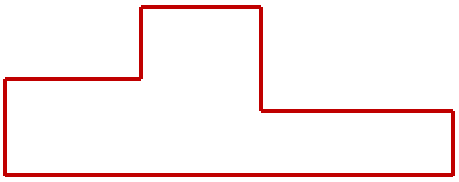
ME251A- Engineering Design and Graphics
Fits and Tolerances

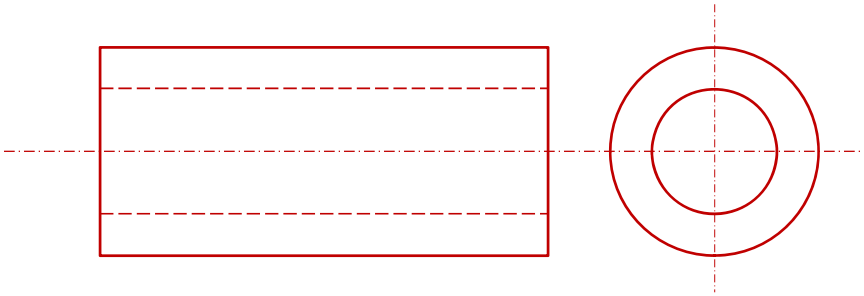
Why do we need dimensional tolerances?

- Manufacturing and inspection limitations make it difficult to make parts to exact dimensions like 50 mm diameter
- For example, let us design a steel rod to withstand a force of 7854 N without breaking!
  - The material is steel having a strength of 100 MPa (N/mm^2)
  - Simple calculation shows that the area of cross-section should be $A=7854/100 = 78.54\ mm^2$
  - Thus the rod should have a diameter of 10 mm. So if the wire diameter is 10 mm it will not break.
- This size is called the **basic dimension**: The dimension obtained from design calculations
- But it will be very difficult and expensive to machine a rod to exactly 10 mm
- Solution: Give a range within which the diameter should lie, say 10.0 mm to 10.2 mm. **How to decide this range?**

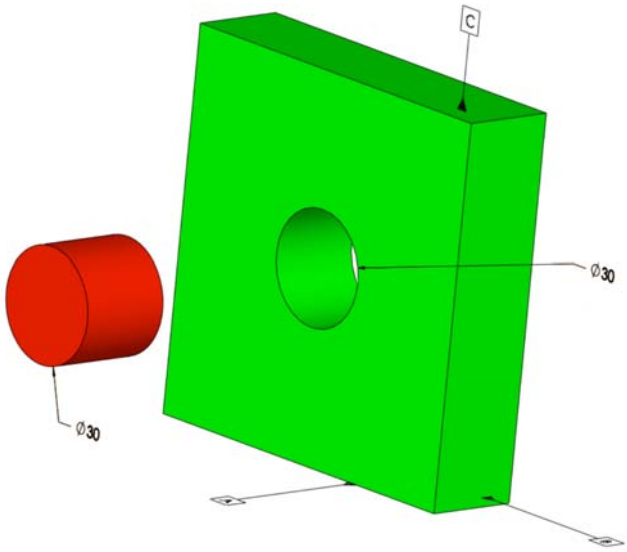
Geometrical tolerances

- Straightness
- Flatness
- Circularity
- Cylindricity
- Parallelism
- Perpendicularity

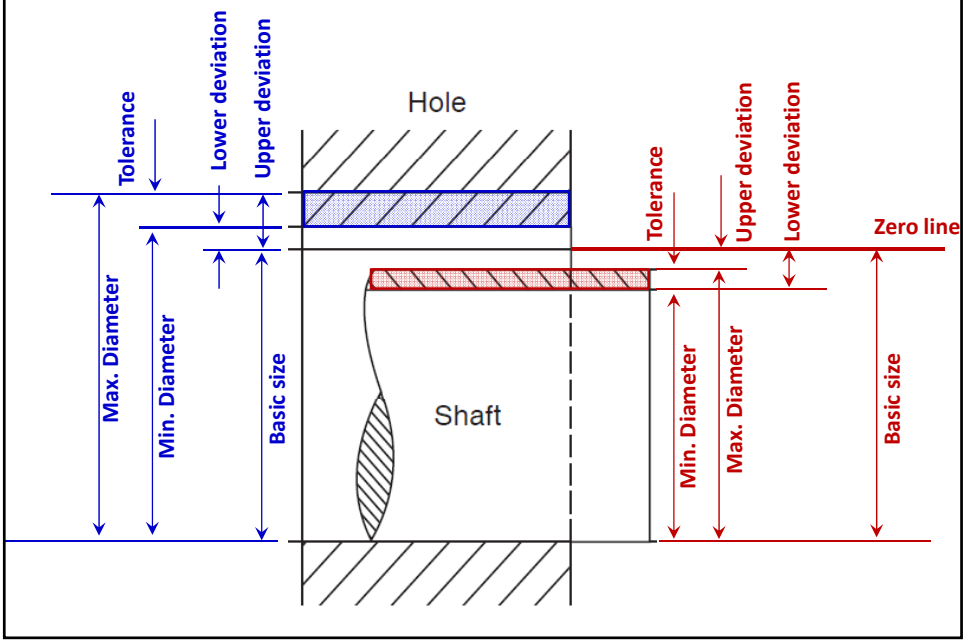




Importance of tolerance in assembly



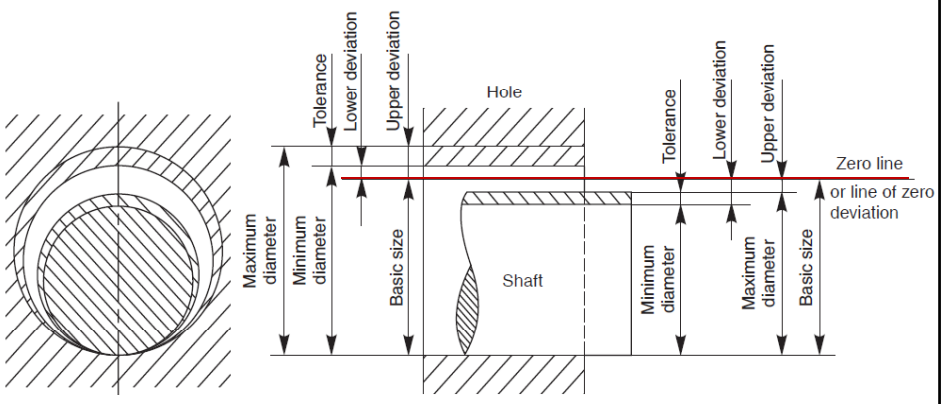
Definition of Terms in Dimensional Tolerance



Definition of terms

- Basic dimension (size): The dimension obtained from design calculations
- Limits: The two extreme sizes allowable for a part
  - Upper limit
  - Lower limit
- Tolerance: Difference between limits
- Deviation: **Algebraic difference** between actual manufactured size and basic size
  - Upper deviation: Difference between upper limit and basic size
  - Lower deviation: Difference between lower limit and basic size
  - Fundamental deviation: The one closest to basic size
- Allowance: Dimensional difference between the maximum limit of two mating parts- **provided intentionally**

Definition of terms



International Tolerance Grade (IT Grade)

- Group of tolerances which has the same relative level of accuracy
- IT 01 is the most precise and IT 16 is most coarse
- Tolerance value depends on **basic size**

	Measuring Tools						Materials										
IT Grade	01	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
							Fits							Commercial manufacturing				

Standard tolerance unit (μm); $i = 0.45\left[D\right]^{1/3} + 0.001D$

D is the geometric mean size of the step in mm

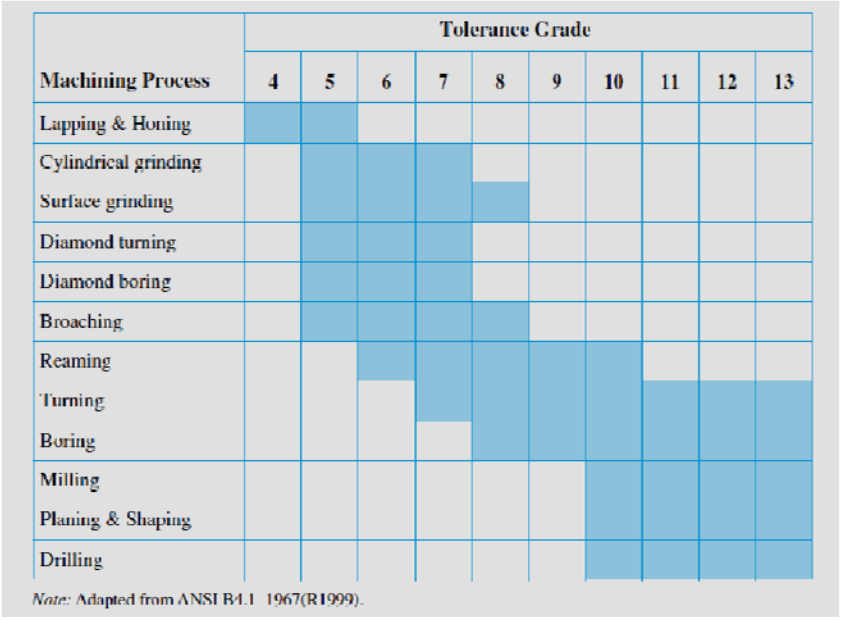
Grade	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
Tol.	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

IT Tolerance grades

Table 19.2 International tolerance grades in microns (0.001 mm)

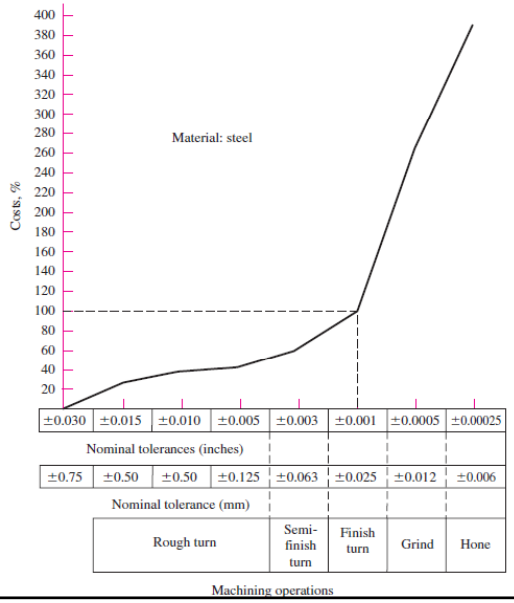
Basic size (mm)		*International Tolerance Grades*																	
Over	*Up to*	*01*	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
0	3	0.3	0.5	0.8	1.2	2.0	3	4	6	10	14	25	40	60	100	140	250	400	600
3	6	0.4	0.6	1.0	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
6	10	0.4	0.6	1.0	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900
10	18	0.5	0.8	1.2	2.0	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
18	30	0.6	1.0	1.5	2.5	4	6	9	13	21	33	52	54	130	210	330	520	840	1300
30	50	0.6	1.0	1.5	2.5	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600
50	80	0.8	1.2	2.0	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
80	120	1.0	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
120	180	1.2	2	3.5	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
180	250	2.0	3	4.5	7	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900
250	315	2.5	4	6	8	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200
315	400	3.0	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
400	500	4.0	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000
500	630	4.5	6	9	11	16	22	30	44	70	110	175	280	440	700	1100	1750	2800	4400
630	800	5.0	7	10	13	18	25	35	50	80	125	200	320	500	800	1250	2000	3200	5000
800	1000	5.5	8	11	15	21	29	40	56	90	140	230	360	560	900	1400	2300	3600	5600
1000	1250	6.5	9	13	18	24	34	46	66	105	165	260	420	660	1050	1650	2600	4200	6600
1250	1600	8	11	15	21	29	40	54	78	125	195	310	500	780	1250	1950	3100	5000	7800
1600	2000	9	13	18	25	35	48	92	92	150	230	370	600	920	1500	2300	3700	6000	9200
2000	2500	11	15	22	30	41	57	77	110	175	280	440	700	1100	1750	2800	4400	7000	11000

Tolerance grades for different machining processes

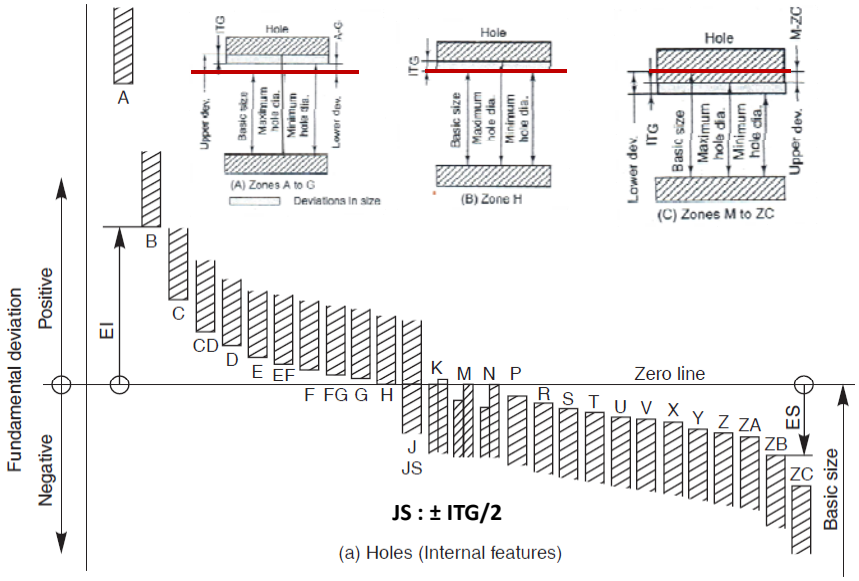


Note: Adapted from ANSI B4.1 1967(R1999).

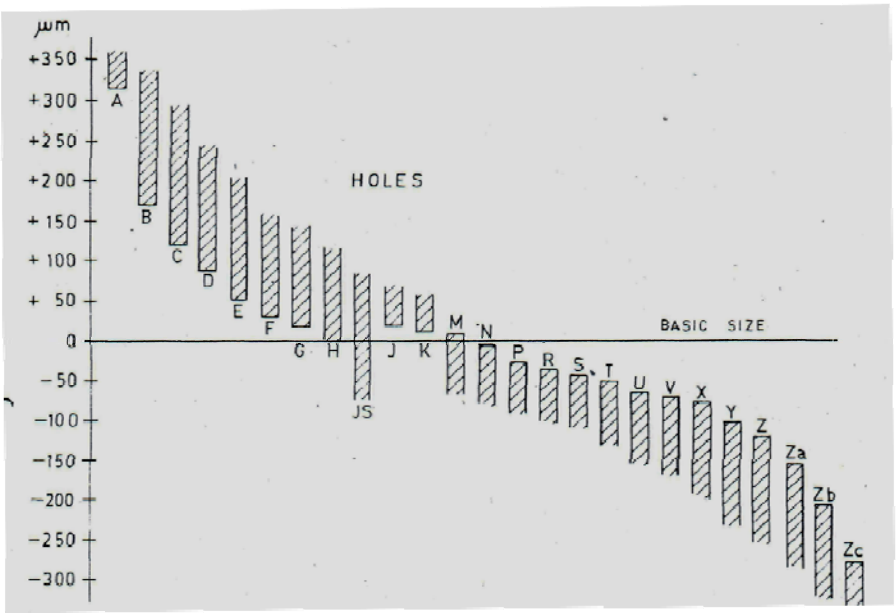
Manufacturing cost versus tolerance



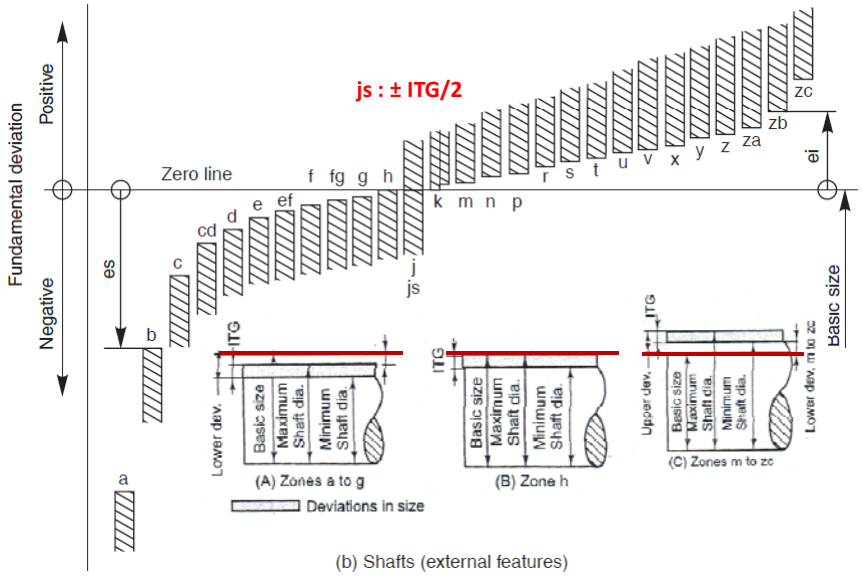
Fundamental Deviation: Holes



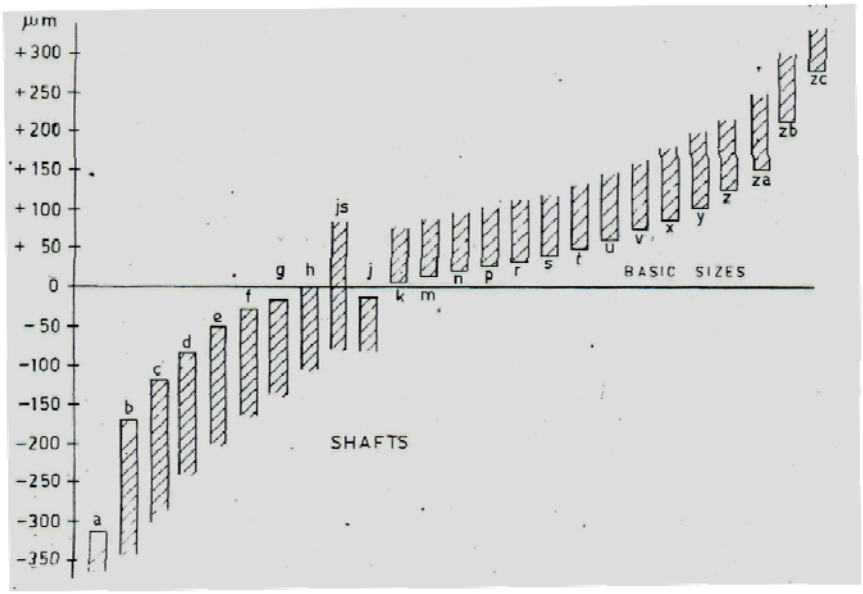
Holes with basic size 30-40 mm



Fundamental Deviation: Shafts



Shafts with basic size 30-40 mm



Fundamental Deviation: Shafts

Fundamental deviation in microns (1 micron = 0.001 mm)

Diameter steps in mm		*Upper deviation (es)*								js⁺	*Lower deviation (ei)*				
		a	*b*	*c*	*d*	*e*	*f*	*g*	*h*		*j*			*k*	
over	*upto*	*All grades*									5.6	7	8	*4 to 7*	≤ 3, > 7
—	*3	– 270	– 140	– 60	– 20	– 14	– 6	– 2	0		– 2	– 4	– 6	– 0	– 0
3	6	– 270	– 140	– 70	– 30	– 20	– 10	– 4	0		– 2	– 4	—	+ 1	0
6	10	– 280	– 150	– 80	– 40	– 25	– 13	– 5	0		– 2	– 5	—	+ 1	0
10	14	– 290	– 150	– 95	– 50	– 32	– 16	– 6	0	± IT/2	– 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		– 5	– 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											

Examples

- 40j7
  - 40 is the basic size in mm
  - j indicates it is a shaft and the upper deviation is -10 μm for IT grade 7
  - For basic size in the range (30-50 mm), the tolerance for IT grade 7 is 25 μm
  - Upper limit (Max. Diameter) = **39.990 mm**
  - Lower limit (Min. Diameter) = **39.965 mm**
- 80JS7
  - 80 is the basic size in mm
  - JS indicates it is a hole with symmetric tolerance of **± ITG/2**
  - For basic size in the range (80-80 mm), the tolerance for IT grade 7 is 30 μm
  - Upper limit (Max. Diameter) = **80.015 mm**
  - Lower limit (Min. Diameter) = **79.985 mm**

How to decide what tolerance has to be specified