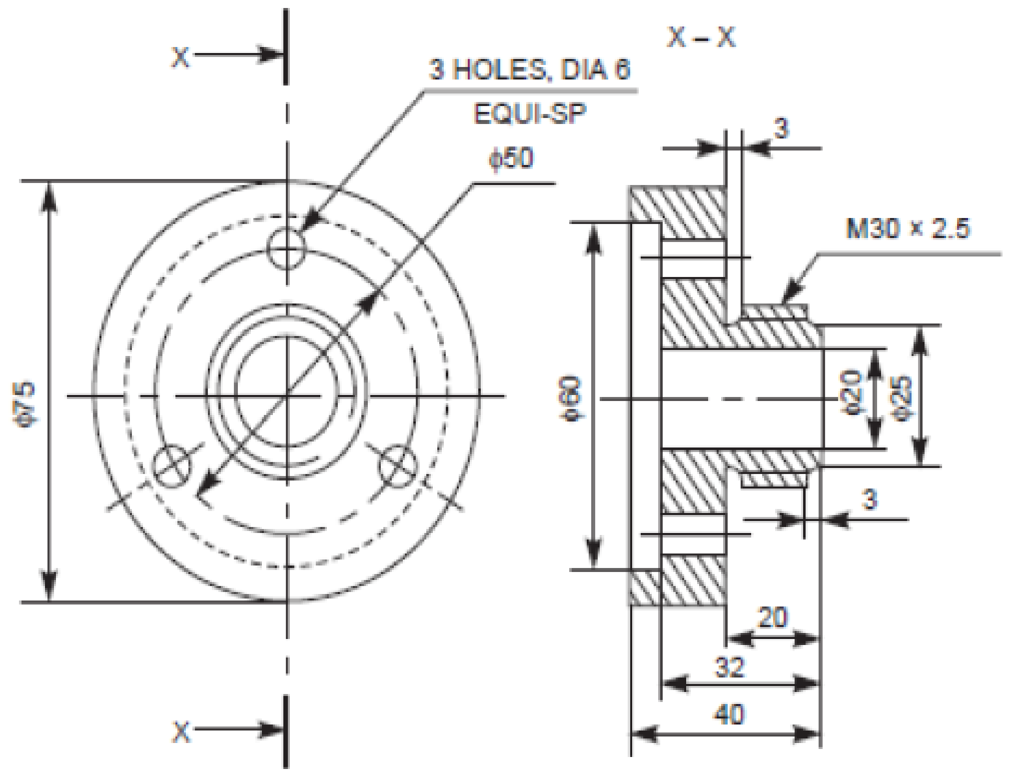
MECHANICAL DRAWING

Introduction to Limits , Fits & Tolerances

CLASSIFICATION OF DRAWINGS

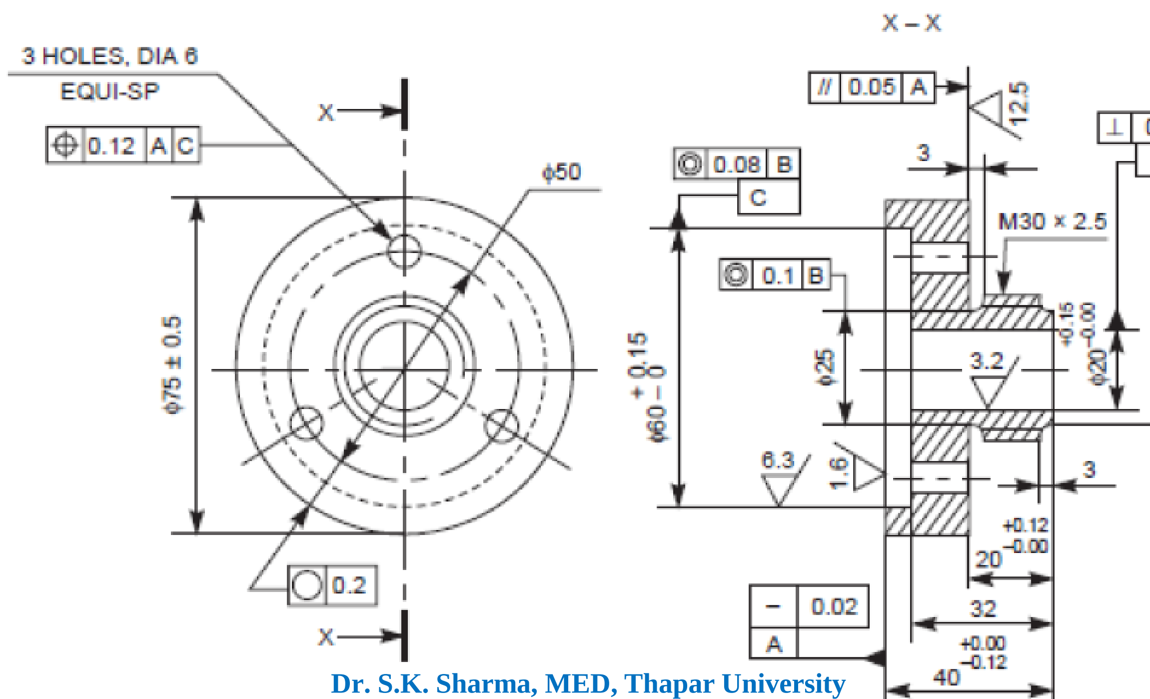
- Machine Drawing-
- Pertaining to machine parts or components.
- presented through a number of orthographic views.
- Size & shape of component is fully understood.



CLASSIFICATION OF DRAWINGS

- Production Drawing –

- Referred as working drawing.
- Should furnish all dimensions, limits & special finishing processes such as heat treatment, honing, lapping, surface finish, etc.
- Title should also mention the material used for the product, number of parts required.



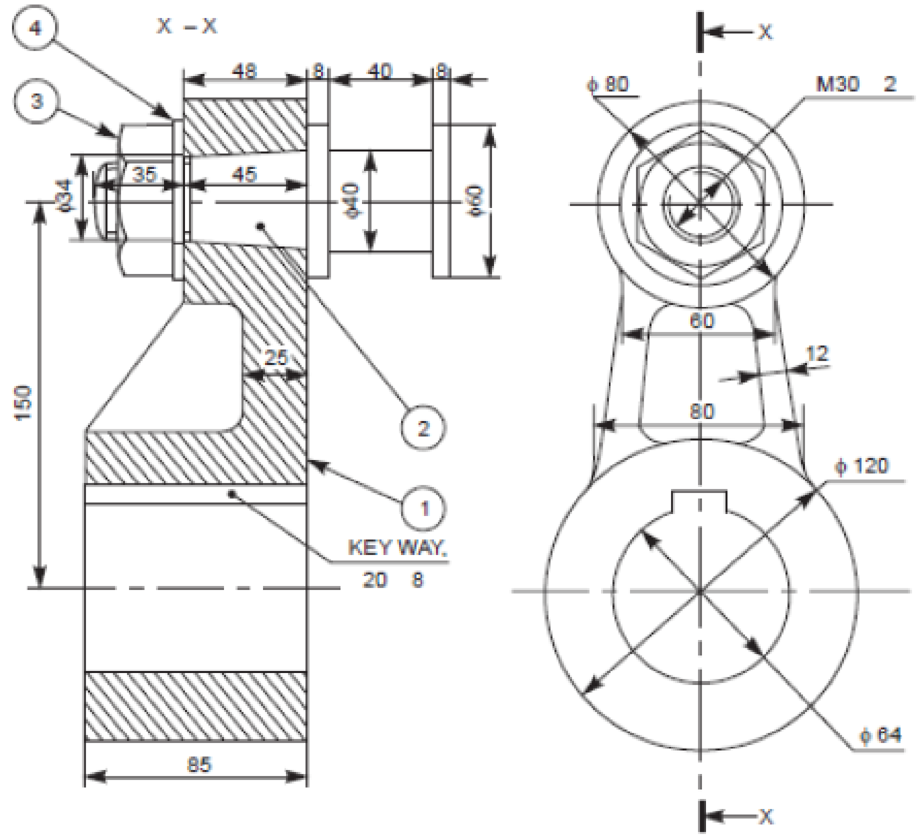
CLASSIFICATION OF DRAWINGS

- **Part Drawing-**

- Detailed drawing of a component to facilitate its manufacture.
- Follows principles of orthographic projection

- **Assembly Drawing-**

- A drawing that shows the various parts of a machine in their correct working locations.



Parts List

Part No.	Name	Material	Qty
1	Crank	Forged Steel	1
2	Crank Pin	45C	1
3	Nut	MS	1
4	Washer	MS	1

TERMINOLOGY

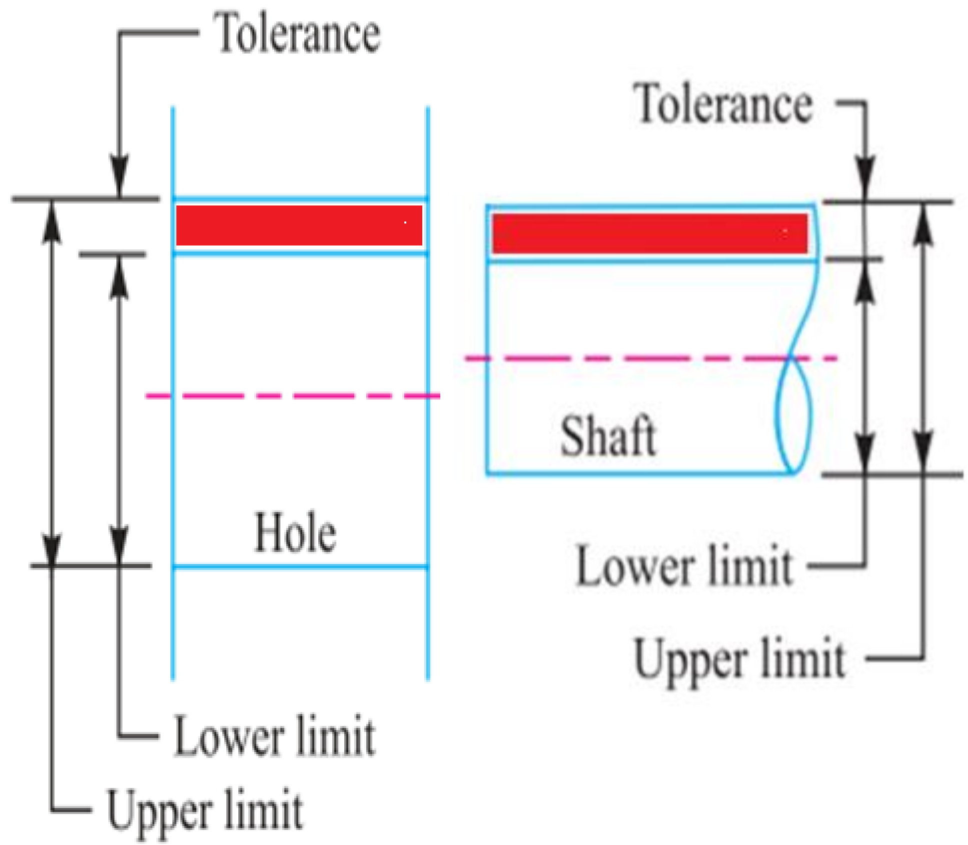
- **BASIC SIZE:** calculated by designer to withstand the expected loads without failure.
- **STANDARD SIZE:** for interchangeability . e.g. Bolts, nuts etc.

NATURAL VARIABILITY OF PROCESSES: Inherent Variations in the size due to natural conditions like variations in material, environmental fluctuations, vibrations, human variability, measurements etc. It is an unavoidable process.

- **ACTUAL SIZE:** measured dimension of a part. Bound to have variations.

LIMITS

- There are two extreme possible sizes of a component.
- The largest permissible size for a component is called upper limit and smallest size is called lower limit.



TOLERANCE

- It is the difference between lower and upper limits
- Narrow range, specially for fitting parts.

DEVIATIONS

- Difference between actual manufactured size and Basic size.

- **LOWER DEVIATION:** It is the algebraic difference between the minimum limit of size and the basic size.

- **UPPER DEVIATION:** It is the algebraic difference between the maximum limit and the basic size.

ZERO LINE

- It is the straight line corresponding to the basic size. The deviations are measured from this line.

HOLE

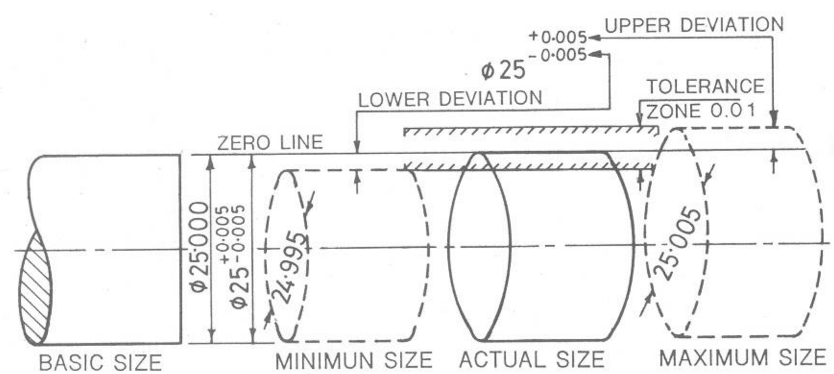
Max Hole size – Basic Size = Upper Deviation

Min Hole size – Basic Size = Lower Deviation

SHAFT

Max shaft size – Basic Size = Upper Deviation

Min shaft size – Basic Size = Lower Deviation



Fundamental Deviation

- Upper or lower deviation whichever is closer to zero line.

Sum up:

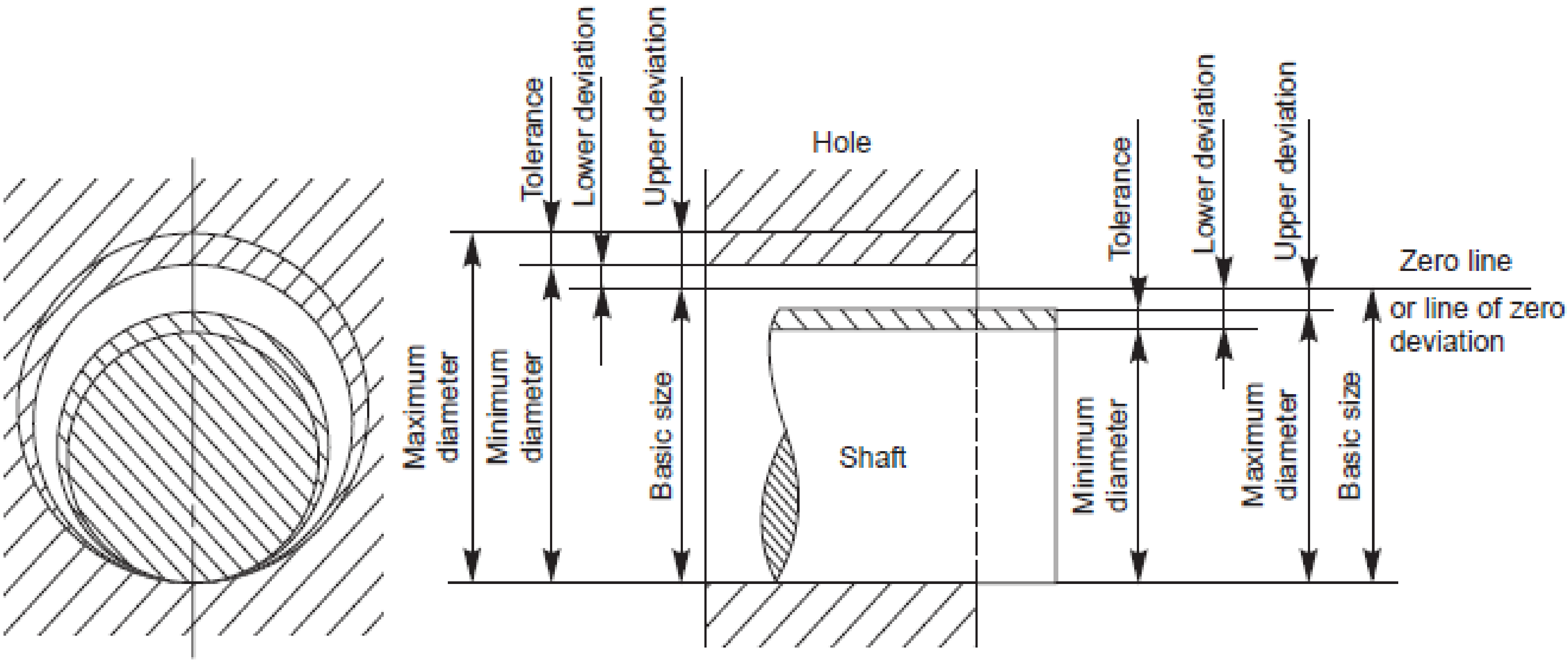


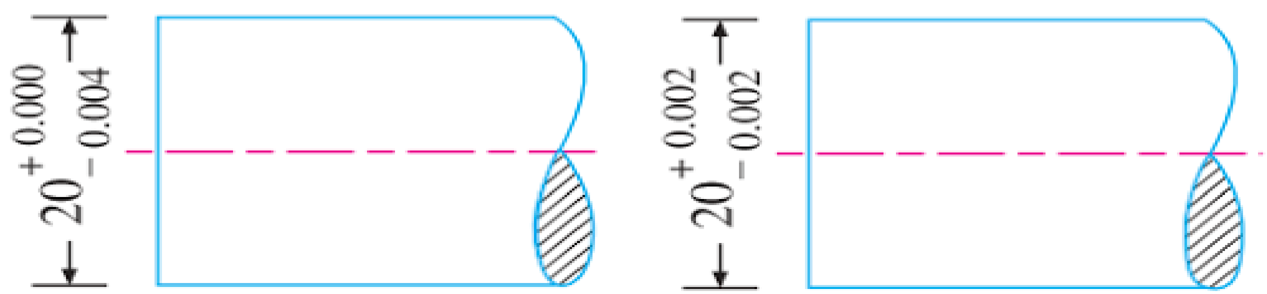
Diagram illustrating basic size deviations and tolerances

POSITIONAL TOLERANCES

- Two types of positional tolerances are used:

1. Unilateral tolerances
2. Bilateral tolerances

- When tolerance is on one side of basic size, it is called unilateral and if it is both in plus and minus then it is known as bilateral tolerance.



(*a*) Unilateral tolerance (*b*) Bilateral tolerance.

Who decides Tolerances???

- Designer suggests the tolerance zone depending on the functionality/application.
- Largely decides the manufacturing processes to be used.
- Manufacturing $cost = \frac{1}{Tolerance\ Zone}$
- Size of the component also influences the tolerance.

International tolerances (IT) Grades

- Grouping of tolerance with almost same level of relative accuracy.
- 18 Grades

IT0 1	IT0	IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
MOST PRECISE															MOST COARSE		
HIGH					COST OF PRODUCTION										LOW		

IT Grades Vs Manufacturing Processes

Tolerance grade	Manufacturing process and applications	Machine required
IT01, IT0 IT1 to IT5	Super finishing process, such as lapping, diamond boring etc. Use: Gauges	Super finishing machines
IT6	Grinding	Grinding machines
IT7	Precision turning, broaching, honing	Boring machine, honing machine
IT8	Turning, boring and reaming	Lathes, capstan and automats
IT9	Boring	Boring machines
IT10	Milling, slotting, planing, rolling and extrusion	Milling machine, slotting machine, planing machine and extruders
IT11	Drilling, rough turning	Drilling machine, lathes
IT12, IT13, IT14	Metal forming processes	Presses
IT15	Die casting, stamping	Die casting machine, hammer machine
IT16	Sand casting	—

IT Grades Vs Size

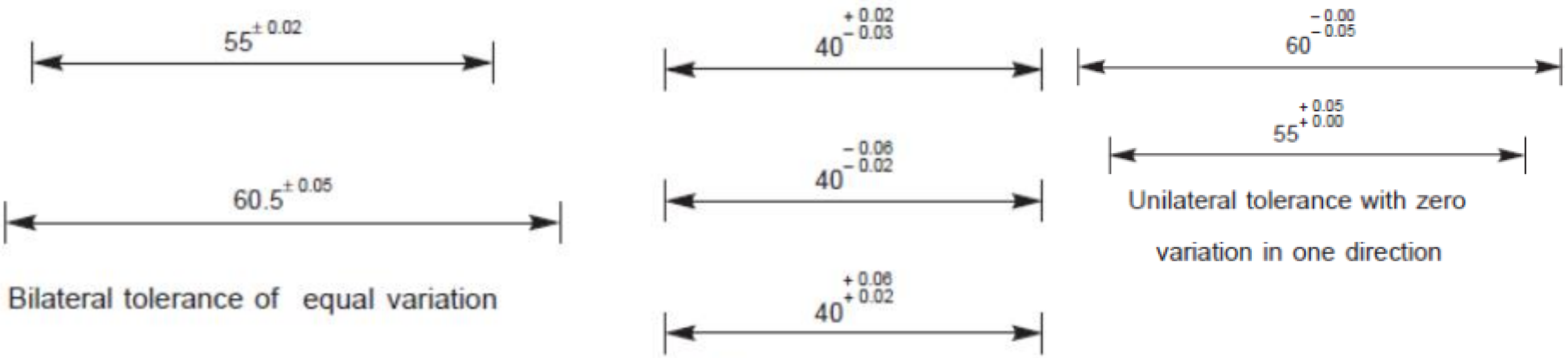
FUNDAMENTAL TOLERANCES OF GRADES 01, 0 AND 1 TO 16

Diameter steps in mm	Values of tolerance in microns (1 micron = 0.001 mm)																	
	Tolerance grades																	
	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14*	15*	16*
To and inc 3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
Over 3 To and inc 6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
Over 6 To and inc 10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
Over 10 To and inc 18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
Over 18 To and inc 30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
Over 30 To and inc 50	0.6	1	1.5	2.5	4	7	11	16	25	39	60	110	160	250	390	620	1000	1600
Over 50 To and inc 80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
Over 80 To and inc 120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
Over 120 To and inc 180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
Over 180 To and inc 250	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
Over 250 To and inc 315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
Over 315 To and inc 400	3	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
Over 400 To and inc 500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1150	2500	4000

* Upto 1 mm, Grades 14 to 16 are not provided.

Representation of Tolerances

- **Method 1 (Basic Size with Deviations):**



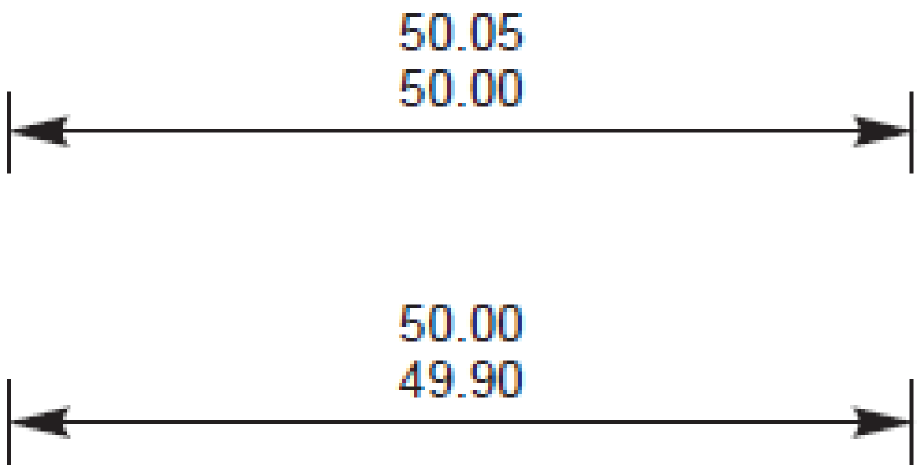
Bilateral tolerance of equal variation

Bilateral tolerance of unequal variation

Unilateral tolerance with zero variation in one direction

Representation of Tolerances

- **Method 2 (Maximum & Minimum Limits):**

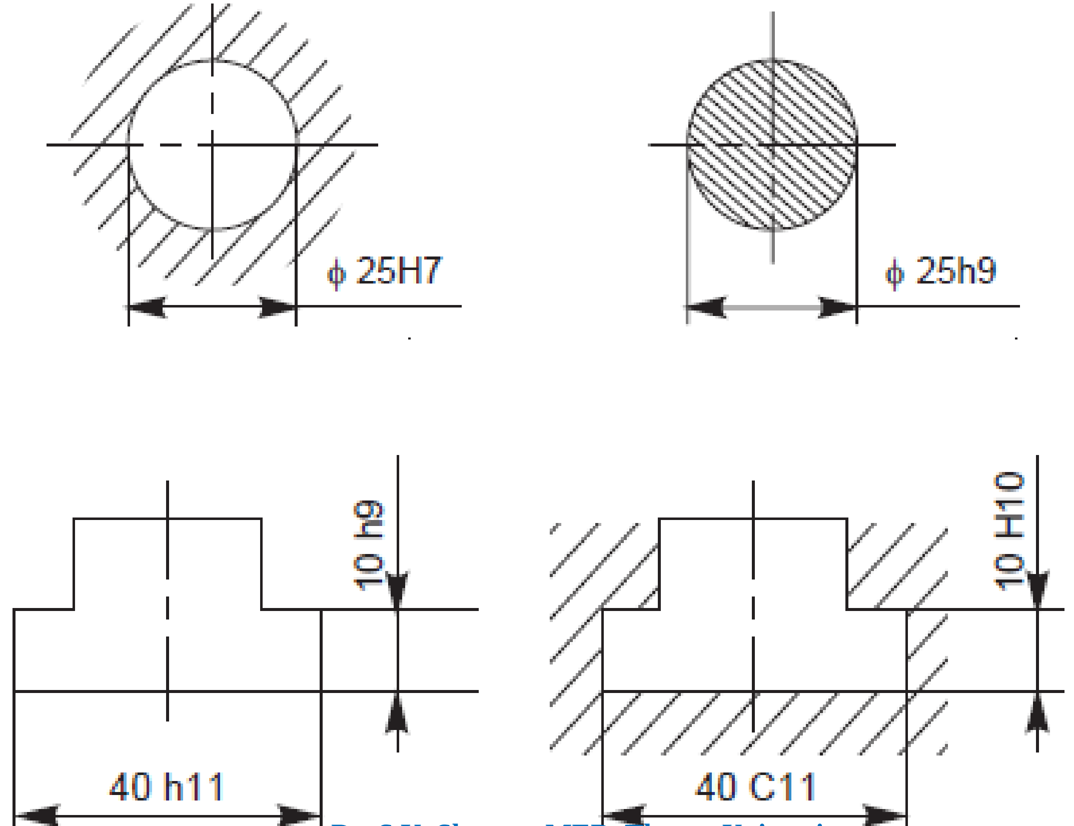


Maximum and minimum size directly indicated

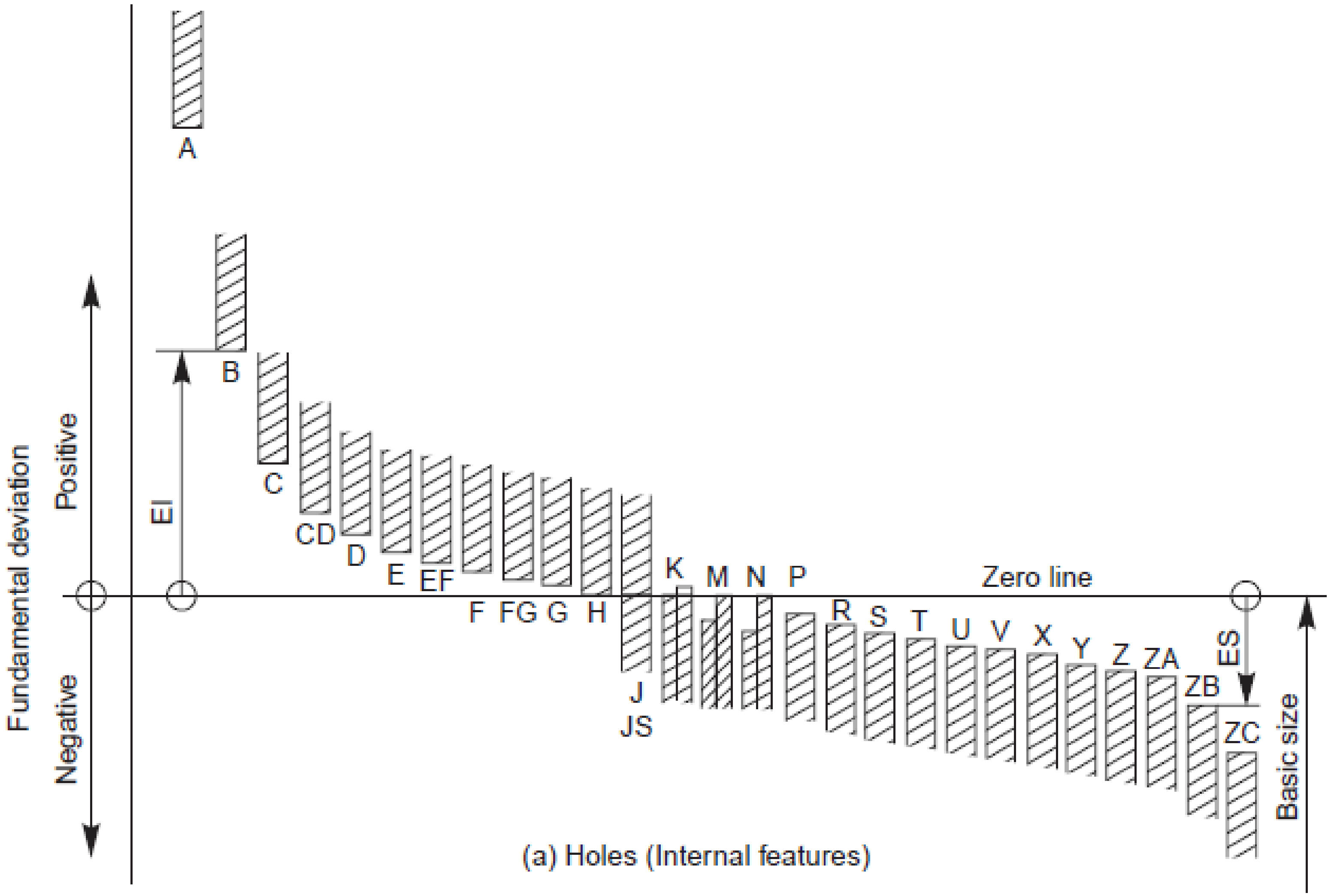
Representation of Tolerances

- **Method 3 (Basic Size + Fundamental Deviation + Tolerance)**

BASIC SIZE+ Alphabet + Number



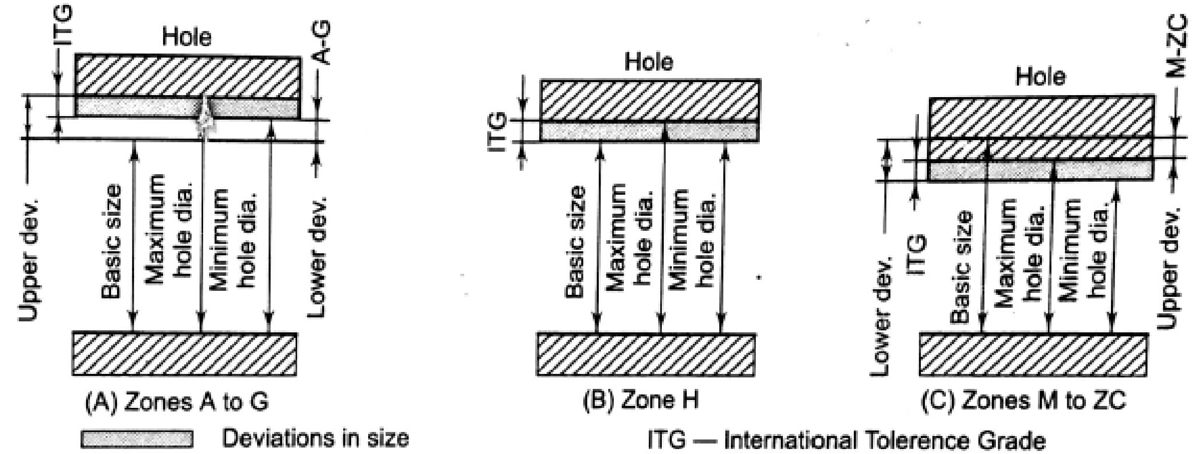
Fundamental Deviation for Holes

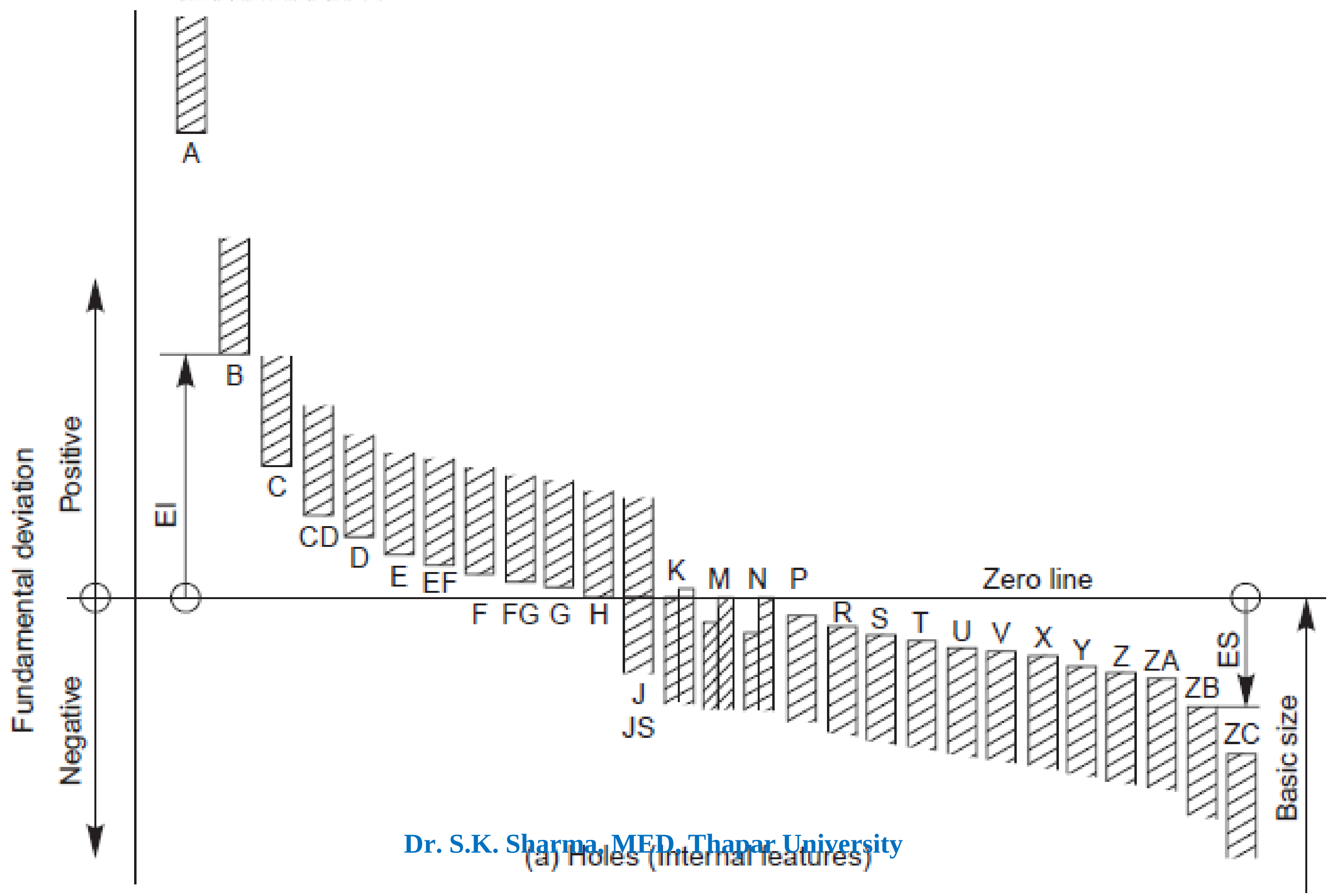


(a) Holes (Internal features)

Table 19.5 Fundamental deviations for holes

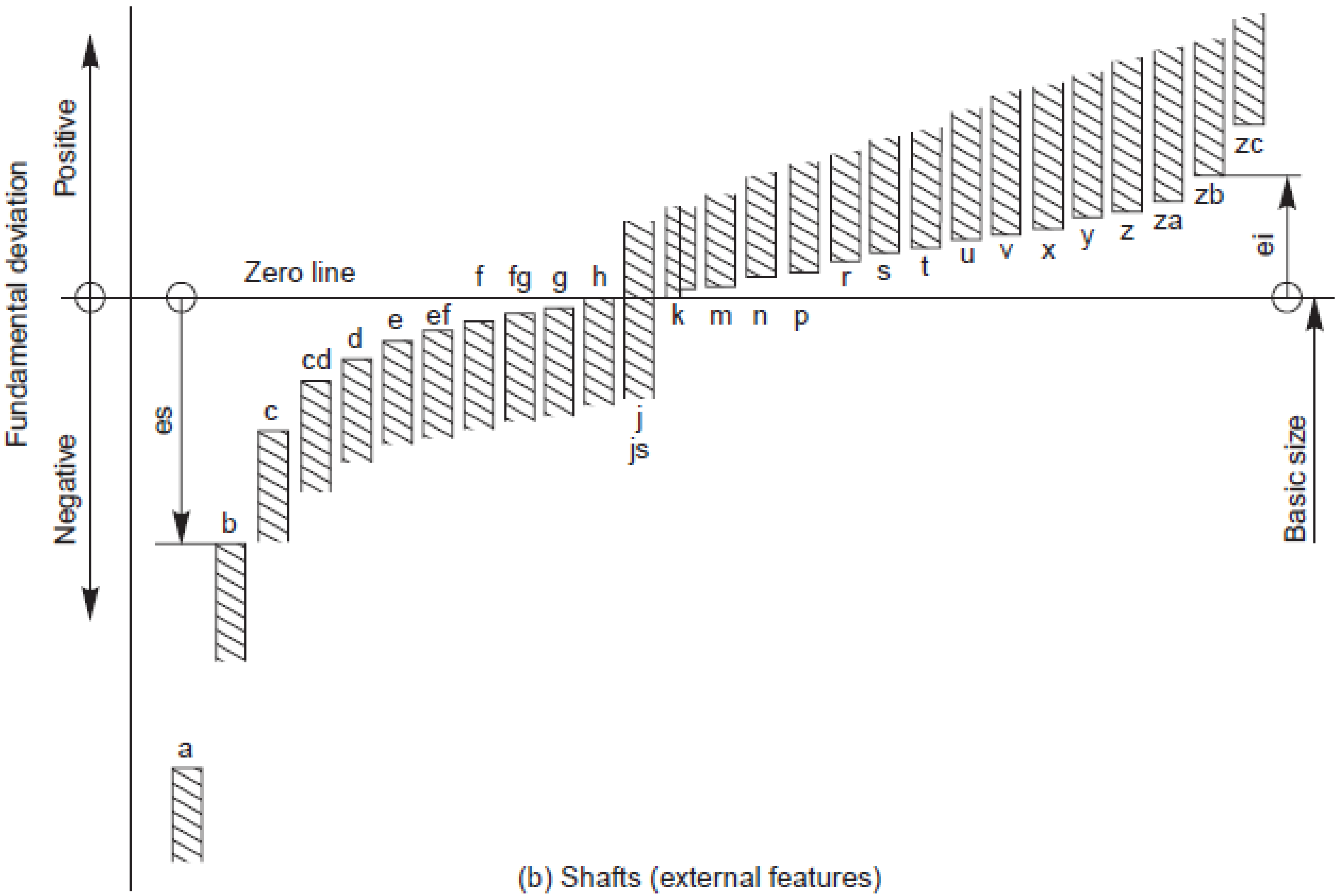
Diameter in mm		Lower deviation in microns									Upper deviation in microns																
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*JS*	*J*	*J*	*K*	*M*	*N*	*P*	*R*	*S*	*T*	*U*	*V*	*X*	*Y*	*Z*	*ZA*	*ZB*	*ZC*
		Grades									Grades																
Over	Up to	All	All	All	All	All	All	All	All	All	6	7	7	>8	<8	>7	>7	>7	>7	>7	>7	>7	>7	>7	>7	>7	>7
–	3	270	140	60	20	14	6	2	0	±IT/2	2	4	0	–2	–4	–6	–10	–14	–	–18	–	–20	–	–26	–32	–40	–60
3	6	270	140	70	30	20	10	4	0	±IT/2	5	6	3	–4	–8	–12	–15	–19	–	–23	–	–28	–	–35	–42	–50	–80
6	10	280	150	80	40	25	13	5	0	±IT/2	5	8	5	–6	–10	–15	–19	–23	–	–28	–	–34	–	–42	–52	–67	–97
10	14	290	150	95	50	32	16	6	0	±IT/2	6	10	6	–7	–12	–18	–23	–28	–	–33	–	–40	–	–50	–64	–90	–130
14	18	290	150	95	50	32	16	6	0	±IT/2	6	10	6	–7	–12	–18	–23	–28	–	–33	–39	–45	–60	–77	–108	–	150
18	24	300	160	110	65	40	20	7	0	±IT/2	8	12	6	–8	–15	–22	–28	–35	–	–41	–47	–54	–63	–73	–98	–136	–188
24	30	300	160	110	65	40	20	7	0	±IT/2	8	12	6	–8	–15	–22	–28	–35	–41	–48	–55	–64	–75	–88	–118	–160	–218
30	40	310	170	120	80	50	25	9	0	±IT/2	10	14	7	–9	–17	–26	–34	–43	–48	–60	–68	–80	–94	–112	–148	–200	–274
40	50	320	180	130	80	50	25	9	0	±IT/2	10	14	7	–9	–17	–26	–34	–43	–54	–70	–81	–97	–114	–136	–180	–242	–325
50	65	340	190	140	100	60	30	10	0	±IT/2	13	18	9	–11	–20	–32	–41	–53	–66	–87	–102	–122	–144	–172	–226	–300	–405
65	80	360	200	150	100	60	30	10	0	±IT/2	13	18	9	–11	–20	–32	–43	–59	–75	–102	–120	–146	–174	–210	–274	–360	–480
80	100	380	220	170	120	72	36	12	0	±IT/2	16	22	10	–13	–23	–37	–51	–71	–91	–124	–146	–178	–214	–258	–335	–445	–585
100	120	410	240	180	120	72	36	12	0	±IT/2	16	22	10	–13	–23	–37	–54	–79	–104	–144	–172	–210	–254	–310	–400	–525	–690
120	140	460	260	200	145	85	43	14	0	±IT/2	18	26	12	–15	–27	–43	–63	–92	–122	–170	–202	–248	–300	–365	–470	–620	–800
140	160	520	280	210	145	85	43	14	0	±IT/2	18	26	12	–15	–27	–43	–65	–100	–134	–190	–228	–280	–340	–415	–535	–700	–900
160	180	580	310	230	145	85	43	14	0	±IT/2	18	26	12	–15	–27	–43	–68	–108	–146	–210	–252	–310	–380	–465	–600	–780	–1000
180	200	660	340	240	170	100	50	15	0	±IT/2	22	26	13	–17	–31	–50	–77	–122	–166	–236	–284	–350	–425	–520	–670	–880	–1150
200	225	740	380	260	170	100	50	15	0	±IT/2	22	30	13	–17	–31	–50	–80	–130	–180	–258	–310	–385	–470	–575	–740	–960	–1250
225	250	820	420	280	170	100	50	15	0	±IT/2	22	30	13	–17	–31	–50	–84	–140	–196	–584	–340	–425	–520	–640	–820	–1050	–1350
250	280	920	480	300	190	110	56	17	0	±IT/2	25	36	16	–20	–34	–56	–94	–158	–218	–315	–385	–475	–580	–710	–920	–1200	–1550
280	315	1050	540	330	190	110	56	17	0	±IT/2	25	36	16	–20	–34	–56	–98	–170	–240	–350	–425	–525	–650	–790	–1000	–1300	–1700
315	355	1200	600	360	210	125	62	18	0	±IT/2	29	39	17	–21	–37	–62	–108	–190	–268	–390	–475	–590	–730	–900	–1150	–1500	–1900
355	400	1350	680	400	210	125	62	18	0	±IT/2	29	39	17	–21	–37	–62	–114	–208	–294	–435	–530	–660	–820	–1000	–1300	–1650	–2100
400	450	1500	760	440	230	135	68	20	0	±IT/2	33	43	18	–23	–40	–68	–126	–232	–330	–490	–595	–740	–920	–1100	–1450	–1850	–2400
450	500	1650	840	480	230	135	68	20	0	±IT/2	33	43	18	–23	–40	–68	–132	–252	–360	–540	–660	–820	–1000	–1250	–1600	–2100	–2600





(a) Holes (internal features)

Fundamental Deviation for Shafts

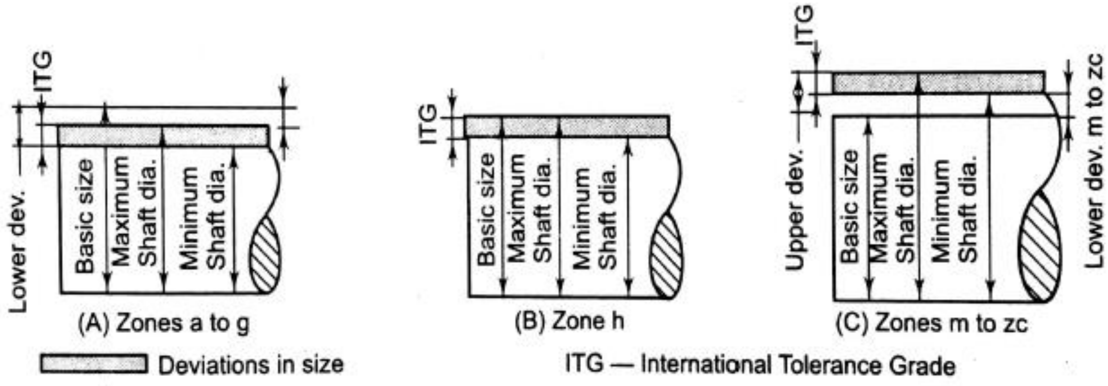


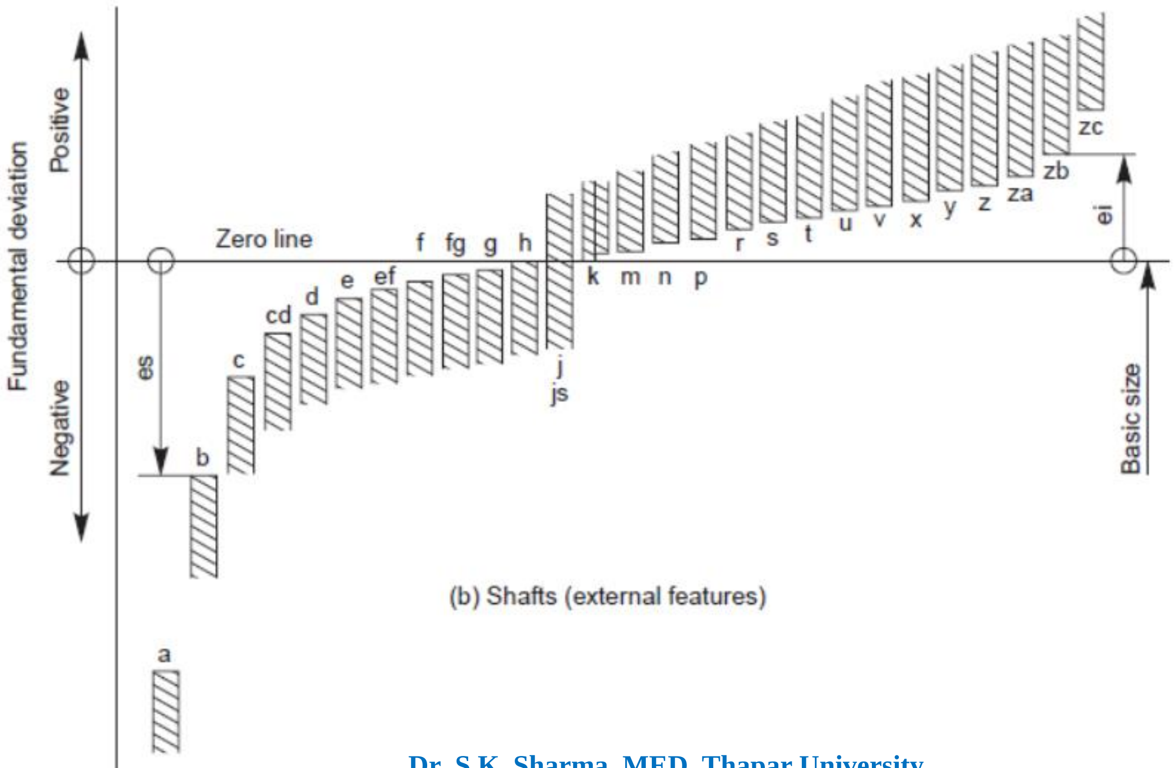
(b) Shafts (external features)

Table 19.6 Fundamental deviations for shafts

Diameter in mm		Upper deviation in microns									Lower deviation in microns																	
		a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*JS*	*j*	*j*	*k*	*m*	*n*	*p*	*r*	*s*	*t*	*u*	*v*	*x*	*y*	*z*	*za*	*zb*	*zc*
		Grades									Grades			Grades													
Over	Up to	All	All	All	All	All	All	All	All	All	5,6	7	4-7	All	All	All	All	All	All	All	All	All	All	All	All	All	All
–	3	−270	−140	−60	−20	−14	−6	−2	0	±IT/2	−2	−4	0	2	4	6	10	14	–	18	–	20	–	26	32	40	60
3	6	−270	−140	−70	−30	−20	−10	−4	0	±IT/2	−2	−4	1	4	8	12	15	19	–	23	–	28	–	35	42	50	80
6	10	−280	−150	−80	−40	−25	−13	−5	0	±IT/2	−2	−5	2	6	10	15	19	23	–	28	–	34	–	42	52	67	97
10	14	−290	−150	−95	−50	−32	−16	−6	0	±IT/2	−3	−6	3	7	12	18	23	28	–	33	–	40	–	50	64	90	130
14	18	−290	−150	−95	−50	−32	−16	−6	0	±IT/2	−3	−6	4	7	12	18	23	28	–	33	39	45	–	60	77	108	150
18	24	−300	−160	−110	−65	−40	−20	−7	0	±IT/2	−4	−8	2	8	15	22	28	35	–	41	47	54	63	73	98	136	188
24	30	−300	−160	−110	−65	−40	−20	−7	0	±IT/2	−4	−8	2	8	15	22	28	35	41	48	55	64	75	88	118	160	218
30	40	−310	−170	−120	−80	−50	−25	−9	0	±IT/2	−5	−10	2	9	17	26	34	43	48	60	68	80	94	112	148	200	274
40	50	−320	−180	−130	−80	−50	−25	−9	0	±IT/2	−5	−10	2	9	17	26	34	43	54	70	81	97	114	136	180	242	325
50	65	−340	−190	−140	−100	−60	−30	−10	0	±IT/2	−7	−12	2	11	20	32	41	53	66	87	102	122	144	172	226	300	405
65	80	−360	−200	−150	−100	−60	−30	−10	0	±IT/2	−7	−12	2	11	20	32	43	59	75	102	120	146	174	210	274	360	480
80	100	−380	−220	−170	−120	−72	−36	−12	0	±IT/2	−9	−15	3	13	23	37	51	71	91	124	146	178	214	258	335	445	585
100	120	−410	−240	−180	−120	−72	−36	−12	0	±IT/2	−9	−15	3	13	23	37	54	79	104	144	172	210	254	310	400	525	690
120	140	−460	−260	−200	−145	−85	−43	−14	0	±IT/2	−11	−18	3	15	27	43	63	92	122	170	202	248	300	365	470	620	800
140	160	−520	−280	−210	−145	−85	−43	−14	0	±IT/2	−11	−18	3	15	27	43	65	100	134	190	228	280	340	415	535	700	900
160	180	−580	−310	−230	−145	−85	−43	−14	0	±IT/2	−11	−18	3	15	27	43	68	108	146	210	252	310	380	465	600	780	1000
180	200	−660	−340	−240	−170	−100	−50	−15	0	±IT/2	−13	−21	4	17	31	50	77	122	166	236	284	350	425	520	670	880	1150
200	225	−740	−380	−260	−170	−100	−50	−15	0	±IT/2	−13	−21	4	17	31	50	80	130	180	258	310	385	470	575	740	960	1250
225	250	−820	−420	−280	−170	−100	−50	−15	0	±IT/2	−13	−21	4	17	31	50	84	140	196	584	340	425	520	640	820	1050	1350
250	280	−920	−480	−300	−190	−110	−56	−17	0	±IT/2	−16	−26	4	20	34	56	94	158	218	315	385	475	580	710	920	1200	1550
280	315	−1050	−540	−330	−190	−110	−56	−17	0	±IT/2	−16	−26	4	20	34	56	98	170	240	350	425	525	650	790	1000	1300	1700
315	355	−1200	−600	−360	−210	−125	−62	−18	0	±IT/2	−18	−28	4	21	37	62	108	190	268	390	475	590	730	900	1150	1500	1900
355	400	−1350	−680	−400	−210	−125	−62	−18	0	±IT/2	−18	−28	4	21	37	62	114	208	294	435	530	660	820	1000	1300	1650	2100
400	450	−1500	−760	−440	−230	−135	−68	−20	0	±IT/2	−20	−32	5	23	40	68	126	232	330	490	595	740	920	1100	1450	1850	2400
450	500	−1650	−840	−480	−230	−135	−68	−20	0	±IT/2	−20	−32	5	23	40	68	132	252	360	540	660	820	1000	1250	1600	2100	2600

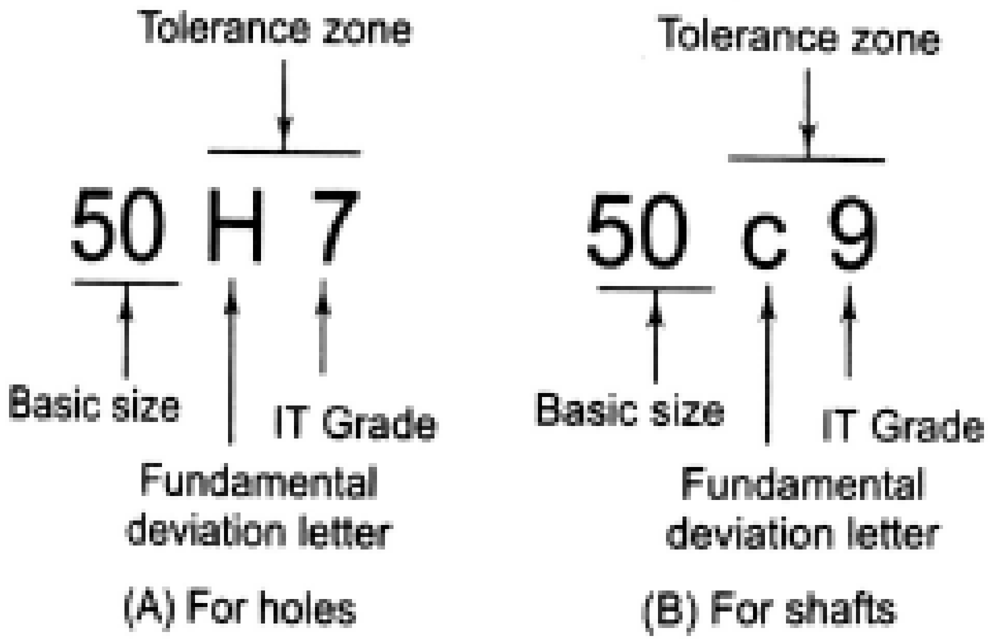
Fundamental Deviation for Shafts



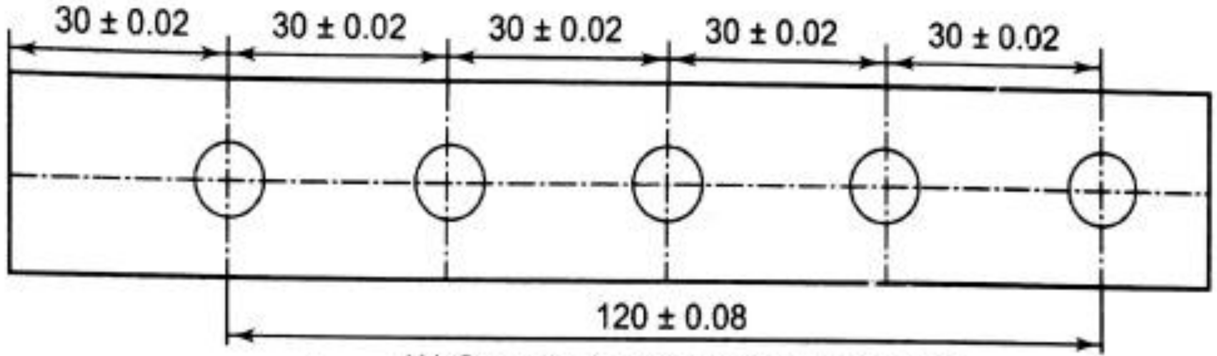


(b) Shafts (external features)

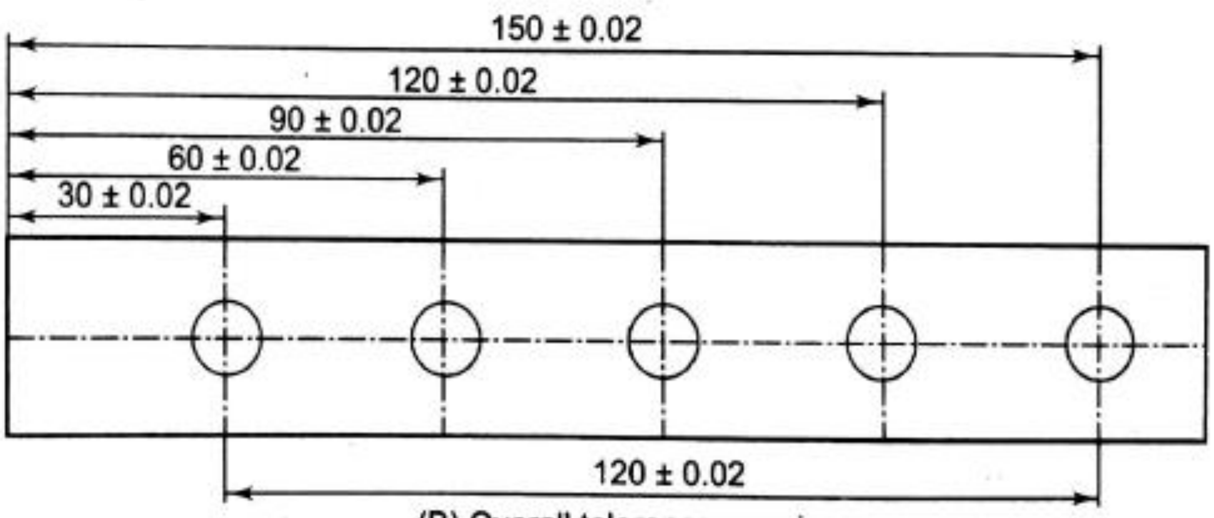
Examples:


Tolerance zone
50 H 7
Basic size
IT Grade
Fundamental deviation letter
(A) For holes
Tolerance zone
50 c 9
Basic size
IT Grade
Fundamental deviation letter
(B) For shafts

Cumulative & No Cumulative Tolerances



(A) Overall tolerance gets accumulated



(B) Overall tolerance remains same

Example 1 Figure 19.S1 shows overall limits on length as 100.0 and 99.5. Two holes are drilled at equal distance from center line at distance of 30 mm. Calculate the limits for size A. The same tolerance as of A is applied for the vertical distance between the center lines of the circles. Calculate the limits for size B.

Solution Size A is maximum when size 100 is maximum and tolerance on size 30 is minimum. Hence:

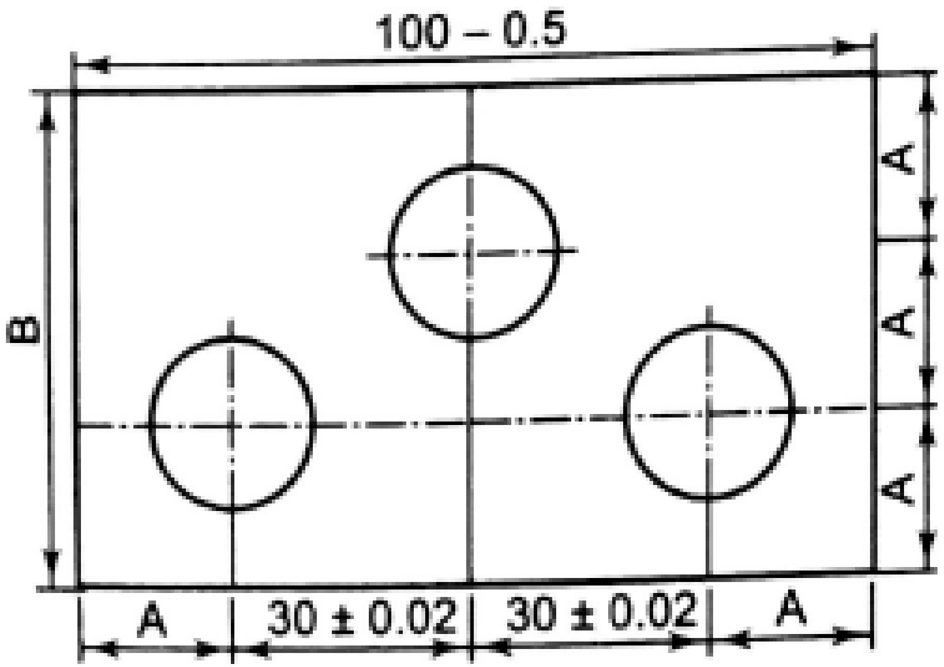
$2A\,(\text{Maximum}) = 100 - 2 \times (29.98) = 100 - 59.96 = 40.04$. Hence maximum $A = 20.02$

Size A is minimum when size 100 is minimum and tolerance on size 30 is maximum. Hence:

$2A\,(\text{Minimum}) = 99.5 - 2 \times (30.02) = 99.5 - 60.04 = 39.46$. Hence minimum $A = 19.73$

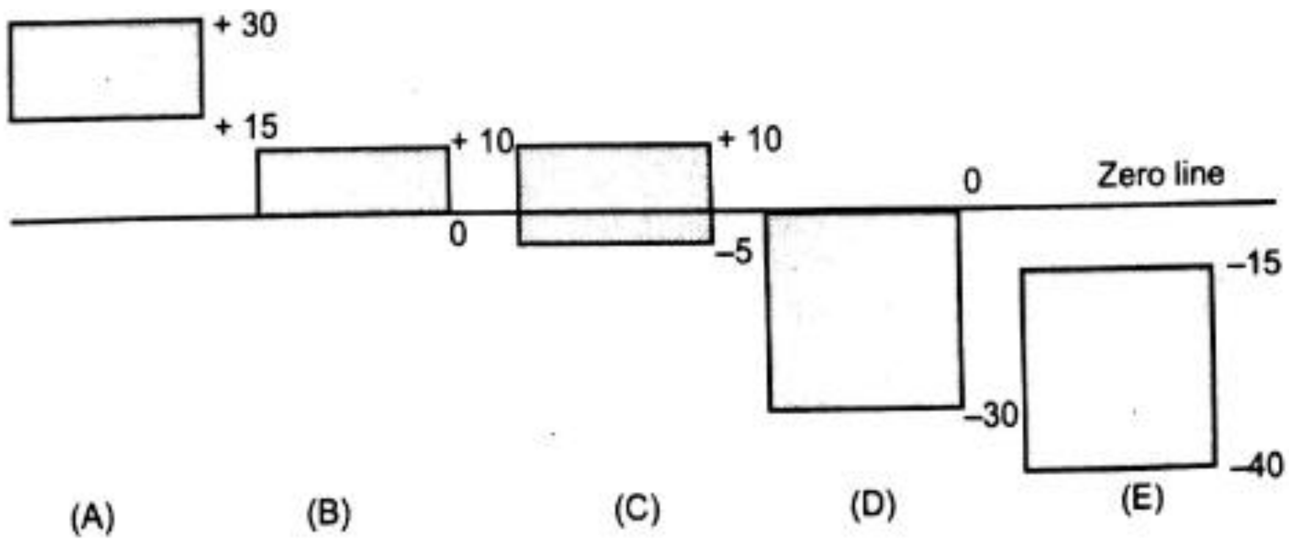
Therefore maximum size of A is 20.02 and minimum size is 19.73. or $A = 20\,^{0.02}_{0.27}$

Since $B = 3A$, hence maximum size of B = 60.06 and minimum size = 59.19. or $B = 60\,^{0.06}_{0.81}$



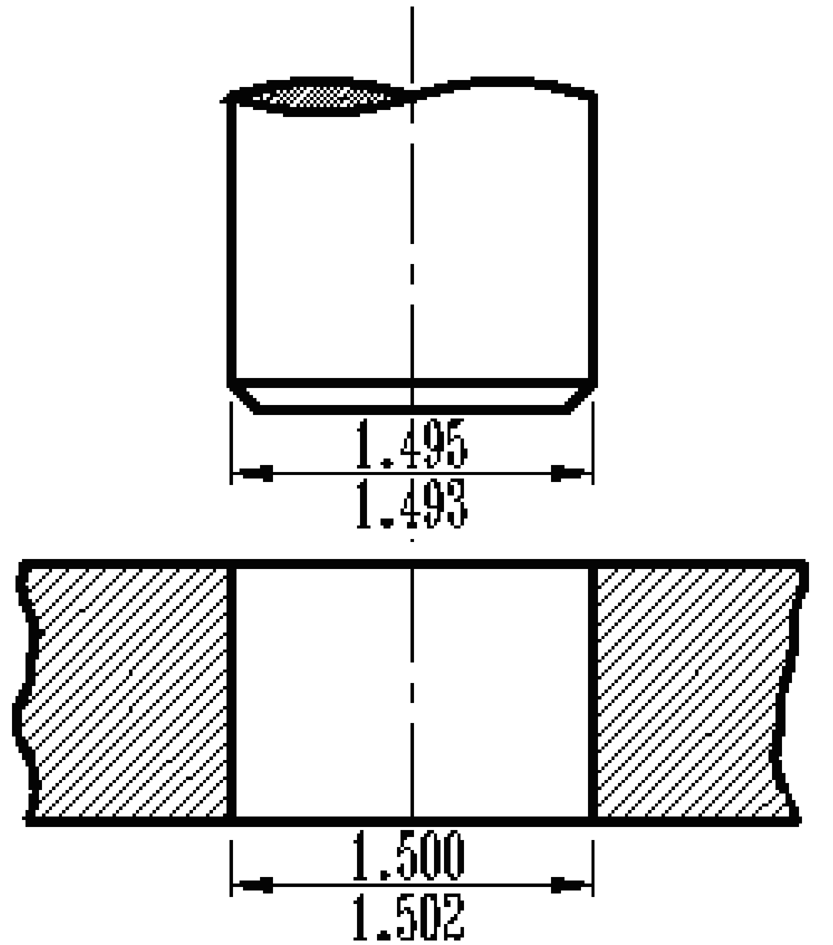
Example 2 A schematic representation of 80 mm basic size is shown by zero line in Fig. 19.S2. The deviation is shown in microns by shaded area for 5 cases from A to E. Calculate the following for each case:

a. Lower deviation
b. Upper deviation
c. Upper limit size
d. Lower limit size



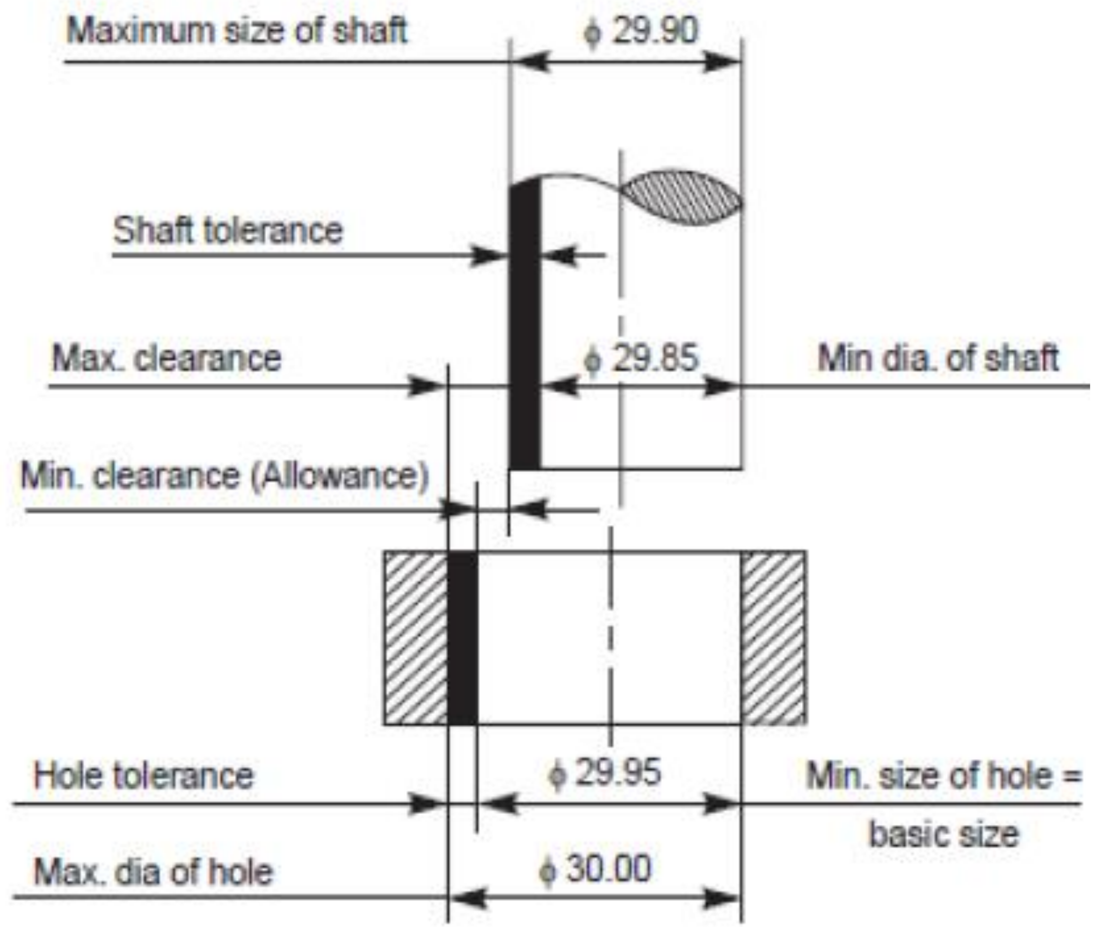
FITS

- The degree of tightness or looseness between two mating parts is called a fit.



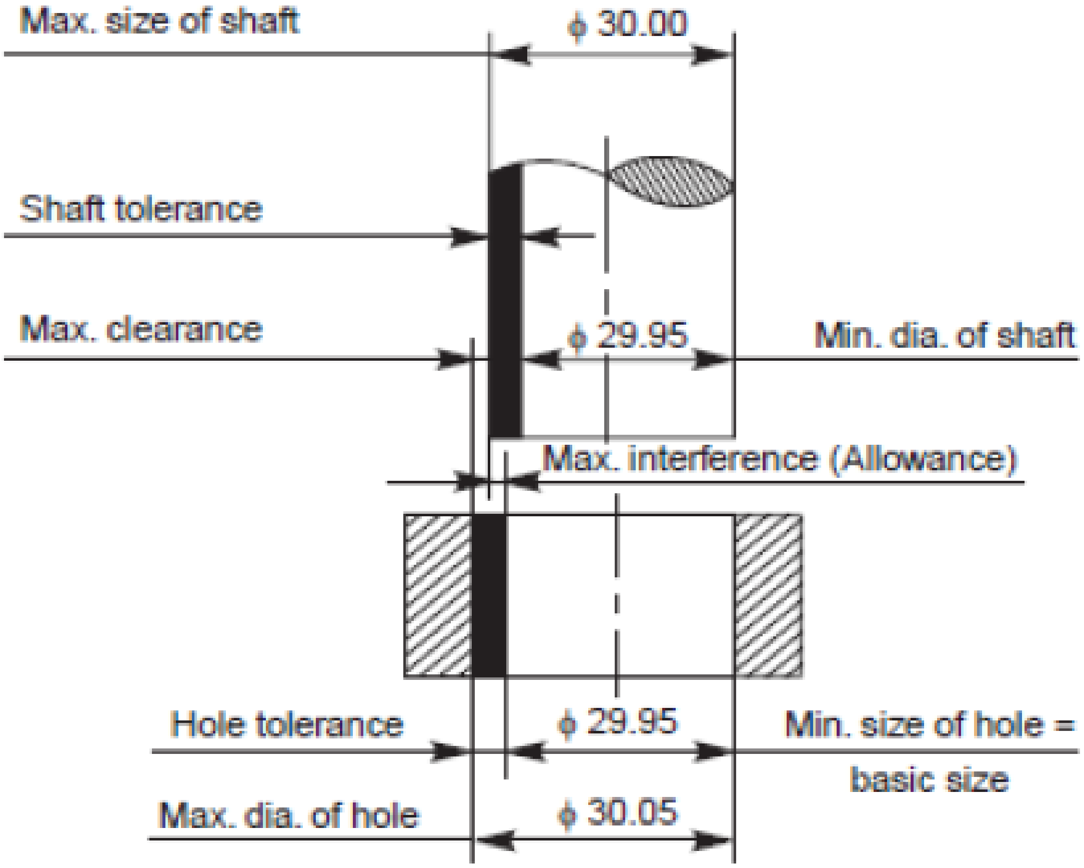
TYPES OF FITS

1. CLEARANCE FIT: There is a clearance or looseness in this type of fits. These fits maybe slide fit, easy sliding fit, running fit etc.



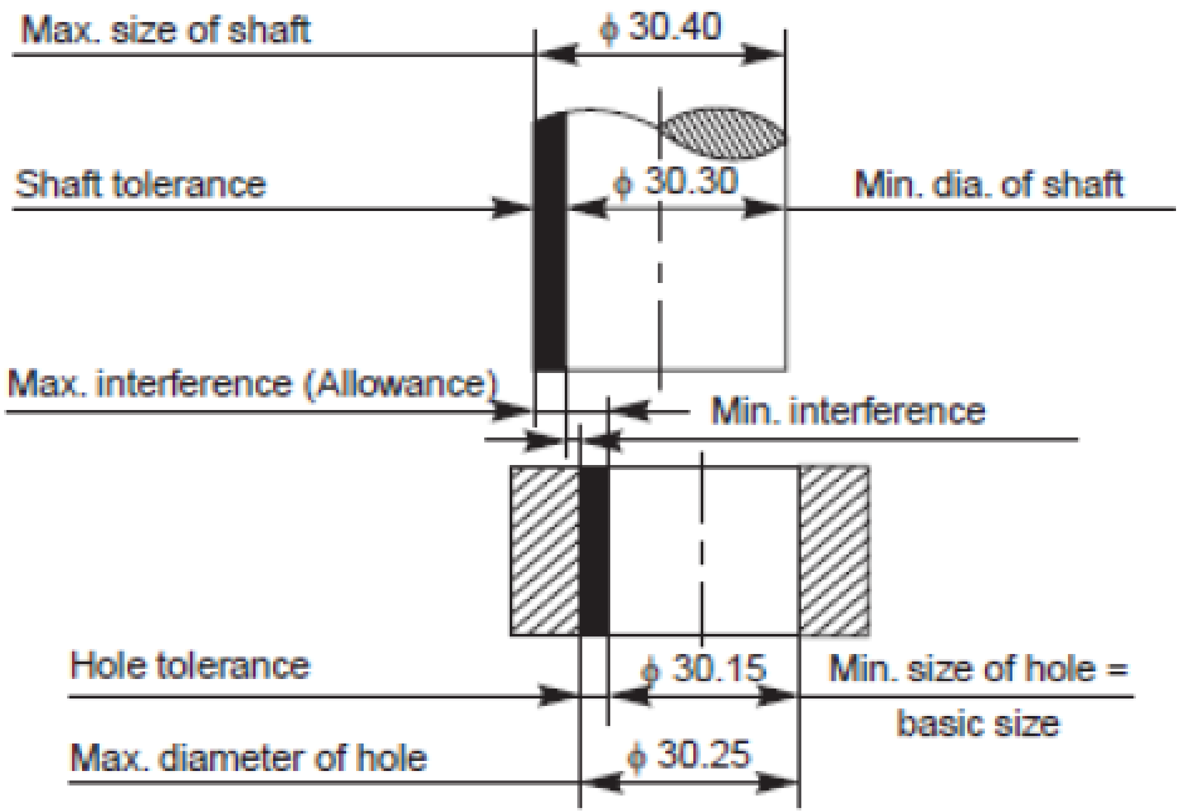
2. Transition Fit –

This fit may result in either an interference or a clearance, depending upon the actual values of the tolerance of individual parts.

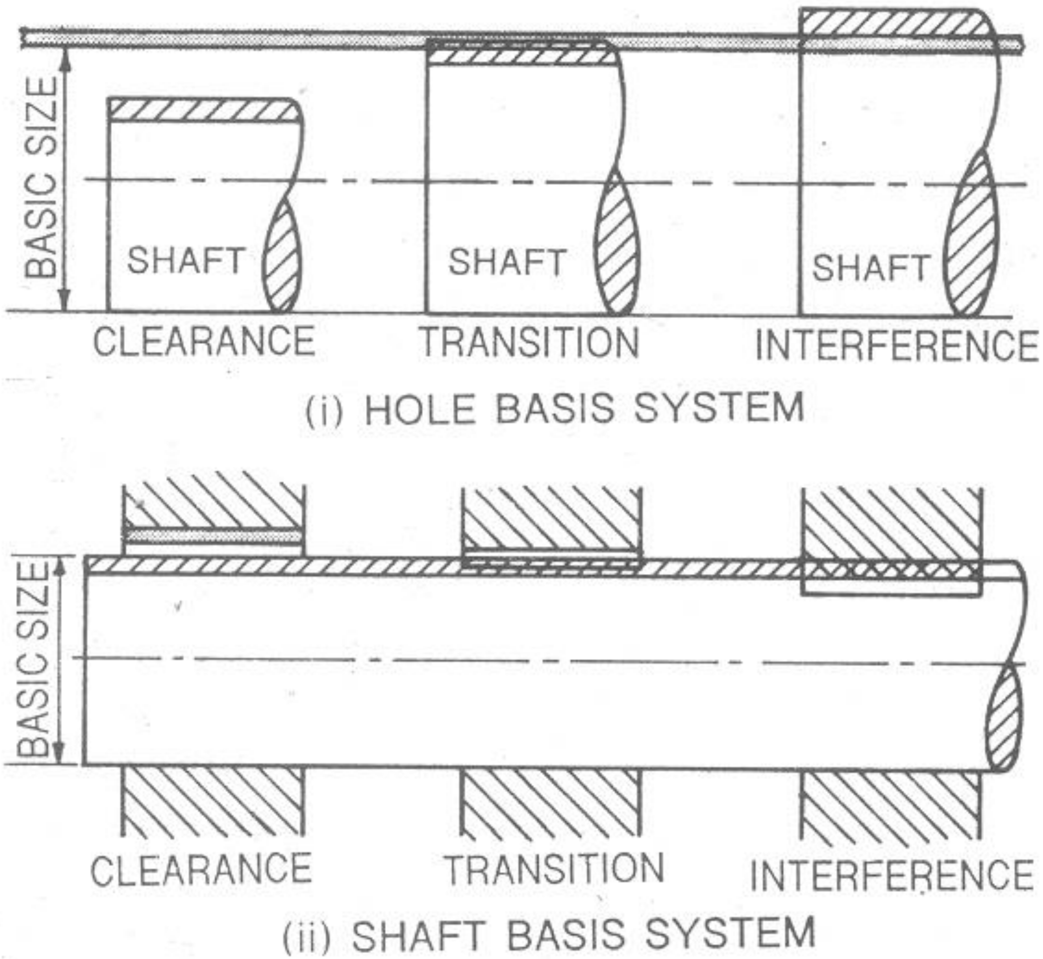


3. Interference Fit -

If the difference between the hole and shaft sizes is negative before assembly; an interference fit is obtained.



To obtain different types of fits, it is general practice to vary tolerance zone of one of the mating parts



<u>HOLE BASED SYSTEM-</u>
Size of hole is kept constant, shaft size is varied to get different fits.

<u>SHAFT BASED SYSTEM-</u>
Size of shaft is kept constant, hole size is varied to get different fits.