The University of Tennessee at Martin

MARTIN School of Engineering

Interference Fits

Lecture 15

Engineering 473

Machine Design

MARTIN

Standards

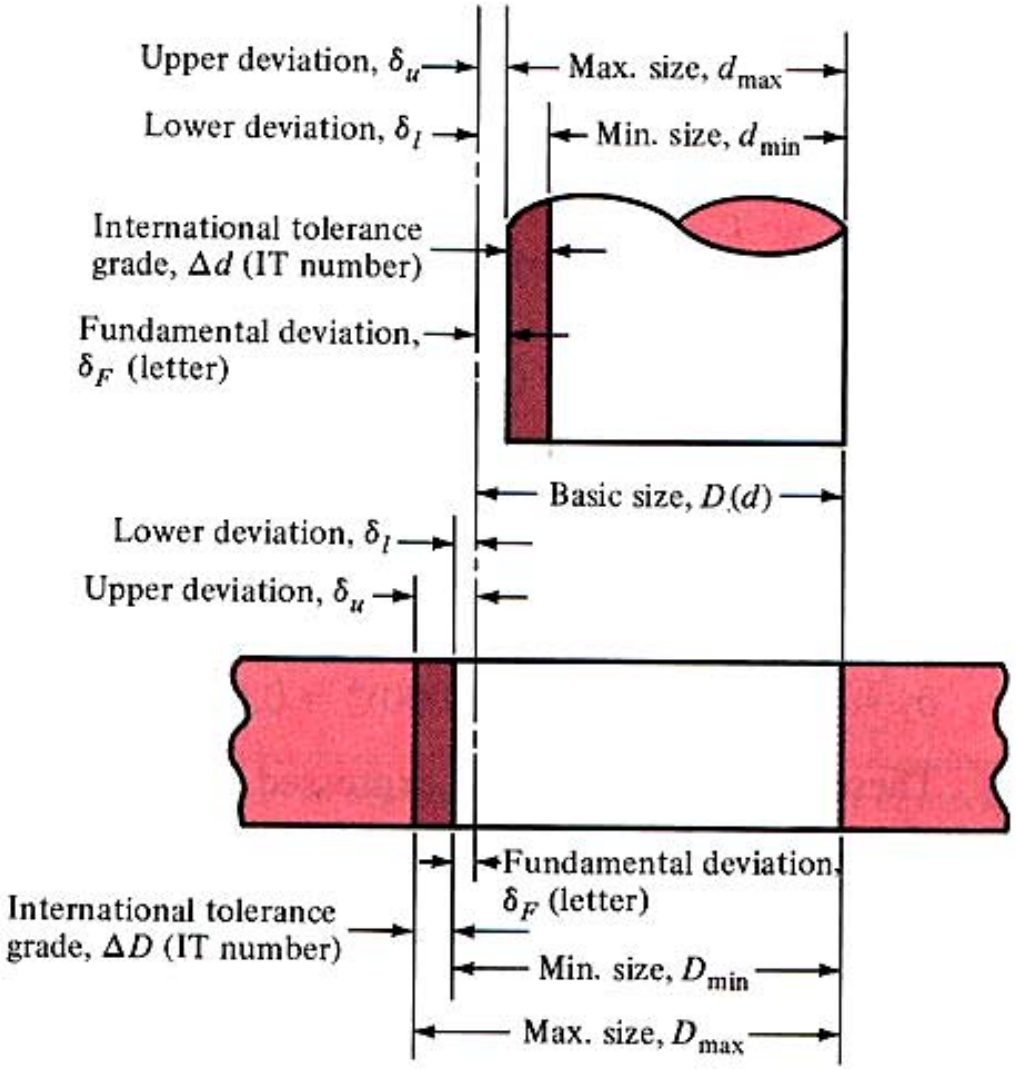
US Customary

Preferred Limits and Fits for Cylindrical Parts, ANSI B4.1-1967.

Metric

Preferred Metric Limits and Fits, ANSI B4.2-1978.

Limits and Fits
(Metric Nomenclature)



$D \equiv$ basic size of hole

$d \equiv$ basic size of shaft

$\delta_u \equiv$ upper deviation

$\delta_l \equiv$ lower deviation

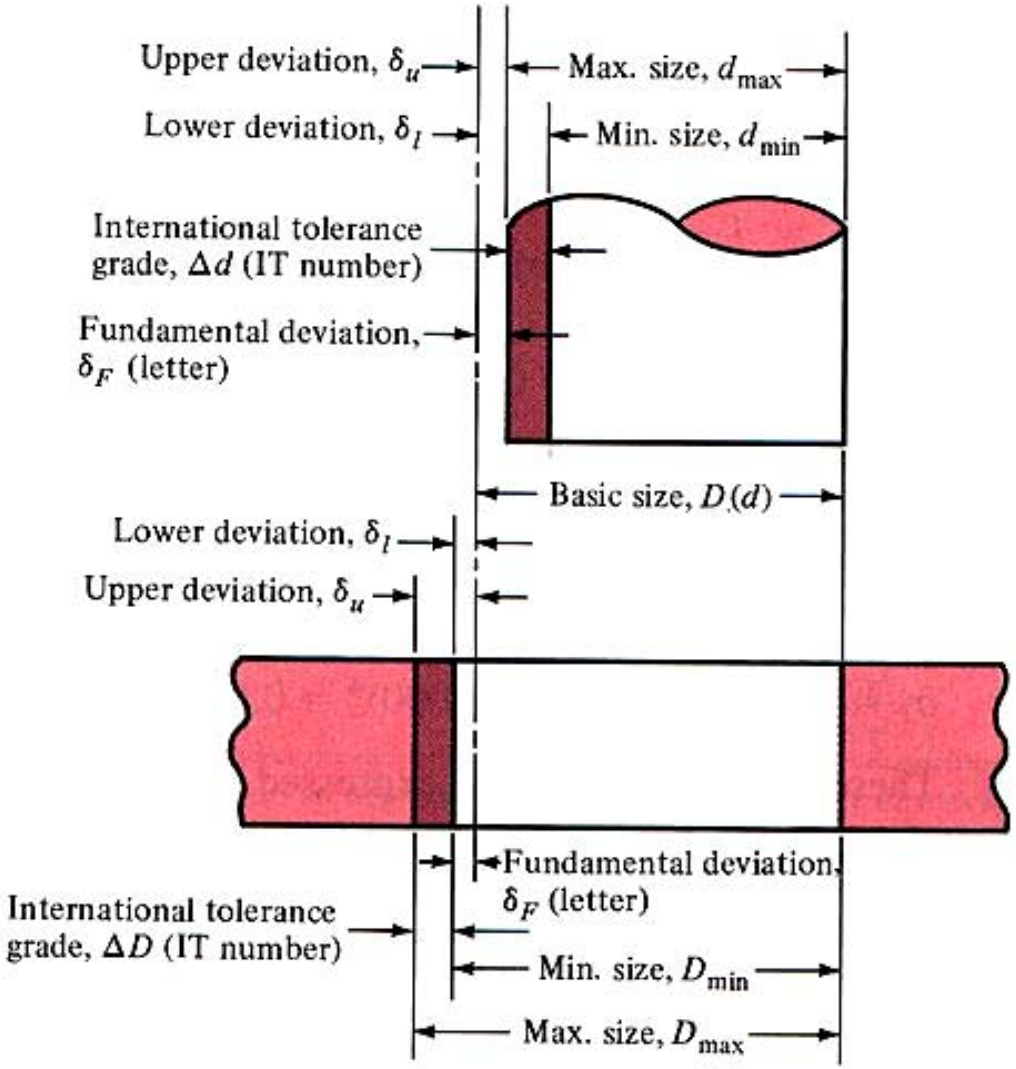
$\delta_F \equiv$ fundamental deviation

$\Delta D \equiv$ tolerance grade for hole

$\Delta d \equiv$ tolerance grade for shaft

Shigley, 4-9

Tolerance Grade Numbers



Tolerance – **difference between the maximum and minimum size limits of a part.**

International Tolerance Grade Numbers are used to specify the size of a tolerance zone.

In the ANSI standard, the tolerance is the same for both the internal (hole) and external (shaft) parts having the same Tolerance Grade Numbers.

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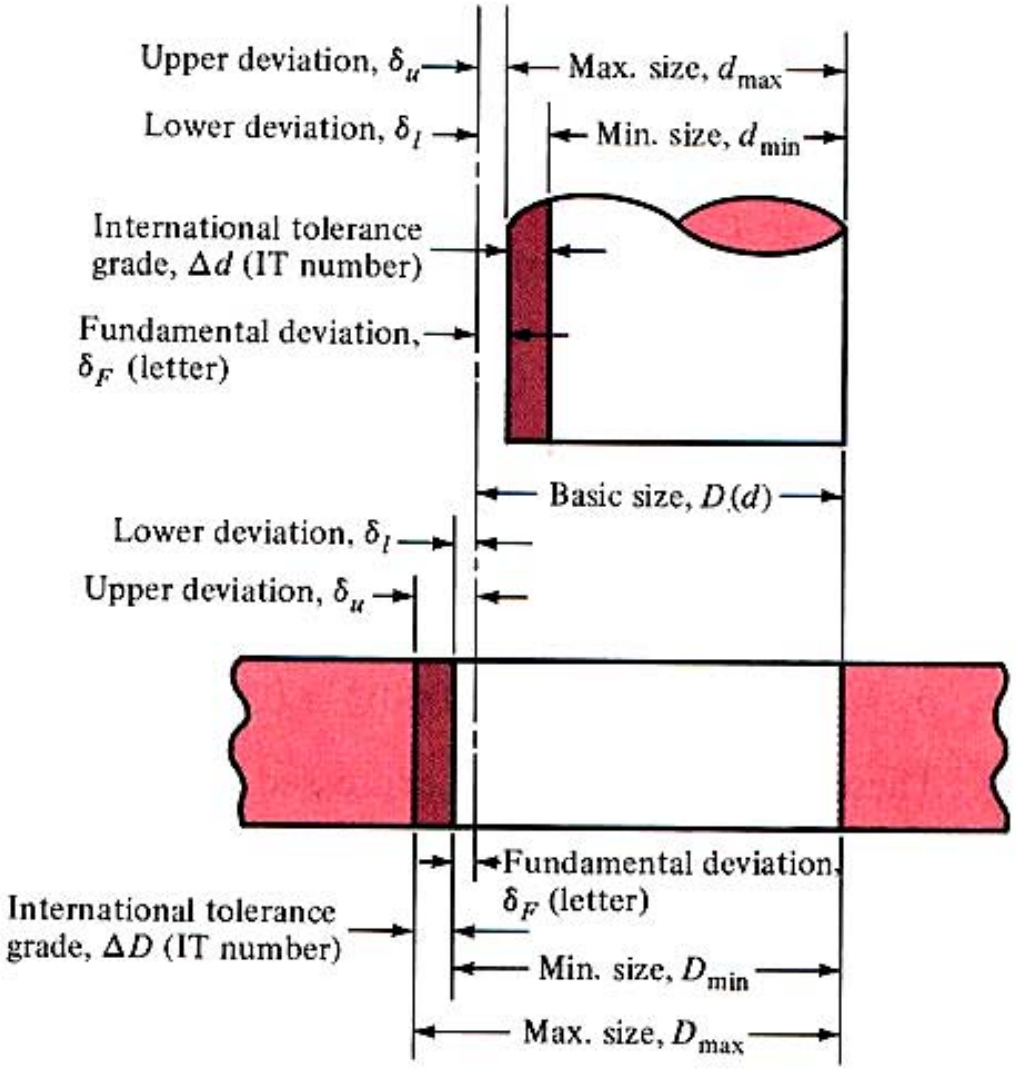
Tolerance Grade Numbers



IT0 through IT16 are contained in the standard.

Grade Number

IT11

International Tolerance

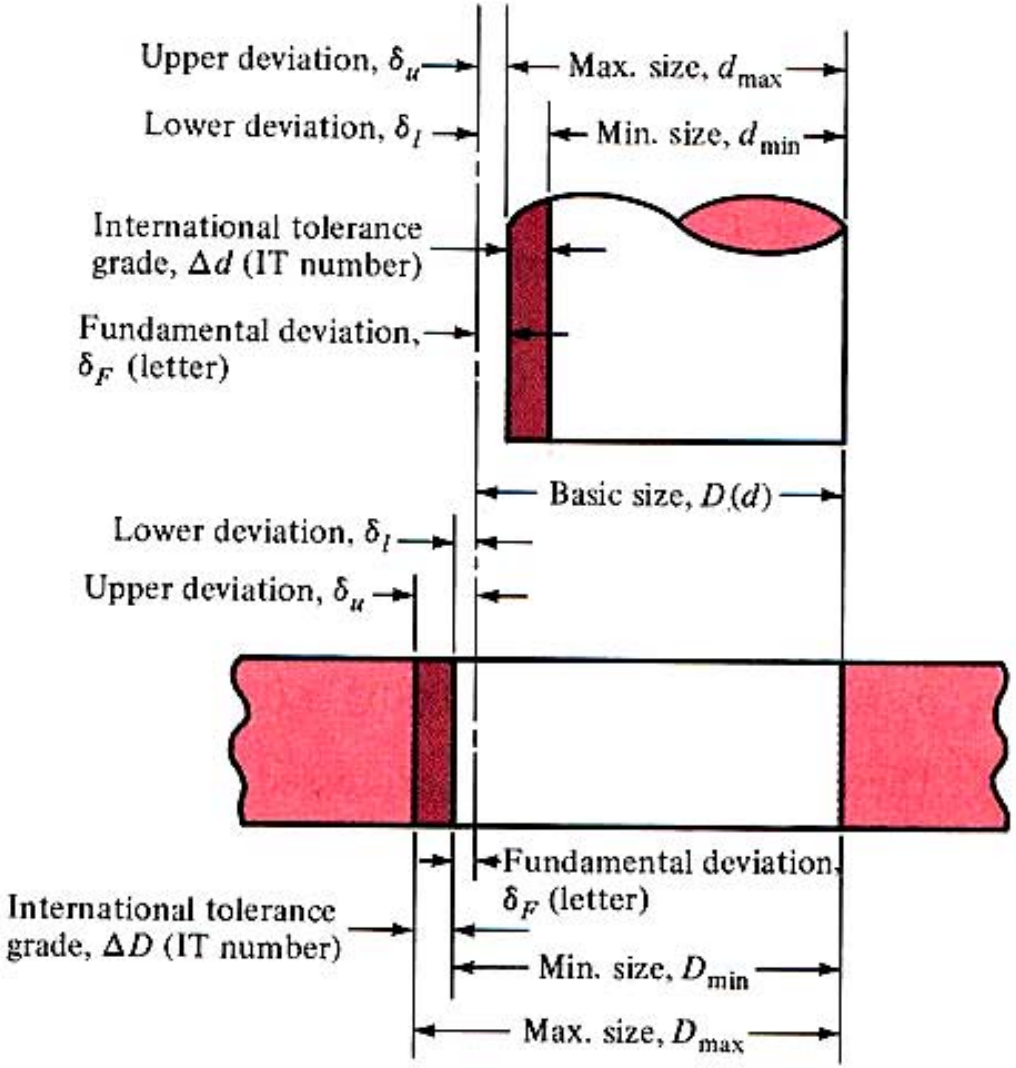
Tolerance Grades Table

BASIC SIZES	TOLERANCE GRADES					
	IT6	IT7	IT8	IT9	IT10	IT11
0–3	0.006	0.010	0.014	0.025	0.040	0.060
3–6	0.008	0.012	0.018	0.030	0.048	0.075
6–10	0.009	0.015	0.022	0.036	0.058	0.090
10–18	0.011	0.018	0.027	0.043	0.070	0.110
18–30	0.013	0.021	0.033	0.052	0.084	0.130
30–50	0.016	0.025	0.039	0.062	0.100	0.160
50–80	0.019	0.030	0.046	0.074	0.120	0.190
80–120	0.022	0.035	0.054	0.087	0.140	0.220
120–180	0.025	0.040	0.063	0.100	0.160	0.250
180–250	0.029	0.046	0.072	0.115	0.185	0.290
250–315	0.032	0.052	0.081	0.130	0.210	0.320
315–400	0.036	0.057	0.089	0.140	0.230	0.360

Souce: Preferred Metric Limits and Fits, ANSI B4.2-1978. See also BSI 4500.

Shigley, Table A-11

Fundamental Deviations



Example of Fit Specification

32H7 Hole

32g6 Shaft

Upper Case => Hole

Lower Case=> shaft

δ_F, Fundamental Deviation

32g6

Tolerance Grade, IT6

D = d = 32 mm (Basic Size)

Shigley, 4-9

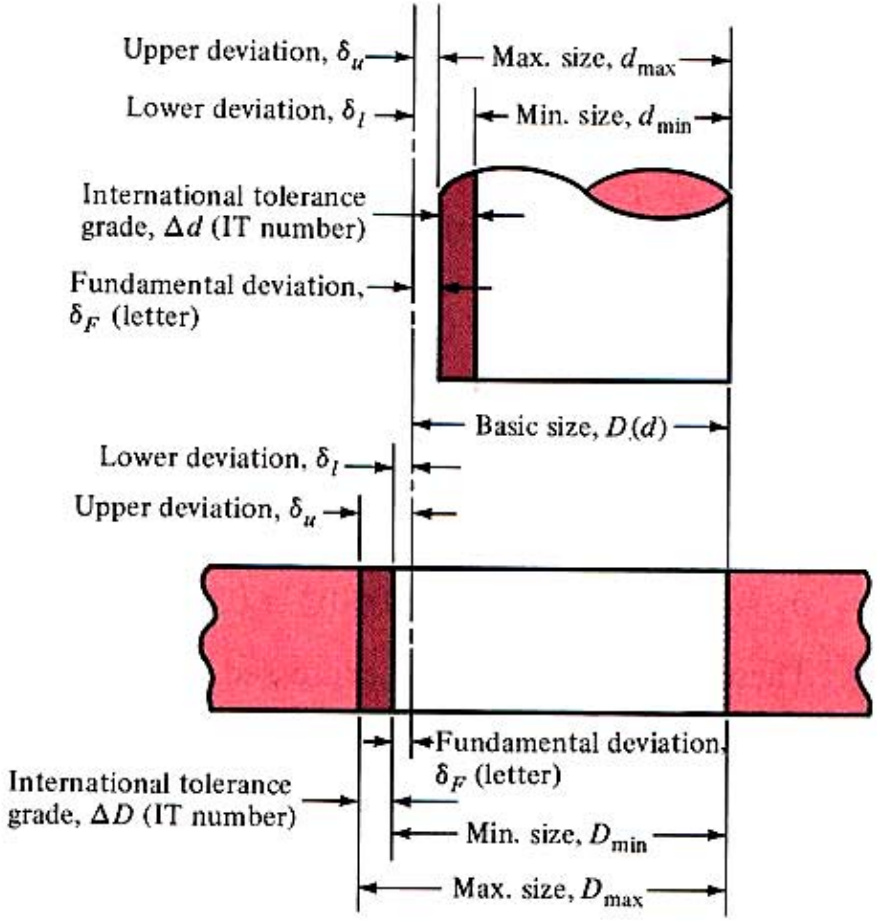
Fundamental Deviations for Shafts

BASIC SIZES	UPPER-DEVIATION LETTER					LOWER-DEVIATION LETTER				
	c	d	f	g	h	k	n	p	s	u
0–3	−0.060	−0.020	−0.006	−0.002	0	0	+0.004	+0.006	+0.014	+0.018
3–6	−0.070	−0.030	−0.010	−0.004	0	+0.001	+0.008	+0.012	+0.019	+0.023
6–10	−0.080	−0.040	−0.013	−0.005	0	+0.001	+0.010	+0.015	+0.023	+0.028
10–14	−0.095	−0.050	−0.016	−0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
14–18	−0.095	−0.050	−0.016	−0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
18–24	−0.110	−0.065	−0.020	−0.007	0	+0.002	+0.015	+0.022	+0.035	+0.041
24–30	−0.110	−0.065	−0.020	−0.007	0	+0.002	+0.015	+0.022	+0.035	+0.048
30–40	−0.120	−0.080	−0.025	−0.009	0	+0.002	+0.017	+0.026	+0.043	+0.060
40–50	−0.130	−0.080	−0.025	−0.009	0	+0.002	+0.017	+0.026	+0.043	+0.070
50–65	−0.140	−0.100	−0.030	−0.010	0	+0.002	+0.020	+0.032	+0.053	+0.087
65–80	−0.150	−0.100	−0.030	−0.010	0	+0.002	+0.020	+0.032	+0.059	+0.102
80–100	−0.170	−0.120	−0.036	−0.012	0	+0.003	+0.023	+0.037	+0.071	+0.124
100–120	−0.180	−0.120	−0.036	−0.012	0	+0.003	+0.023	+0.037	+0.079	+0.144
120–140	−0.200	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.092	+0.170
140–160	−0.210	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.100	+0.190
160–180	−0.230	−0.145	−0.043	−0.014	0	+0.003	+0.027	+0.043	+0.108	+0.210
180–200	−0.240	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.122	+0.236
200–225	−0.260	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.130	+0.258
225–250	−0.280	−0.170	−0.050	−0.015	0	+0.004	+0.031	+0.050	+0.140	+0.284
250–280	−0.300	−0.190	−0.056	−0.017	0	+0.004	+0.034	+0.056	+0.158	+0.315
280–315	−0.330	−0.190	−0.056	−0.017	0	+0.004	+0.034	+0.056	+0.170	+0.350
315–355	−0.360	−0.210	−0.062	−0.018	0	+0.004	+0.037	+0.062	+0.190	+0.390
355–400	−0.400	−0.210	−0.062	−0.018	0	+0.004	+0.037	+0.062	+0.208	+0.435

Source: Preferred Metric Limits and Fits, ANSI B4.2-1978. See also BSI 4500.

Shigley, Table A-12

Lower and Upper Deviations



Shaft letter codes c,d,f,g, and h

Upper deviation = fundamental deviation
Lower deviation = upper deviation – tolerance grade

Shaft letter codes k,n,p,s, and u

Lower deviation = fundamental deviation
Upper deviation = lower deviation + tolerance grade

Hole letter code H

Lower deviation = 0
Upper deviation = tolerance grade

Shigley, 4-9

Preferred Fits Using the Basic-Hole System

TYPE OF FIT	DESCRIPTION	SYMBOL
Clearance	*Loose running* fit: for wide commercial tolerances or allowances on external members	H11/c11
	Free running fit: not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures	H9/d9
	Close running fit: for running on accurate machines and for accurate location at moderate speeds and journal pressures	H8/f7
	Sliding fit: where parts are not intended to run freely, but must move and turn freely and locate accurately	H7/g6
	Locational clearance fit: provides snug fit for location of stationary parts, but can be freely assembled and disassembled	H7/h6
Transition	*Locational transition* fit for accurate location, a compromise between clearance and interference	H7/k6
	Locational transition fit for more accurate location where greater interference is permissible	H7/n6
Interference	*Locational interference* fit: for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements	H7/p6
	Medium drive fit: for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron	H7/s6
	Force fit: suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical	H7/u6

Source: *Preferred Metric Limits and Fits*, ANSI B4.2-1978. See also BS 4500.

Shigley Table 4-5

Loose Running Fit
(Example)

Determine the "loose running fit" tolerances for a shaft and hole that have a basic diameter of 32 mm.

From Table 4-5, Specification is 32H11/32c11

	Hole	Shaft
Tolerance Grade	0.160 mm	0.160 mm (0.0063 in)
Upper deviation	0.160 mm	-0.120 mm
Lower deviation	0.000 mm	-0.280 mm
Max Diameter	32.160 mm (1.266 in)	31.880 mm (1.255 in)
Min Diameter	32.000 mm (1.260 in)	31.720 mm (1.225 in)
Ave Diameter	32.080 mm (1.263 in)	31.800 mm (1.252 in)

Max Clearance $C_{max} = D_{max} - d_{min} = 0.44\,\text{mm}\,(0.017\,\text{in})$

Min Clearance $C_{min} = D_{min} - d_{max} = 0.12\,\text{mm}\,(0.005\,\text{in})$

Loose Running Fit
(Example Continued)

Dimension Tolerances Shown on Drawing

Hole	Shaft
$32.080^{+0.080}_{-0.080}$	$31.800^{+0.080}_{-0.080}$

Force Fit
(Example)

Determine the "force fit" tolerances for a shaft and hole that have a basic diameter of 32 mm.

From Table 4-5, Specification is 32H7/32u6

	Hole	Shaft
Tolerance Grade	0.025 mm (0.001 in)	0.016 mm (0.0006 in)
Upper deviation	0.025 mm	0.076 mm
Lower deviation	0.000 mm	0.060 mm
Max Diameter	32.025 mm (1.261 in)	32.076 mm (1.262 in)
Min Diameter	32.000 mm (1.260 in)	32.060 mm (1.262 in)
Ave Diameter	32.013 mm (1.260 in)	32.068 mm (1.263 in)

Max Clearance $C_{max} = D_{max} - d_{min} = -0.035\,\text{mm}\,(-0.001\,\text{in})$

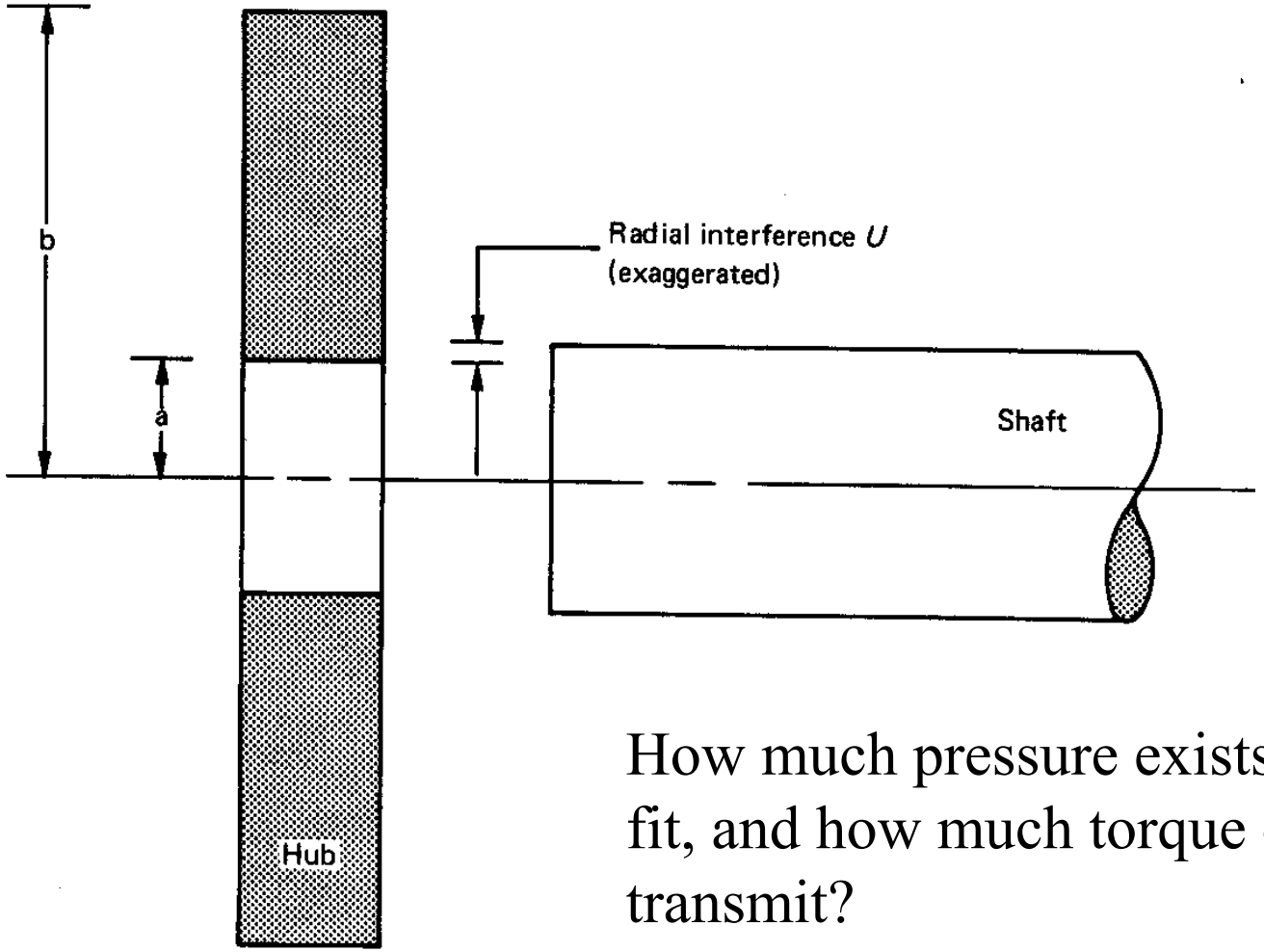
Min Clearance $C_{min} = D_{min} - d_{max} = -0.076\,\text{mm}\,(-0.003\,\text{in})$

Force Fit
(Example Continued)

Dimension Tolerances Shown on Drawing

Hole	Shaft
$32.013^{+0.012}_{-0.013}$	$32.068^{+0.008}_{-0.008}$

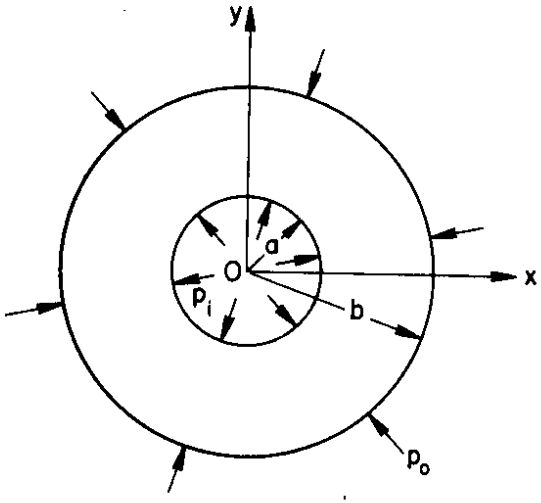
Interference Pressures & Torques



How much pressure exists in a force fit, and how much torque can it transmit?

Deutschman, Fig. 18-2

Lame' Equations for Thick Walled Cylinders

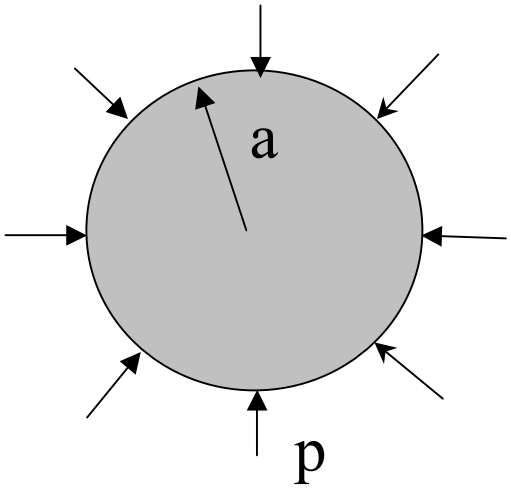


$$\sigma_r = \frac{a^2 p_i - b^2 p_o}{b^2 - a^2} - \frac{(p_i - p_o)a^2 b^2}{(b^2 - a^2)r^2}$$

$$\sigma_\theta = \frac{a^2 p_i - b^2 p_o}{b^2 - a^2} + \frac{(p_i - p_o)a^2 b^2}{(b^2 - a^2)r^2}$$

$$u = \frac{1-\nu}{E}\frac{(a^2 p_i - b^2 p_o)r}{b^2 - a^2} + \frac{1+\nu}{E}\frac{(p_i - p_o)a^2 b^2}{(b^2 - a^2)r}$$

Shaft Displacement and Stresses



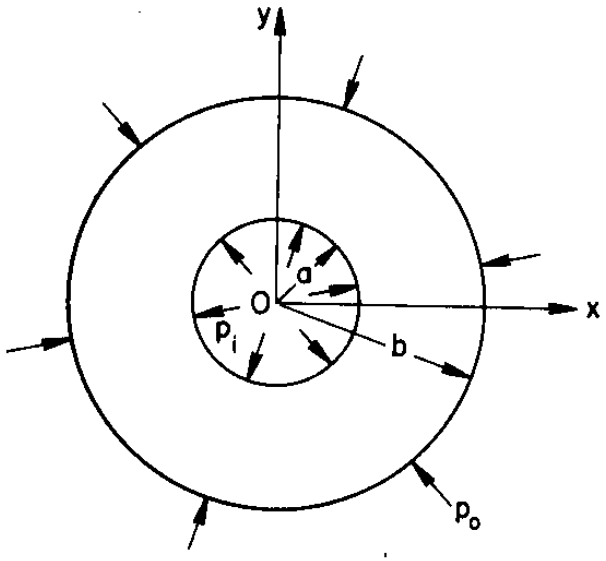
For external pressure and zero inside radius, Lame's equations reduce to -

$$\sigma_r = -p$$

$$\sigma_\theta = -p$$

$$u_s = -\frac{1-\nu_s}{E_s} pa$$

Hub Displacement and Stresses



$$p_o = 0$$

$$\sigma_r = p\frac{a^2 - b^2}{b^2 - a^2}$$

$$\sigma_\theta = p\frac{a^2 + b^2}{b^2 - a^2}$$

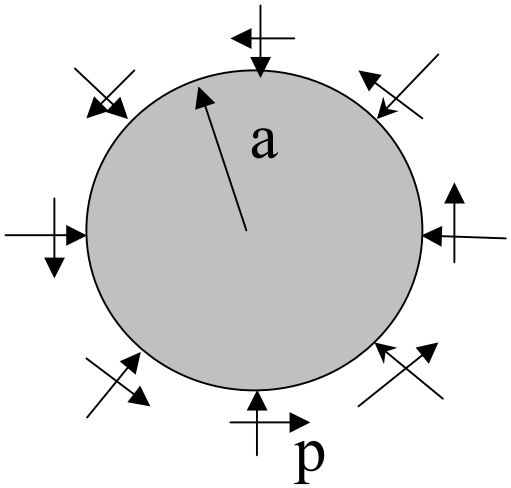
$$u_h = \frac{pa}{E_h}\left(\frac{a^2 + b^2}{b^2 - a^2} + \nu_h\right)$$

Interference Pressure Equation

$$|C| = u_h - u_s = ap\left(\frac{\frac{b^2 + a^2}{b^2 - a^2} + \nu_h}{E_h} + \frac{1 - \nu_s}{E_s}\right)$$

$$p = \frac{|C|}{a\left(\frac{\frac{b^2 + a^2}{b^2 - a^2} + \nu_h}{E_h} + \frac{1 - \nu_s}{E_s}\right)}$$

Maximum Torque without Slipping



$$F_n = p \cdot 2 \cdot \pi \cdot a \cdot L$$

$$F_f = \mu F_n$$

$$\text{Torque} = F_f \cdot a$$

L= Hub Thickness

Assignment

1. A 4-in diameter, 2-in face width, 20-tooth cast iron pinion gear is to transmit a maximum torque of 1200 in-lb at low speed. Find the required radial interference on 1 in diameter steel shaft and the stress in the gear due to the press fit. Use the dedendum radius as the outside radius of the pinion gear.
2. Determine the dimension and tolerance to be specified on a drawing for a shaft and hole having a basic size of 50 mm. The fit must allow a snug fit but be freely assembled and disassembled.