16	-32	-52	-130	-320	-49	-108	-191	-320	-330 -650	-540 -860	-1050 -1370	-150 -202
Over 315 up to 355	+226 +190	+144 +108	+98	+73	+40	+18	0	0	0	0	-18	-62	-125	-210	-360 -720	-600 -960	-1200 -1560	-169 -226
Over 355 up to 400	+244 +208	+150 +114	+62	+37	+4	-18	-36	-57	-140	-360	-54	-119	-214	-350	-400 -760	-680 -1040	-1350 -1710	-187 -244
Over 400 up to 450	+272 +232	+166 +126	+108	+80	+45	+20	0	0	0	0	-20	-68	-135	-230	-440 -840	-760 -1160	-1500 -1900	-209 -272
Over 450 up to 500	+292 +252	+172 +132	+68	+40	+5	-20	-40	-63	-155	-400	-60	-131	-232	-385	-480 -880	-840 -1240	-1650 -2050	-229 -292

NOMINAL SIZE RANGE mm	R7	P7	N7	K7	JS7	H7	H8	H9	H11	G7	F8	E9	D10	C11	B11	A11
From 1 up to 3	-10 -20	-6 -16	-4 -14	0 -10	+5 -5	+10 0	+14 0	+25 0	+60 0	+12 +2	+20 +6	+39 +14	+60 +20	+120 +60	+200 +140	+330 +270
Over 3 up to 6	-11 -23	-8 -20	-4 -16	+3 -9	+6 -6	+12 0	+18 0	+30 0	+75 0	+16 +4	+28 +10	+50 +20	+78 +30	+145 +70	+215 +140	+345 +270
Over 6 up to 10	-13 -28	-9 -24	-4 -19	+5 -10	+7.5 -7.5	+15 0	+22 0	+36 0	+90 0	+20 +5	+35 +13	+61 +25	+98 +40	+170 +80	+240 +150	+370 +280
Over 10 up to 14	-16	-11	-5	+6	+9	+18	+27	+43	+110	+24	+43	+75	+120	+205	+260	+400
Over 14 up to 18	-34	-29	-23	-12	-9	0	0	0	0	+6	+16	+32	+50	+95	+150	+290
Over 18 up to 24	-20	-14	-7	+6	+10.5	+21	+33	+52	+130	+28	+53	+92	+149	+240	+290	+430
Over 24 up to 30	-41	-35	-28	-15	-10.5	0	0	0	0	+7	+20	+40	+65	+110	+160	+300
Over 30 up to 40	-25	-17	-8	+7	+12.5	+25	+39	+62	+160	+34	+64	+112	+180	+280 +120	+330 +170	+470 +310
Over 40 up to 50	-50	-42	-33	-18	-12.5	0	0	0	0	+9	+25	+50	+80	+290 +130	+340 +180	+480 +320
Over 50 up to 65	-30 -60	-21	-9	+9	+15	+30	+46	+74	+190	+40	+76	+134	+220	+330 +140	+380 +190	+530 +340
Over 65 up to 80	-32 -62	-51	-39	-21	-15	0	0	0	0	+10	+30	+60	+100	+340 +150	+390 +200	+550 +360
Over 80 up to 100	-38 -73	-24	-10	+10	+17.5	+35	+54	+87	+220	+47	+90	+159	+260	+390 +170	+440 +220	+600 +380
Over 100 up to 120	-41 -76	-59	-45	-25	-17.5	0	0	0	0	+12	+36	+72	+120	+400 +180	+460 +240	+630 +410
Over 120 up to 140	-48 -88													+450 +200	+510 +260	+710 +460
Over 140 up to 160	-50 -90	-28 -68	-12 -52	+12 -28	+20 -20	+40 0	+63 0	+100 0	+250 0	+54 +14	+106 +43	+185 +85	+305 +145	+460 +210	+530 +280	+770 +520
Over 160 up to 180	-53 -93													+480 +230	+560 +310	+830 +580
Over 180 up to 200	-60 -106													+530 +240	+630 +340	+950 +660
Over 200 up to 225	-63 -109	-33 -79	-14 -60	+13 -33	+23 -23	+46 0	+72 0	+115 0	+290 0	+61 +15	+122 +50	+215 +100	+355 +170	+550 +260	+670 +380	+1030 +740
Over 225 up to 250	-67 -113													+570 +280	+710 +420	+1110 +820
Over 250 up to 280	-74 -126	-36	-14	+16	+26	+52	+81	+130	+320	+69	+137	+240	+400	+620 +300	+800 +480	+1240 +920
Over 280 up to 315	-78 -130	-88	-66	-36	-26	0	0	0	0	+17	+56	+110	+190	+650 +330	+860 +540	+1370 +1050
Over 315 up to 355	-87 -144	-41	-16	+17	+28.5	+57	+89	+140	+360	+75	+151	+265	+440	+720 +360	+960 +600	+1500 +1200
Over 355 up to 400	-93 -150	-98	-73	-40	-28.5	0	0	0	0	+18	+62	+125	+210	+760 +400	+1040 +680	+1710 +1350
Over 400 up to 450	-103 -166	-45	-17	+18	+31.5	+63	+97	+155	+400	+83	+165	+290	+480	+840 +440	+1160 +760	+1900 +1500
Over 450 up to 500	-109 -172	-108	-80	-45	-31.5	0	0	0	0	+20	+68	+135	+230	+880 +480	+1240 +840	+2050 +1650

Metals

Objectives: At the end of this lesson you shall be able to
- **name the commonly used ferrous metals and raw material used for producing pig iron**
- **describe the properties of pig iron and its deriving process**
- **explain the types and properties of cast iron, wrought iron and uses**
- **explain the alloys of copper, aluminium, tin lead, zinc**
- **state this properties and uses.**

Metals which contain iron as a major content are called ferrous metals. Ferrous metals of different properties are used for various purposes.

The ferrous metals and alloys used commonly are:

- Pig-iron
- Cast iron
- Wrought iron
- Steels and alloy steels.

Different processes are used to produce iron and steel.

Pig-iron is obtained by the chemical reduction of iron ore. This process of reduction of the iron ore to pig-iron is known as SMELTING.

The main raw materials required for producing pig-iron are:

- Iron ore
- Coke
- Flux.

Iron ore

The types of iron ores

- Magnetite
- Hematite
- Limonite
- Carbonate.

These ores contain iron in different proportions and are 'naturally' available.

Coke

Coke is the fuel used to give the necessary heat to carry on the reducing action. The carbon from the coke in the form of carbon monoxide combines with the iron ore to reduce it to iron.

Flux

This is the mineral substance charged into a blast furnace to lower the melting point of the ore, and it combines with the non-metallic portion of the ore to form a molten slag.

Limestone is the most commonly used flux in the blast furnace.

Blast furnace (Fig 1)

The furnace used for smelting iron ore is the blast furnace. The product obtained from smelting in the blast furnace is pig-iron. The main parts of the blast furnace are:

- Throat
- Stack
- Bosh
- Hearth
- Double bell charging mechanism
- Tuyeres.

Smelting in a blast furnace

The raw materials are charged in alternate layers of iron ore, coke and flux in the furnace by means of a double bell mechanism. (Figs 1 & 2)

Fig 1

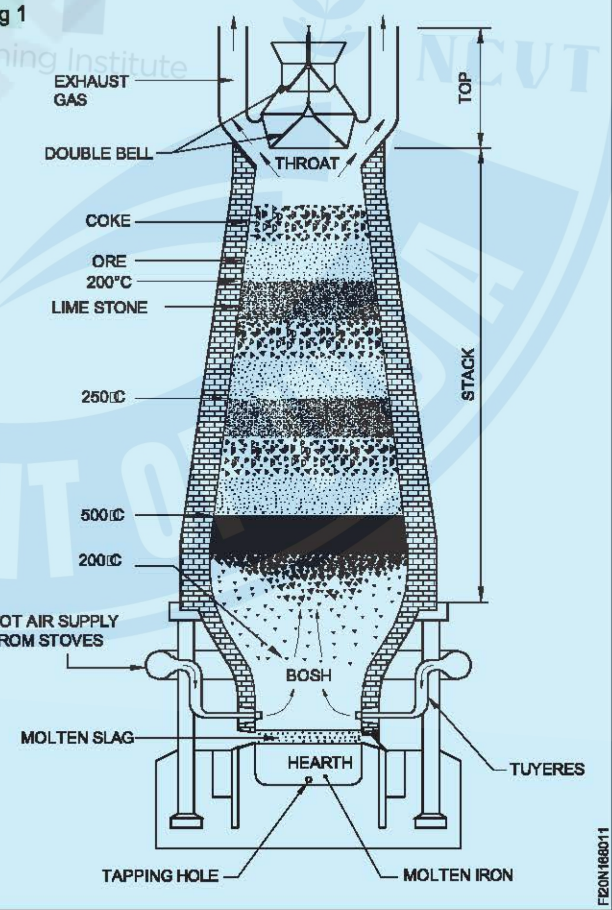
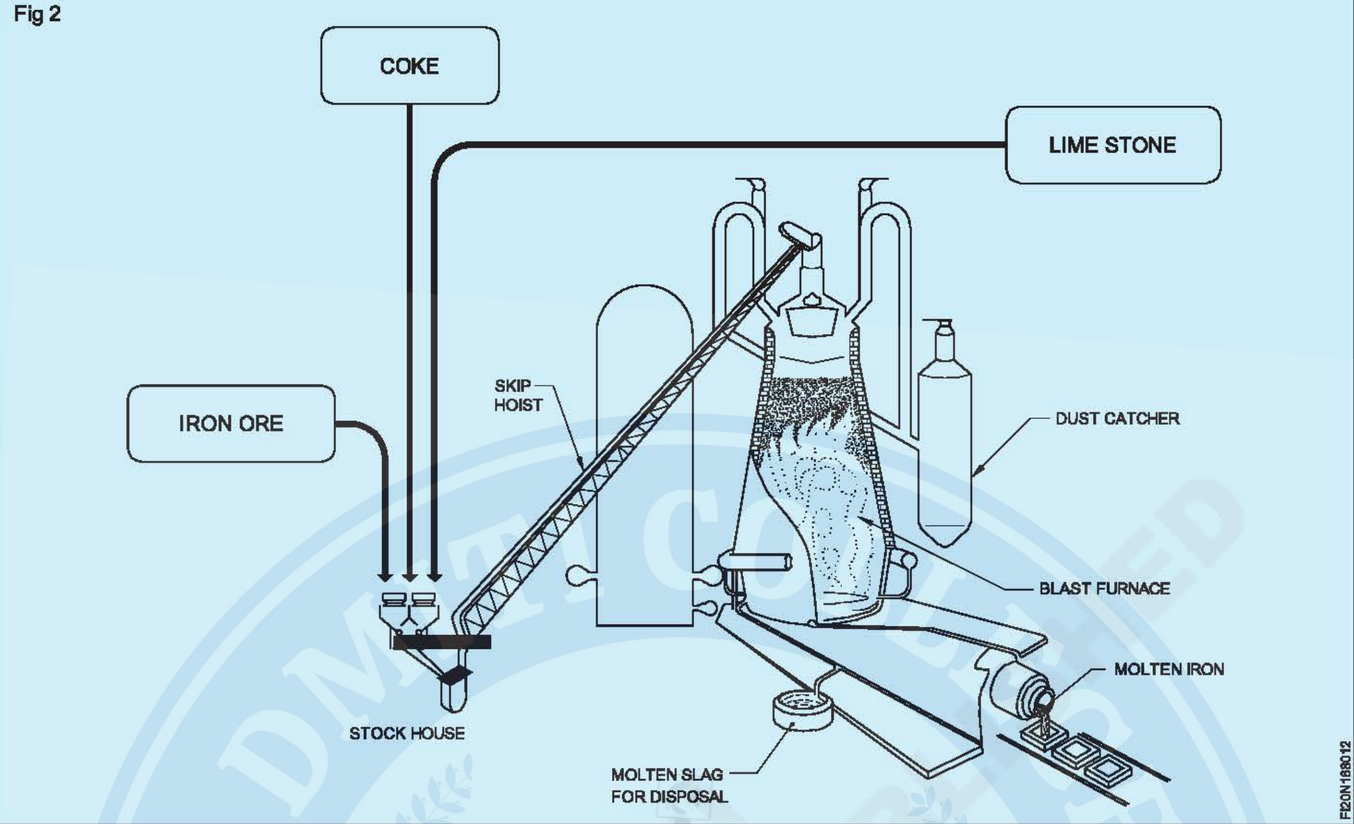


Fig 2



The hot blast is forced into the furnace through a number of nozzles (Fig1) called tuyeres.

The temperature of the furnace just above the level of the tuyeres (meltingzone) is between 1000° C to 1700° C when all the substances start melting.

The limestone, which serves as a flux, combines with the non-metalic substances in the ore to form a molten slag which floats on the top of the molten iron. The slag is tapped off through the slag hole.

The molten iron is tapped at intervals through a separate tapping hole.

The molten iron may be cast in pig beds or used in other processing plants for steel making.

Properties and use of pig-iron: Pig-iron absorbs varying amounts of carbon, silicon, sulphur, phosphorus and manganese during the smelting process. A high amount of carbon makes the pig-iron very hard and brittle, and unsuitable for making any useful article.

Pig-iron is, therefore, refined and remeitted and used to produce other varieties of iron and steel.

Cast iron (types): Cast iron is an alloy of iron, carbon and silicon. The carbon content ranges from 2 to 4%.

Types of cast iron

The following are the types of cast iron.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Nodular cast iron

Grey cast iron

This is widely used for the casting of machinery parts and can be machined easily.

Machine bases, tables, slide ways are made of cast iron because it is dimensionally stable after a period of aging.

Because of its graphite content, cast iron provides an excellent bearing and sliding surface.

The melting point is lower than that of steel and as grey cast iron possesses good fluidity, intricate casting can be made.

Grey cast iron is widely used for machine tools because of its ability to reduce vibration and minimize tool chatter.

Grey cast iron, when not alloyed, is quite brittle and has relatively low tensile strength. Due to this reason it is not used for making components subjected to high stress or impact loads.

Grey cast iron is often alloyed with nickel, chromium, vanadium or copper to make it tough.

Grey cast iron is weldable but the base metal needs pre-heating.

White cast iron: This is very hard and is very difficult to machine, and for this reason, it is used in components which should be abrasion-resistant.

White cast iron is produced by lowering the silicon content and by rapid cooling. When cooled in this manner, it is called chilled cast iron.

White cast iron cannot be welded.

Malleable cast iron: Malleable cast iron has increased ductility, tensile strength and toughness when compared with grey cast iron.

Malleable cast iron is produced from white cast iron by a prolonged heat-treatment process lasting for about 30 hours.

Nodular cast iron: This is very similar to malleable cast iron. But this is produced without any heat treatment. Nodular cast iron is also known as:

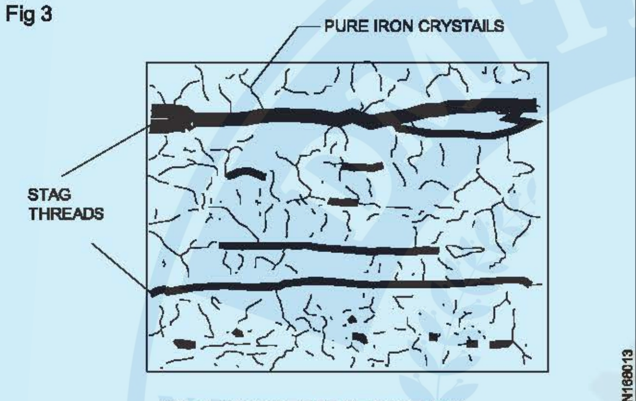
Nodular iron - ductile iron - spheroidal graphite iron

This has good machinability, castability, resistance to wear, low melting point and hardness.

Malleable and nodular castings are used for machine parts where there is a higher tensile stress and moderate impact loading. These castings are less expensive and are an alternative to steel casting.

Wrought iron and plain carbon steels: Wrought iron is the purest form of iron. The analysis of wrought iron shows as much as 99.9% of iron. (Fig 3)

Fig 3



MICROSTRUCTURE OF WROUGHT IRON

When heated, wrought iron does not melt, but only becomes pasty and in this form it can be forged to any shape.

Modern methods used to produce wrought iron in large quantities are the:

- Puddling process
- Aston or Byers process.

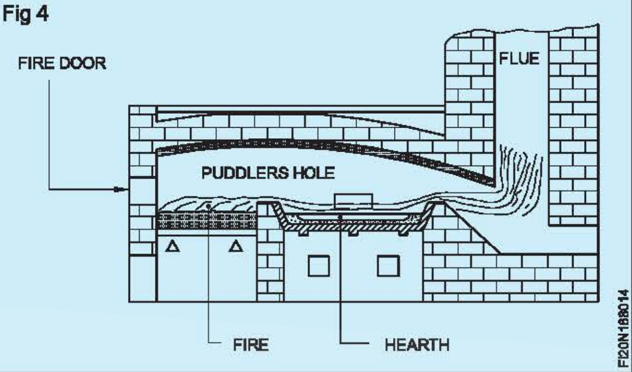
Puddling process

Wrought iron is manufactured by refining pig-iron.

By refining pig-iron silicon is removed completely, a greater amount of phosphorus is removed, and graphite is converted to combined carbon.

The above process is carried out in a puddling furnace.

Fig 4



Puddling furnace

This furnace is a coal-fired reverberator furnace. (Fig 4)

The term reverberator is applied because the charge is not in actual contact with the fire, but receives its heat by reflection from the dome shaped furnace roof.

The product obtained is taken out from the furnace in the form of balls (or blooms) having a mass of about 50 kgs.

The hot metal is then passed through grooved rollers which convert blooms into bars called Muck bars or Puddle bars.

These bars are cut into short lengths, fastened together in piles, reheated to welding temperatures and again rolled into bars.

Aston process: In this process molten pig-iron and steel scrap are refined in a Bessemer converter.

The refined molten metal is poured into an open hearth furnace in the iron silicate stage. This removes most of the carbon.

The slag cools the molten metal to a pasty mass which is later squeezed in a hydraulic press to remove most of the slag. Rectangular blocks known as blooms are formed from this mass.

The hot bloom is immediately passed through rolling mills to produce products of wrought iron of different shapes and sizes.

COMPOSITION OF WROUGHT IRON

Carbon	-	0.02 to 0.03%
Silicon	-	0.1 to 0.2%
Manganese	-	0.02 to 0.1%
Sulphur	-	0.02 to 0.04%
Phosphorous	-	0.05 to 0.2%
Iron forms of the rest of the content.		

Properties and uses of Wrought Iron

Properties	Uses
Malleable and ductile. It can neither be hardened nor tempered.	Architectural works.
Tough, shock-resistant fibrous structure; easy for forge welding. Ultimate tensile strength of about 350 newtons per sq. mm.	Crane hooks, chain links, bolts and nuts & railway couplings.
No effect in salt water.	Marine works.
Will not retain the magnetism.	Temporary magnets. Core of dynamos.
Corrosion resistant.	Agricultural equipment.
Easy to forge - wide temperature range 850°C to 1350°C.	Pipes, flanges etc.

Steel (plain carbon steel)

Steel is fundamentally an alloy of iron and carbon, with the carbon content varying up to 1.5%. The carbon present is in a combined state.

Plain carbon steels are classified according to their carbon content.

Classification and content of Plain Carbon Steel is given in Table 1.

Table 1

Classification and content of Plain Carbon Steel

Name of the plain carbon steel	Percentage of Carbon	Properties and uses
Dead mild	0.1 to 0.125 %	Highly ductile. Used for making wire steel rods, thin sheets & solid drawn tubes.
Mild steel	0.15 to 0.3%	Relatively soft and ductile. Used for general workshop purposes, boiler plates, bridge work, structural sections and drop forgings.
Medium carbon	0.3 to 0.5%	Used for making axles, drop forgings, high tensile tubes, wires and agricultural tools.
- do -	0.5 to 0.7%	Harder, tougher and less ductile. Used for making springs, locomotive tyres, large forging dies, wire ropes, hammers and snaps for riveters.
High carbon steel	0.7 to 0.9%	Harder, less ductile and slightly less tough. Used for making springs, small forging dies, shear blades and wood chisels.
- do -	0.9 to 1.1%	Used for making cold chisels, press dies, punches, wood-working tools, axes,etc.
- do -	1.1% to 1.4%	Used for making hand files, drills, gauges, metal-cutting tools & razors.

Non-ferrous metals - copper: Metals without iron are called non-ferrous metals. Eg. Copper, Aluminium, Zinc, Lead and Tin.

Copper: This is extracted from its ores 'MALACHITE' which contains about 55% copper and 'PYRITES' which contains about 32% copper.

Properties: Reddish in colour. Copper is easily distinguishable because of its colour.

The structure when fractured is granular, but when forged or rolled it is fibrous.

It is very malleable and ductile and can be made into sheets or wires.

It is a conductor of electricity. Copper is extensively used as electrical cables and parts of electrical apparatus which conduct electric current. (Fig 5)

Copper is a good conductor of heat and also highly resistant to corrosion. For this reason it is used for boiler fire boxes, water heating apparatus, water pipes and vessels in brewery and chemical plants. Also used for making soldering iron.

The melting temperature of copper is 1083° C.

The tensile strength of copper can be increased by hammering or rolling. (Fig 6)

Fig 5

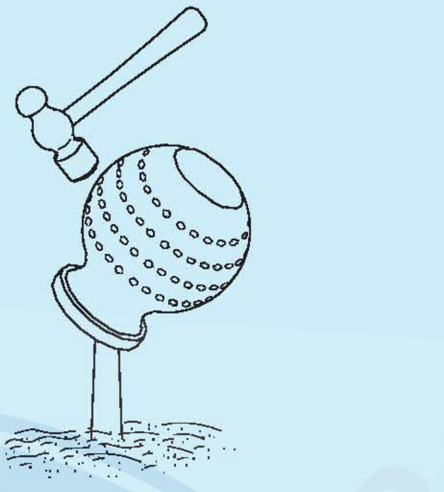
Copper alloys

Brass

It is an alloy of copper and zinc. For certain types of brass small quantities of tin or lead are added. The colour of brass depends on the percentage of the alloying elements. The colour is yellow or light yellow, or nearly white. It can be easily machined. Brass is also corrosion-resistant.

Brass is widely used for making motor car radiator core and water taps etc. It is also used in gas welding for hard soldering/brazing. The melting point of brass ranges from

Fig 6



880 to 930°C.

Brasses of different composition are made for various applications. The following Table-2 gives the commonly used brass alloy compositions and their application.

Bronze

Bronze is basically an alloy of copper and tin. Sometimes zinc is also added for achieving certain special properties. Its colour ranges from red to yellow. The melting point of bronze is about 1005°C. It is harder than brass. It can be easily machined with sharp tools. The chip produced is granular. Special bronze alloys are used as brazing rods. Bronze of different compositions are available for various applications. Table-3 gives the type compositions and applications of different bronzes.

Table 2 - Composition of different types of Brass

Name	Composition (%)			Applications
	Copper	Zinc	Other elements	
Cartridge brass	70	30	-	Most ductile of the copper/zinc alloys. Widely used in sheet metal pressing for severe deep drawing operations. Originally developed for making cartridge cases, hence its name.
Standard brass	65	35	-	Cheaper than cartridge brass and less ductile. Suitable for most engineering processes.
Basic brass	63	37	-	The cheapest of the cold working brasses. It lacks ductility and is only capable of withstanding simple forming operations.
Muntz metal	60	40	-	Not suitable for cold working, but suitable for hot-working. Relatively cheap due to its high zinc content. It is widely used for extrusion and hot-stamping processes.
Free-cutting brass	58	39	3% lead	Not suitable for cold working but excellent for hot working and high speed machining of low strength components.
Admirality brass	70	29	1% tin	This is virtually cartridge brass plus a little tin to prevent corrosion in the presence of salt water.
Naval brass	62	37	1% tin	This is virtually Muntz metal plus a little tin to prevent corrosion in the presence of salt water.
Gilding metal	95	5	-	Used for jewellery.

Table 3 - Composition of different types of bronze

Name	Composition (%)				Applications
	Copper	Zinc	Phosphorus	Tin	
Low tin bronze	96	-	0.1 to 0.25	3.9 to 3.75	This alloy can be severely cold-worked to harden it so that it can be used for springs where good elastic properties must be combined with corrosion resistance,fatigue-resistance and electrical conductivity. Eg.Contact blades
Drawn phosphor/ bronze	94	-	0.1 to 0.5	5.9 to 5.5	This alloy is used for turned components requiring strength and corrosion resistance, such as valve spindles.
Cast phosphor/ bronze	89.75 to 89.97		0.03 to 0.25	10	Usually cast into rods and tubes for making bearing bushes and worm wheels. It has excellent anti-friction properties.
Admirality gun-metal	88	2	-	10	This alloy is suitable for sand casting where fine-grained, pressure-tight components such as pump and valve bodies are required.
Leaded gun-metal (free cutting)	85	5 (5%lead)	-	5	Also known as 'red brass' this alloy is used for the same purposes as standard, admiralty gun-metal. It is rather less strong but has improved toughness and machining properties.
Leaded (plastic) bronze	74	(24%lead)	-	2	This alloy is used for lightly loaded bearings where alignment is difficult. Due to its softness, bearings made from this alloy "bed in" easily.

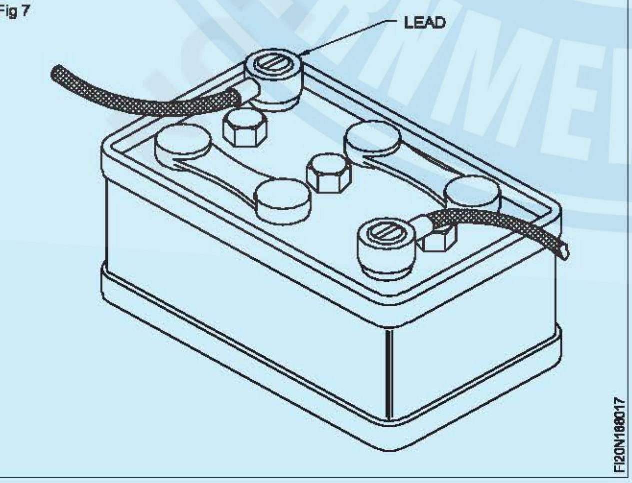
Lead

Lead is a very commonly used non-ferrous metal and has a variety of industrial applications.

Lead is produced from its ore 'GALENA'. Lead is a heavy metal that is silvery in colour when molten. It is soft and malleable and has good resistance to corrosion. It is a good insulator against nuclear radiation. Lead is resistant to many acids like sulphuric acid and hydrochloric acid.

It is used in car batteries, in the preparation of solders etc. It is also used in the preparation of paints. (Fig 7)

Fig 7



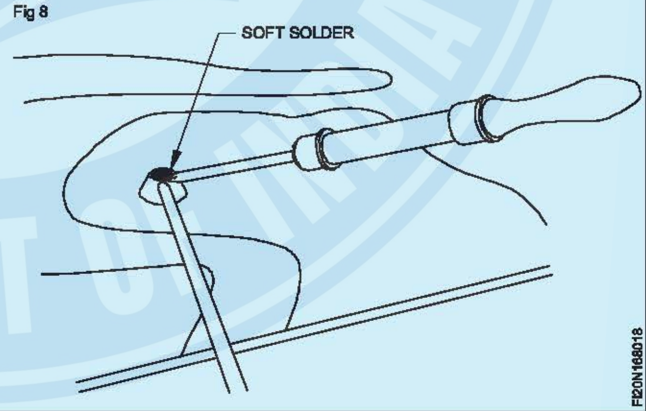
Lead Alloys

Babbit metal

Babbit metal is an alloy of lead, tin, copper and antimony. It is a soft, anti-friction alloy, often used as bearings.

An alloy of lead and tin is used as 'soft solder. (Fig 8)

Fig 8



Zinc

Zinc is a commonly used metal for coating on steel to prevent corrosion. Examples are steel buckets, galvanized roofing sheets, etc.

Zinc is obtained from the ore-calamine or blende.

Its melting point is 420° C.

It is brittle and softens on heating; it is also corrosion-resistant. Due to this reason it is used for battery containers and is coated on roofing sheets etc.

Galvanized iron sheets are coated with zinc.

Tin: Tin is produced from cassiterite or tinstone. It issilvery white in appearance, and the melting point is 231° C. It is soft and highly corrosion-resistant.

It is mainly used as a coating on steel sheets for the production of food containers. It is also used with other metals, to form alloys.

Example: Tin with copper to form bronze. Tin with lead to

Aluminium: Aluminium is a non-ferrous metal which is extracted from 'BAUXITE'. Aluminium is white or whitish grey in colour. It has a melting point of 660° C. Aluminium has high electrical and thermal conductivity. It is soft and ductile, and has low tensile strength. Aluminium is very widely used in aircraft industry and fabrication work because of its lightness. Its application in the electrical industry is also on the increase. It is also very much in use in household heating appliances. Some typical aluminium alloys, their composition and applications are given in the table that follows. (Table 4)

ALUMINIUM ALLOYS - COMPOSITION - USES

Composition(%) (Only the percentage of alloying elements is shown. The remaining is aluminium.)						**Category**	**Applications**
Copper	Silicon	Iron	Manganese	Magnesium	Other elements		
0.1 max.	0.5 max.	0.7 max.	0.1 max.	-	-	Wrought. Not heat treatable.	Fabricated assemblies, Electrical conductors. Food and brewing, processing plants. Architectural decorations.
0.15 max.	0.6 max.	0.75 max.	1.0 max.	4.5 to 5.5	0.5 Chromium	Wrought. Not heat treatable.	High strength ship building and engineering products. Good corrosion resistance.
1.6	10.0	-	-	-	-	Cast, not heat treatable.	General purpose alloy for moderately stressed pressure die-castings.
-	10.0 to 13.0	-	-	-	-	Cast, not heat treatable	One of the most widely used alloys. Suitable for sand,gravity and pressure die castings. Excellent foundry characteristics Used for large marine, automotive and general engineering castings.
4.2	0.7	0.7	0.7	0.7	0.3 Titanium (option)	Wrought. Heat treatable.	Traditional'Duralumin'. General machining alloy. Widely used for stressed components in aircraft.
-	0.5	-	-	0.6	-	Wrought. Heat treatable.	Corrosion-resistant alloy for lightly stressed components such as glazing bars, window sections and automotive body components.
1.8	2.5	1.0	-	0.2	0.15 Titanium 1.2 Nickel	Cast. Heat treatable.	Suitable for sand and gravity die casting. High rigidity with moderate strength and shock resistance. A general purpose alloy
-	-	-	-	10.5	0.2 Titanium	Cast. Heat treatable.	A strong, ductile and highly corrosion-resistant alloy used for air craft and marine castings, both large and small.

Simple scrapers and scraping

Objectives: At the end of this lesson you shall be able to
- **state the necessity of scraping surfaces**
- **state what is high spots**
- **state what is bearing surface**
- **list the types of scrapers used, material and size**
- **hold the scraper at correct angle/position.**

Necessity of scraping surface: Scrapers are used to correct slight errors on all flat or curved surfaces that must be finished more decorate.

Scraping is used to produce a high degree of fit between two flat or two curved surfaces particularly where the surfaces can rub together in use.

After a surface is filed or machined as accurately as possible, it can be further improved by rough scraping after which finish scraping is employed. Finish scraping is used to remove minute amount of material.

High spots and bearing surfaces: On the surface plate apply the coating of Prussian blue or red lead mixed with oil or apply used carbon. Placing the job to be scraped, move the job under light downward pressure keeping all edges of the job within the limits of surface. Carefully lift off the job in a perpendicular direction.

Study the patches of marking compound before you begin scraping.

– First test having 3 shiny patches. Only patch 3 would be scraped (high spots) (Fig 1)

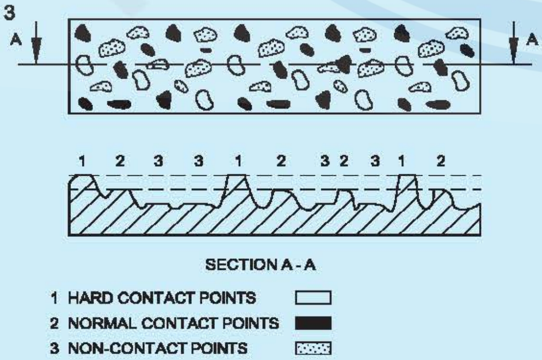
Fig 1

– Second test having even distribution of marking compound. (High spots) (Fig 2)

Fig 2

– Types of bearing contact obtained (Fig 3)

Fig 3



1 Metal contact with the surface plate. The points have been rubbed shiny.

2 They have been conduct with the marking compound and coloured by it. This portion is called normal contact point.

3 Non-contact point, have not been in contact with the marking compound.

– After third scraping completed and testing the shining shows the shiny spots are more than those coloured with marking compound. The patches are greater in number in size more evenly distributed. (High spots) (Fig 4)

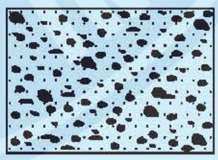
Fig 4

– The enlarged view of the pattern of scraping marks on the small patches shown in Fig 5.

Fig 5

– Further testing, scraping would produce a more even distribution of larger number of smaller sized patches (bearing spots). (Fig 6)

Fig 6



In 25 mm SQ = 25 bearing parts.

Types and uses of scraper: For scraping flat surfaces

– Flat scrapers with rectangular blades. (Fig 7)

Fig 7

Used for scraping large flat surfaces. The working edge is not thicker than 3 mm.

– Hook scrapers with rectangular blades. (Fig 8)

Fig 8

Hook scrapers are used for scraping the center portion of large flat surface where it is not convenient to use of flat scraper.

For scraping curved surfaces

– Half round scraper is curved slightly towards the curved surfaces. (Fig 9)

Fig 9

It is used to scrape bearing blocks or brasses, pressure is applied in radial direction and cutting edge moved at right angles to its length. So that scraping marks are circumferential.

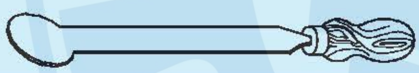
– Three square or triangular scraper

Each of the three faces are hallow ground Fig 10. It is used for scraping small diameter holes and deburring edges of accurate holes. The cutting edge is moved at right angles to its length.

Fig 10

– Bull-nose scraper is forged to a disc like end. (Fig 11) It is used for scraping large bearings. It can be used two ways either with the circumferential movement of a flat scraper or with the longitudinal movement of flat scraper.

Fig 11



Scraper material: High grade tool steel or special alloy steel and tungsten carbide tipped tool.

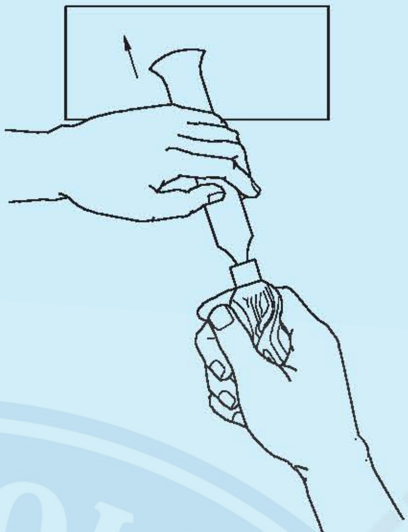
Specification: The overall length of blade and handle may range from 150 to about 500 mm.

Holding position of flat scraper: The handle of the scraper is held and pushed by right hand. Hold the right elbow out of from the body when beginning forward cutting stroke. As you finish the short cutting stroke bring the elbow into the body.

The blade is guided and pressed down by the left hand. Grasp the blade with the root of the little finger above the blade and about 40 mm to 50 mm from the cutting edge. (Fig 12)

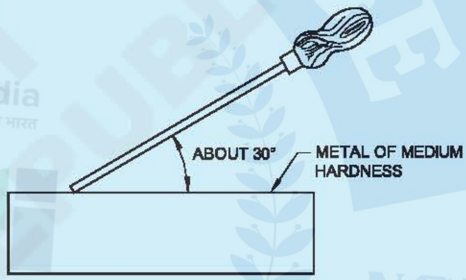
Curl the little finger and second finger lightly around the blade. The first finger lies loosely around the blade and thumb lies on top of the blade and at right angle to it.

Fig 12



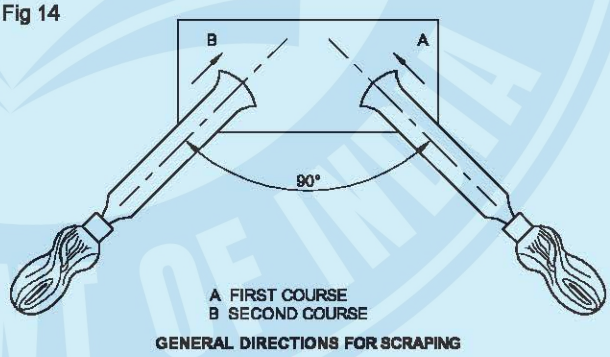
For work of average hardness blade of scraper is held at an angle about 30° to surface. For very hard work the angle may be greater, while for softer metals this angle may be decreased to about 20°. (Fig 13)

Fig 13



After scraping in one general direction and testing in the surface plate. Change the general direction of scraping by about 90°. (Fig 14)

Fig 14



Care and maintenance of scrapers

- Scrapers must be sharp and kept with good condition to handle.
- Cover the cutting edge with rubber or leather sheath.
- After use apply grease on cutting edge to avoid corroding.
- Scraper should not fall down from the bench.
- Don't mix with other tool.

Testing true flat surfaces by three-plate method (Whitworth principle)

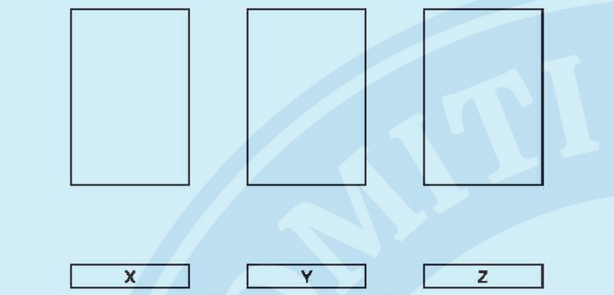
Objective: At the end of this lesson you shall be able to
- **originate flat scraped surfaces by the three-plate method.**

How does one obtain a flat surface?

It is easy to say that it is scraped but how does one know where to take off the high points.

If three plates are compared with one another in alternate pairs, they will only mate perfectly in all positions when they are absolutely flat. (Fig 1)

Fig 1



File and ensure that all the three plates are finished to size and square. (Fig 2)

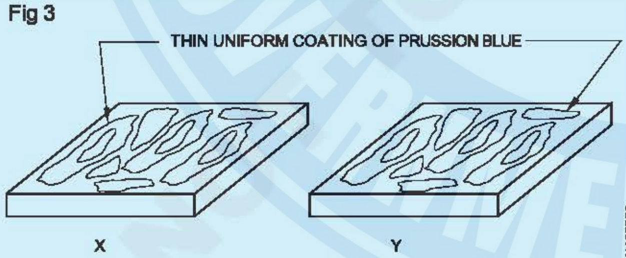
Fig 2

Check the level with the knife edge/straight edge

Stamp the plates X,Y and Z with a letter punch.

Apply a very thin uniform coating of Prussion blue on the feces of plates X and Y which are to be scrapped. (Fig 3)

Fig 3



Keep both the pieces together and rub the plates back and forth against each other. (Fig 4)

Observe the high spots on the plates X and Y remove by scraping. (Fig 5)

Clean the faces with knitted cotton cloth.

Rub with an oilstone gently to remove the burrs and again clean with knitted cotton cloth.

Repeat the same procedure till both the faces are mating with good bearing surfaces.

Fig 4

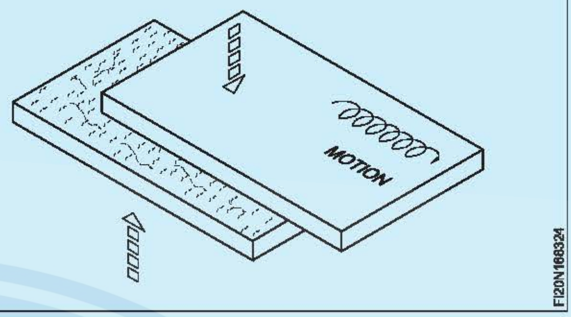
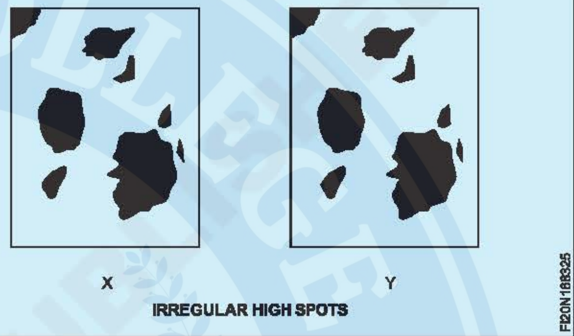


Fig 5



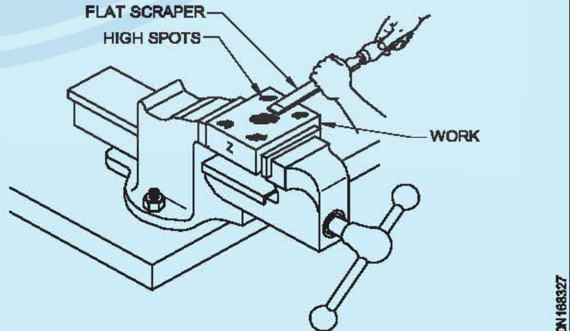
Apply a very thin uniform coating or Prussion blue on the face of the plate Z which is to be scraped.

Keep the faces of the plates X and Z together and rub the plates back and forth against each other.

Observe the high spots on the plate Z and remove by scraping (Figs 6 and 7)

Fig 6

Fig 7



Do not scrape plate X. This is taken as a reference surface.

Repeat the same procedure till both the faces of the plates X and Z are mating with good

Repeat the procedure till the faces of plates Y and Z are mating with good bearing surfaces.

Now one cycle of operation is completed.

Note: Plate X will mate with plates Y and Z but Y and Z will not mate. All the three plates mate only when all the three are flat.

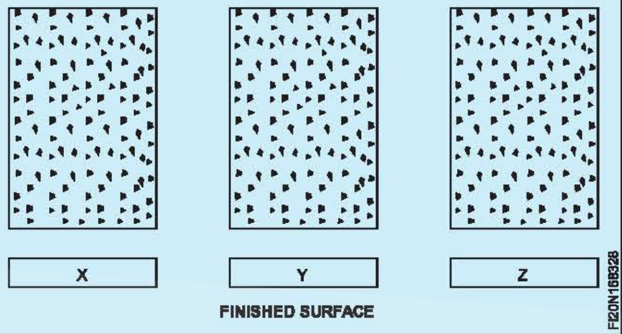
Repeat the cycle a number of times till interchangeable, flat, good bearing surfaces are achieved.

Clean all the plates with kerosene.

Use knitted cotton cloth for cleaning.

A good bearing surface is achieved when 5 to 10 points are visible and uniformy distribuited per cm^2 on the workpiece surfaces after finishing. (Fig 8)

Fig 8



Three trainees will work in a group for this exercise.

Each trainee will be given one plate for scraping.

Each trainee will compare his plate with those of the other trainees as per the above procedure and generate flat surfaces by the three-plate method.

Scraping curved surfaces

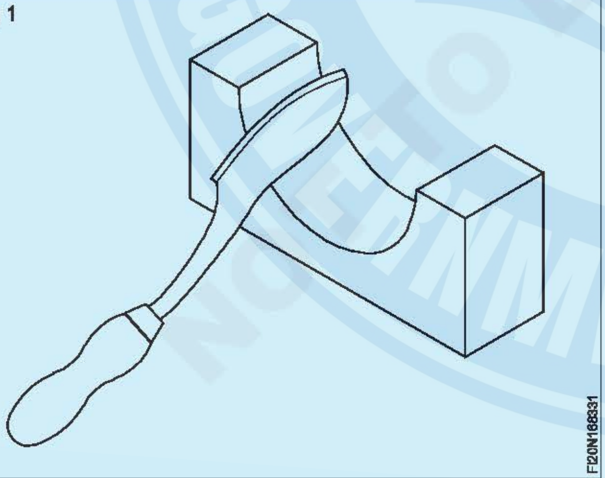
Objective: At the end of this lesson you shall be able to
- **scrape and test curved surfaces.**

A half round scraper is the most suitable scraper for scraping curved surfaces. This method of scrapping differs from that of flat scraping.

Method

For scraping curved surfaces the handle is held by hand in such a way as to facilitate the movement of the scraper in the required direction. (Fig 1)

Fig 1



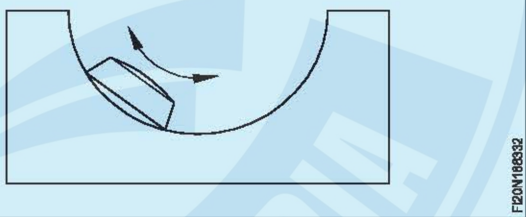
Pressure is exerted with other hand on the shank for cutting.

Rough scraping will need excessive pressure with longer strokes.

For fine scraping, pressure is reduced and the stroke length also becomes shorter.

Cutting action takes place both on forward and return strokes. (Fig 2)

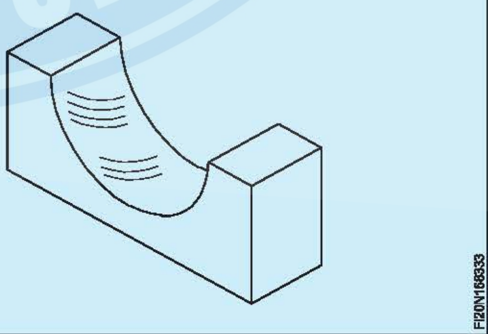
Fig 2

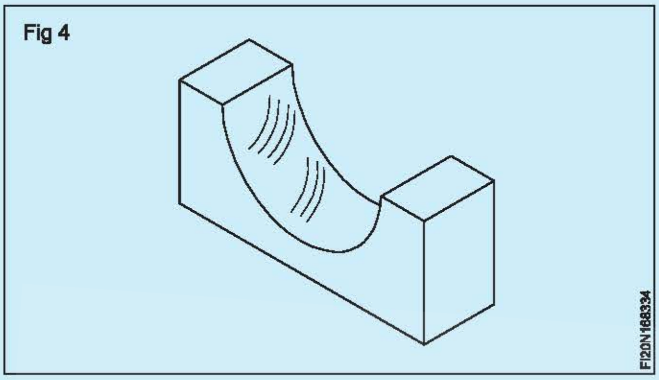


During the forward movement one cutting edge acts, and on the return stroke, the other cutting edge acts.

After each pass, change the direction of cutting. This ensures a uniform surface. (Figs 3 & 4)

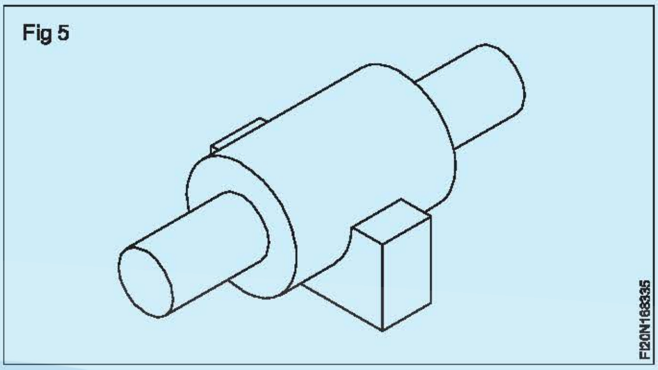
Fig 3





Use a master bar to check the correctness of the surface being scraped. (Fig 5)

Apply a thin coating of Prussian blue on the master bar to locate the high spots.



Vernier micrometer, screw thread micrometer, graduation & Measuring process

Objectives: At the end of this lesson you shall be able to
- **state the graduations of a vernier micrometer (metric)**
- **read a vernier micrometer**

Vernier micrometer

Ordinary metric micrometers can measure only to an accuracy of ±.01 mm.

For taking more accurate measurements, vernier micrometers are useful. Vernier micrometers can measure to an accuracy of ±.001 mm.

Construction and graduation

Vernier micrometers are very similar to ordinary micrometers in construction. The difference is in the graduation. These micrometers have additional, equally spaced graduations (vernier graduations) given above the datum line. There are ten such vernier graduation lines marked parallel above the datum line. (Fig 1) The space between these 10 lines is equal to 9 divisions in the thimble. (Fig 1)

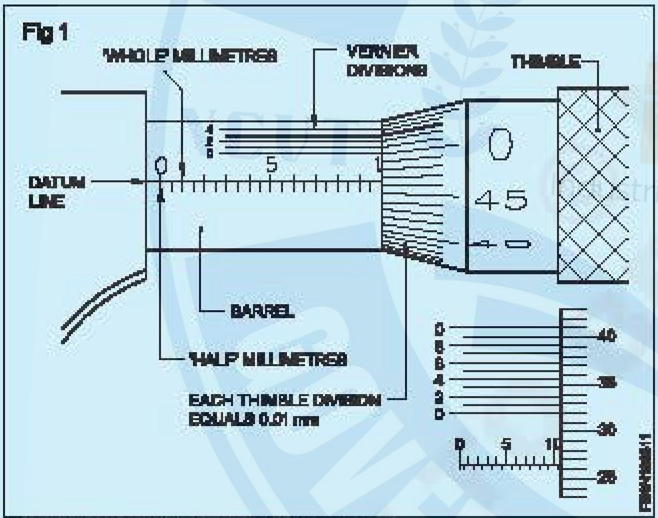


Fig 1

The value of 10 vernier divisions is

.01 mm X 9

=.09 mm.

The value of a vernier division

$$\frac{0.09}{10} = .009\text{mm}$$

The least count = 1 thimble division – 1 Vernier division
= 0.01 – 0.009mm = .001 mm

Reading a vernier micrometer (Fig 2)

Example

After measuring, read the full mm divisions visible on the barrel.

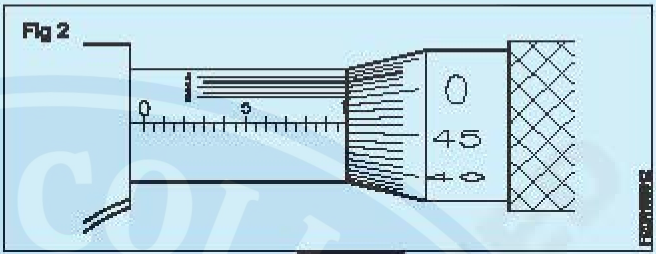


Fig 2

full divisions in mm. | 9 mm |

Note the half divisions, if any, visible on the barrel.

| 1 half division |

Read the thimble divisions below the datum line. (Fig 2)

| 46 divisions |

Note the vernier division coinciding with the thimble division.

| 3rd division |

Add up all the readings together

Calcuation

The range of micrometer is 0 to 25 mm

A Full mm division visible before the thimble edge = 1.00 x 9 = 9.00 mm

B Half mm division visible after the full mm divsion on barrel. = 0.5 x 1 = 0.50 mm

C Thimble division below the index line = 46 X 0.01 = 0.46 mm

D Vernier division coinsiding with thimble division = 3 X 0.001 = 0.003 mm

Reading = 9.963 mm

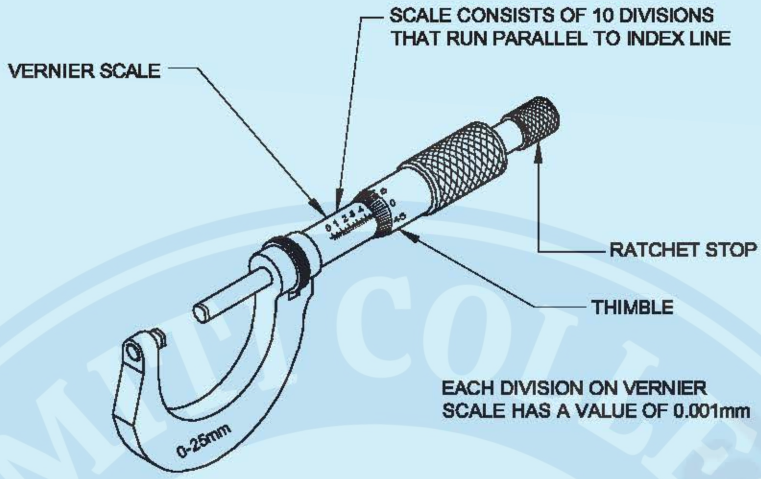
Vernier micrometers are made of invar steel. (Fig 3)

Care and maintenance

- Clean the circumference of the spindle and both measuring faces with dry linen cloth regularly before use.
- Clean and apply thin layer of oil on the spindle and measurring faces after the use.

- Care should be taken while handling the micrometer and not to drop on floor.
- Recalibrate the vernier micrometer if it is accidently dropped.
- Store vernier micrometer in a ventilated place with low humidity and ideally at room temperature.
- Ensure that there is a gap between measuring faces, when it is not in use.

Fig 3



VERNIER MICROMETER (METRIC)

FI20N168613

Calibration of measuring instrument

Objectives: At the end of this lesson you shall be able to
- **state the importance of calibration**
- **state calibration and its procedure.**

Why calibration is important ?

The accuracy of all measuring devices degrade over time. This is typically caused by normal wear and tear. However, changes in accuracy can also be caused by electric or mechanical shock or a hazardous manufacturing environment in which it is being used, it may degrade very quickly or over a long period of time. The bottom line is that, calibration improves the accuracy of the measuring device. Accurate measuring devices improve product quality.

When should you calibrate your measuring device?

A measuring device should be calibrated:

- According to recommendation of the manufacturer.
- After any mechanical or electrical shock.
- Periodically (annually, quarterly, monthly).

What is calibration: Calibration is defined as a scientific and systematic method of identifying deviations (error) in a instrument by comparing with a master, having higher accuracy and rational traceability.

It is also referred as checking the integrity of an instrument, alternately ascertaining whether the instrument is fit enough to be used for measurement.

The instrument calibration is carried out as per (ISS) Indian Standard Specification published by the Bureau of Indian standards (BIS), which also gives the permissible error, that can be allowed in the relavant standard for each instrument.

Calibration is mandatory in most of the global quality standards and is covered under a special clause called measuring system analysis (MSA) for automobile industry standard ISO/TS 16949. Calibration should be carried out by an accredited laboratory or by following relevant documents of the certifying agency, NABL India (National Accreditation Board for calibration testing laboratories, the accrediting body in our country.

Apart from following the standard specification for calibration of an instrument, the environmental condition of the lab is critical with respect to temperature, humidity, vibrations proper lighting, magnetic interference etc., which are specified in IS:199 or the NABL document, essential criteria for the calibration lab, which should adopt the quality system standard (QSS) as per ISO/IEC/170235 - 2015. The vital factor in calibration of an instrument is the frequency of calibration, which is determined based on the importance & criticality of the measurement process.

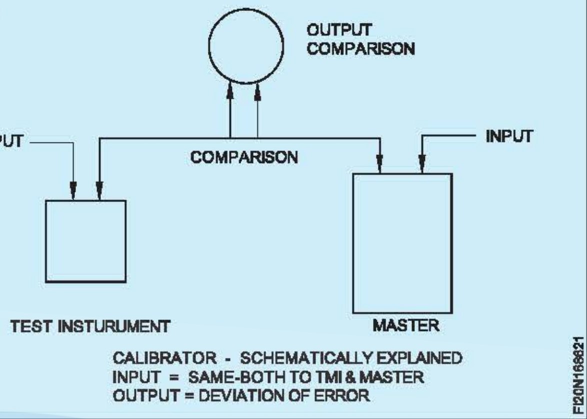
A good calibrated instrument will maintain both precision & accuracy, the essential requirement of any measuring system

Calibration of your measuring instruments has two objectives. It checks the accuracy of the instrument and it determines the traceability of the measurement. In practice, calibration also includes repair of the device if it is out of calibration. A report is provided by the calibration expert, which shows the error in measurements with the measuring device before and after the calibration.

To explain how calibration is performed we can use an external micrometer as an example. Here, accuracy of the scale is the main parameter for calibration. In addition,

these instruments are also calibrated for zero error in the fully closed position and flatness and parallelism of the measuring surfaces. For the calibration of the scale, a calibrated slip gauge is used. A calibrated optical flat is used to check the flatness and parallelism.

Fig 1



Mechanical fasteners

Objectives: At the end of this lesson you shall be able to
- **define mechanical fasteners**
- **classification of fasteners**
- **state the application of various fasteners & their uses.**

Definition

A mechanical fastener is a device that mechanically joins two (or) more components together easily and also can be dismantled without damaging any components using hand tools (or) power tools.

Classification

According to the need and usage they are classified into three categories.

- Temporary (or) removable fasteners
- Semi permanent fasteners
- Permanent fasteners

Temporary (or) removable fasteners

- The fasteners like bolts, nuts, screws, studs etc., enable us to join two (or) more components easily and also can be dismantled without damaging any component using hand tools (or) power tools.
- The most common types of male fasteners used in industry are hexagonal head, square head, flat (or) counters sunk head, round head, socket head (or) allen head, button head and socket set screws etc.
- The most common types of female fasteners (ie nuts) used in industry are regular hexagonal nut, square nut, round nut and nylon ring elastic stop nuts etc.

Uses: These types of fasteners are used for assembling two (or) more components together to make a sub-assembly (or) to make a full assembly.

Semi permanent fasteners: The fasteners like rivets are used to hold the plates (or) steel sections firmly. The rivets are placed through the pre drilled appropriate holes in parts to be joined (or) assembled. By using rivet sets, the tail part of the shank is formed into the head closing the hole.

The plates are held between the heads on cooling. Rivet is a cylindrical rod either carbon steel (or) wrought iron (or) non-ferrous metal. It consists of a head and shank tapering at the end facilitating easy placement in the rivet holes. During dismantling the rivets may be drilled to remove the plates already joined together without spoiling them. This process is a permanent as well as a semi-permanent in nature. According to the head type the rivets are called snap head, pan head, countersunk head, flat head etc.

Uses

Rivets are used in ship building, bridge girders, structural towers, goods wagons, boilers and heavy pressure vessels industry and also for small scale applications too.

Permanent fasteners

Arc welding, gas welding and brazing are the operations used in industry during permanent fastening of components and structures. Once the arc welding, gas welding and brazings has been done, the components (or) the structures cannot be separated without damage, hence these type of fastening is called permanent fastening.

Uses

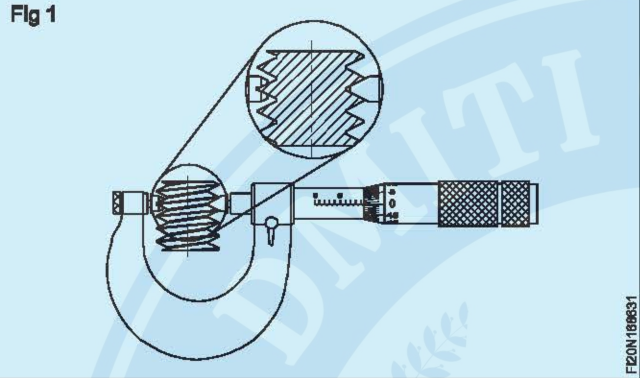
To hold steel plates (or) structures together like goods wagon building, ship building, bridge structures assembling etc. Sometimes before doing welding the components (or) the parts hold together with temporary fasteners like bolts, nuts, screws, rivets etc.

Screw thread micrometer - Thread measurement (effective diameter) using screw thread micrometer

Objectives: At the end of this lesson you shall be able to
- **state the features of a screw thread micrometer**
- **state the features of the three-wire system of measurement with the help of tables**
- **select the best wire with the help of tables for using in the three-wire method.**

The Screw thread micrometer: This micrometer (Fig 1) is used to measure the effective diameter of the screw threads. This dimension is important, because the area of the thread flanks in the vicinity of the pitch line is where the greatest transmission of force occurs between mating threads.

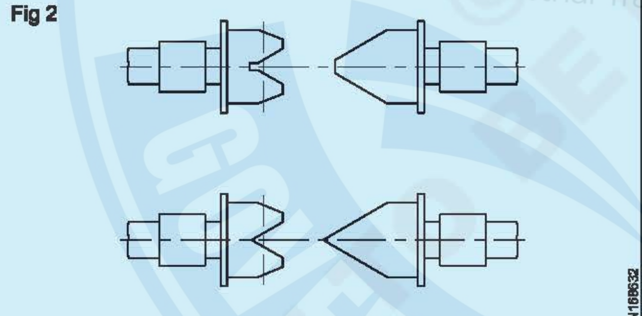
Fig 1



This is very similar to the ordinary micrometer in construction but has facilities to change the anvils.

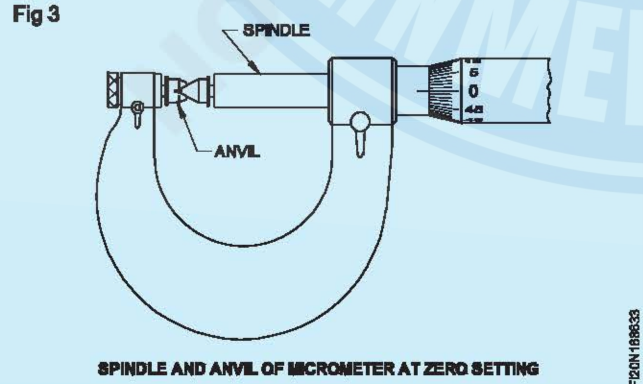
The anvils are replaceable and are changed according to the profile and pitch of the different systems of threads. (Figs 2 & 3)

Fig 2



INTERCHANGEABLE ANVILS

Fig 3



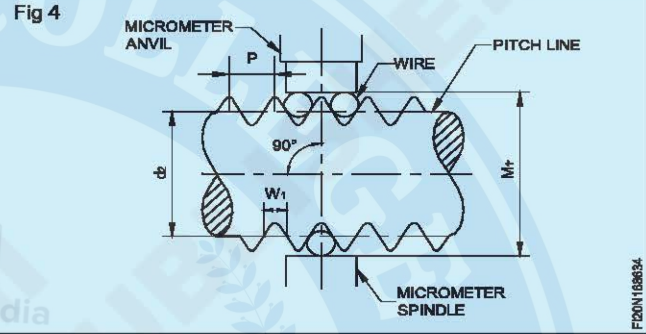
SPINDLE AND ANVIL OF MICROMETER AT ZERO SETTING

The three-wire method: This method uses three wires of the same diameter for checking the effective diameter and the flank form. The wires are finished with a high degree of accuracy.

The size of the wires used depends on the pitch of the thread to be measured.

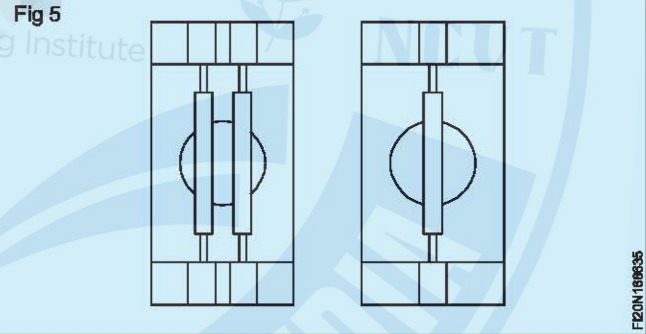
For measuring the effective diameter, three wires are suitable placed between the threads. (Fig 4)

Fig 4



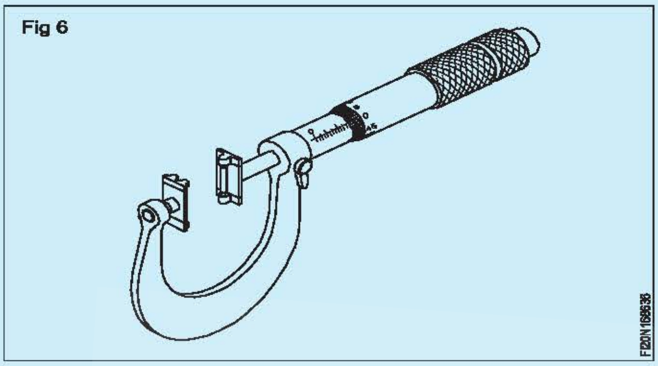
The measuring wires are fitted in wire-holders which are supplied in pairs. One holder has provisions to fix one wire and the other for two wires. (Fig 5)

Fig 5



While measuring the screw thread, the holder with the one wire is placed on the spindle of the micrometer and the other holder with two wires is fixed on the anvil. (Fig 6)

Selection of 'best wire' (Fig 7)**:** The best wire is the one which, when placed in the thread groove, will make contact at the nearest to the effective diameter. The selection of the wire is based on the type of thread and pitch to be measured. The selection of the wire can be calculated and determined but readymade charts are available from which the selection can be made.



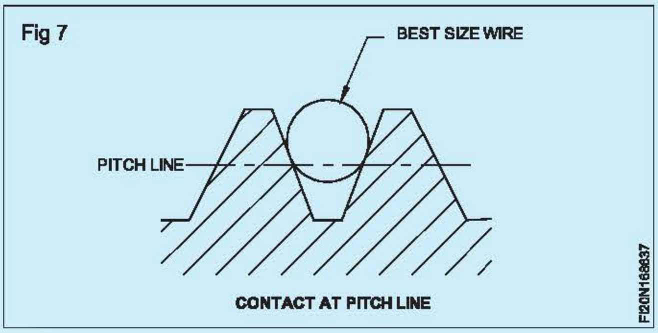


Table 1

Measurement with measuring wires. Metric threads with coarse pitch (M)

Thread designation	Pitch P (mm)	Basic measurement mean d_2(mm)	Measuring wire dia. W_1(mm)	Dimension over wire M_1(mm)
M1	0.25	0.838	0.15	1.072
M 1.2	0.25	1.038	0.15	1.272
M 1.4	0.3	1.205	0.17	1.456
M 1.6	0.35	1.373	0.2	1.671
M 1.8	0.35	1.573	0.2	1.870
M 2	0.4	1.740	0.22	2.055
M 2.2	0.45	1.908	0.25	2.270
M 2.5	0.45	2.208	0.25	2.569
M 3	0.5	2.675	0.3	3.143
M 3.5	0.6	3.110	0.35	3.642
M 4	0.7	3.545	0.4	4.140
M 4.5	0.75	4.013	0.45	4.715
M 5	0.8	4.480	0.45	5.139
M 6	1	5.350	0.6	6.285
M 8	1.25	7.188	0.7	8.207
M 10	1.5	9.026	0.85	10.279
M 12	1.75	10.863	1.0	12.350
M 14	2	12.701	1.15	14.421
M 16	2	14.701	1.15	16.420
M 18	2.5	16.376	1.45	18.464
M 20	2.5	18.376	1.45	20.563
M 22	2.5	20.376	1.45	22.563
M 24	3	22.051	1.75	24.706
M 27	3	25.051	1.75	27.705
M 30	3.5	27.727	2.05	30.848

Table 2

Measurement with measuring wires. Metric threads with fine pitch (M)

Thread designation	Basic measurement d_2(mm)	Measuring wire dia.mean W_1(mm)	Dimension over wire M_1(mm)
M 1 x 0.2	0.870	0.12	1.057
M 1.2 x 0.2	1.070	0.12	1.257
M 1.6 x 0.2	1.470	0.12	1.557
M 2 x 0.25	1.838	0.15	2.072
M 2.5 x 0.35	2.273	0.2	2.570
M 3 x 0.35	2.773	0.2	3.070
M 4 x 0.5	3.675	0.3	4.142
M 5 x 0.5	4.675	0.3	5.142
M 6 x 0.75	5.513	0.45	6.214
M 8 x 1	7.350	0.6	8.285
M 10 x 1.25	9.188	0.7	10.207
M 12 x 1.25	11.188	0.7	12.206
M 14 x 1.5	13.026	0.85	14.278
M 16 x 1.5	15.026	0.85	16.278
M 18 x 1.5	17.026	0.85	18.277
M 20 x 1.5	19.026	0.85	20.277
M 22 x 1.5	21.026	0.85	22.277
M 24 x 2	22.701	1.15	24.420
M 27 x 2	25.701	1.15	27.420
M 30 x 2	28.701	1.15	30.419

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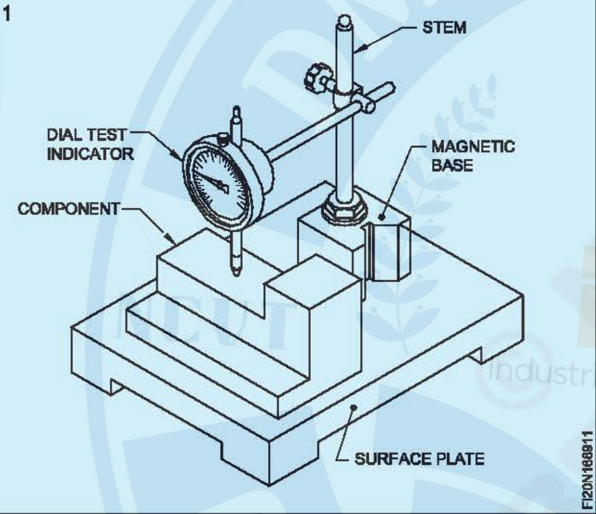
Dial test indicator, comparators, digital dial indicator

Objectives: At the end of this lesson you shall be able to
- **state the principle of a dial test indicator**
- **identify the parts of a dial test indicator**
- **state the important features of a dial test indicator**
- **state the functions of a dial test indicator**
- **identify the different types of stands.**

Dial test indicators are instruments of high precision, used for comparing and determining the variation in the sizes of a component. (Fig 1) These instruments cannot give the direct reading of the sizes like micrometers and vernier calipers. A dial test indicator magnifies small variations in sizes by means of a pointer on a graduated dial. This direct reading of the deviations gives an accurate picture of the conditions of the parts being tested.

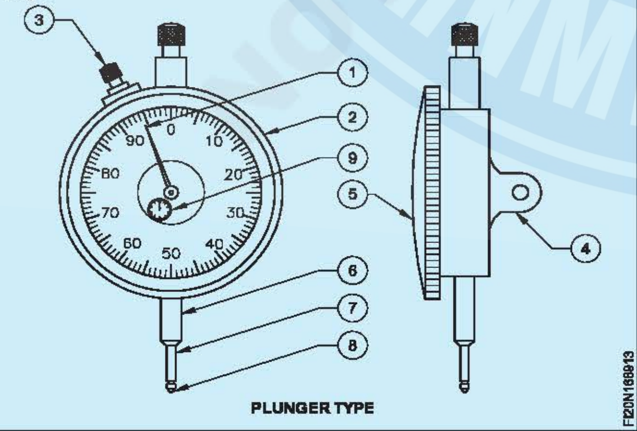
Fig 1



Principle of working: The magnification of the small movement of the plunger or stylus is converted into a rotary motion of the pointer on a circular scale. (Fig 2)

Types: Two types of dial test indicators are in use according to the method of magnification. They are

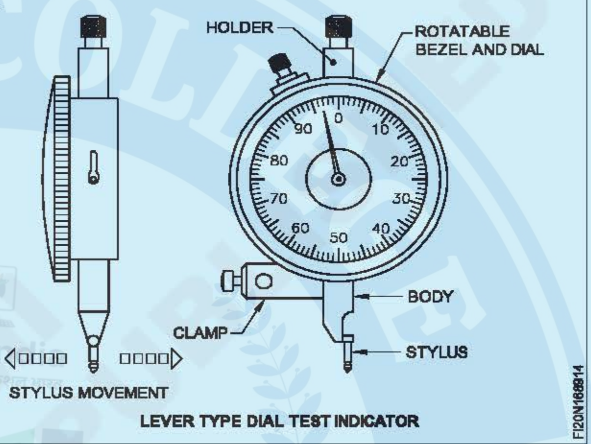
Fig 3



Plunger type (Fig 3)

Lever type (Fig 4)

Fig 4



The Plunger Type dial test indicator

The external parts and features of a dial test indicator are as shown in Fig 3.

Dial test indicators are made out of Inver steel material

1 Pointer
2 Rotatable bezel
3 Bezel clamp
4 Back lug
5 Transparent dial cover
6 Stem
7 Plunger
8 Anvil
9 Revolution counter

For converting the linear motion of the plunger, a rack and pinion mechanism is used. (Fig 2)

The lever type dial test indicator (Fig 4)

In the case of this type of dial test indicators, the magnification of the movement is obtained by the mechanism of the lever and scroll. (Fig 5)

It has a stylus with a ball- type contact, operating in the horizontal plane.

Fig 2

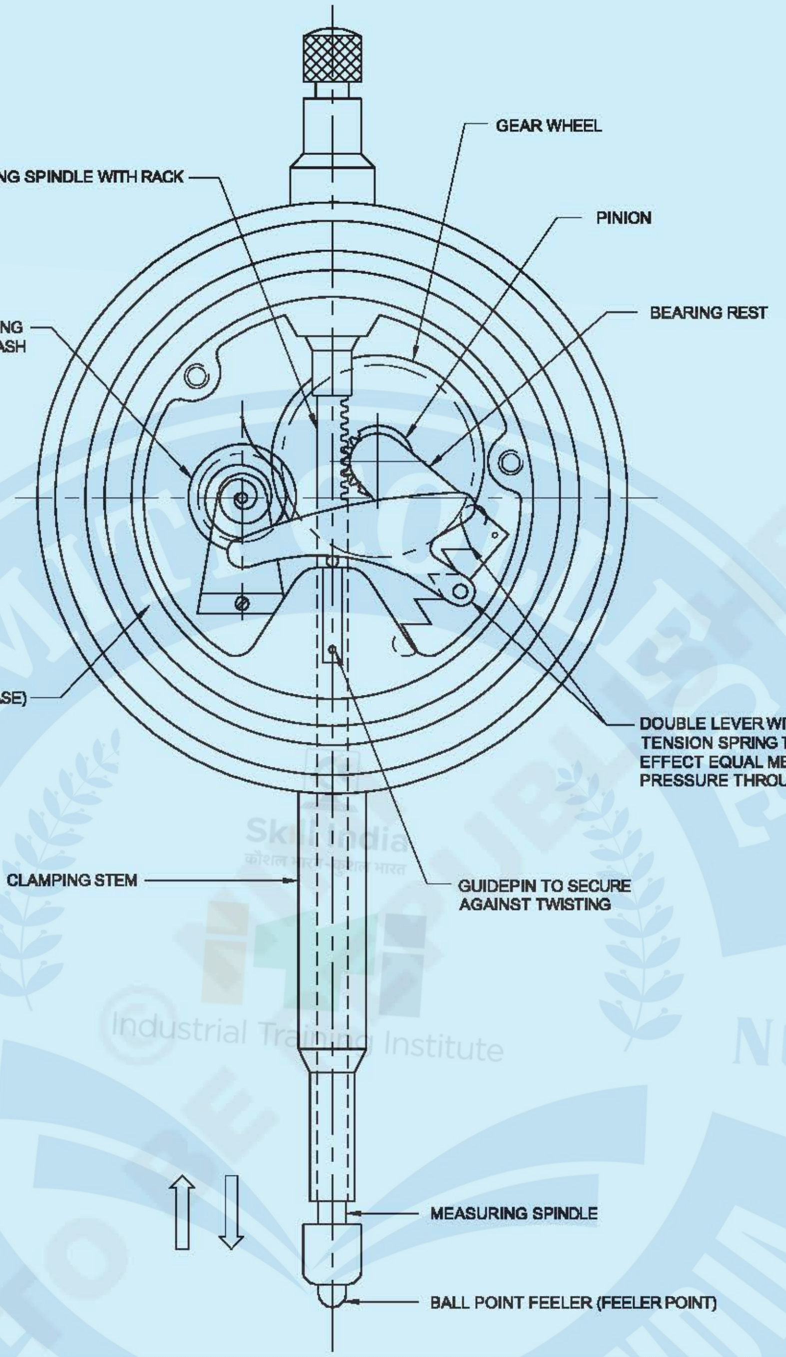
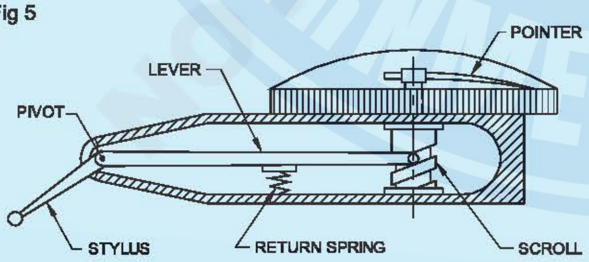


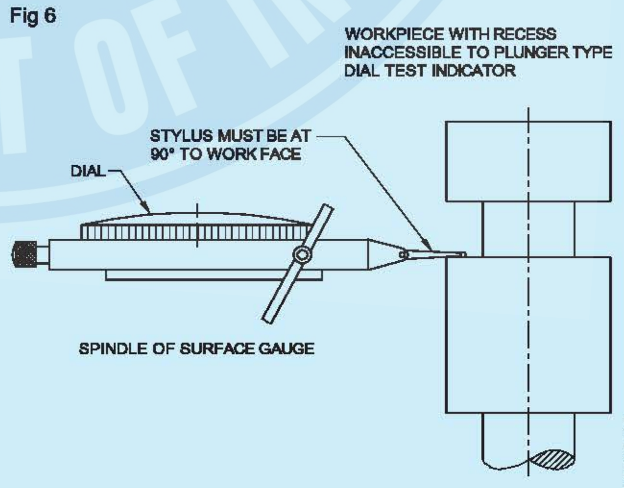
Fig 5



MECHANISM OF THE LEVER TYPE DIAL TEST INDICATOR

This can be conveniently mounted on a surface gauge stand, and can be used in places where the plunger type dial test indicator application is difficult. (Fig 6)

Fig 6



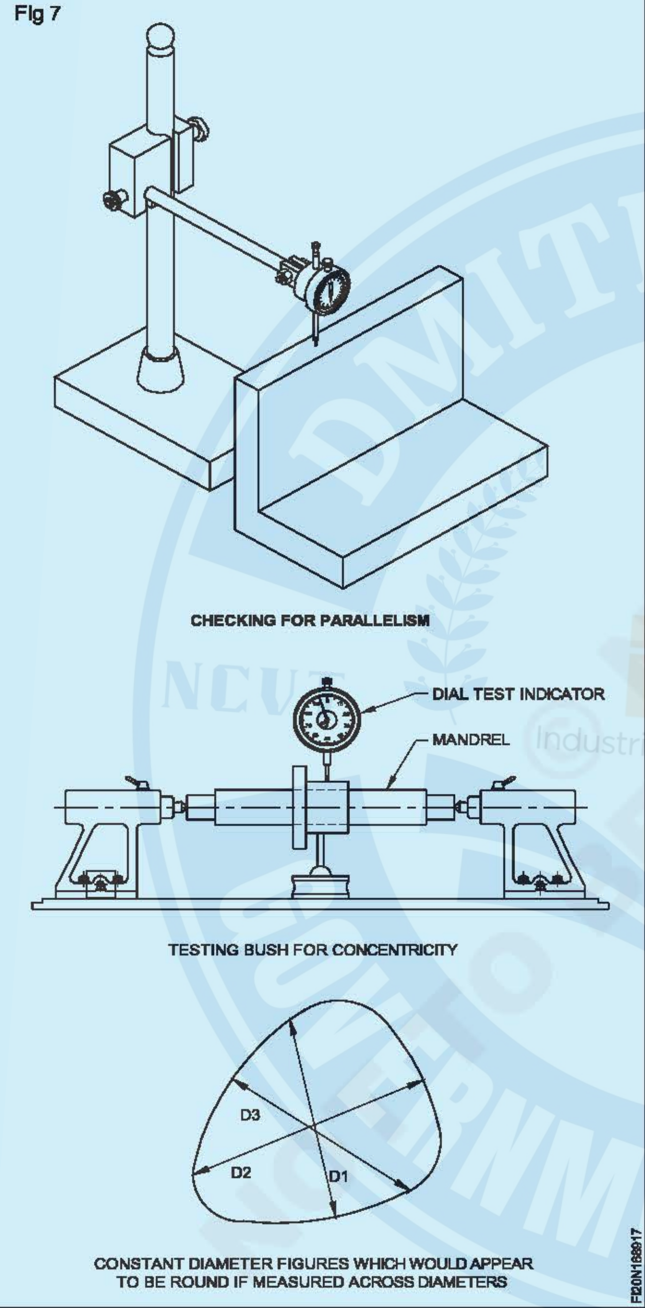
Important features of dial test indicators

An important feature of the dial test indicator is that the scale can be rotated by a ring bezel, enabling it to be set readily to zero.

Many dial test indicators read plus in clockwise direction from zero, and minus in the anti-clockwise direction so as to give plus and minus indications.

Uses (Figure 7 shows few applications)

Fig 7



To compare the dimensions of a workpiece against a known standard, eg.slip gauges.

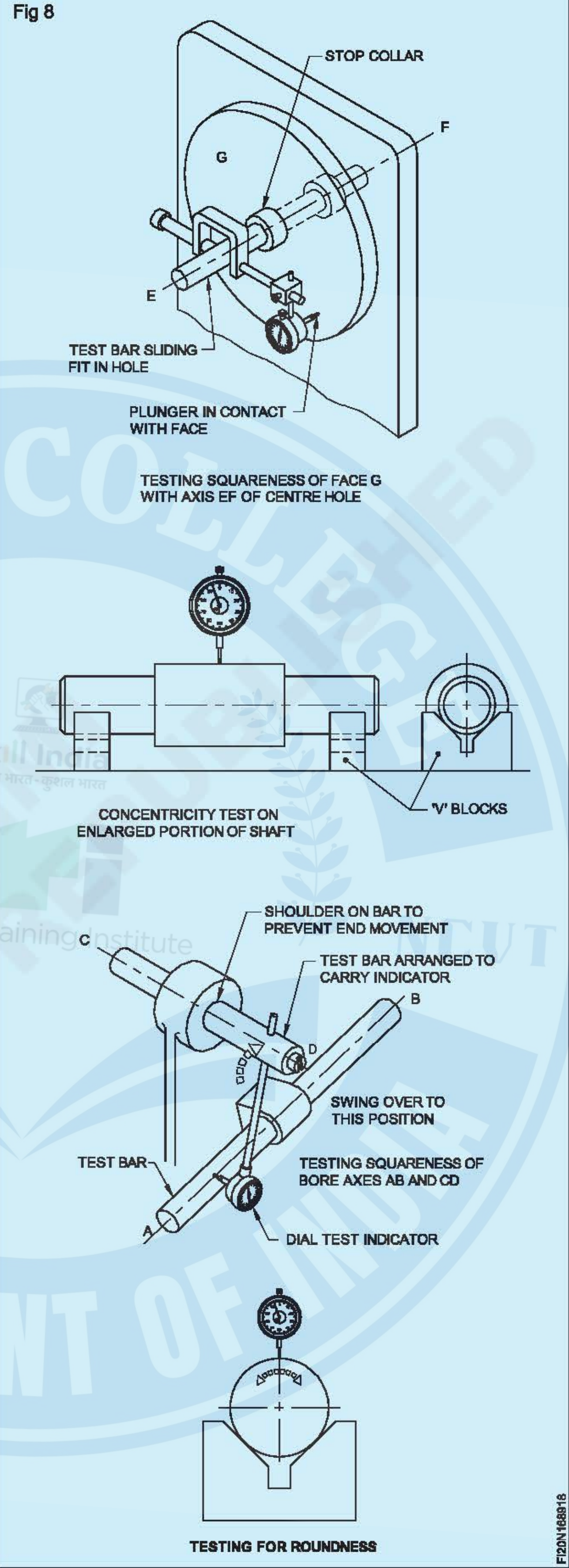
To check plane surfaces for parallelism and flatness.

To check parallelism of shafts and bars.

To check concentricity of holes and shafts.

Indicator stands (Fig 8)

Fig 8



Dial test indicators are used in conjunction with stands for holding them so that the stand itself may be placed on a datum surface of machine tools.

The different types of stands are (Fig 9)

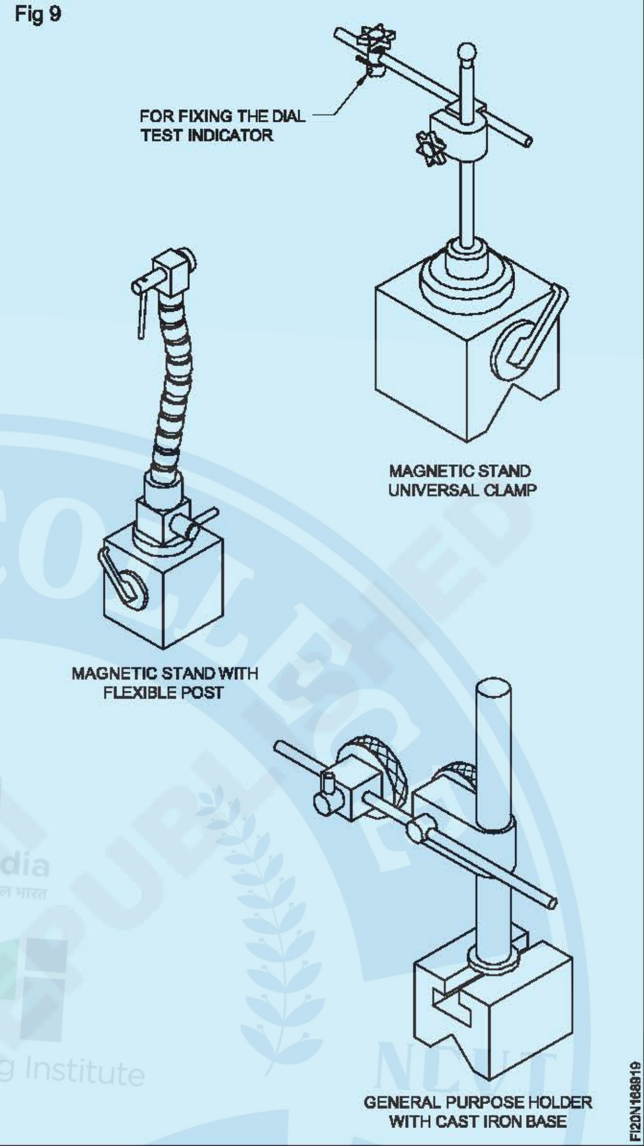
- Magnetic stand with universal clamp
- Magnetic stand with flexible post
- General purpose holder with cast iron base.

The arrows indicate the provisions in the clamps for insertion of the dial test indicator.

Care and maintenance of dial test indicator.

- Keep the dial test indicator spindle and point clean using a soft cloth.
- Store the dial test indicator in a safe, dry place and cover them to keep the dust and moisture out.
- Do the dial test indicator under gaging conditions at intervals during the operating day.

Fig 9



Comparators

Objectives: At the end of this lesson you shall be able to
- **state the principle of working of comparator gauges**
- **state the essential features of a good comparator gauge**
- **state the purpose of a comparator gauge.**
- **explain the parts and method of measurements o n bore dial gauge.**

Purpose of a comparator gauge

The purpose of all comparator gauges is to indicate the difference in the size between the standard (slip gauge or ring gauge) and the work being measured by means of some form of pointer on a scale at a magnification which is sufficient to read to the accuracy required. Almost every possible principle known to the Science of Physics for providing magnification has been used for the construction of these comparator gauges.

Essential features of a good comparator gauge

- Should be compact.
- Maximum rigidity.
- Maximum compensation for temperature effects.
- No backlash in the movement of the plunger and recording mechanism.
- Straight line characteristics of the scale readings.

- Most suitable measuring pressure which remains uniform throughout the scale.
- Indicator should be consistent in its return to zero.
- Method of indication should be clear and the pointer 'dead beat' (ie. free from oscillations).
- Should be able to withstand reasonable wrong usage.
- Should have a wide range of operations.

Principles of working

The following principles are employed in the commonly used comparator gauges.

- Mechanical
- Electronics
- Pneumatic
- Optical

Mechanical comparators

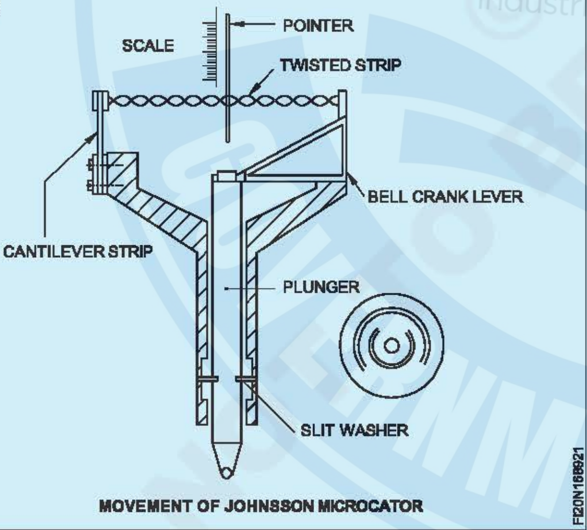
These are widely used and the familiar ones are the dial indicator fitted to the comparator stand, microcator, sigma comparator and red comparator.

Dial indicator fitted to the comparator stand.

Here, the plunger type dial indicator is used. The magnification is achieved by a suitable combination of gears, rack and pinion, steel band and levers. Generally the magnification range is between 100 or 1000 (least count 10 micron or 1 micron).

Microcator (Fig 1)

Fig 1



This is a simple and ingenious design, giving a very high magnification up to 25000 times (0.02 μ ie. 0.00002 mm. least count) It is compact, robust and free from friction and backlash.

When the plunger moves up, the bell crank lever is tilted and the twisting strip elongates. The helix angle in the twisted strip reduces and this causes the pointer, which is fixed along t

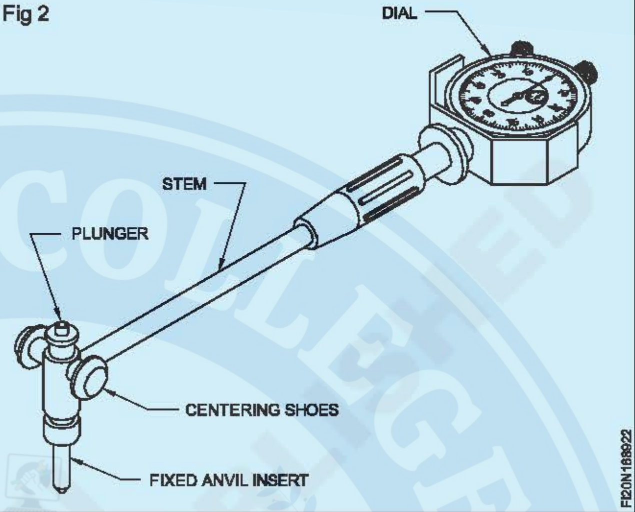
he helix of the strip, to move to one side. This movement is then read on the scale fitted behind it. When the plunger moves down, the entire process of movement is reversed and the pointer moves to the opposite side and this reading is read against the scale.

Bore dial gauge

This is a precision measuring instrument used for measuring the internal dimensions. The bore dial gauge is normally available as a two-point, self-cantering type

Dial bore gauge (Fig 2)

Fig 2



Stem: This holds all the components together and contains the mechanism for transmitting the plunger motion to the dial.

Fixed anvil/inserts

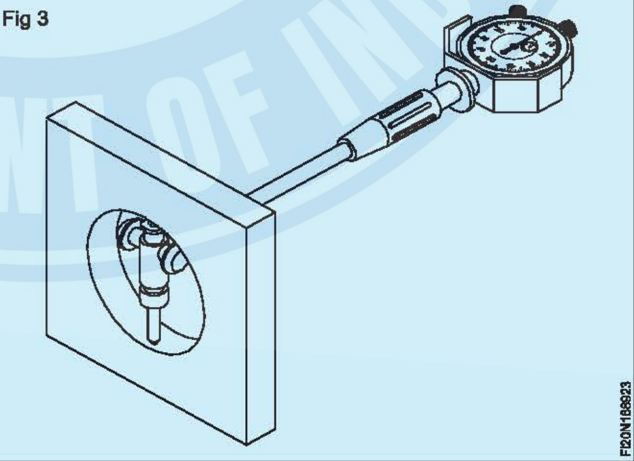
These anvils are interchangeable. The selection of the anvil is made depending on the diameter of the bore to be measured. For certain types of bore dial gauges, extension rings/washers are provided for extending the range of measurement.

Sliding plunger: This actuates the movement of the dial for reading the measurement.

Centering shoes/spherical supports

Certain types of bore dial gauges are provided with a pair of ground discs. (Fig 3)

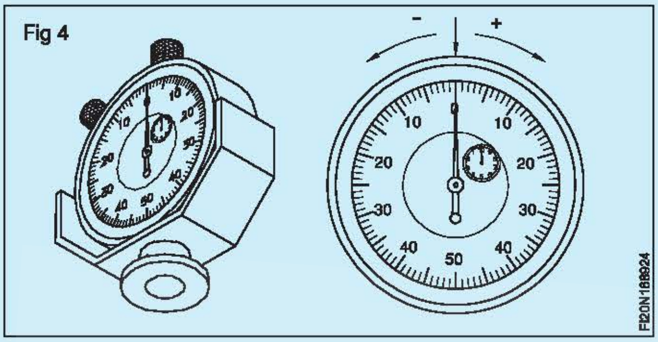
Fig 3



This maintains the alignment of the measuring faces in the centre of the bore. For some types, two spherical supports which are spring-loaded are provided.

Dial Indicator (Fig 4)

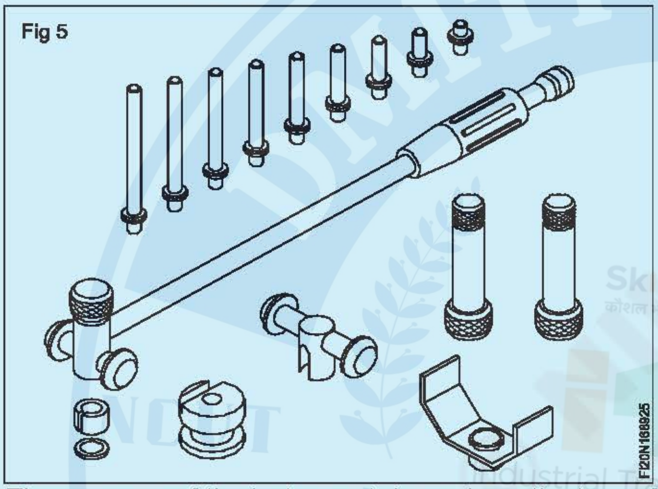
Fig 4



This has graduations marked on the dial. The graduations has marked in clockwise and anticlockwise directions.

Bore dial gauges are available in various sizes with different measuring ranges. These are interchangeable measuring rods (external rods or combination washers) for measuring different sizes. (Fig 5)

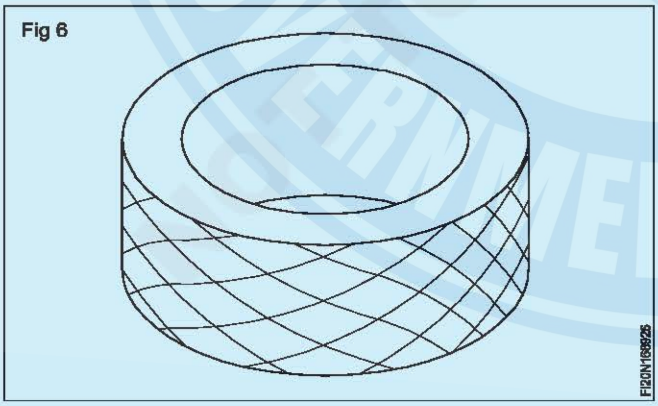
Fig 5



The accuracy of the instrument depends on the type of graduations on the dial. The most frequently used instruments have accuracies of 0.001 mm and 0.01 mm.

The dial gauge should be set to zero before taking measurement. Setting rings are available for zero setting. (Fig 6)

Fig 6



While taking measurements press the spring-loaded end (plunger) as it enters into the setting device or in the bore being measured. Slightly rock and steady the device for keeping the measuring faces in position. (Fig 7)

Slip gauges fixed in a setting fixture can also be used for zero setting. (Fig 8)

Fig 7

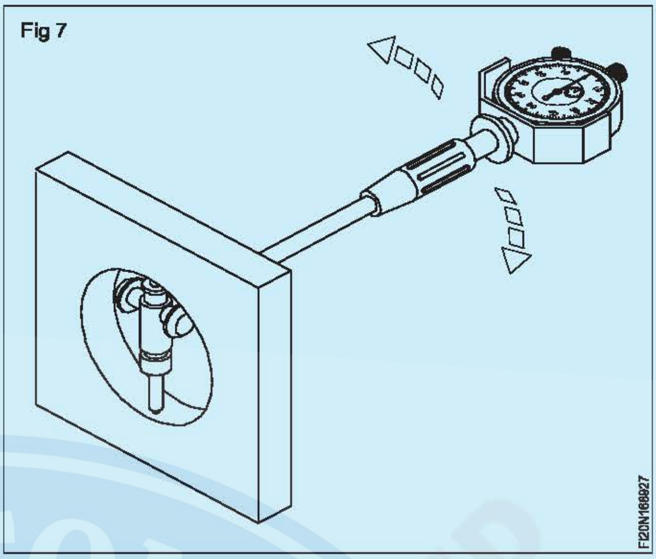
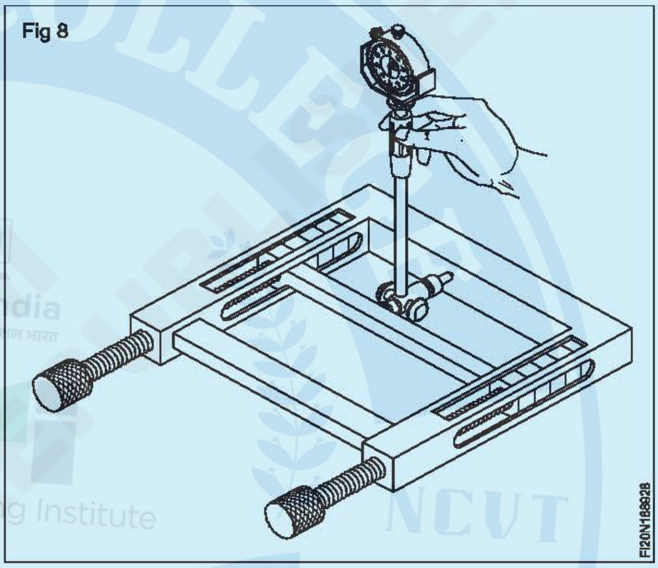
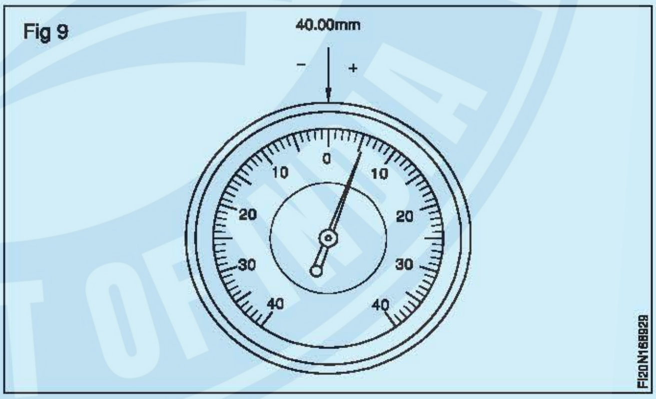


Fig 8



Reading the dial indicator (Fig 9)

Fig 9



When taking the reading, first check the measuring range and the subdivisions of the scale. The indicator in the figure has a range of 0.8 mm and is graduated 0-40 in both directions. Thus the value of each division is 0.01 mm.

The indicator shows positive deviations in the clockwise direction and negative deviations in the anticlockwise direction.

Classroomassignment		
Basic measurement		**Value measured**
30.0 mm		29.97 - 29.98 ☐ 30.02 - 30.03 ☐ 30.03 - 30.04 ☐ 30.04 - 30.05 ☐
23.0 mm		22.92 - 22.93 ☐ 22.93 - 22.94 ☐ 22.94 - 22.95 ☐ 22.96 - 22.97 ☐
47.8 mm		47.86 - 47.87 ☐ 47.88 - 47.89 ☐ 47.92 - 47.93 ☐ 47.96 - 47.97 ☐

53.0 mm		52.92 - 52.93 ☐ 52.93 - 52.94 ☐ 53.96 - 53.97 ☐ 53.97 - 53.98 ☐
65.0 mm		64.75 - 64.76 ☐ 64.79 - 64.80 ☐ 64.83 - 64.84 ☐

Digital dial indicator

Objectives: At the end of this lesson you shall be able to
- **define digital dial indicator.**

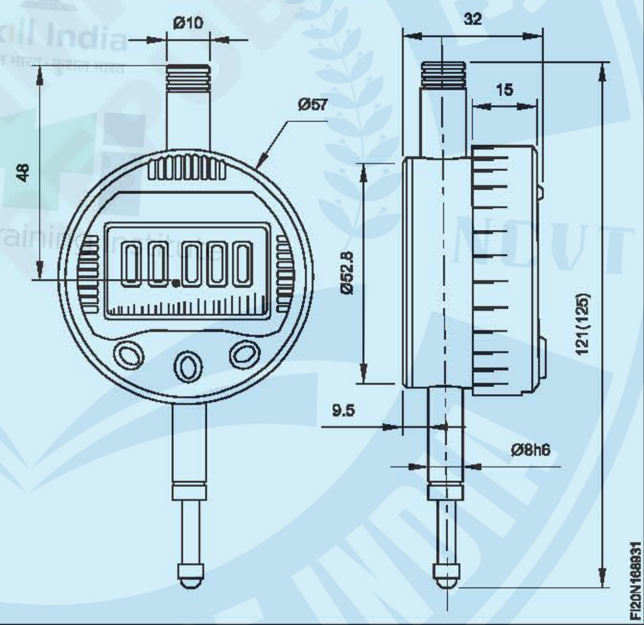
Digital dial indicator: With the advent of electronics, the clock face (dial) in some indicators are now a days replaced with digital displace (usually LCD's) and the dial readings are also replaced by linear encoders.

Digital indicators have some advantages over their analog predecessors, many models of digital indicator can record and transmit the data electronically through a computer, through an interface such as RS 232 or USB, this facilitates statistical process control (SPC), because a computer can record the measurement results in a tabular dataset (such as database table or spread sheet) and interpret them (by performing statistical analysis on them). This obviates manual recordings of long columns of numbers, which not only reduce the risk of the operator by avoiding errors (such as digit transpositions) but also really improves the productivity of the process by freeing the human efforts from time - consuming data recording and copying tasks.

Another advantages is that they can be switched between metric and british units by the press of a button, thus avoids the provision of separate unit conversion system.

Therefore the digital dial indicator is having more advantage over the ordinary dial indicator.

Fig 1 DIGITAL DIAL INDICATOR



The digital dial indicator accuracy is 0.001mm in metric and 0.0001 inch in british.

Measurement of quality in cylindrical bore using three point internal micrometer

Objectives: This shall help you to
- **state the uses of a three-point internal micrometer**
- **identify the parts of a three-point internal micrometer**
- **state the features of the three-point internal micrometer.**

The three-point internal micrometers (Fig 1) are useful for:

- Measuring the diameters of through and blind holes.
- Checking cylindricity and roundness of bores.

The commonly used three-point internal micrometers have a least count of 0.005 mm.

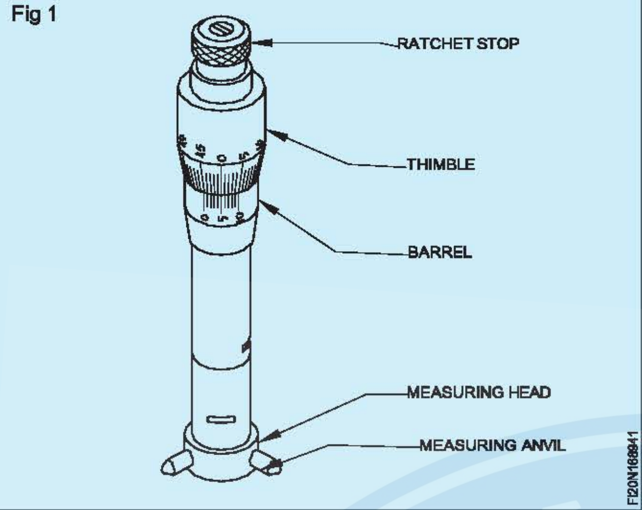


Fig 1

Parts

- Measuring head consisting of three measuring anvils
- Ratchet stop
- Thimble
- Barrel

This micrometer has a cone spindle which advances when the thimble is rotated clockwise. The movement of the cone spindle makes the measuring anvils to move forward and backward uniformly. The three measuring anvils facilitate self-alignment of the instrument within the bore.

Three-point internal micrometers are available in different sizes permitting measurement within a range.

The ratchet stop permits uniform pressure between the anvils and the work-surface being measured.

These micrometers are provided with one or more zero setting rings. (Fig 2)

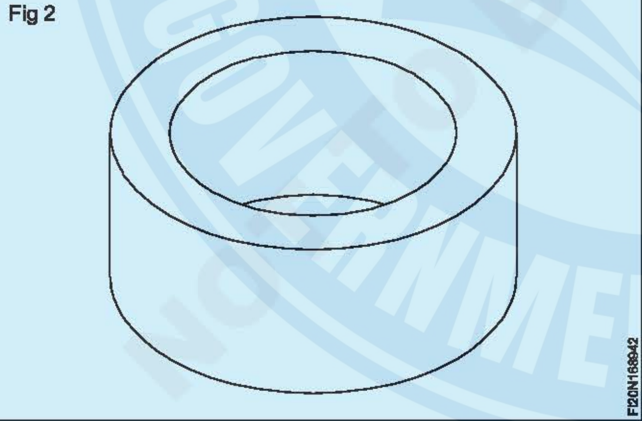


Fig 2

Before taking measurement, the zero setting has to be checked using setting ring. (Fig 3)

The position of the anvils can be reset by loosening the barrel using a screwdriver provided for this purpose.

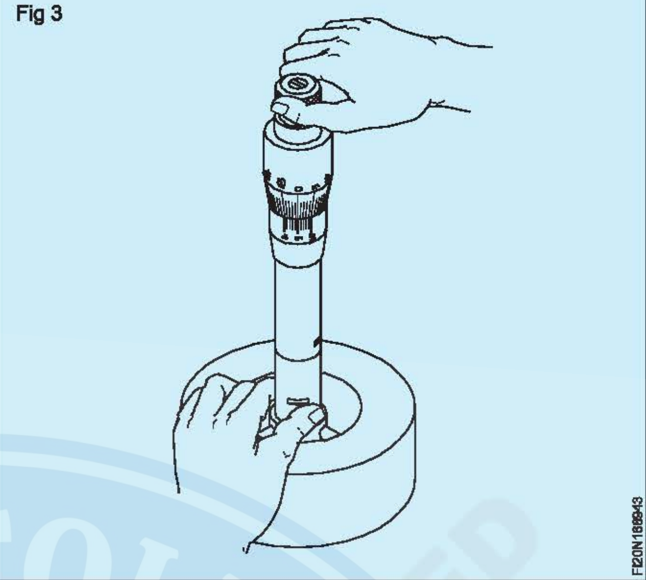


Fig 3

Depending on the depth of the bore the length of the micrometer cab be varied using an extension rod. (Fig 4)

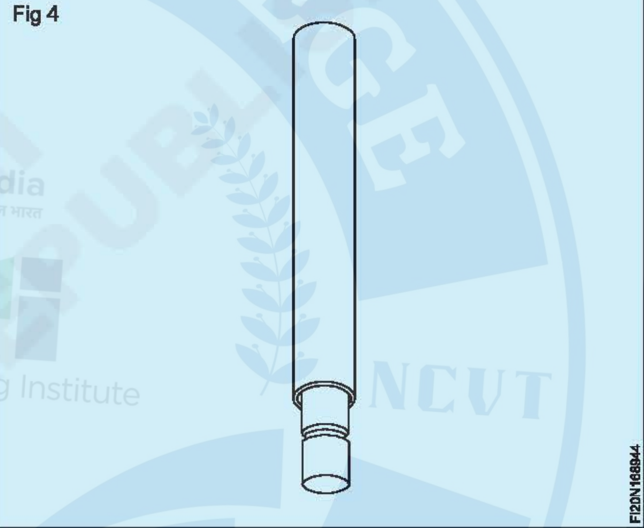


Fig 4

A spanner is provided for changing the extension rods. (Fig 5)

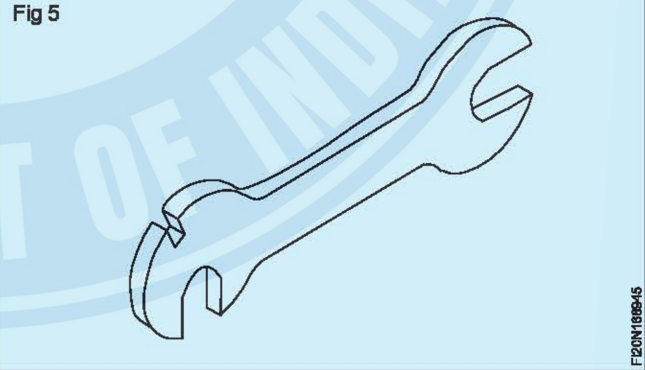


Fig 5

These instruments are available in various sizes for different uses.

They are also available in analogue or digital read-outs.