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Design and Professional Practice 2

Tolerance, Clearance and Fit

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Aims and Objectives

- Considerations that must be made when components fit together

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Tolerance, Clearance and Fit

- The dimensions of manufactured components vary from the nominal design value.
- The permissible limits of this variation is known as the tolerance.
- This variation depends upon:
    - The material;
    - The manufacturing process;
    - The nature of dimension.

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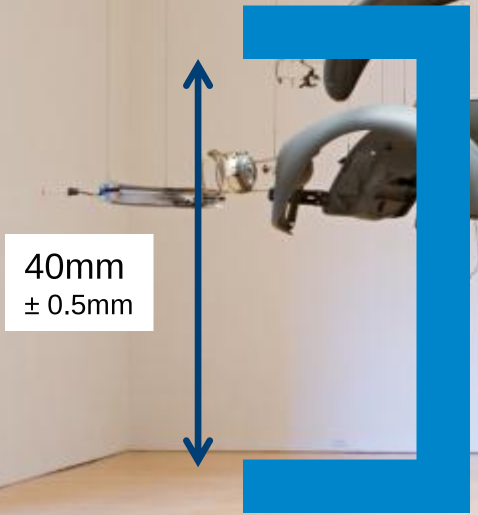
Tolerance, Clearance and Fit

- Tolerances need special consideration whenever one part fits within another.
- Stacks of components have a compounding variation.

Tolerance Stack Example



- A component with a 40mm internal recesses.
  - The tolerance on the recess is ±0.5mm.
  - The upper limit of the recess is 40.5mm.
  - The lower limit of the recess is 39.5mm.

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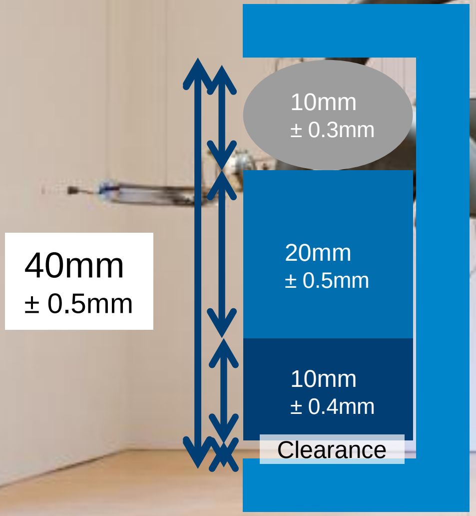
Tolerance Stack Example



- A stack of components fit within the recess, each has their own tolerance.
- The difference between the recess and the stack is the clearance.

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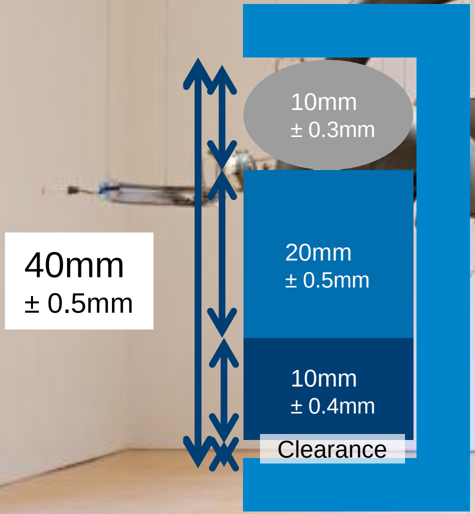
Tolerance Stack Example



- In this example the components are unlikely to fit in the recess more than 50% of the time.
- The worst case example has the stack length as:

Maximum stack length

10 + 20 + 10 + (0.3 + 0.5 + 0.4) = 41.2 mm

Minimum stack length

10 + 20 + 10 – (0.3 + 0.5 + 0.4) = 38.8 mm

- The clearance is therefore between -1.7mm and 1.7mm

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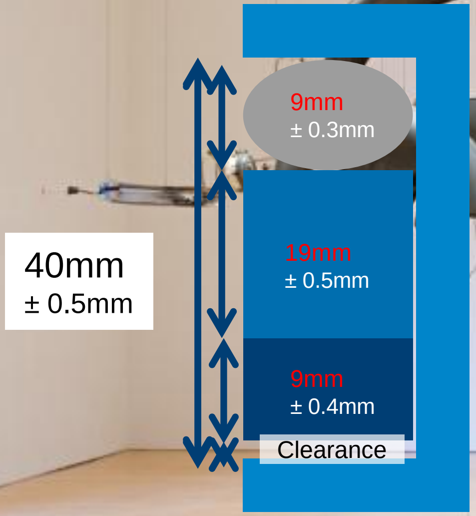
Tolerance Stack Example



- Having adjusted the stack nominal dimensions the worst case scenario now stacks up as:

Maximum stack length

$$9 + 19 + 9 + (0.3 + 0.5 + 0.4) = 38.2 \text{ mm}$$

Minimum stack length

$$9 + 19 + 9 - (0.3 + 0.5 + 0.4) = 35.8 \text{ mm}$$

- Giving a clearance of between 1.3mm and 4.7mm
- An alternative solution would be to adjust the tolerances of the components in the stack, however these are linked to the manufacturing process.

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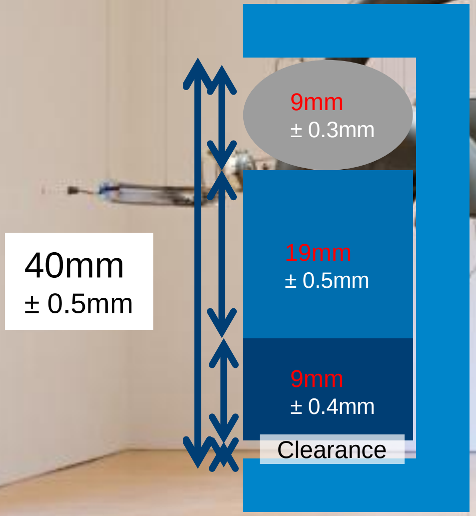
Tolerance Stack Example



$$\sigma_{sys} = \sqrt{\sum\nolimits_{i=1}^{n} \sigma_i^2}$$

- Most stack lengths will be less than 38.2mm.
- Instead of using the worst case scenario, it is preferred to use statistical techniques such as Root Mean Square (RSS) to total up the system variance.
- In this example the system variance would be:

Stack variance = $\sqrt{0.3^2 + 0.5^2 + 0.4^2}$ = 0.71 mm
Maximum stack length = 9 + 19 + 9 + 0.71 = 37.71 mm
Minimum stack length = 9 + 19 + 9 – 0.71 = 36.29 mm

- This gives a clearance of between 1.79mm and 4.21mm

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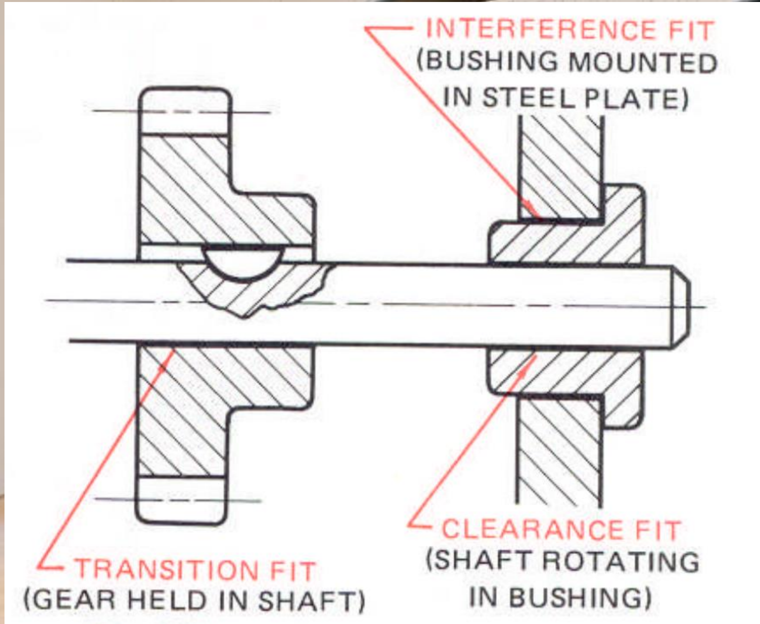
Principles of Fit



- The fit is defined as the designed-in clearance or interference between two parts.
- This fit will depend on the intended function.
- There are a variety of fits:
    - Running / sliding fit
    - Location fit
    - Clearance fit
    - Transition fit
    - Interference fit
    - Shrink (force) fit

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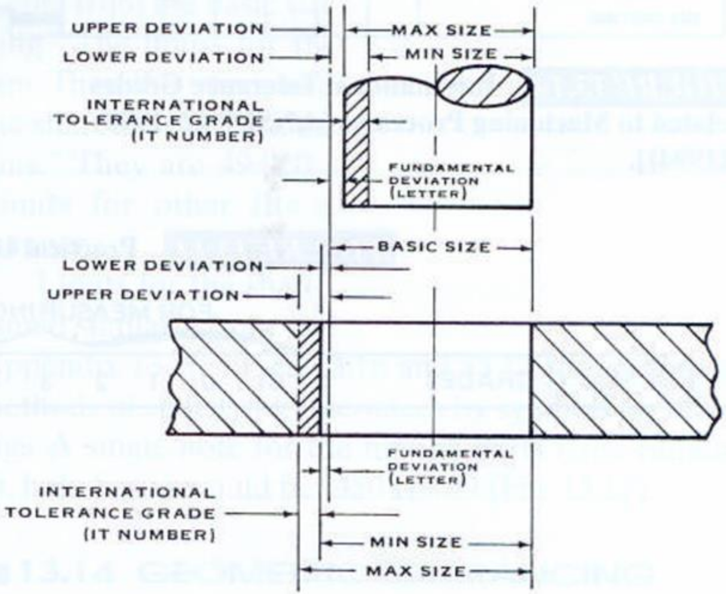
Principles of Fit

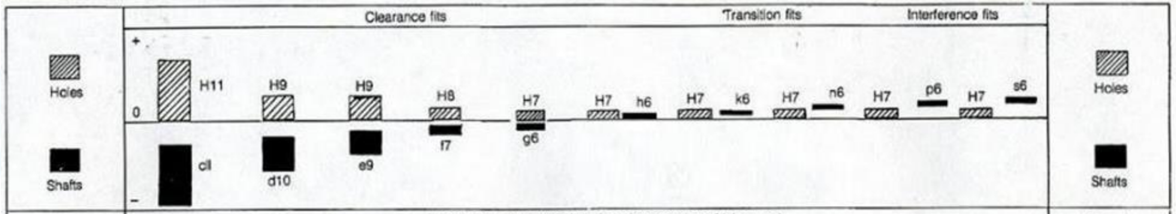
	ISO Symbol		
	Hole Basis	Shaft[a] Basis	Description
Clearance Fits	H11/c11	C11/h11	***Loose-running*** fit for wide commercial tolerances or allowances on external members.
Clearance Fits	H9/d9	D9/h9	***Free-running*** fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.
Clearance Fits	H8/f7	F8/h7	***Close-running*** fit for running on accurate machines and for accurate location at moderate speeds and journal pressures.
Clearance Fits	H7/g6	G7/h6	***Sliding*** fit not intended to run freely, but to move and turn freely and locate accurately.
Transition Fits	H7/h6	H7/h6	***Locational clearance*** fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.
Transition Fits	H7/k6	K7/h6	***Locational transition*** fit for accurate location, a compromise between clearance and interference.
Transition Fits	H7/n6	N7/h6	***Locational transition*** fit for more accurate location where greater interference is permissible.
Interference Fits	H7/p6	P7/h6	***Locational interference*** fit for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.
Interference Fits	H7/s6	S7/h6	***Medium drive*** fit for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.
Interference Fits	H7/u6	U7/h6	***Force*** fit suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.

More clearance ↑

More interference ↓

Principles of Fit





Upper and lower deviations for tolerance class (Values μm)

Basic size (mm) Above	Up to and incl.	H11 +	c11 −	H9 +	d10 −	H9 +	e9 −	H8 +	f7 −	H7 +	g6 −	H7 +	h6 +	H7 +	k6 +	H7 +	n6 +	H7 +	p6 +	H7 +	s6 +	Basic size (mm) Above	Up to and incl.
0	3	60 / 0	60 / 120	25 / 0	20 / 60	25 / 0	14 / 39	14 / 0	6 / 16	10 / 0	2 / 8	10 / 0	6 / 0	10 / 0	6 / 0	10 / 0	10 / 4	10 / 0	12 / 6	10 / 0	20 / 14	0	3
3	6	75 / 0	70 / 145	30 / 0	30 / 78	30 / 0	20 / 50	18 / 0	10 / 22	12 / 0	4 / 12	15 / 0	9 / 0	15 / 0	10 / 1	15 / 0	19 / 10	15 / 0	24 / 15	15 / 0	32 / 23	3	6
6	10	90 / 0	80 / 170	36 / 0	40 / 98	36 / 0	25 / 61	22 / 0	13 / 28	15 / 0	5 / 14	18 / 0	11 / 0	18 / 0	12 / 1	18 / 0	23 / 12	18 / 0	29 / 18	18 / 0	39 / 28	6	10
10	18	110 / 0	95 / 205	43 / 0	50 / 120	43 / 0	32 / 75	27 / 0	16 / 34	18 / 0	6 / 17	21 / 0	13 / 0	21 / 0	15 / 2	21 / 0	28 / 15	21 / 0	35 / 22	21 / 0	48 / 35	10	18
18	30	130 / 0	110 / 240																			18	30
30	40	160 / 0	120 / 280	62 / 0	80 / 180	62 / 0	50 / 112	39 / 0	25 / 50	25 / 0	9 / 25	25 / 0	16 / 0	25 / 0	18 / 2	25 / 0	33 / 17	25 / 0	42 / 26	25 / 0	59 / 43	30	40
40	50	160 / 0	130 / 290																			40	50
50	65	190 / 0	140 / 330	74 / 0	100 / 220	74 / 0	60 / 134	46 / 0	30 / 60	30 / 0	10 / 29	30 / 0	19 / 0	30 / 0	21 / 2	30 / 0	39 / 20	30 / 0	51 / 32	30 / 0	72 / 53	50	65
65	80	190 / 0	150 / 340																	30 / 0	78 / 59	65	80
80	100	220 / 0	170 / 390	87 / 0	120 / 260	87 / 0	72 / 159	54 / 0	36 / 71	35 / 0	12 / 34	35 / 0	22 / 0	35 / 0	25 / 3	35 / 0	45 / 23	35 / 0	59 / 37	35 / 0	93 / 71	80	100
100	120	220 / 0	180 / 400																	35 / 0	101 / 79	100	120
120	140	250 / 0	200 / 450																	40 / 0	117 / 92	120	140
140	160	250 / 0	210 / 460	100 / 0	145 / 305	100 / 0	84 / 185	63 / 0	43 / 83	40 / 0	14 / 39	40 / 0	25 / 0	40 / 0	28 / 3	40 / 0	52 / 27	40 / 0	68 / 43	40 / 0	125 / 100	140	160
160	180	250 / 0	230 / 480																	40 / 0	133 / 108	160	180
180	200	290 / 0	240 / 530																	46 / 0	151 / 122	180	200
200	225	290 / 0	260 / 550	115 / 0	170 / 355	115 / 0	100 / 215	72 / 0	50 / 96	46 / 0	15 / 44	46 / 0	29 / 0	46 / 0	33 / 4	46 / 0	60 / 31	46 / 0	79 / 50	46 / 0	159 / 130	200	225
225	250	290 / 0	280 / 570																	46 / 0	169 / 140	225	250
250	280	320 / 0	300 / 620	130 / 0	190 / 400	130 / 0	110 / 240	81 / 0	56 / 108	52 / 0	17 / 49	52 / 0	32 / 0	52 / 0	36 / 4	52 / 0	66 / 34	52 / 0	88 / 56	52 / 0	190 / 158	250	280
280	315	320 / 0	330 / 650																	52 / 0	202 / 170	280	315
315	355	360 / 0	360 / 720	140 / 0	210 / 440	140 / 0	125 / 265	89 / 0	62 / 119	57 / 0	18 / 54	57 / 0	36 / 0	57 / 0	40 / 4	57 / 0	73 / 37	57 / 0	98 / 62	57 / 0	226 / 190	315	355
355	400	360 / 0	400 / 760																	57 / 0	244 / [illegible]	355	400
400	450	400 / 0	440 / 840	155 / 0	230 / 480	155 / 0	135 / 290	97 / 0	68 / 131	63 / 0	20 / 60	63 / 0	40 / 0	63 / 0	45 / 5	63 / 0	80 / 40	63 / 0	108 / 68	63 / 0	272 / 232	400	450
450	500	400 / 0	480 / 880																	63 / 0	292 / 252	450	500

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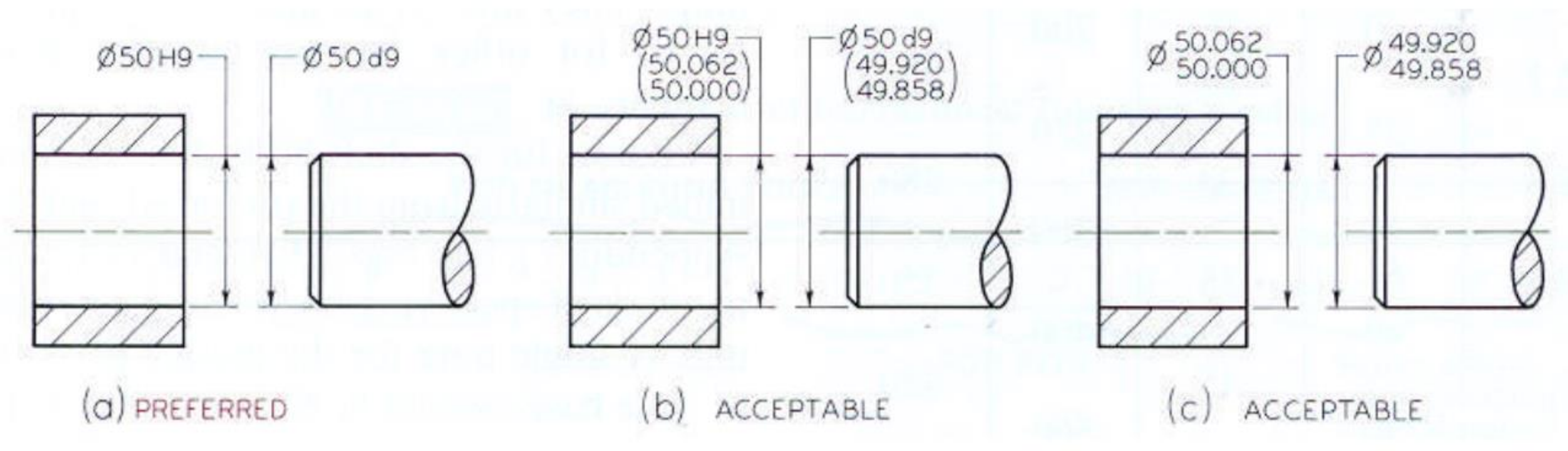
Principles of Fit



Displaying fits in engineering drawings

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Summary

- Tolerance is the permissible variation in a manufactured component
- A Tolerance stack is the variation over a collection of connected components
- Clearance is the space left to make sure interconnecting parts will fit
- Fit describes the different allowances of clearance and tolerance for interconnecting parts

For further information:

- Mechanical Design – by Peter R. N. Childs (ISBN 0-340-69236-7)