



Engineering / Technical Drawing

A Guide to the Production & Interpretation of Drawings to
BS8888



Lecture 5
Limits and Fits

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Origins of Standardisation

- Mating components e.g.

- Nuts & Bolts
- Shafts & Bushes
- Gears



- Matching pairs.... this lack of standardisation was wasteful & time-consuming
- Maintenance of machinery was difficult (replacement parts were not available)





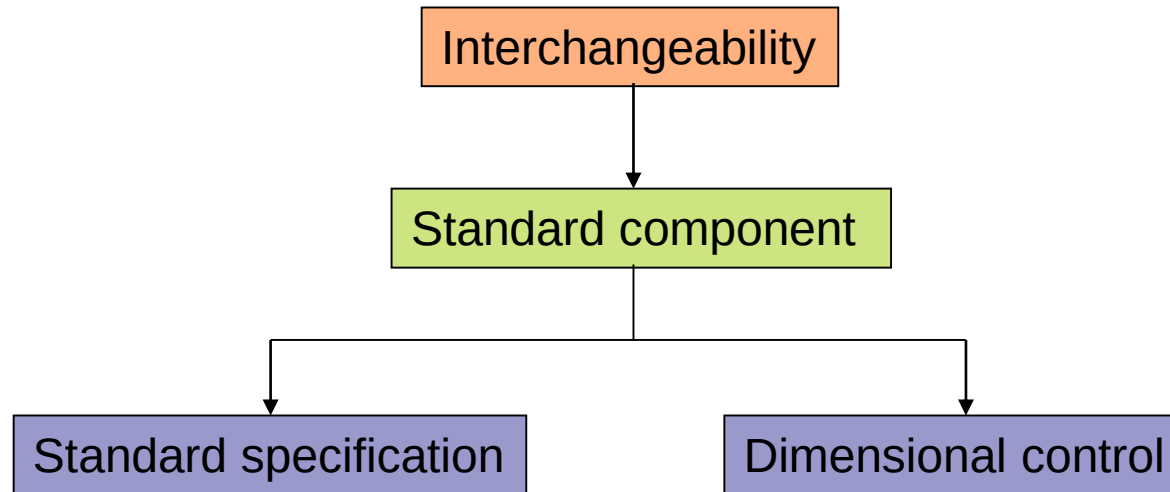
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Standardisation

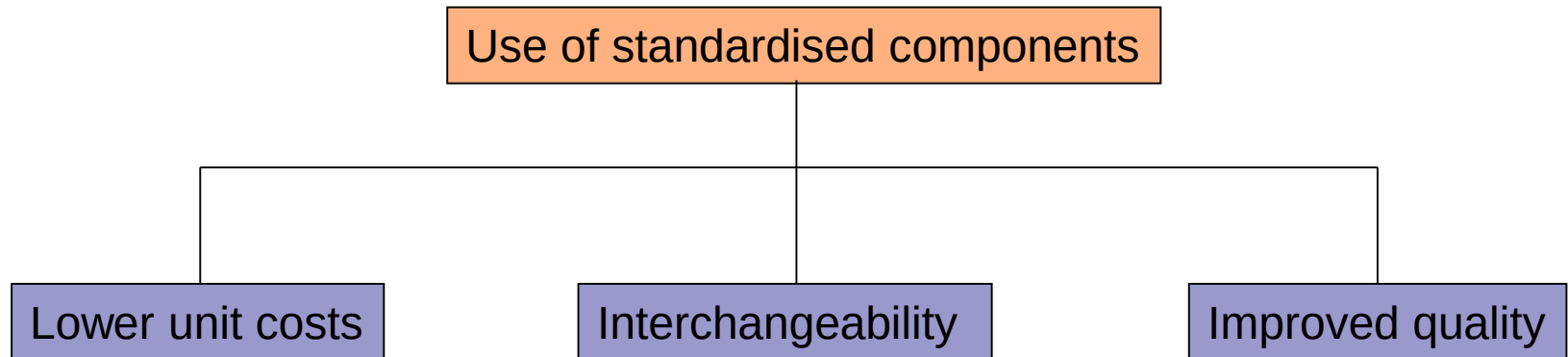


BSI and ISO aim to co-ordinate the efforts of producers and users in the improvement, standardisation and simplification of engineering/industrial components and materials

- By simplifying production and distribution
- By eliminating the waste of time and materials involved in the production of unnecessary varieties of patterns & sizes of articles for the same purpose
- By setting standards of quality
- By setting standards of dimension (size)
- By setting standards of performance and service life
- By promoting the general adoption of BS's &/or IS's

Standardisation

Standardisation may be summarised as follows:



Standardisation

Lower Unit Costs

- are achieved when components are produced in large batch sizes or by continuous flow production techniques using semi or fully automated processes
- Not only are the direct labour costs reduced but together with overhead costs, they are spread over a large number of components. This reduces the cost per unit component
- Large batch & continuous production permits the bulk purchasing of materials, which further reduces costs
- By keeping the range of sizes of components to the minimum necessary to satisfy the needs of industry, storage and distribution costs are also kept to a minimum



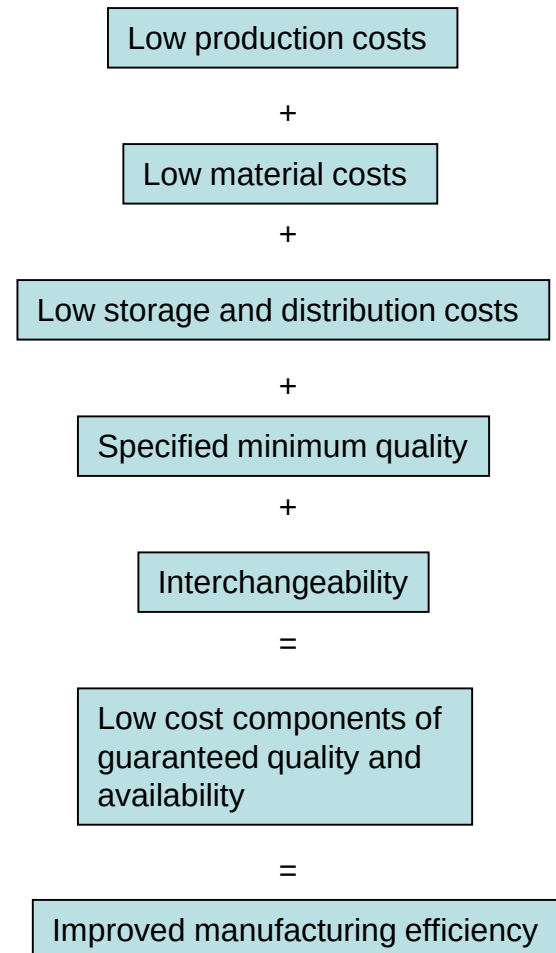
Standardisation

Improved Quality

Is achieved by the use of standard specifications which prescribe minimum standards of:

- 1) Material quality
- 2) Dimensional accuracy
- 3) Performance
- 4) Reliability
- 5) Safety

The accumulative effects of standardisation and interchangeability within the engineering industry has been summarised on the chart



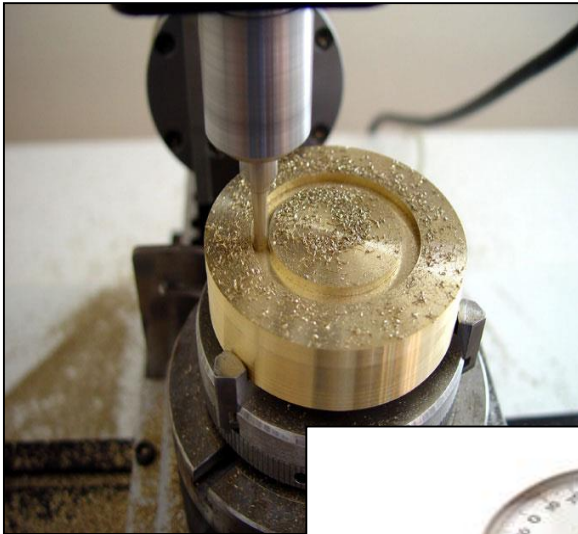
Toleranced Dimensions

- The diagram shows a shaft that has been dimensioned so that its diameter lies between 75.000mm & 74.981mm
- The designer has decided, in his/her wisdom, that any shaft lying between these sizes will function satisfactorily in the application for which it is intended
- The dimensions given are called **limits of size**
- The algebraic difference between the limits is called the tolerance

- $75.000 - 74.981 = 0.019 = \text{tolerance}$



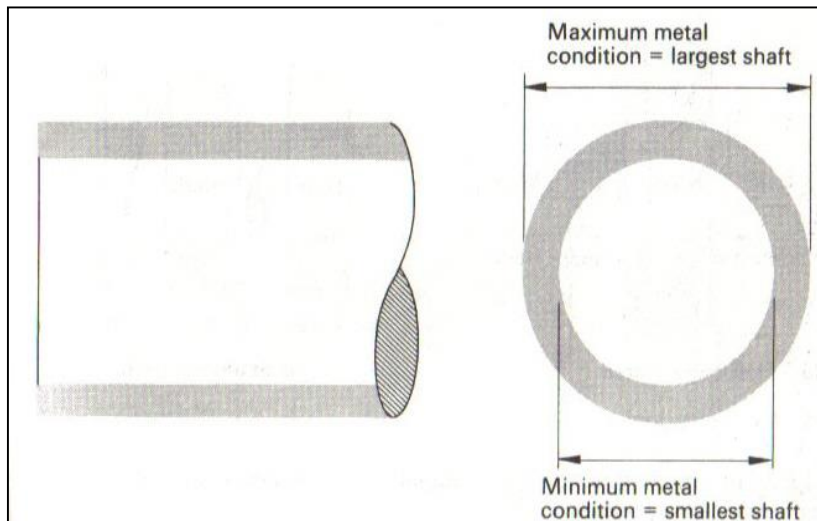
Why Provide Toleranced Dimensions?



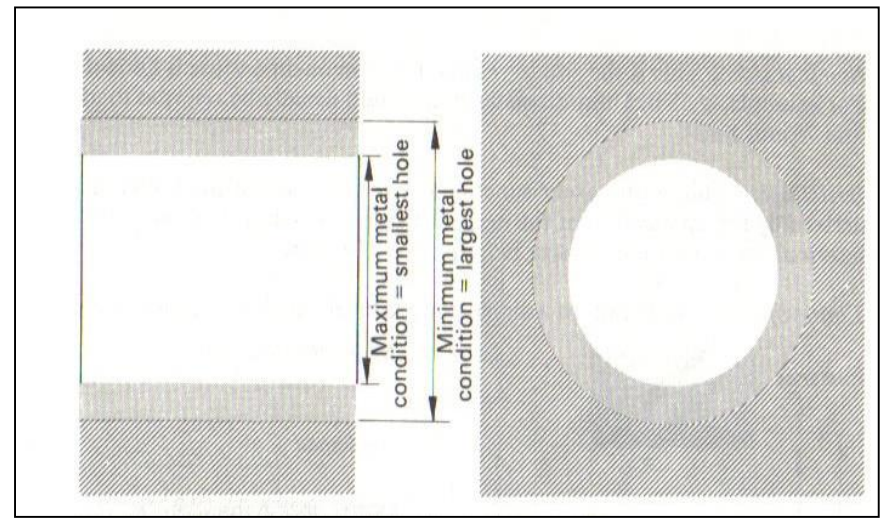
- It is not possible to manufacture any workpiece to an exact size
- If it were, hypothetically, possible to do so, there is no means of measuring such a workpiece exactly
- To achieve interchangeability through standardisation, two things are required:
 - a) a standard specification
 - b) dimensional control

Maximum & Minimum Metal Condition

- The terms **maximum metal condition** & **minimum metal condition** are often met in connection with limit systems and the gauging of workpieces



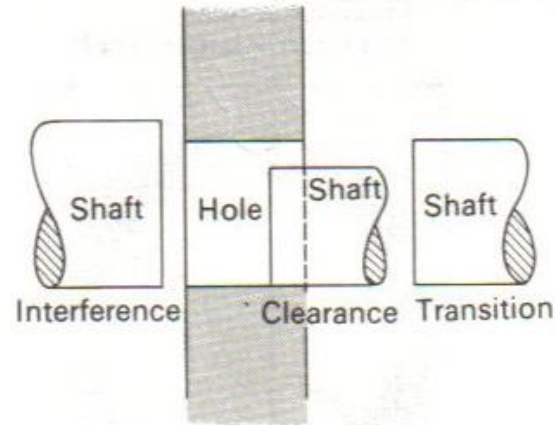
Metal Conditions (Shaft)



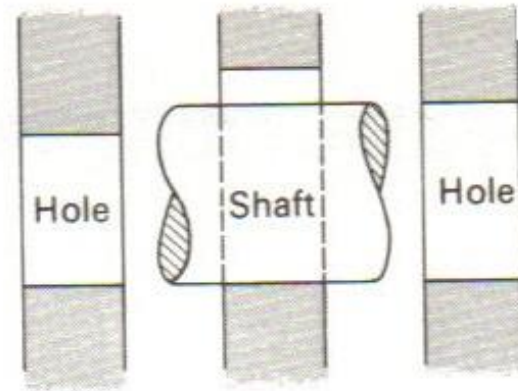
Metal Conditions (Hole)

Hole & Shaft Basis Systems

- To obtain a given class of fit between two mating components, such as a shaft and bearing, the fit may be obtained in two ways:
- 1) By having a constant size hole in the bearing and changing the shaft to suit. This is called a **hole basis system**
- 2) By having a constant size of shaft and changing the hole size to suit. This is called a **shaft basis system**
- The hole basis system is more easily employed since it is easier to maintain a standard hole size (reamers & drills)

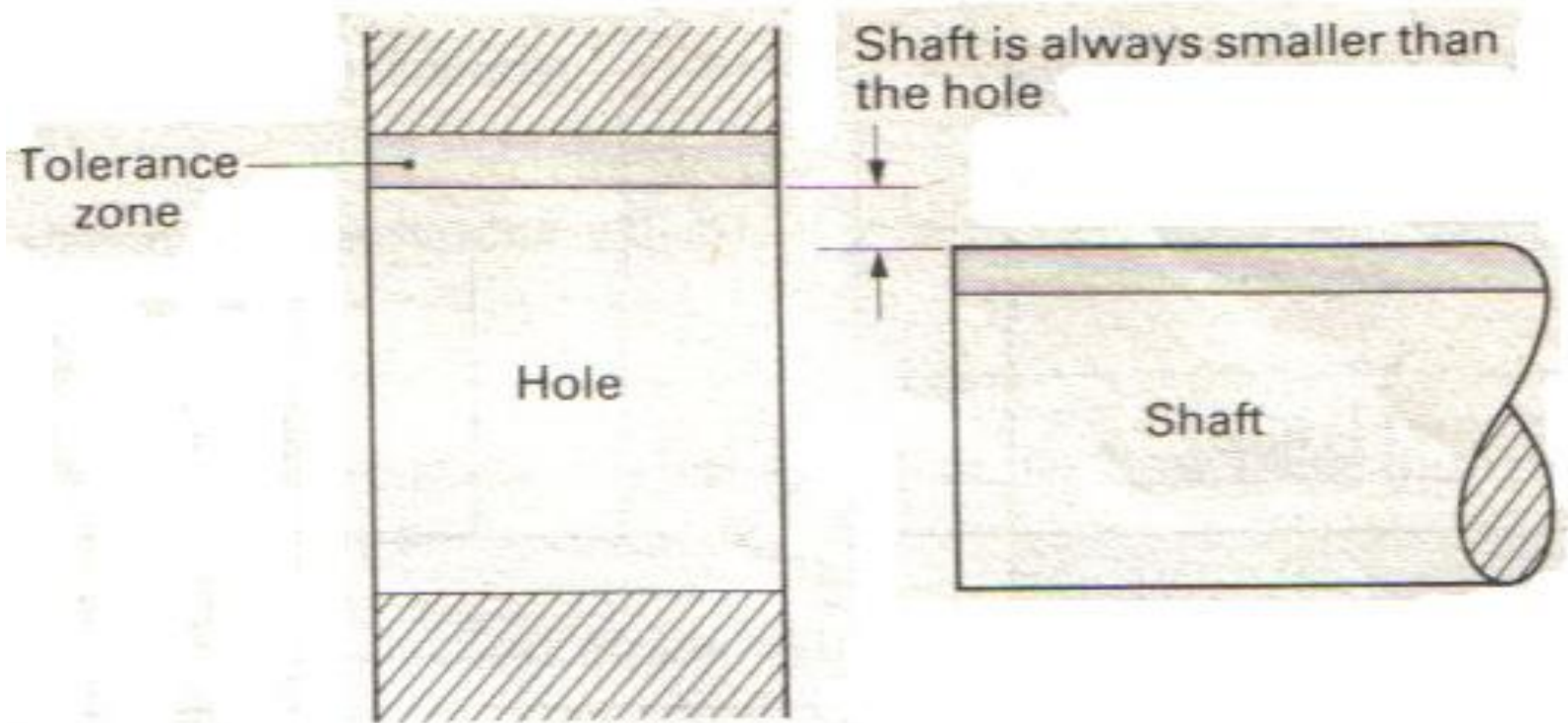


The Hole Basis System

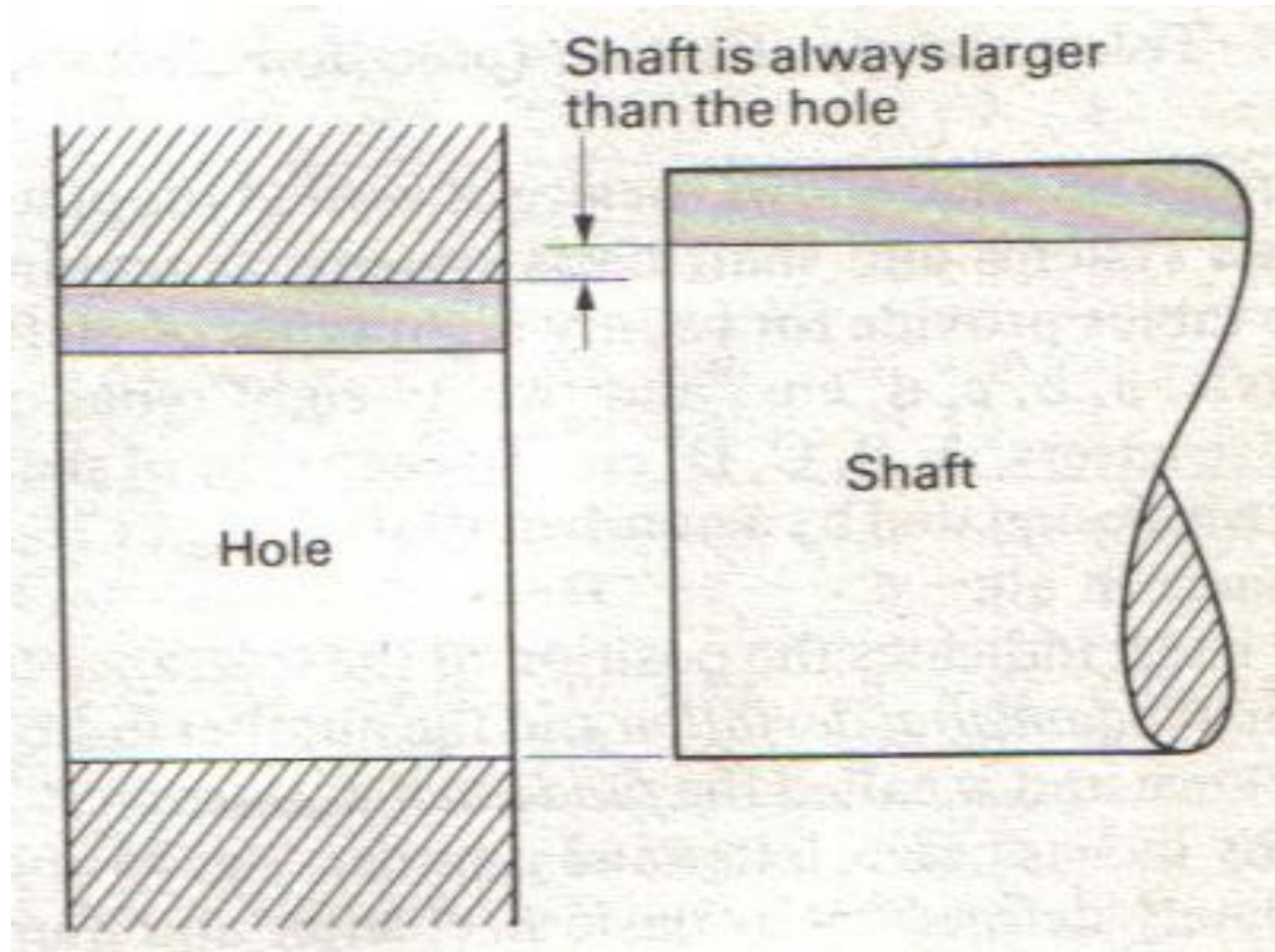


The Shaft Basis System

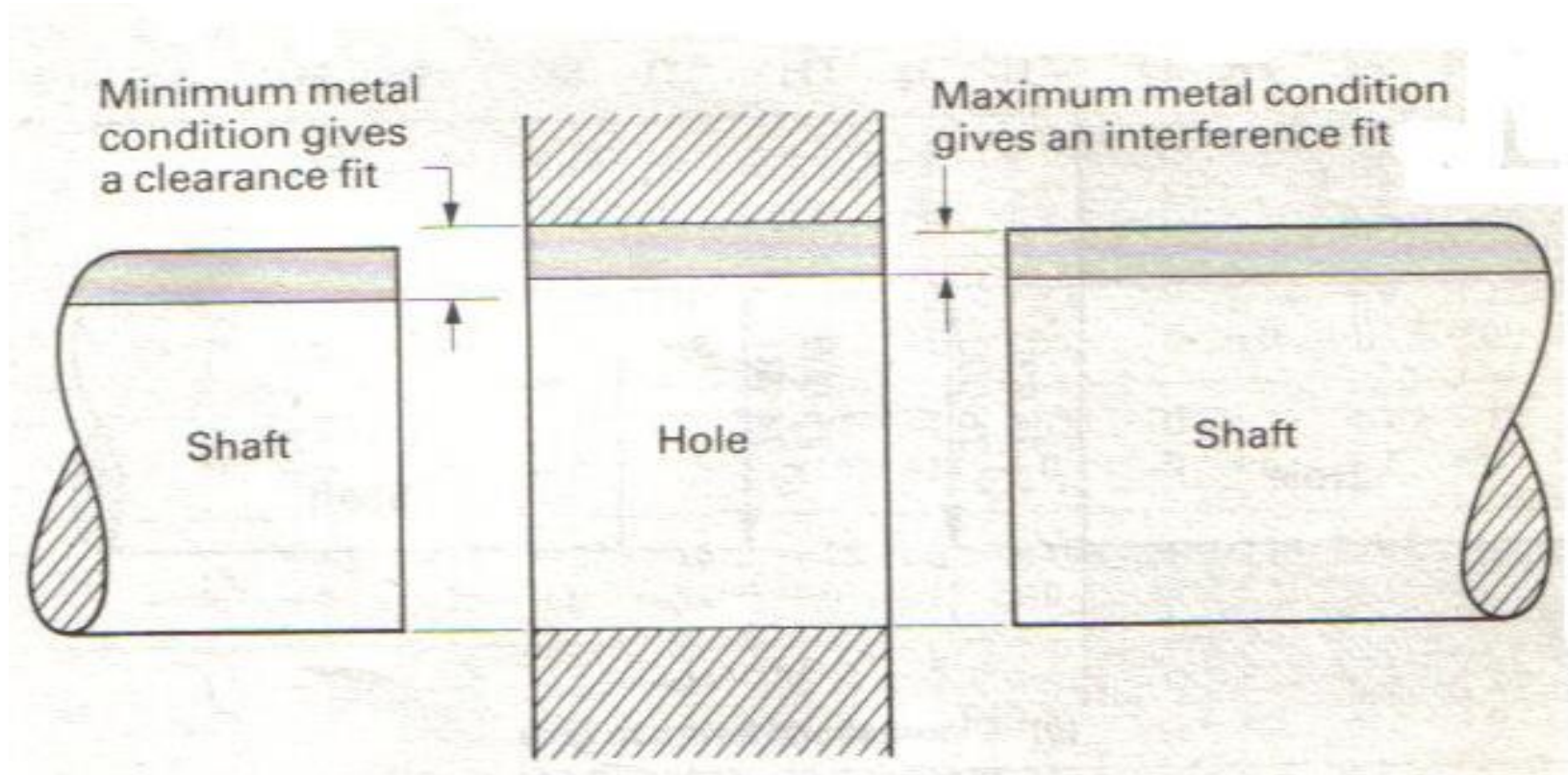
Classifications of Fit – Clearance



Classifications of Fit – Interference



Classifications of Fit – Transition



Limit and Fits Definitions

- **Nominal size**
 - This is the size by which the component feature is known. E.g. a 75.015mm hole would usually be referred to as ‘the 75mm hole’
- **Basic size**
 - This is the exact functional size from which the limits are derived by the application of the necessary tolerances and clearance. The nominal size and the basic size are frequently the same
- **Limits of size**
 - The limits of a dimension are the maximum and minimum sizes by which it is permissible to manufacture a given workpiece if it is to function correctly
- **Tolerance**
 - This is the algebraic difference between the upper and lower limits of size. Its magnitude and disposition is determined by the functional needs of the component and the economics of production
- **Minimum clearance**
 - This used to be known as allowance and is the arithmetical difference between the maximum metal condition for a shaft and the maximum metal condition for the hole i.e. the largest shaft and the smallest hole giving the tightest fit that will function correctly

Limit and Fit Definitions cont...

- **Actual size**
 - The measured size correct to 20°C
 - Unilateral tolerances are those where the tolerance zones lie to one side only of the basic size
 - Bilateral tolerances are those where the tolerance zones cross the basic size
- **Clearance fit**
 - This occurs when the shaft is smaller than the hole no matter what combination of shaft and hole is selected
- **Transition fit**
 - Transition fit occurs when:
 - The largest shaft and the smallest hole gives an interference fit
 - The smallest shaft and the largest hole gives a clearance fit
- **Interference fit**
 - This occurs when the shaft is larger than the hole even when the largest shaft and the smallest hole is selected or the smallest shaft and the largest hole

Primary Selection of Fits (Abstract from BS 4500)

Normal sizes Over mm	Up to mm	Loose clearance		Average clearance		Close clearance		Precision clearance		Transition		Interference	
		H9	e9	H8	f7	H7	g6	H7	h6	H7	k6	H7	p6
—	3	+25 +0	-14 -39	+14 +0	-6 -16	+10 +0	-2 -8	+10 +0	-0 -6	+10 +0	+6 +0	+10 +0	+12 +6
3	6	+30 +0	-20 -50	+18 +0	-10 -22	+12 +0	-4 -12	+12 +0	-0 -8	+12 +0	+9 +1	+12 +0	+20 +12
6	10	+36 +0	-25 -61	+22 +0	-13 -28	+15 +0	-5 -14	+15 +0	-0 -9	+15 +0	+10 +1	+15 +0	+24 +15
10	18	+43 +0	-32 -75	+27 +0	-16 -34	+18 +0	-6 -17	+18 +0	-0 -11	+18 +0	+12 +1	+18 +0	+20 +18
18	30	+52 +0	-40 -92	+33 +0	-20 -41	+21 +0	-7 -20	+21 +0	-0 -13	+21 +0	+15 +2	+21 +0	+35 +22
30	50	+62 +0	-50 -112	+39 +0	-25 -50	+25 +0	-9 -25	+25 +0	-0 -16	+25 +0	+18 +2	+25 +0	+42 +26
50	80	+74 +0	-60 -134	+46 +0	-30 -60	+30 +0	-10 -29	+30 +0	-0 -19	+30 +0	+21 +2	+30 +0	+51 +32
80	120	+87 +0	-72 -159	+54 +0	-36 -71	+35 +0	-12 -34	+35 +0	-0 -22	+35 +0	+25 +3	+35 +0	+59 +37
120	180	+100 +0	-85 -185	+63 +0	-43 -83	+40 +0	-14 -39	+40 +0	-0 -25	+40 +0	+28 +3	+40 +0	+68 +43
180	250	+115 +0	-100 -215	+72 +0	-50 -96	+46 +0	-15 -44	+46 +0	-0 -29	+46 +0	+33 +4	+46 +0	+79 +50
250	315	+130 +0	-110 -240	+81 +0	-56 -108	+52 +0	-17 -49	+52 +0	-0 -32	+52 +0	+36 +4	+52 +0	+88 +56
315	400	+140 +0	-125 -265	+89 +0	-62 -119	+57 +0	-18 -54	+57 +0	-0 -36	+57 +0	+40 +4	+57 +0	+98 +62
400	500	+155 +0	-135 -290	+97 +0	-68 -131	+63 +0	-20 -60	+63 +0	-0 -40	+63 +0	+45 +5	+63 +0	+108 +68

Type of fit required

Types of shaft (lower case)

Types of hole (upper case)

Hole size (nominal)

Limits & Fits Example 1

- To derive the dimensions for a hole and shaft of nominal diameter 40mm so that an average clearance fit is obtained
- Since the nominal size of the shaft/hole is 40mm, the 30 -50mm band is selected from the limits and fits table
- The following conditions then apply:

Nominal size	H8	f7
30-50mm	+39	-25
	+0	-50

Tolerance unit 0.001mm

Limits & Fits Example 1 cont...

Hole diameter: (upper limit) $40 + 0.039 = 40.039\text{mm}$
(lower limit) $40 + 0.000 = 40.000\text{mm}$

Shaft diameter: (upper limit) $40 - 0.025 = 39.975\text{mm}$
(lower limit) $40 - 0.050 = 39.950\text{mm}$

Since only an *average clearance fit is required*, there is no benefit to working to an accuracy of three decimal places. The engineer would use his/her experience and reduce cost of manufacture by rounding off the limits to:

Hole diameter: (upper limit) = 40.04mm
(lower limit) = 40.00mm

Shaft diameter: (upper limit) = 39.98mm
(lower limit) = 39.95mm

(Had a close or precision clearance been required, rounding off would not have been permissible)

Limits & Fits Example 1 cont...

Other information which can be obtained from the dimensions:

Hole tolerance = $40.04 - 40.00 = \underline{\underline{0.04\text{mm}}}$

Shaft tolerance = $39.98 - 39.95 = \underline{\underline{0.03\text{mm}}}$

Maximum

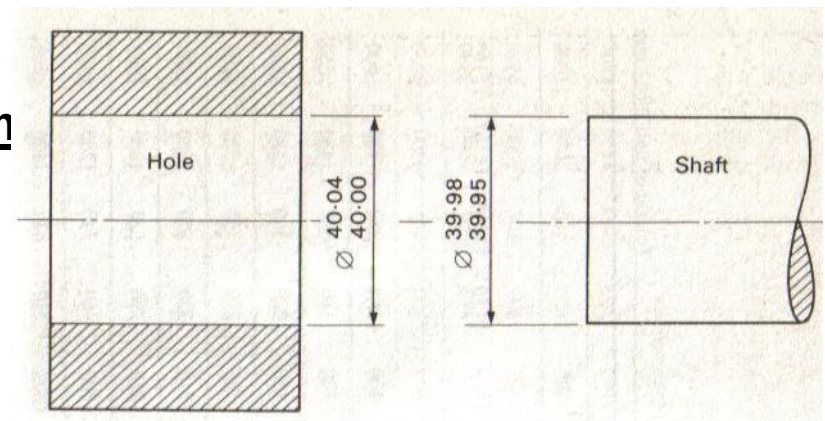
Clearance = $40.04 - 39.95 = \underline{\underline{0.09\text{mm}}}$

$\downarrow \qquad \qquad \downarrow$
(largest hole) (smallest shaft)

Minimum

Clearance = $40.00 - 39.98 = \underline{\underline{0.02\text{mm}}}$

$\downarrow \qquad \qquad \downarrow$
(smallest hole) (largest shaft)



Limits & Fits

- Limits & Fits tables provide:
 - 28 types of hole designated by upper case letters A,B,C,D etc.
 - 28 types of shaft designated by lower case letters a,b,c,d etc.
- To each type of shaft or hole, the grade of tolerance is designated by a number, 01,0,1,2,...16, thus giving 18 grades of tolerance in total.

Limits & Fits

75mm H7/h6

Feature
Dimension



Basic size of
Feature

Letter



Position of tolerance with
respect to the basic size



Fundamental
deviation

Number



Magnitude of tolerance



Fundamental
tolerance

Selection of Tolerance Grades

- The closer the limits, the more difficult it is to manufacture a component to a size which lies between them
- Ensure that the manufacturing process selected is capable of the required level of precision

Class of Work

IT	Class of work
16	Sand casting
15	Stamping
14	Die casting, plastic moulding
13	Presswork, and extrusion
12	Light presswork, tube drawing
11	Drilling, rough turning, boring
10	Milling, slotting, planing, rolling
9	Low grade capstan & automatic lathe work
8	Centre lathe, capstan & automatic
7	High quality turning, broaching, honing
6	Grinding, fine honing
5	Machine lapping, fine grinding
4	Gauge making, precision lapping
3	High quality gap gauges
2	High quality plug gauges
1	Slip gauges, reference gauges

Standard Tolerances

Table 4.2 Standard tolerances

Tolerance unit 0.001 mm

Nominal sizes		Tolerance grades																	
Over	Up to and including	IT01	IT0	IT1	IT2	IT3	IT4	IT5	IT6†	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14*	IT15*	IT16*
mm	mm																		
—	3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250	400	600
3	6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
6	10	0.4	0.6	1	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	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
18	30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
30	50	0.6	1	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	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
80	120	1	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	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	5	7	9	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600
400	500	4	6	8	10	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000
500	630	—	—	—	—	—	—	—	44	70	110	175	280	440	700	1100	1750	2800	4400
630	800	—	—	—	—	—	—	—	50	80	125	200	320	500	800	1250	2000	3200	5000
800	1000	—	—	—	—	—	—	—	56	90	140	230	360	560	900	1400	2300	3600	5600
1000	1250	—	—	—	—	—	—	—	66	105	165	260	420	660	1050	1650	2600	4200	6600
1250	1600	—	—	—	—	—	—	—	78	125	195	310	500	780	1250	1950	3100	5000	7800
1600	2000	—	—	—	—	—	—	—	92	150	230	370	600	920	1500	2300	3700	6000	9200
2000	2500	—	—	—	—	—	—	—	110	175	280	440	700	1100	1750	2800	4400	7000	11000
2500	3150	—	—	—	—	—	—	—	135	210	330	540	860	1350	2100	3300	5400	8600	13500

* Not applicable to sizes below 1 mm

† Not recommended for fits in sizes above 500 mm

Example

- If the diameter of a shaft is 40mm & the tolerance is 0.03mm

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Tolerance unit 0.001 mm

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3	6	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750
6	10	0.4	0.6	1	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	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
18	30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
30	50	0.6	1	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	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
80	120	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200

A tolerance grade between IT7 & IT8 should be designated

Example

- A tolerance grade between IT7 & IT8 should be designated

Suitable tolerance grade



- Therefore a good turned finish would provide a sufficient level of accuracy

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3	6	+30 +0	-20 -50	+18 +0	-10 -22	+12 +0	-4 -12	+12 +0	-0 -8	+12 +0	+9 +1	+12 +0	+20 +12
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120	180	+100 +0	-85 -185	+63 +0	-43 -83	+40 +0	-14 -39	+40 +0	-0 -25	+40 +0	+28 +3	+40 +0	+68 +43
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250	315	+130 +0	-110 -240	+81 +0	-56 -108	+52 +0	-17 -49	+52 +0	-0 -32	+52 +0	+36 +4	+52 +0	+88 +56
315	400	+140 +0	-125 -265	+89 +0	-62 -119	+57 +0	-18 -54	+57 +0	-0 -36	+57 +0	+40 +4	+57 +0	+98 +62
400	500	+155 +0	-135 -290	+97 +0	-68 -131	+63 +0	-20 -60	+63 +0	-0 -40	+63 +0	+45 +5	+63 +0	+108 +68

Standard Tolerances – IT Grades

Table 4.2 Standard tolerances

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6	10	0.4	0.6	1	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	3	5	8	11	18	27	43	70	110	180	270	430	700	1100
18	30	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520	840	1300
30	50	0.6	1	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	3	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900
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500	630	—	—	—	—	—	—	—	44	70	110	175	280	440	700	1100	1750	2800	4400
630	800	—	—	—	—	—	—	—	50	80	125	200	320	500	800	1250	2000	3200	5000
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1000	1250	—	—	—	—	—	—	—	66	105	165	260	420	660	1050	1650	2600	4200	6600
1250	1600	—	—	—	—	—	—	—	78	125	195	310	500	780	1250	1950	3100	5000	7800
1600	2000	—	—	—	—	—	—	—	92	150	230	370	600	920	1500	2300	3700	6000	9200
2000	2500	—	—	—	—	—	—	—	110	175	280	440	700	1100	1750	2800	4400	7000	11000
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