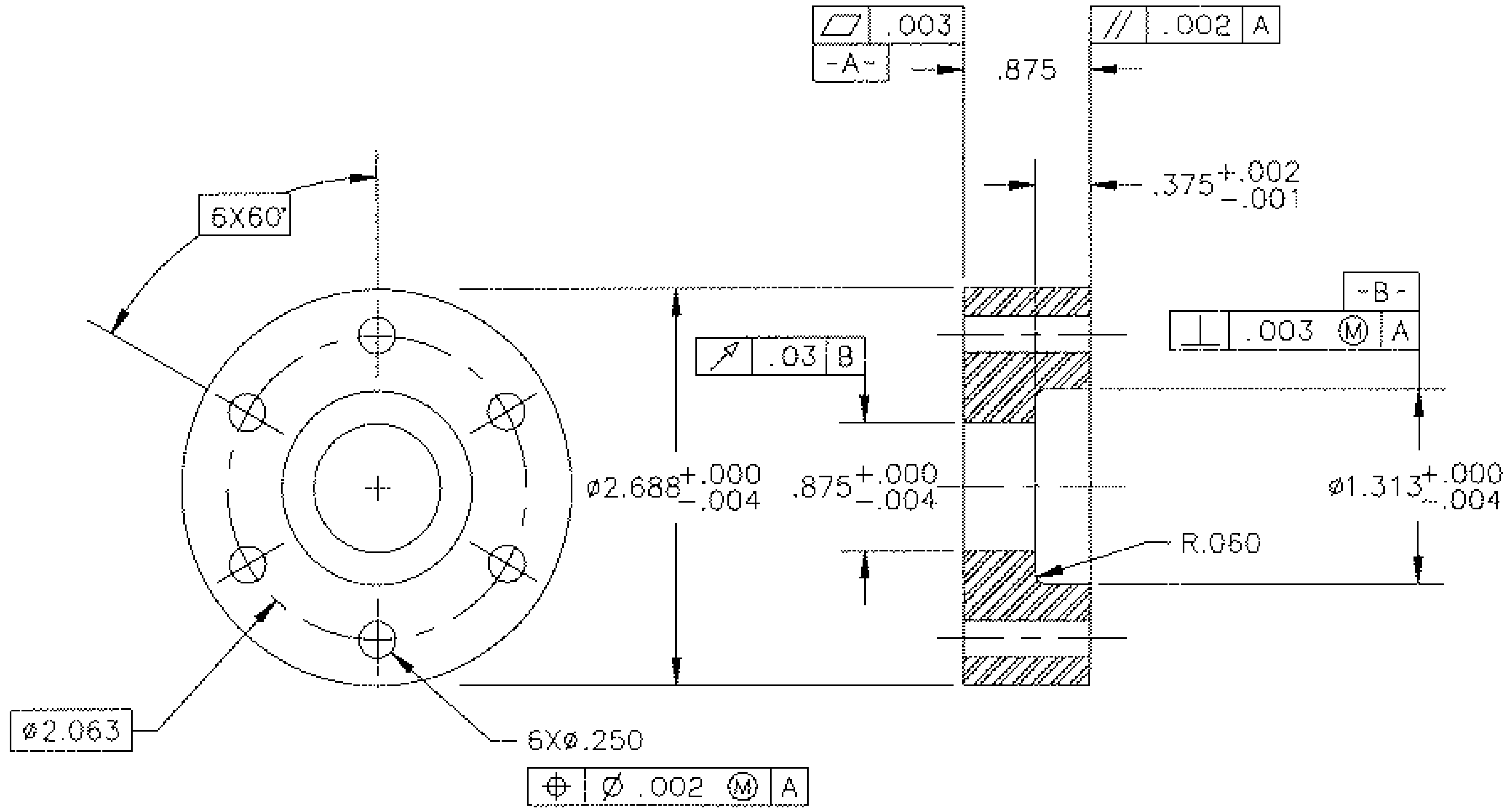
1

CHAPTER ONE

Fits and Tolerances



.003
-A-
.875
// .002 A
.375 +.002 −.001
6X60°
-B-
⊥ .003 Ⓜ A
.03 B
ø2.688 +.000 −.004
.875 +.000 −.004
ø1.313 +.000 −.004
R.060
ø2.063
6Xø.250
⌖ Ø .002 Ⓜ A

Why tolerances and fits are required?

Due to the **inevitable inaccuracy of manufacturing methods**, a part cannot be made precisely to a given dimension, the difference between maximum and minimum limits of size of a part is the tolerance.

Tolerance is the total amount that a specific dimension is permitted to vary.

There is no such thing as an "exact size". Tolerance is key to interchangeable parts.

When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called a **fit**.

Examples of Interchangeable Manufacture

Bottle caps **Rims** **Tires**

Advantages For Interchangeable Manufacture

Replacement: One such part can freely replace another, without any custom fitting (such as filling).

Easy to Assembly: This interchangeability allows easy assembly of new devices

Repairing: Easier repair of existing devices.

Minimizing time and cost: Minimizing both the time and skill required of the person doing the assembly or repair.

Rapid Manufacturing: Machine tool enables the components to be manufactured more rapidly

How to decide tolerance?

- Functional requirements of mating parts
- Cost of production
- Available manufacturing process

Choose as coarse tolerance as possible without compromising functional requirements.

Proper balance between cost and quality of parts.

1.1 Dimensional Tolerances

Some of the dimensional tolerances terms are defined as follows:

1. **Dimension** (A dimension is "a numerical value expressed in appropriate units of measure and indicated on a drawing and in other documents along with lines, symbols, and notes to define the size or geometric characteristic, or both, of a part or part feature")
2. **Size** (It is a number expressed in a particular unit in the measurement of length)
3. **Basic size** (the theoretical size used as a starting point for the application of tolerances)
4. **Actual size (of a part)** (the measured size of the finished part after machining)
5. **Design size** (The ideal size for each component (shaft and hole) based upon a selected fit)

6. Limits of size (the maximum and minimum sizes shown by the tolerance dimension)

7. Maximum limit of size (Is the maximum size permitted for the part)

8. Minimum limit of size (it is the minimum size permitted for the part limit of size)

9. Maximum material limit (condition) (is the condition of a part when it contains the most amount of material. The MMC of an external feature (such as a shaft) is the upper limit. The MMC of an internal feature(such as a hole) is the lower limit)

10. Minimum material limit (condition) (is the condition of a part when it contains the least amount of material possible. The LMC of an external feature is the lower limit of the part. The LMC of an internal feature is the upper limit of the part.)

11. Tolerance (Tolerance is the difference between maximum limit of size and minimum limit of size)

12. Zero line (Basic size) (it represents the basic size)

13. Upper deviation (It is the algebraic difference between minimum limit of size and its corresponding basic size)

14. Lower deviation (It is the algebraic difference between minimum limit of size and its corresponding basic size)

15. Tolerance zone (a region representing the difference between the upper and the lower limits)

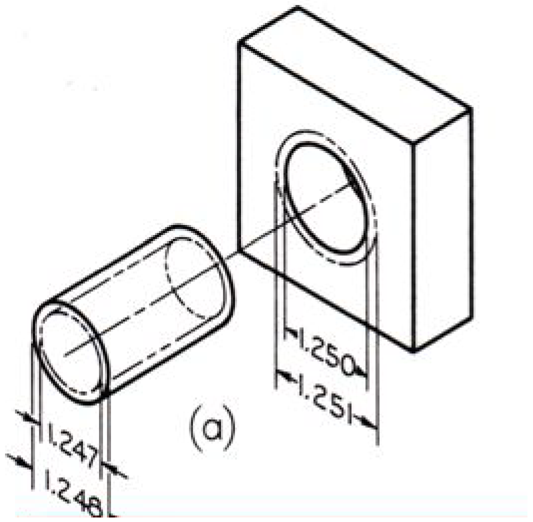
16. Unilateral tolerance (In this method of presenting the limits, variation is allowed only on one side of the zero line)

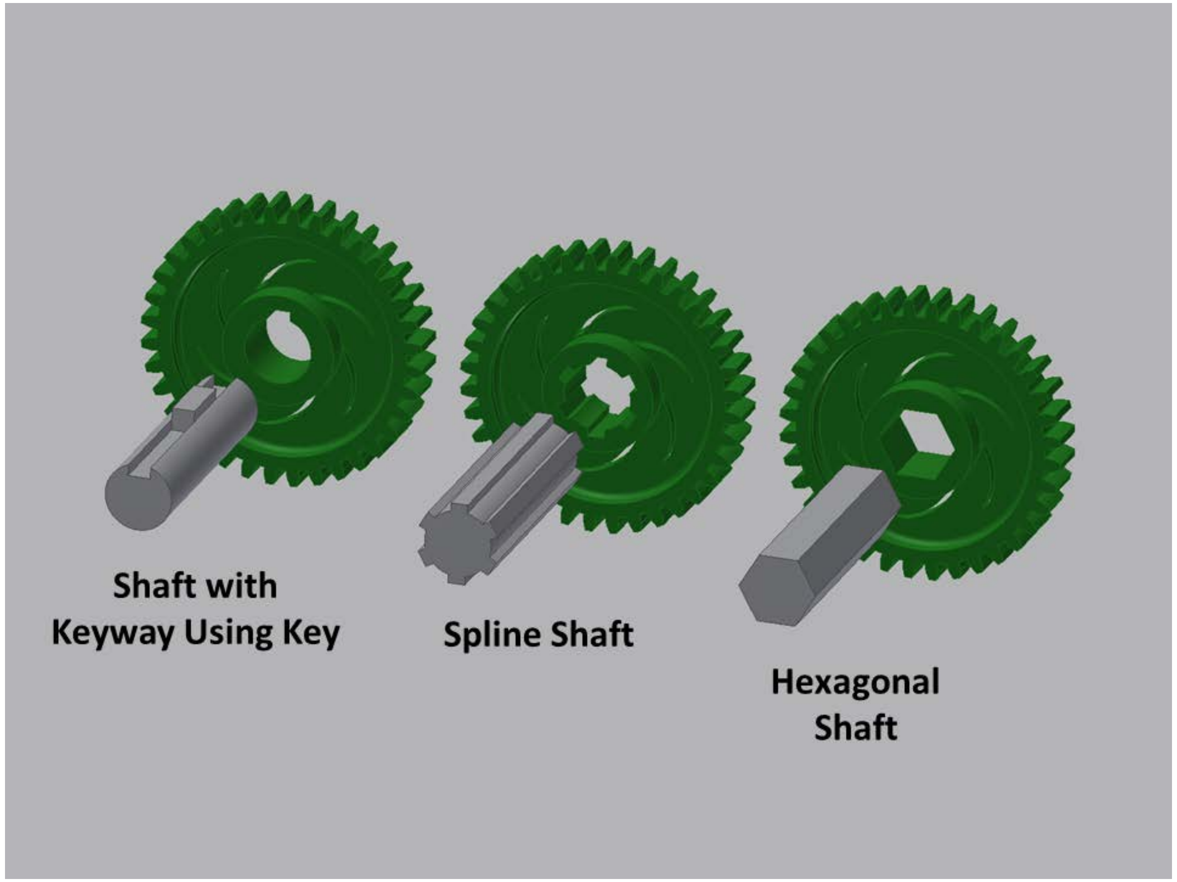
17. Bilateral tolerance (Here the limits variation is allowed on either sides of the zero line)

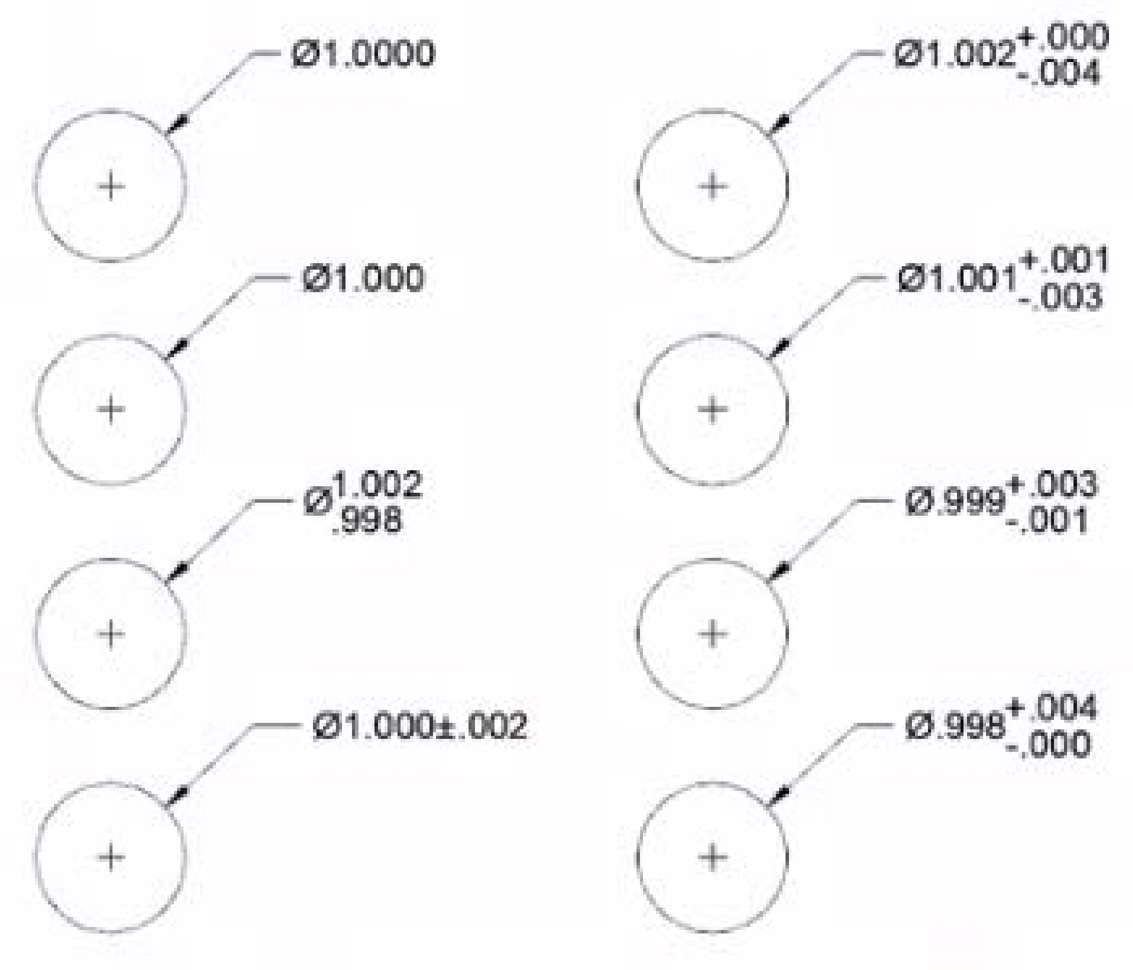
18. Shaft (it refers to any external feature of a part, including any non cylindrical features as well)

19. Hole (the term used for any internal feature of a part including any non cylindrical as well)

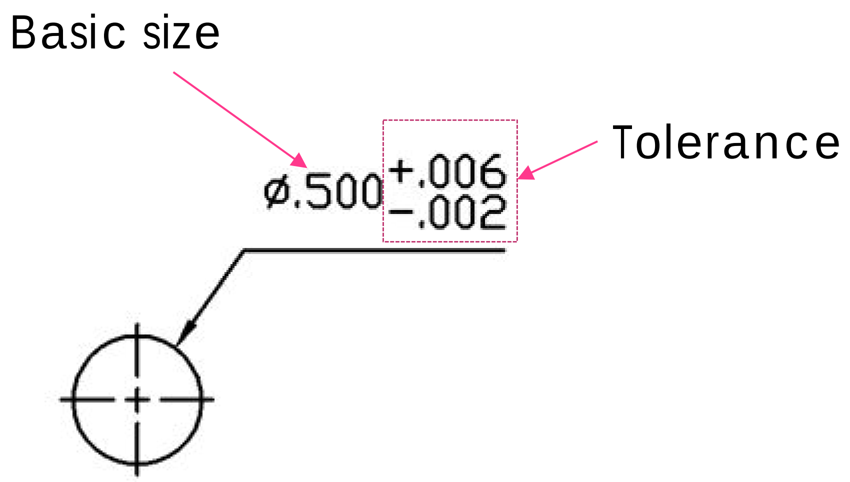
Examples of holes and shafts

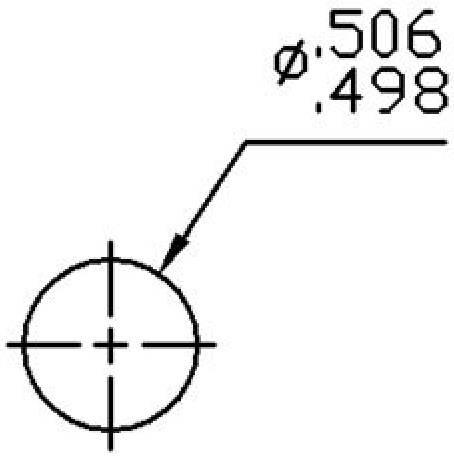




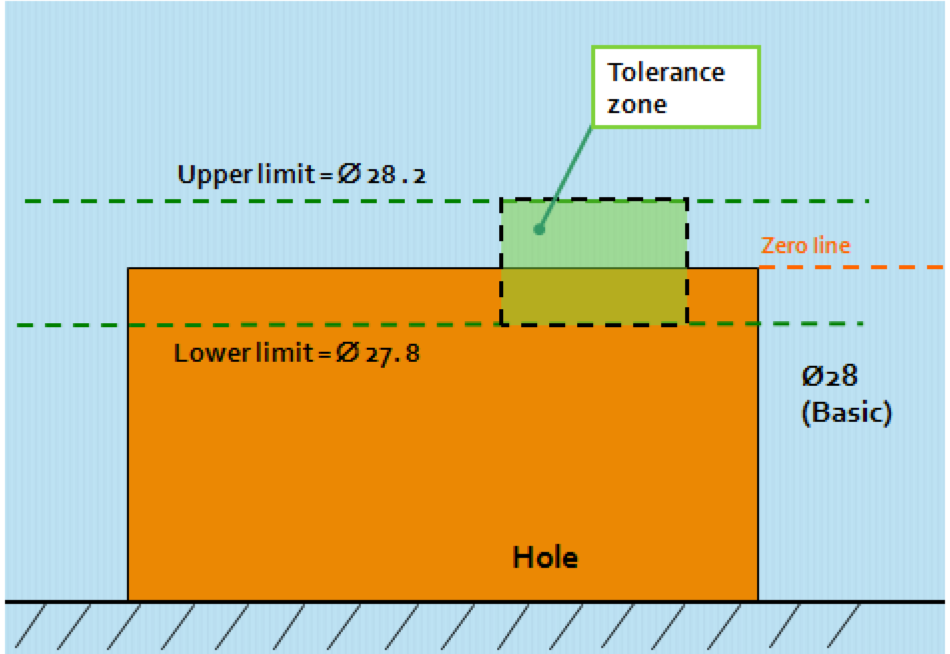


Video link to understand tolerances:
https://www.youtube.com/watch?v=KiXHABfRHfQ

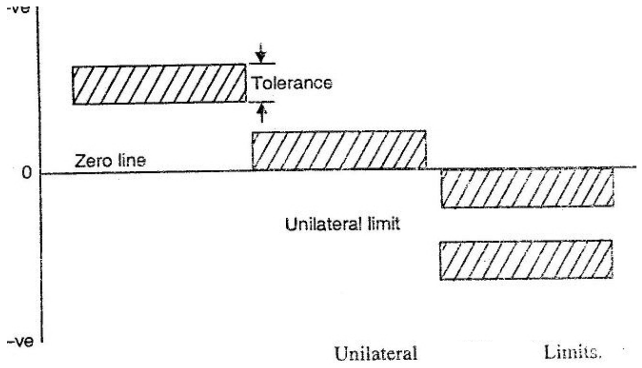




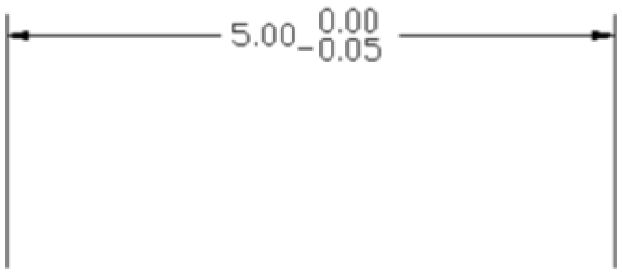
Resulting limit dimensions


Tolerance zone
Upper limit = Ø 28.2
Zero line
Lower limit = Ø 27.8
Ø28
(Basic)
Hole

Unilateral tolerance

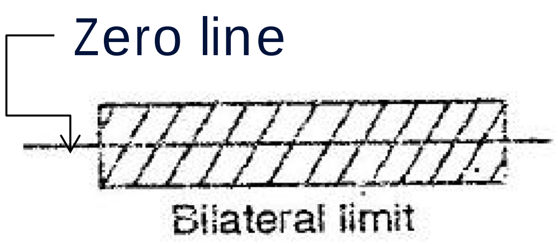


Unilateral Tolerance

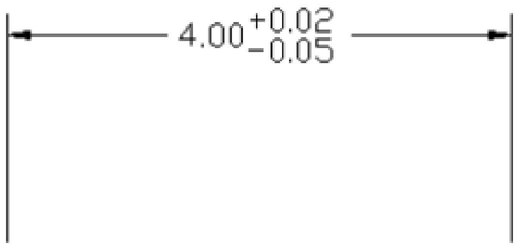


Unilateral Tolerance allows variation in only one direction. From basic size.

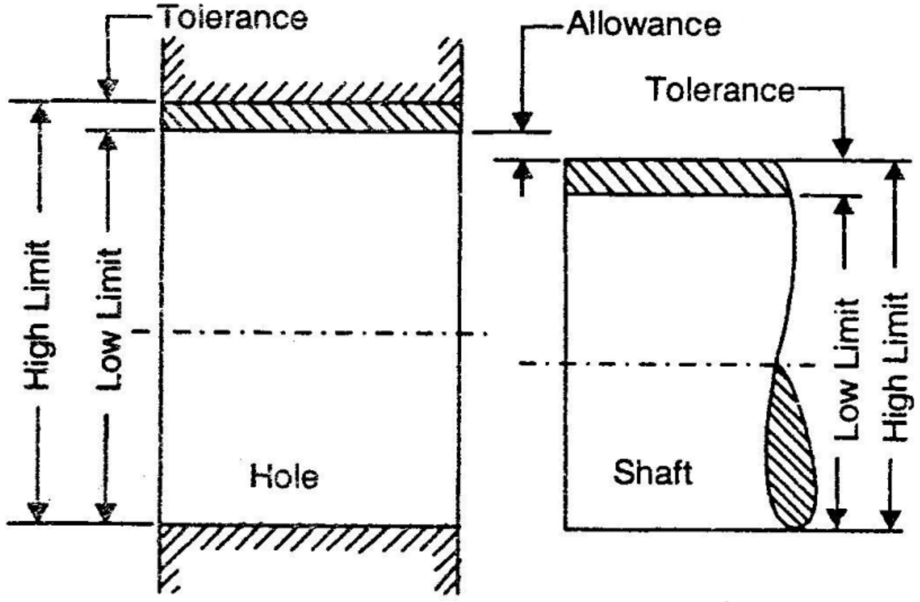
Bilateral tolerance



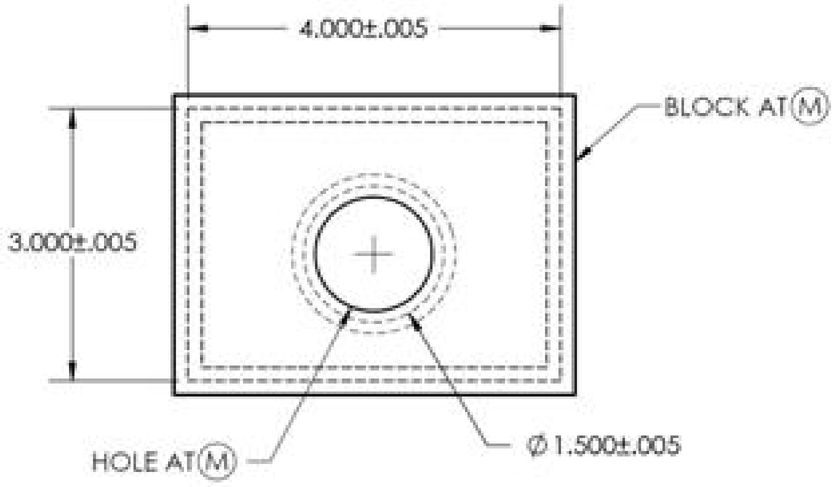
Bilateral Tolerance



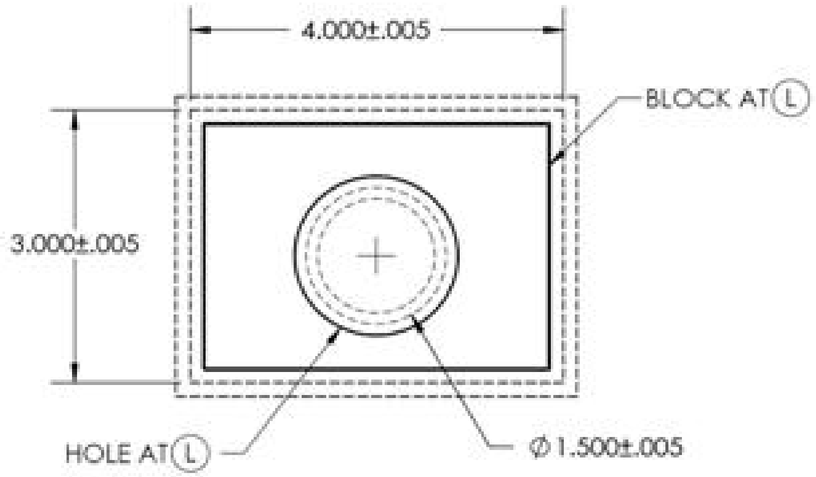
Bilateral Tolerance allow variation in either direction from basic size.



Limits and Tolerance.

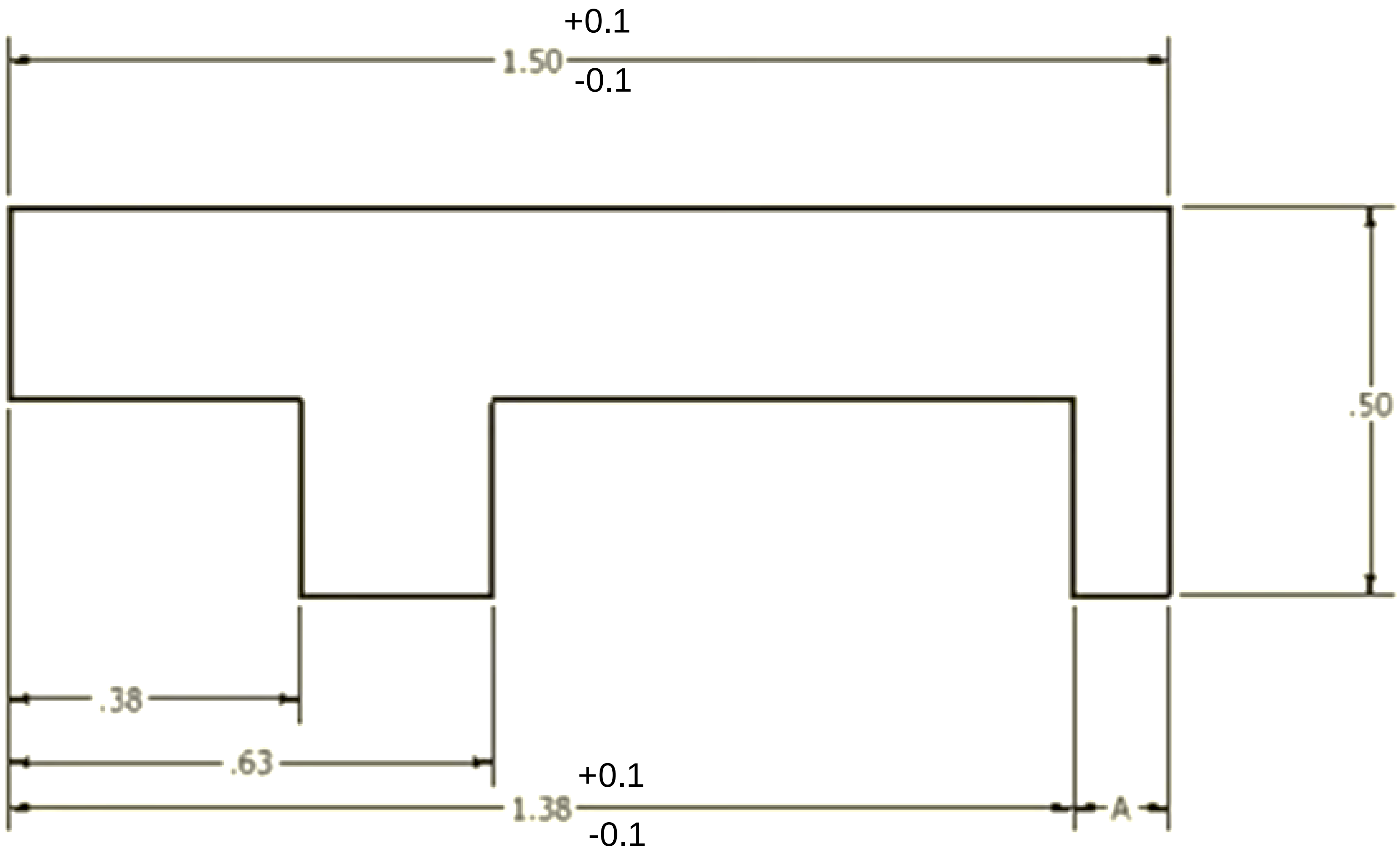


Maximum Material Condition

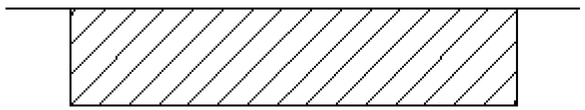


Least Material Condition

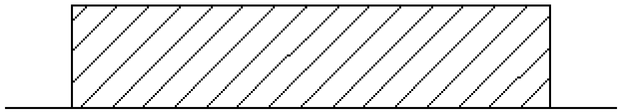
Calculate the maximum and minimum possible dimension for A



20. Basic shaft (the shaft chosen as a basis for the shaft basis system of fit)



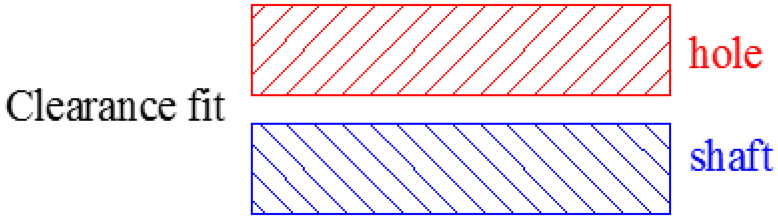
21. Basic hole (the hole chosen as a basis for the hole basis system of fit)

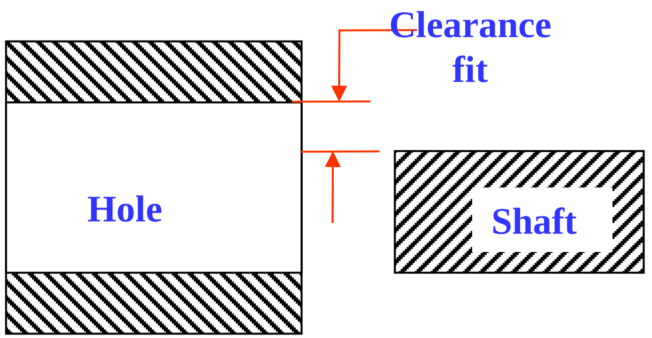


22. Fit (Fit is the relationship that exists between two mating parts, a hole and shaft with respect to their dimensional difference)

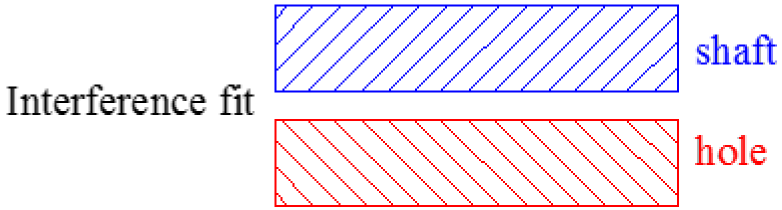
23. Basic size of a fit (common value of the basic size of the two parts of a fit)

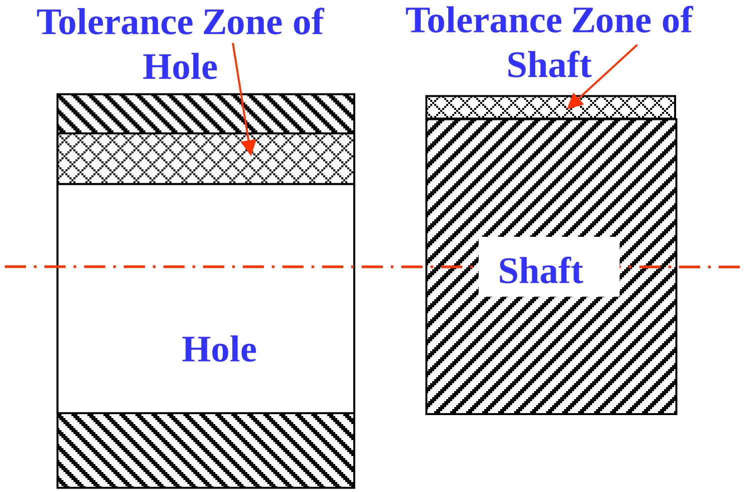
24. Clearance fit



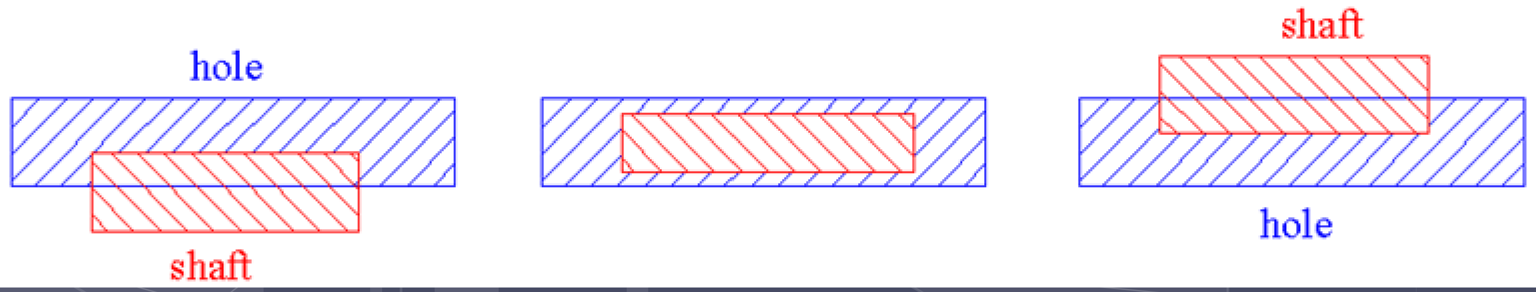


25. Interference fit

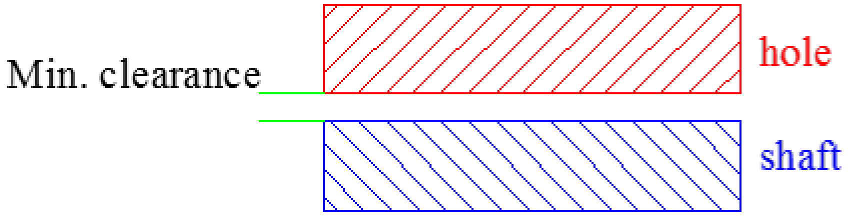




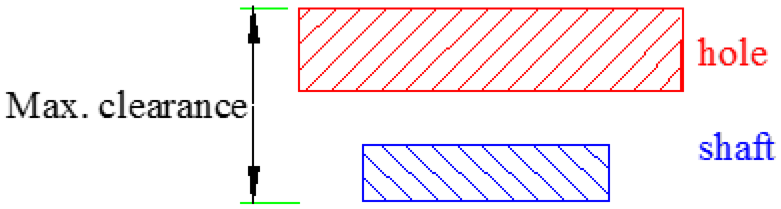
26. Transition fit

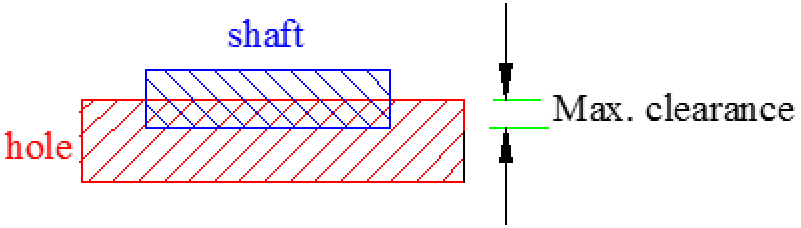


27. Minimum clearance

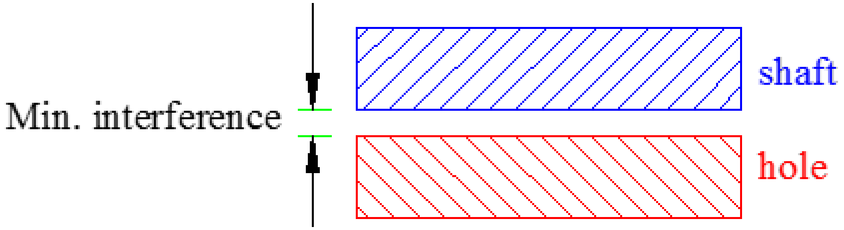


28. Maximum clearance

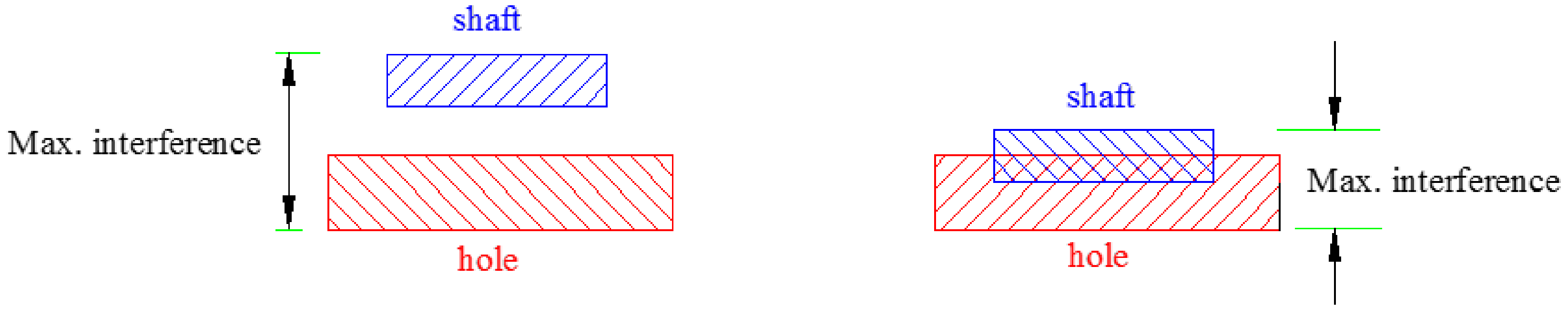




29. Minimum interference



30. Maximum interference



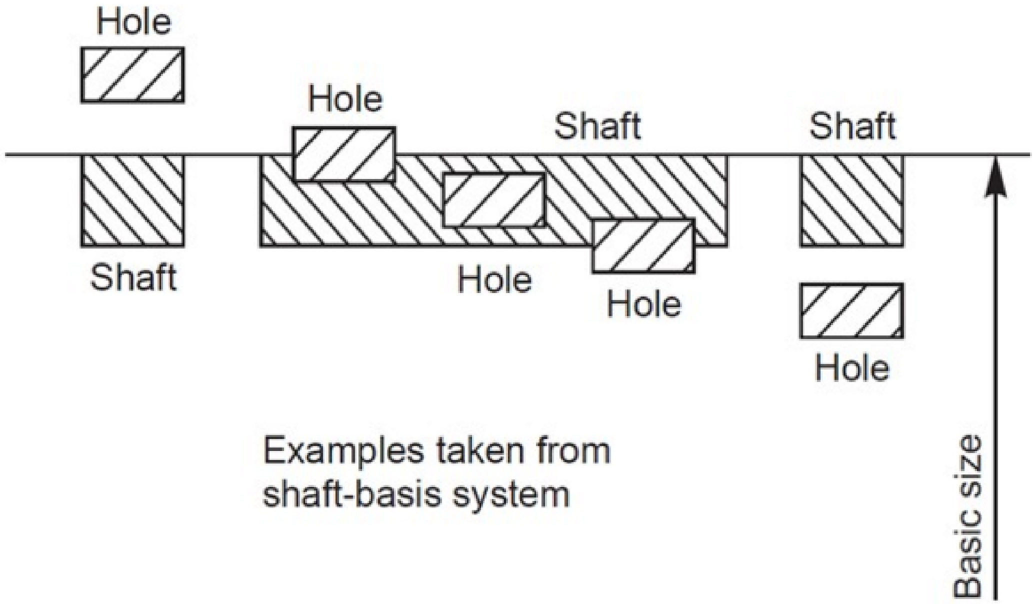
31. Shaft-basis system of fits

32. Hole-basis system of fits

Figure 1.3: Basic hole and shaft system

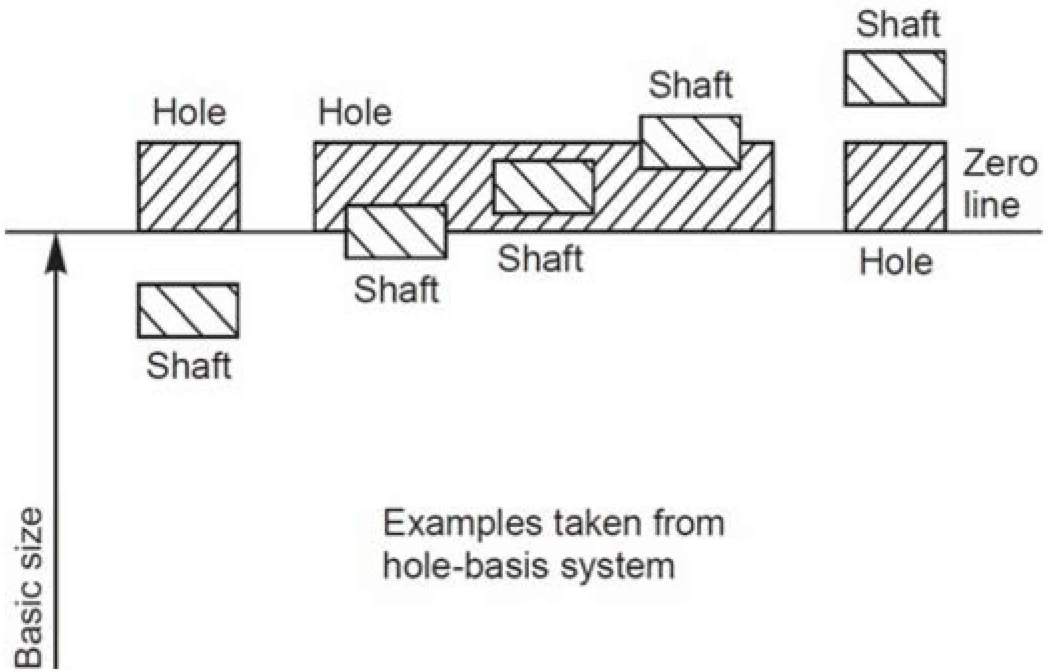
31 - Basic Shaft System of fits

In this system the size of the shaft remains the same and the hole size is varied to get the required fit. **Maximum shaft size is taken as the basic size,** an allowance is assigned, and tolerances are applied on both sides of and away from this allowance.

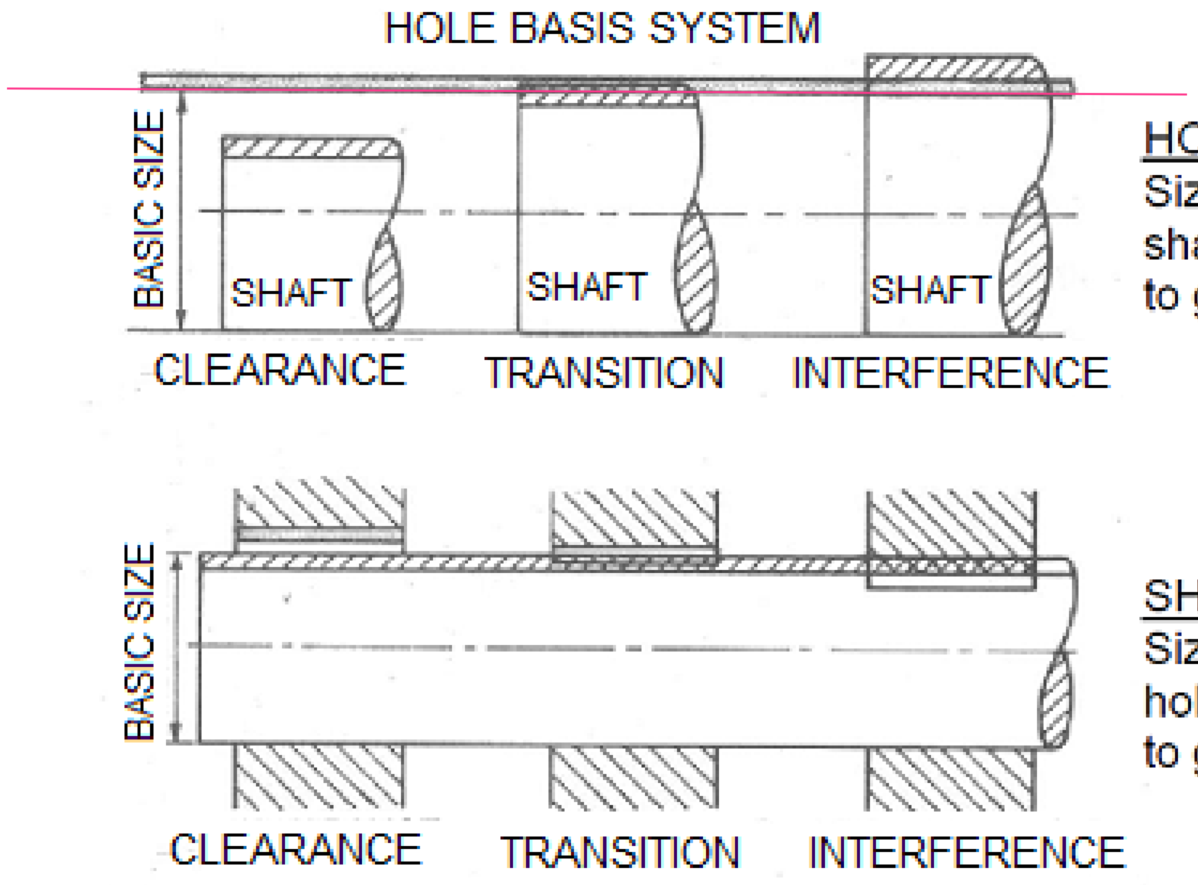


32 - Basic Hole System of fits

In this system the size of the hole remains the same and shaft size is varied to get the required fit. Minimum hole is taken as the basic size, an allowance is assigned, and tolerances are applied on both sides of and away from this allowance.



HOLE AND SHAFT BASIS SYSTEM



HOLE BASED SYSTEM

Size of hole is kept constant, shaft size is varied to get different fits.

SHAFT BASED SYSTEM

Size of shaft is kept constant, hole size is varied to get different fits.

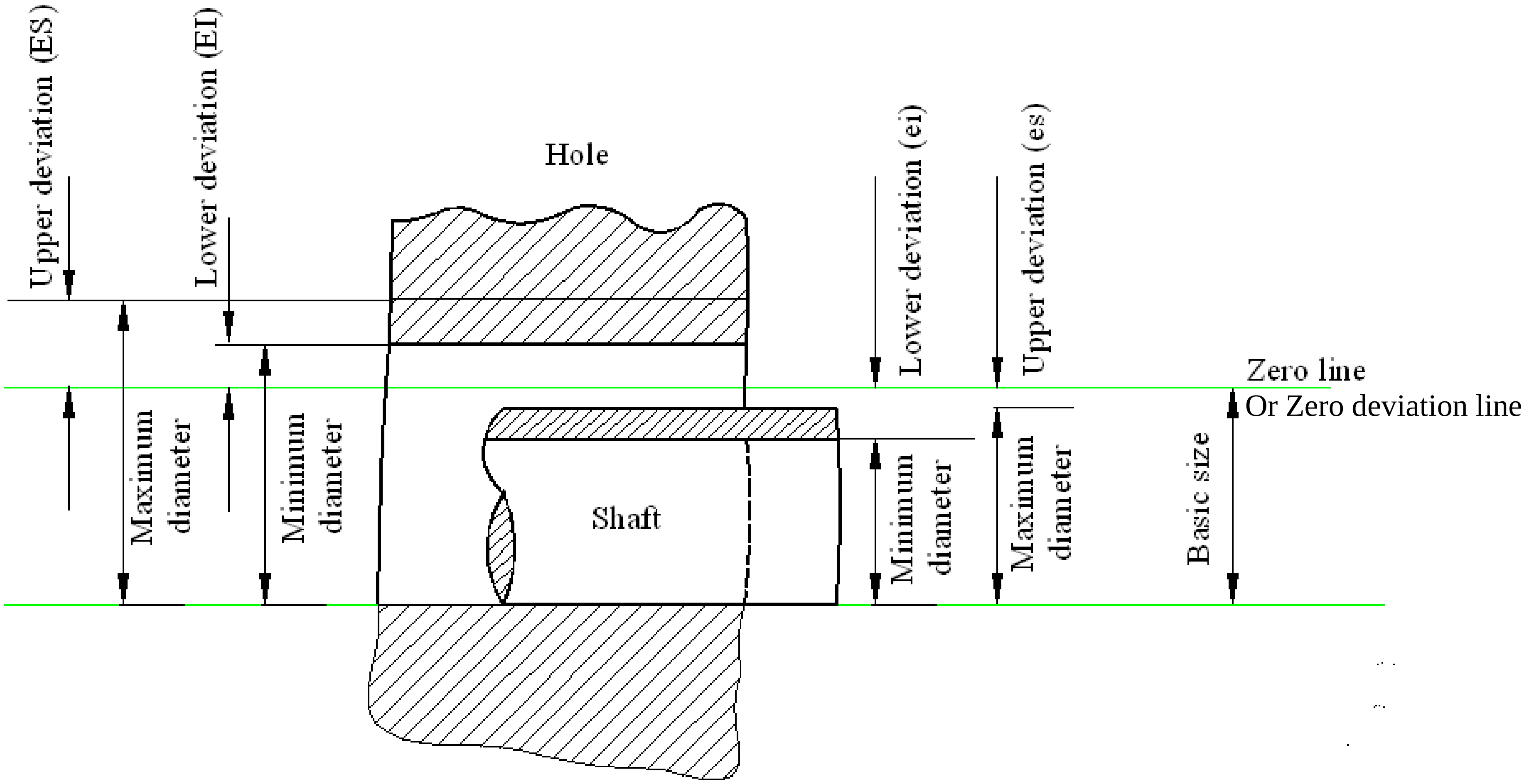
Some definitions

Basic Size: is the size from which limits or deviations are assigned. Basic sizes, usually diameters, should be selected from a table of preferred sizes.

Deviation: is the difference between the basic size and the hole or shaft size.

Upper Deviation: is the difference between the basic size and the permitted maximum size of the part.

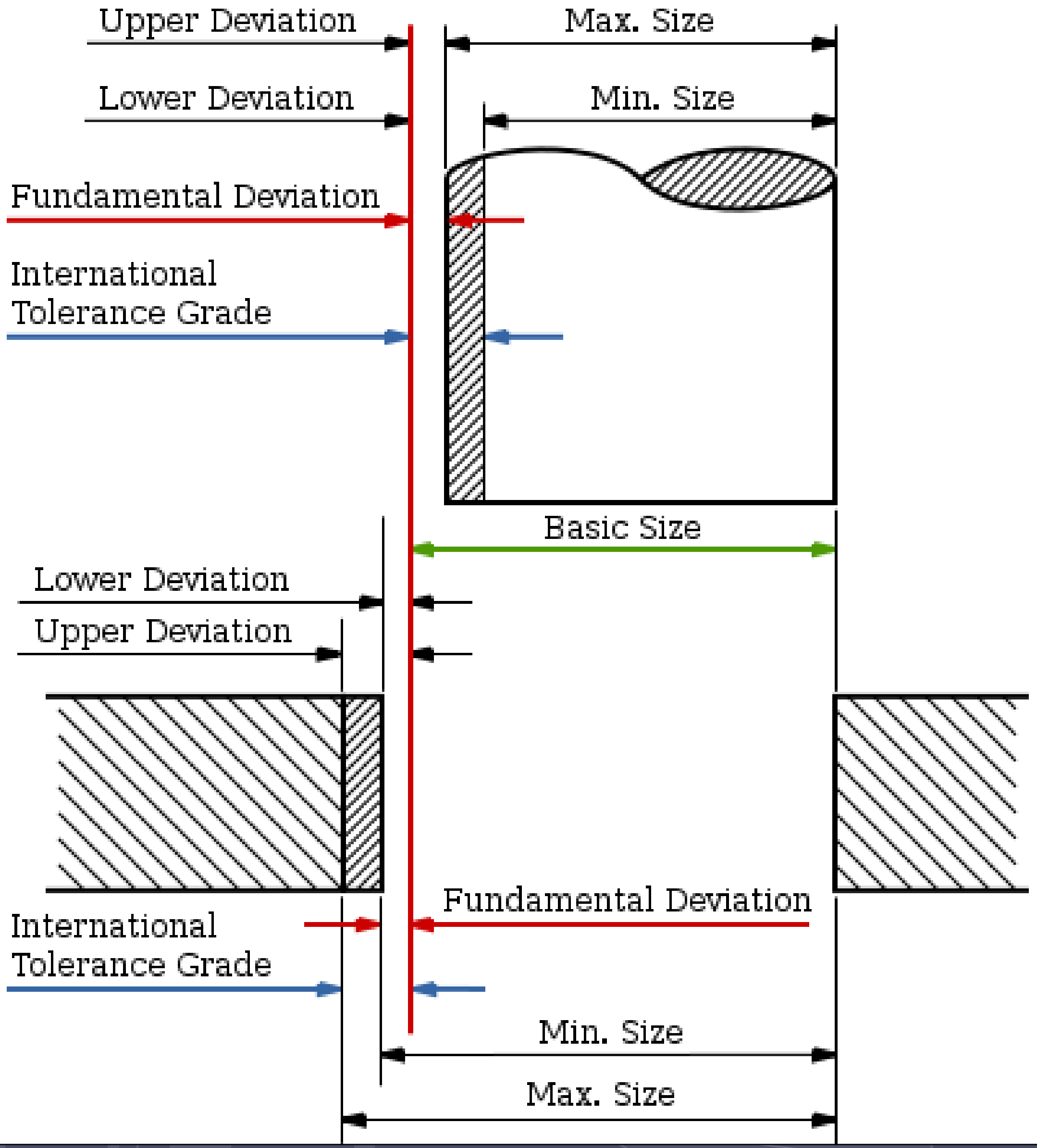
Lower Deviation: is the difference between the basic size and the minimum permitted size of the part.



Upper deviation (ES)
Lower deviation (EI)
Hole
Lower deviation (ei)
Upper deviation (es)
Zero line
Or Zero deviation line
Maximum diameter
Minimum diameter
Shaft
Minimum diameter
Maximum diameter
Basic size

Some Definitions

Fundamental Deviation: is the deviation closest to the basic size. This is identical to the upper deviation for shafts and the lower deviation for holes in a clearance fit.


Upper Deviation
Max. Size
Lower Deviation
Min. Size
Fundamental Deviation
International
Tolerance Grade
Basic Size
Lower Deviation
Upper Deviation
Fundamental Deviation
International
Tolerance Grade
Min. Size
Max. Size

Some Definitions

The hole-basis system of preferred fits is a system in which the basic diameter is the minimum size of the hole. For the generally preferred hole-basis system, the fundamental deviation is specified by the upper-case letter.

The shaft-basis system of preferred fits is a system in which the basic diameter is the maximum size of the shaft. The fundamental deviation is given by the lowercase letter.

Some Definitions

An interference fit results in an interference between two mating parts under all tolerance conditions.

A clearance fit results in a clearance between the two mating parts under all tolerance conditions.

A transition fit results in either a clearance or an interference condition between two assembled parts.

1.2 Symbols for Tolerances and Deviation and Symbols for Fits:

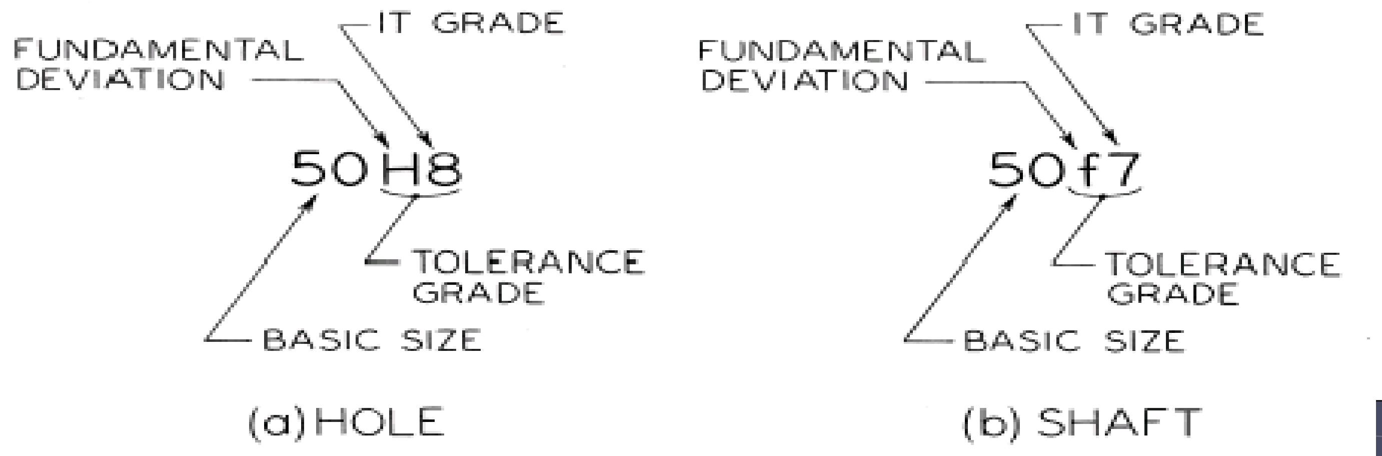
1. Tolerance values (The tolerance value is a function of the basic size and is indicated by a number called the grade.)

2. Tolerance zone position

The position of the tolerance zone with respect to the zero line, is indicated by a letter symbol, a capital letter for holes and a small letter
The tolerance size thus defined by its basic value followed by a symbol composed of a letter and a number. It is established by a combination of the fundamental deviation indicated by a letter and the IT grade number. In the dimension 50H8, the H8 specifies the tolerance zone.

Example for shaft: 45 g7

International Tolerance Grade (IT)



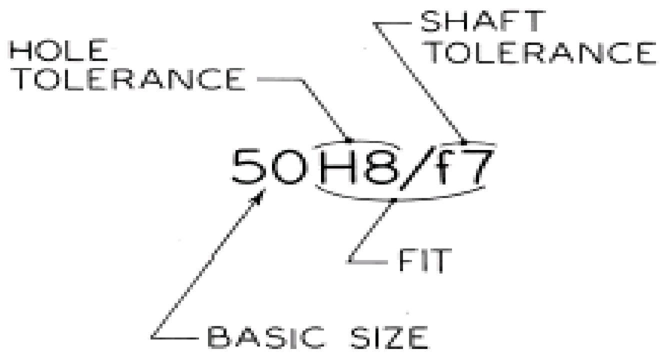
1.2 Symbols for Tolerances and Deviation and Symbols for Fits:

3.A fit (A fit is indicated by the basic size common to both components, followed by symbol corresponding to each component, the hole being quoted first)

Example: 45 H8 g7

Possibly 45 H8 – g7

Or 45 H8/g7



(c) FIT

https://books.google.com.sa/books?id=2ck0AwAAQBAJ&pg=SA6-PA13&lpg=SA6-PA13&dq=fundamental+deviation+selection+fits+IT&source=bl&ots=ZO-M0zNqbP&sig=ofRGWezbxKzJe9uW9zwxVZRZPdk&hl=en&sa=X&redir_esc=y#v=onepage&q=fundamental%20deviation%20selection%20fits%20IT&f=false

1.3: Grades of tolerances:

Eighteen grades of tolerances are provided IT01, ITO and IT1 to IT16

The Table 1.1 gives the possible degrees of precision or grade of tolerance, achieved with different machine tools.

	For Measurig Tools									For Material								
IT Grades	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							For Fits							For Large Manufacturing Tolerances				

Table 1.1: degree of precision or grade of tolerance

Tolerance grade	Intended for	Applicable to components or machines
I T 01	Gauges	Slip blocks, Reference gauges
I T 0		
I T 1		
I T 2		High quality gauges
I T 3		
I T 4		
I T 5	Fits	Ball bearing
I T 6		Grinding, Honing
I T 7		Broaching
I T 8		Center lathe turning
I T 9		Worn automatic lathe
I T 10		Milling
I T 11		Drilling, Rough turning
I T 12	Not for fits	Light press work
I T 13		Press work
I T 14		Die casting
I T 15		Stamping
I T 16		Sand casting

International Tolerance Grade Selection

Representation of Tolerance
2) Number or Grade
IT01, IT0, IT1,….IT16

Tolerance Grade defines range of dimensions (dimensional variation)

There are manufacturing constraints on tolerance grade chosen

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	—

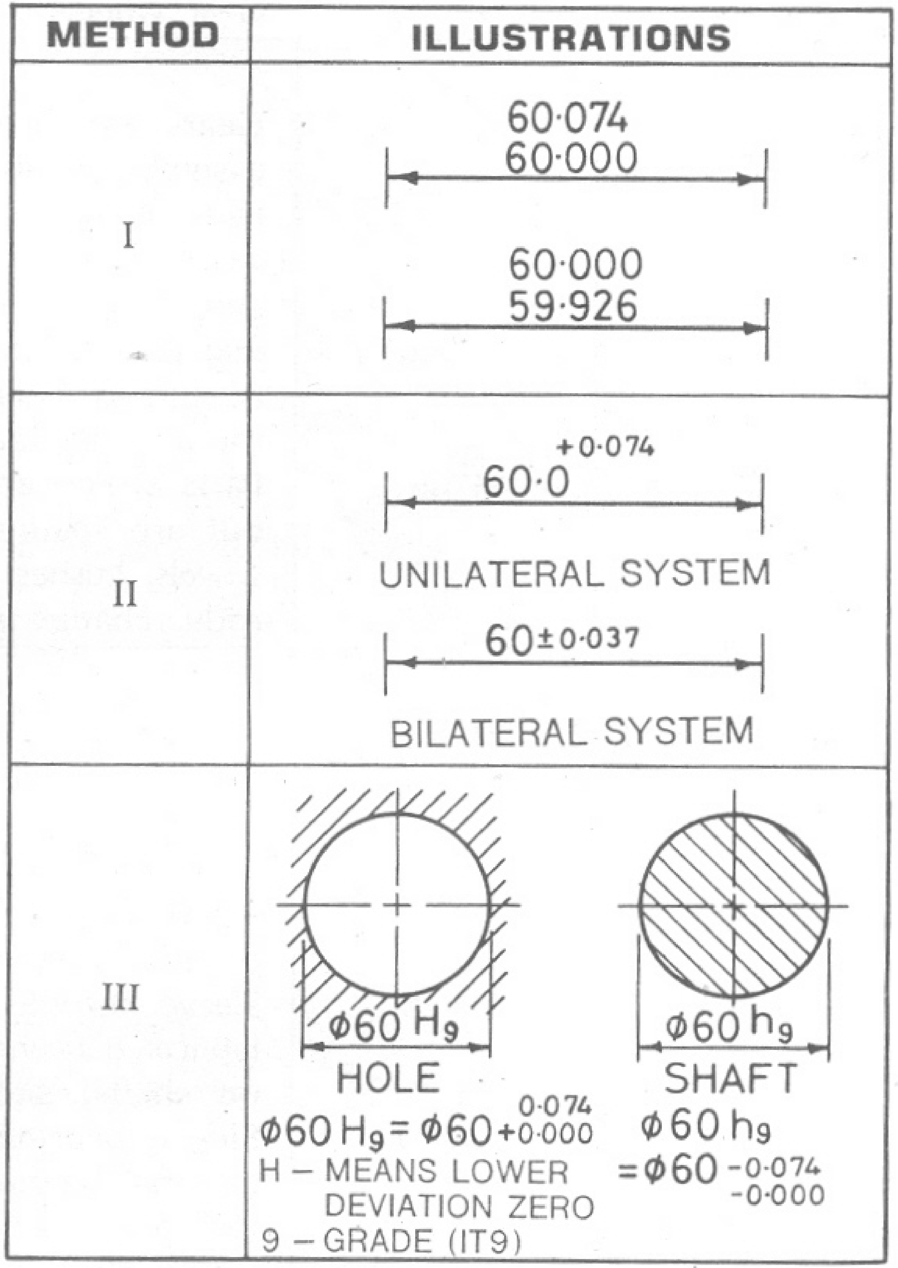
FUNDAMENTAL TOLERANCES OF GRADES 01, 0 AND 1 TO 16

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.

DIAMETER STEPS IN mm		VALUES OF TOLERANCES 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 mm	3	0.3	0.5	0.8	1.2	2	3	4	6	8	10	14	25	40	60	100	140	400	600
Over To and mm	3 6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	400	750
Over To and mm	6 10	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
Over To and mm	10 18	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
Over To and mm	18 30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
Over To and mm	30 50	0.6	1	1.5	2.5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600
Over To and mm	50 80	0.8	1.2	2	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
Over To and mm	80 120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
Over To and mm	120 180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
Over To and mm	180 250	2	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
Over To and mm	250 315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
Over To and mm	315 400	3	5	7	9	13	18	25	36	57	49	140	230	360	570	890	1400	2300	3600
Over To and mm	400 500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000

Example


METHOD
ILLUSTRATIONS
I
60·074
60·000
60·000
59·926
II
+0·074
60·0
UNILATERAL SYSTEM
60±0·037
BILATERAL SYSTEM
III
ϕ60 H9
HOLE
ϕ60 h9
SHAFT
ϕ60 H9 = ϕ60 +0·074 +0·000
H – MEANS LOWER DEVIATION ZERO
9 – GRADE (IT9)
ϕ60 h9
= ϕ60 -0·074 -0·000

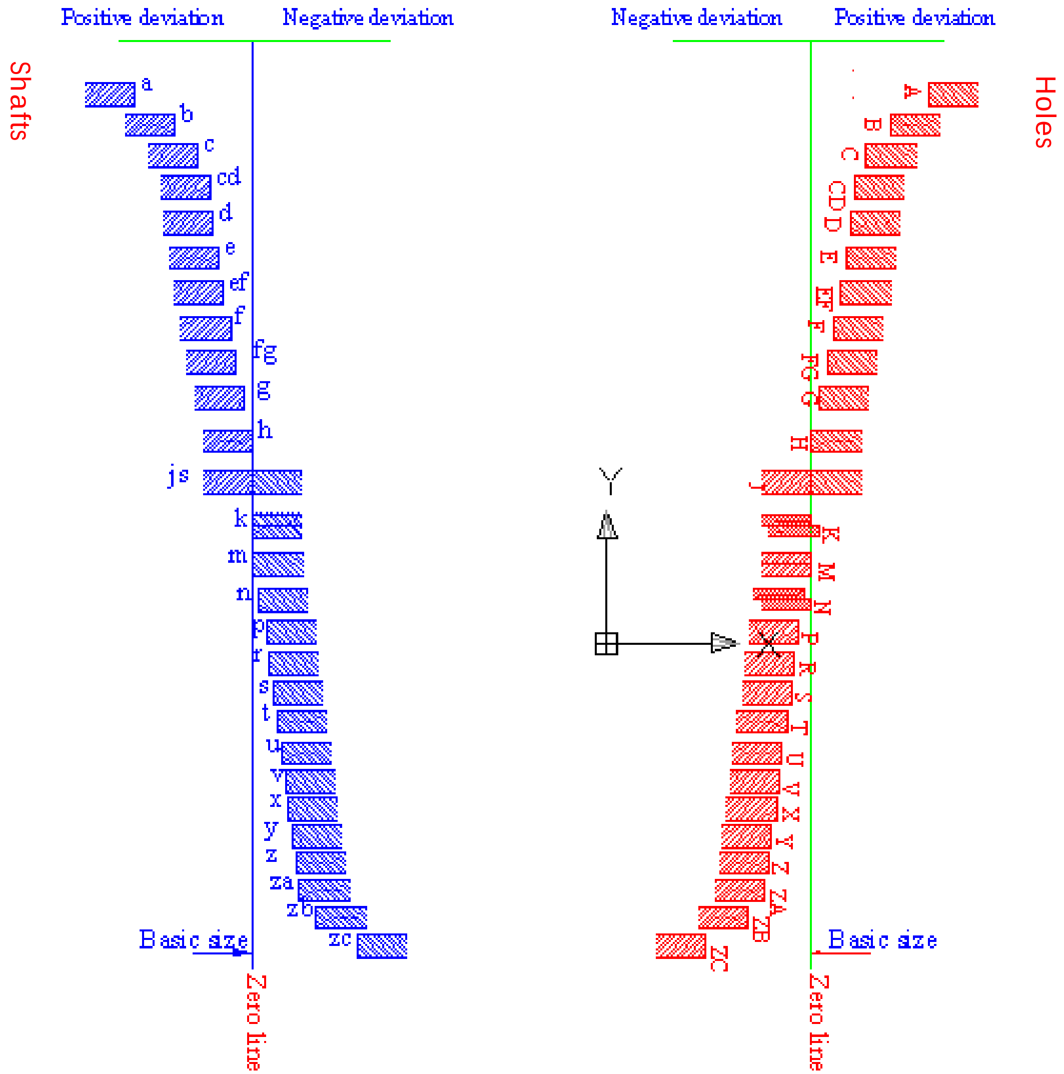
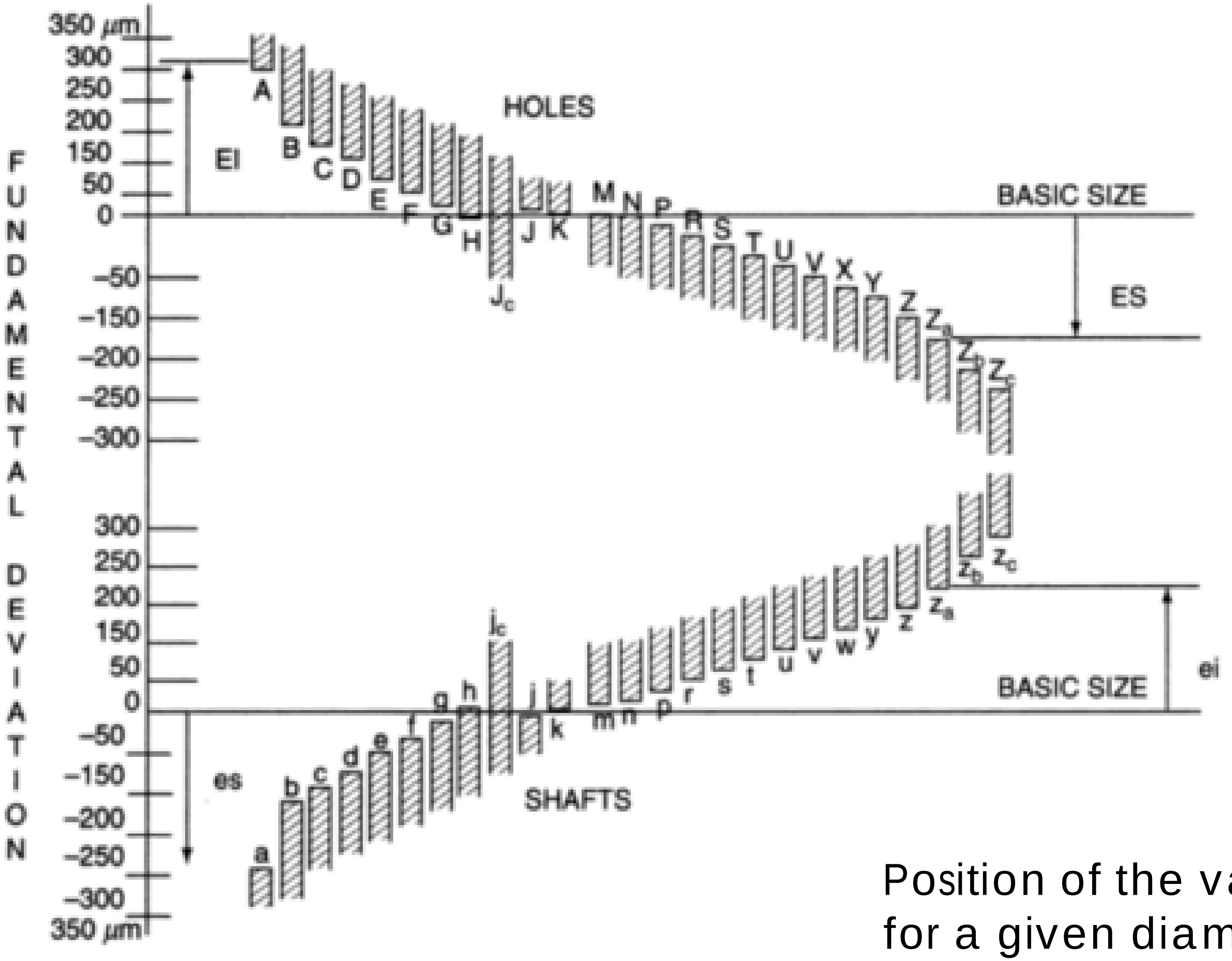
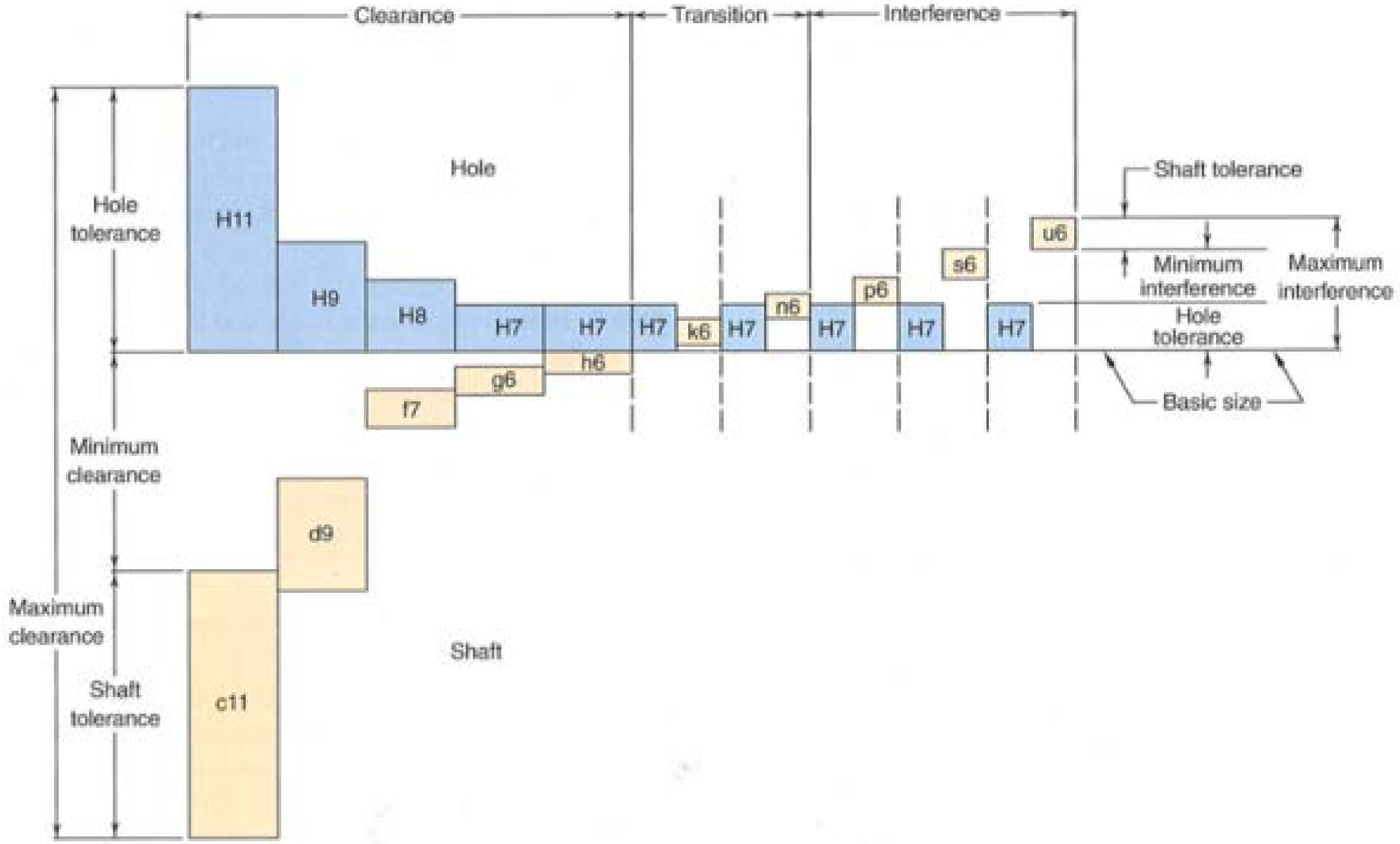


Figure 1.5: Position of the various tolerance zones for a given diameter in the ISO system



Position of the various tolerance zones for a given diameter in the ISO system

Metric Preferred Hole Based System of fit



Metric Preferred shaft Based System of fit

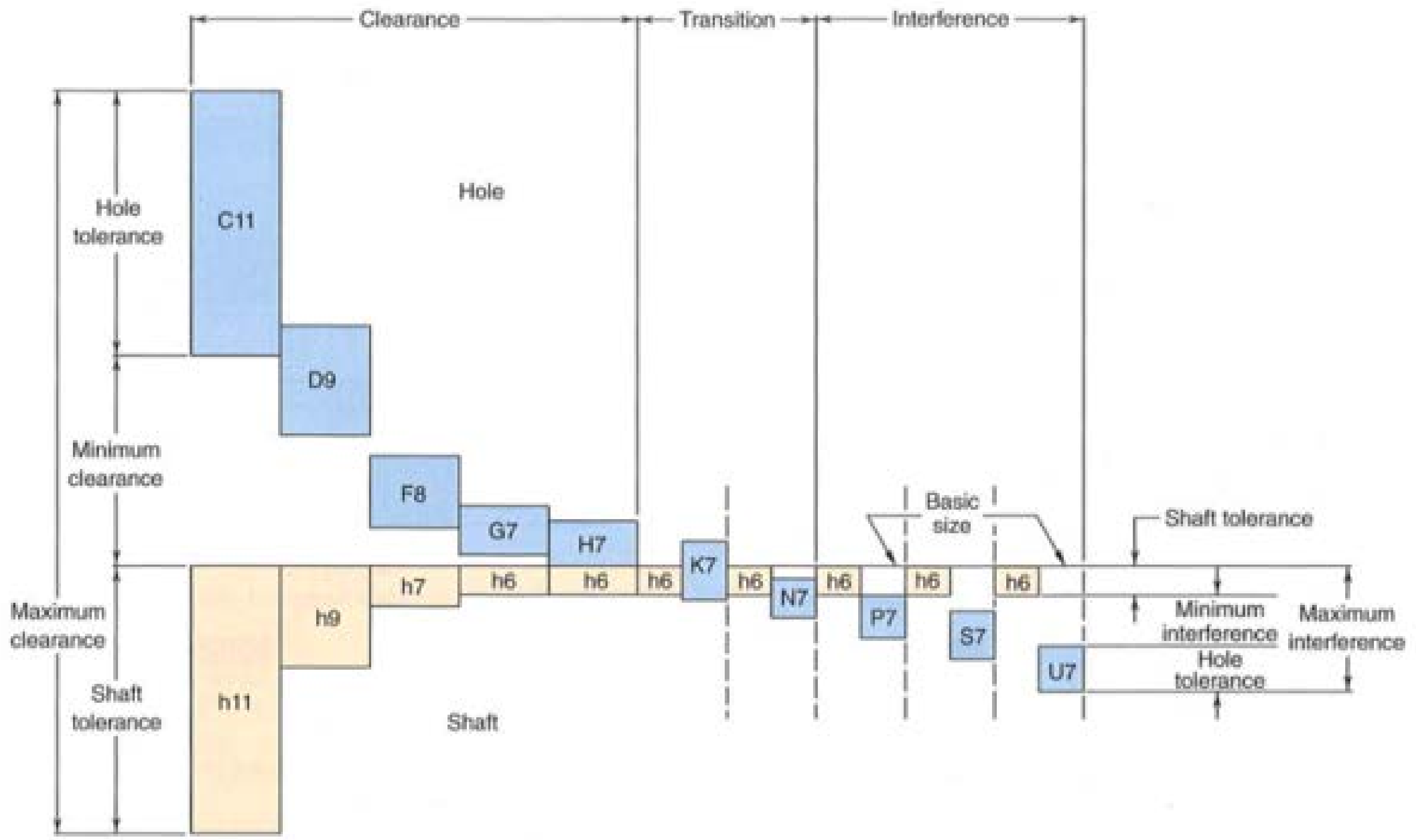


Table for fundamental deviations for shafts

Fundamental deviation		Upper deviation es												Lower deviation ei				
Letter		a[a]	b[a]	c	cd	d	e	ef	f	fg	g	h	js[b]	j			k	
Grade		01 to 16												5–6	7	8	4–7	≤3 >7
Nominal sizes																		
Over	To																	
mm –	mm 3	−270	−140	−60	−34	−20	−14	−10	−6	−4	−2	0	±IT/2	−2	−4	−6	0	0
3	6	−270	−140	−70	−46	−30	−20	−14	−10	−6	−4	0		−2	−4	–	+1	0
6	10	−280	−150	−80	−56	−40	−25	−18	−13	−8	−5	0		−2	−5	–	+1	0
10	14	−290	−150	−95	–	−50	−32	–	−16	–	−6	0		−3	−6	–	+1	0
14	18																	
18	24	−300	−160	−110	–	−65	−40	–	−20	–	−7	0		−4	−8	–	+2	0
24	30																	
30	40	−310	−170	−120	–	−80	−50	–	−25	–	−9	0		−6	−10	–	+2	0
40	50	−320	−180	−130														
50	65	−340	−190	−140	–	−100	−60	–	−30	–	−10	0		−7	−12	–	+2	0
65	80	−360	−200	−150														
80	100	−380	−220	−170	–	−120	−72	–	−36	–	−12	0		−9	−15	–	+3	0
100	120	−410	−240	−180														
120	140	−460	−260	−200	–	−145	−85	–	−43	–	−14	0		−11	−18	–	+3	0
140	160	−520	−280	−210														
160	180	−580	−310	−230														
180	200	−660	−340	−240	–	−170	−100	–	−50	–	−15	0		−13	−21	–	+4	0
200	225	−740	−380	−260														
225	250	−820	−420	−280														
250	280	−920	−480	−300	–	−190	−110	–	−56	–	−17	0		−16	−26	–	+4	0
280	315	−1050	−540	−330														
315	355	−1200	−600	−360	–	−210	−125	–	−62	–	−18	0		−18	−28	–	+4	0
355	400	−1350	−680	−400														
400	450	−1500	−760	−440	–	−230	−135	–	−68	–	−20	0		−20	−32	–	+5	0
450	500	−1650	−840	−480														
Grade		6 to 16																
500	630	–	–	–	–	−260	−145	–	−76	–	−22	0	±IT/2				0	
630	800	–	–	–	–	−290	−160	–	−80	–	−24	0					0	
800	1000	–	–	–	–	−320	−170	–	−86	–	−26	0					0	
1000	1250	–	–	–	–	−350	−195	–	−98	–	−28	0					0	
1250	1600	–	–	–	–	−390	−220	–	−110	–	−30	0					-0	
2000	2500	–	–	–	–	−480	−260	–	−130	–	−34	0					0	
2500	3150	–	–	–	–	−520	−290	–	−145	–	−38	0					0	

[a]Not applicable to sizes up to 1 mm.
[b]In grades 7 to 11, the two symmetrical deviations ± IT/2 should be rounded if the IT value in micrometres is an odd value by replacing it by the even value immediately below.

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Table for fundamental deviations for shafts

Fundamental deviation		Upper deviation ei													
Letter		m	n	p	r	s	t	u	v	x	y	z	za	zb	zc
Grade		01 to 16													
Nominal size															
Over	To														
mm	mm														
–	3	+2	+4	+6	+10	+14	–	+18	–	+20	–	+26	+32	+40	+60
3	6	+4	+8	+12	+15	+19	–	+23	–	+28	–	+35	+42	+50	+80
6	10	+6	+10	+15	+19	+23	–	+28	–	+34	–	+42	+52	+67	+97
10	14	+7	+12	+18	+23	+28	–	+33	–	+40	–	+50	+64	+90	+130
14	18								+39	+45	–	+60	+77	+108	+150
18	24	+8	+15	+22	+28	+35	–	+41	+47	+54	+63	+73	+98	+136	+188
24	30						+41	+48	+55	+64	+75	+88	+118	+160	+218
30	40	+9	+17	+26	+34	+43	+48	+60	+68	+80	+94	+112	+148	+200	+274
40	50						+54	+70	+81	+97	+114	+136	+180	+242	+325
50	65	+11	+20	+32	+ 41	+53	+66	+87	+102	+122	+144	+172	+226	+300	+405
65	80				+43	+59	+75	+102	+120	+146	+174	+210	+274	+360	+480
80	100	+13	−23	+37	+51	+71	+91	+124	+146	+178	+214	+258	+335	+445	+585
100	120				+54	+79	+104	+144	+172	+210	+254	+310	+400	+525	+690
120	140	+15	+27	+43	+63	+92	+122	+170	+202	+248	+300	+365	+470	+620	+800
140	160				+65	+100	+134	+190	+228	+280	+340	+415	+535	+700	+900
160	180				+68	+108	+146	+210	+252	+310	+380	+465	+600	+780	+1000
180	200	+17	+31	+50	+77	+122	+166	+236	+284	+350	+425	+520	+670	+880	+1150
200	225				+80	+130	+180	+258	+310	+385	+470	+575	+740	+960	+1250
225	250				+84	+140	+196	+284	+340	+425	+520	+640	+820	+1050	+1350
250	280	+20	+34	+56	+94	+158	+218	+315	+385	+475	+580	+710	+920	+1200	+1550
280	315				+98	+170	+240	+350	+425	+525	+650	+790	+1000	+1300	+1700
315	355	+21	+37	+62	+108	+190	+268	+390	+475	+590	+730	+900	+1150	+1500	+1900
355	400				+144	+208	+294	+435	+530	+660	+820	+1000	+1300	+1650	+2100
400	450	+23	+40	+68	+126	+232	+330	+490	+595	+740	+920	+1100	+1450	+1850	+2400
450	500				+132	+252	+360	+540	+660	+820	+1000	+1250	+1600	+2100	+2600
Grade		6 to 16													
500	560	+26	+44	+78	+150	+280	+400	+600							
560	630				+155	+310	+450	+660							
630	710	+30	+50	+88	+175	+340	+500	+740							
710	800				+185	+380	+560	+840							
800	900	+34	+56	+100	+210	+430	+620	+940							
900	1000				+220	+470	+680	+1050							
1000	1120	+40	+66	+120	+250	+520	+780	+1150							
1120	1250				+260	+580	+840	+1300							

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Table for fundamental deviations for holes

Fundamental		Lower deviation EI												Upper deviation ES								
Letter		A[a]	B[a]	c	CD	D	E	EF	F	FG	G	H	J[b]	J			K		M		N	
Grade		01 to 16												6	7	8	≤8	>8	≤8[c]	>8	≤8	>8[d]
Nominal sizes																						
Over	To	+	+	+	+	+	+	+	+	+	+			+	+	+						
mm	mm																					
–	3	270	140	60	34	20	14	10	6	4	2	0		2	4	6	0	0	−2	−2	−4	−4
3	6	270	140	70	46	30	20	14	10	6	4	0		5	6	10	−1+Δ	–	−4+Δ	−4	−8+Δ	0
6	10	280	150	80	56	40	25	18	13	8	5	0		5	8	12	−1+Δ	–	−6+Δ	−6	−10+Δ	0
10	14	290	150	95	–	50	32	–	16	–	6	0		6	10	15	−1+Δ	–	−7+Δ	−7	−12+Δ	0
14	18																					
18	24	300	160	110	–	65	40	–	20	–	7	0		8	12	20	−2+Δ	–	−8+Δ	−8	−15+Δ	0
24	30																					
30	40	310	170	120	–	80	50	–	25	–	9	0		10	14	24	−2+Δ	–	−9+Δ	−9	−17+Δ	0
40	50	320	180	130																		
50	60	340	190	140	–	100	60	–	30	–	10	0		13	18	28	−2+Δ	–	−11+Δ	−11	−20+Δ	0
65	80	360	200	150																		
80	100	380	220	170	–	120	72	–	36	–	12	0	±IT/2	16	22	34	−3+Δ	–	−13+Δ	−13	−23+Δ	0
100	120	410	240	180																		
120	140	460	260	200	–	145	85	–	43	–	14	0		18	26	41	−3+Δ	–	−15+Δ	−15	−27+Δ	0
140	160	520	280	210																		
160	180	580	310	230																		
180	200	660	340	240	–	170	100	–	50	–	15	0		22	30	47	−4+Δ	–	−17+Δ	−17	−31+Δ	0
200	225	740	380	260																		
225	250	820	420	280																		
250	280	920	480	300	–	190	110	–	56	–	17	0		25	36	55	−4+Δ	–	−20+Δ	−20	−34+Δ	0
280	315	1050	540	330																		
315	355	1200	600	360	–	210	125	–	62	–	18	0		29	39	60	−4+Δ	–	−21+Δ	−21	−37+Δ	0
335	400	1350	680	400																		
400	450	1500	760	440	–	230	135	–	68	–	20	0		33	43	66	−5+Δ	–	−23+Δ	−23	−40+Δ	0
450	500	1650	840	480																		
Grade		6 to 16																				
500	630	–	–	–	–	260	145	–	76	–	22	0					0		−26		−44	
630	800	–	–	–	–	290	160	–	80	–	24	0					0		−30		−50	
800	1000	–	–	–	–	320	170	–	86	–	26	0					0		−34		−56	
1000	1250	–	–	–	–	350	195	–	98	–	28	0	± IT/2				0		−40		−66	
1250	1600	–	–	–	–	390	220	–	110	–	30	0					0		−48		−78	
1600	2000	–	–	–	–	430	240	–	120	–	32	0					0		−58		−92	

[a]Not applicable to sizes up to 1 mm.
[b]In grades 7 to 11, the two symmetrical deviations ± IT/2 should be rounded if the IT value in micrometres in an odd value by replacing it by the even value immediately below.
[c]Special case: for M6, ES = −9 from 250 to 315 (instead of −11).
[d]Not applicable to sizes up to 1 mm.

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Table for fundamental deviations for holes

Please note that all values in this table are actually negative

Fundamental deviation		Upper deviation ES													Values for Δ*					
Letter		P to ZC	P	R	S	T	U	V	X	Y	Z	ZA	ZB	ZC						
Grade		≤7	>7																	
Nominal sizes															Grades:					
Over	To		–	–	–	–	–	–	–	–	–	–	–	–	3	4	5	6	7	8
mm	mm																			
–	3	Same deviation as for grades above 7 increased by Δ	6	10	14	–	18	–	20	–	26	32	40	60	0	0	0	0	0	0
3	6		12	15	19	–	23	–	28	–	35	42	50	80	1	1.5	1	3	4	6
6	10		15	19	23	–	28	–	34	–	42	52	67	97	1	1.5	2	3	6	7
10	14		18	23	28	–	33	–	40	–	50	64	90	130	1	2	3	3	7	9
14	18							39	45	–	60	77	108	150						
18	24		22	28	35	–	41	47	54	63	73	98	136	188	1.5	2	3	4	8	12
24	30					41	48	55	64	75	88	118	160	218						
30	40		26	34	43	48	60	68	80	94	112	148	200	274	1.5	3	4	5	9	14
40	50					54	70	81	97	114	136	180	242	325						
50	65		32	41	53	66	87	102	122	144	172	226	300	405	2	3	5	6	11	16
65	80			43	59	75	102	120	146	174	210	274	360	480						
80	100		37	51	71	91	124	146	178	214	258	335	445	585	2	4	5	7	13	19
100	120			54	79	104	144	172	210	254	310	400	525	690						
120	140		43	63	92	122	170	202	248	300	365	470	620	800	3	4	6	7	15	23
140	160			65	100	134	190	228	280	340	415	535	700	900						
160	180			68	108	146	210	252	310	380	465	600	780	1000						
180	200		50	77	122	166	266	284	350	425	520	670	880	1150	3	4	6	9	17	26
200	225			80	130	180	258	310	385	470	575	740	960	1250						
225	250			84	140	196	284	340	425	520	640	820	1050	1350						
250	280		56	94	158	218	315	385	475	580	710	920	1200	1550	4	4	7	9	20	29
280	315			98	170	240	350	425	525	650	790	1000	1300	1700						
315	355		62	108	190	268	390	475	590	730	900	1150	1500	1800	4	5	7	11	21	32
355	400			114	208	294	435	530	660	820	1000	1300	1650	2100						
400	450		68	126	232	330	490	595	740	920	1100	1450	1850	2400	5	5	7	13	23	34
450	500			132	252	360	540	660	820	1000	1250	1600	2100	2600						
Grade		6 to 16																		
500	560		78	150	280	400	600													
560	630			155	310	450	660													
630	710		88	175	340	500	740													
710	800			185	380	560	840													
800	900		100	210	430	620	940													
900	1000			220	470	680	1050													
1000	1120		120	250	520	780	1150													
1120	1250			260	580	840	1300													

* In determining K, M, N up to Grade 8 and P to ZC up to Grade 7, add the Δ value appropriate to the grade as indicated, e.g. for P7 from 18 to 30, Δ = 8 therefore ES = −14.

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1.4 Fundamental tolerance unit:

1.4.2 Fundamental deviations:

1.4.2.1 Shaft deviation:

For each letter symbol defining the position of the tolerance zone, the magnitude and sign of one of the two deviations which is known as the fundamental deviations (upper deviation) “es” or lower deviation “ei”

The other deviation is derived from the first one using the magnitude of the standard tolerance “IT”, by means of the following algebraic relationship:

The fundamental deviation given by the formulae in above tables of deviations is, in principle, that corresponding to that limit closet to the zero line, in other words, the upper deviation “es” for shafts (a) to (h), and the lower deviation “ei” for shafts (j) to (Zc).

$$ei = es - IT$$

$$es = ei + IT$$

1.4.2.2 Hole deviation:

For each letter symbol, defining the position of the tolerance zone, the magnitude and sign of the fundamental deviation (lower deviation “EI” for holes (A) to (H) and upper deviation “ES” for holes (J) to (Zc),

The other deviation is derived from the first one, using the magnitude of the tolerance “IT” by means of the following relationships.

$$ES = EI + IT$$

OR

$$EI = ES - IT$$

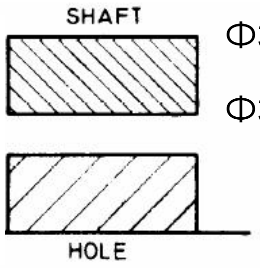
Example

Determine which type of fit is presented by **H7/p6**? For basic size of 30 mm determine the dimensions of the hole and the shaft for the given fit. (**Fit: 30 H7/p6**)

Capital H means basic hole system and upper deviation = zero

H7 : Tol Grade 7 mean 21µ variation

INTERFERENCE FIT



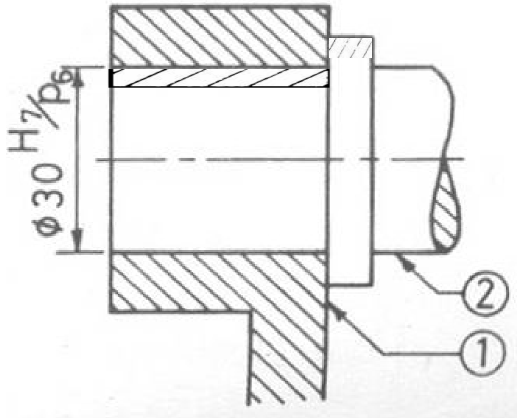
Φ30.035

Φ30.022

Φ30.021

Φ30.000

p6 : Tol Grade 6 means 13µ variation
(p means lower deviation is 22 µ)



Fit: 60 H8/e6

Example

Creating a Clearance Fit using The Basic Hole System

Given the following fit **Φ40 – H11/c11**

From table for hole diameter = 40 and H11 we find

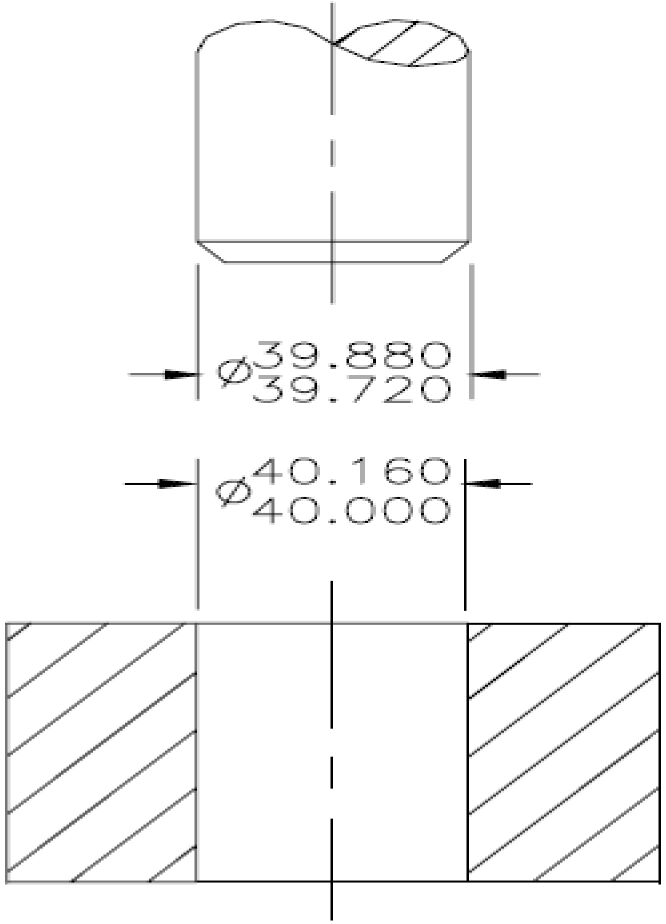
Upper deviation = +160 μm & Lower deviation = 0

From table for shaft diameter = 40 and c11 we find

Upper deviation = -120 μm & Lower deviation = -280 μm

Calculations of dimension limits for hole and shaft

- **Maximum hole diameter = 40 + 0.16 = 40.16 mm**
- **Minimum hole diameter = 40 + 0 = 40 mm**
- **Maximum shaft diameter = 40 +(-120) = 39.88 mm**
- **Minimum shaft diameter = 40 + (-280) = 39.72 mm**



Maximum clearance = Maximum hole diameter – Minimum shaft diameter

= 40.16 – 39.72 = 0.44 mm

Minimum clearance = Minimum hole diameter – Maximum shaft diameter

= 40 – 39.88 = 0.12 mm

Allowances = minimum clearance = 0.12 mm = 120 μm