MECHANICAL DESIGN II
TABLES
&
USEFULL FORMULAS

Chain Drives

Table 21.1. Characteristics of roller chains according to IS: 2403 — 1991.

ISO Chain number	Pitch (p) mm	Roller diameter (d_1) mm Maximum	Width between inner plates (b_1) mm Maximum	Transverse pitch (p_1)mm	Breaking load (kN) Minimum		
					Simple	Duplex	Triplex
05 B	8.00	5.00	3.00	5.64	4.4	7.8	11.1
06 B	9.525	6.35	5.72	10.24	8.9	16.9	24.9
08 B	12.70	8.51	7.75	13.92	17.8	31.1	44.5
10 B	15.875	10.16	9.65	16.59	22.2	44.5	66.7
12 B	19.05	12.07	11.68	19.46	28.9	57.8	86.7
16 B	25.4	15.88	17.02	31.88	42.3	84.5	126.8
20 B	31.75	19.05	19.56	36.45	64.5	129	193.5
24 B	38.10	25.40	25.40	48.36	97.9	195.7	293.6
28 B	44.45	27.94	30.99	59.56	129	258	387
32 B	50.80	29.21	30.99	68.55	169	338	507.10
40 B	63.50	39.37	38.10	72.29	262.4	524.9	787.3
48 B	76.20	48.26	45.72	91.21	400.3	800.7	1201

Table 21.2. Factor of safety (*n*) for bush roller and silent chains.

Type of chain	Pitch of chain (mm)	Speed of the sprocket pinion in r.p.m.								
		50	200	400	600	800	1000	1200	1600	2000
Bush roller chain	12 – 15	7	7.8	8.55	9.35	10.2	11	11.7	13.2	14.8
	20 – 25	7	8.2	9.35	10.3	11.7	12.9	14	16.3	–
	30 – 35	7	8.55	10.2	13.2	14.8	16.3	19.5	–	–
Silent chain	12.7 – 15.87	20	22.2	24.4	28.7	29.0	31.0	33.4	37.8	42.0
	19.05 – 25.4	20	23.4	26.7	30.0	33.4	36.8	40.0	46.5	53.5

Table 21.3. Permissible speed of smaller sprocket or pinion in r.p.m.

Type of Chain	Number of teeth on sprocket pinion	Pitch of chain (p) in mm				
		12	15	20	25	30
Bush roller chain	15	2300	1900	1350	1150	1000
	19	2400	2000	1450	1200	1050
	23	2500	2100	1500	1250	1100
	27	2550	2150	1550	1300	1100
	30	2600	2200	1550	1300	1100
Silent chain	17 – 35	3300	2650	2200	1650	1300

Note: The chain velocity for the roller chains may be as high as 20 m / s, if the chains are properly lubricated and enclosed, whereas the silent chain may be operated upto 40 m / s.

Table 21.4. Power rating (in kW) of simple roller chain.

Speed of smaller sprocket or pinion (r.p.m.)	*Power (kW)*				
	06 B	08 B	10 B	12 B	16 B
100	0.25	0.64	1.18	2.01	4.83
200	0.47	1.18	2.19	3.75	8.94
300	0.61	1.70	3.15	5.43	13.06
500	1.09	2.72	5.01	8.53	20.57
700	1.48	3.66	6.71	11.63	27.73
1000	2.03	5.09	8.97	15.65	34.89
1400	2.73	6.81	11.67	18.15	38.47
1800	3.44	8.10	13.03	19.85	–
2000	3.80	8.67	13.49	20.57	–

Table 21.5. Number of teeth on the smaller sprocket.

Type of chain	*Number of teeth at velocity ratio*					
	1	2	3	4	5	6
Roller	31	27	25	23	21	17
Silent	40	35	31	27	23	19

Table 21.6. Maximum allowable speed for chains in r.p.m.

Type of chain	*Number of teeth on the smaller sprocket (T_1)*	*Chain pitch (p) in mm*				
		12	15	20	25	30
Roller chain	15	2300	1900	1350	1150	1100
	19	2400	2000	1450	1200	1050
	23	2500	2100	1500	1250	1100
	27	2550	2150	1550	1300	1100
	30	2600	2200	1550	1300	1100
Silent chain	17–35	3300	2650	2200	1650	1300

the number of chain links (K)

$$K = \frac{T_1 + T_2}{2} + \frac{2x}{p} + \left[\frac{T_2 - T_1}{2\pi}\right]^2 \frac{p}{x}$$

The value of K as obtained from the above expression must be approximated to the nearest even number.

The centre distance is given by

$$x = \frac{p}{4}\left[K - \frac{T_1 + T_2}{2} + \sqrt{\left(K - \frac{T_1 + T_2}{2}\right)^2 - 8\left(\frac{T_2 - T_1}{2\pi}\right)^2}\right]$$

In order to accommodate initial sag in the chain, the value of the centre distance obtained from the above equation should be decreased by 2 to 5 mm.

1. Load factor (K_1) = 1, for constant load
= 1.25, for variable load with mild shock
= 1.5, for heavy shock loads
2. Lubrication factor (K_2) = 0.8, for continuous lubrication
= 1, for drop lubrication
= 1.5, for periodic lubrication
3. Rating factor (K_3) = 1, for 8 hours per day
= 1.25, for 16 hours per day
= 1.5, for continuous service

BELTS

Table (1) :Flat belt – Leather belt data

Grade of belting width (mm)	Thickness (mm)			
	Single	Double	Triple	Quart rupple
	0 – 200	0 – 300	0 – 600	0 – 2100
Light	3	6	---	---
Medium	4	8	12	17
Heavy	5	10	14	19

Table (2): Flat Belt Width

Width (mm)	Increment (mm)
13 – 25	3
25 – 103	6
103 – 200	12
200 – 750	25
750 – 1400	50
1400 – 2100	100

Table (3): V – Belt Characteristics

Section (No. of belt)	Min. pitch dia. (mm)	Range of small pitch dia. (mm)	Weight Kg/m	Max. speed reduction (r)
A (1 – 6)	75	75 – 125	0.1	12.33
B (2 – 10)	135	135 – 185	0.19	7
C (3 – 10)	225	225 – 325	0.34	5.55
D (5 – 12)	325	325 – 425	0.6	3.7
E (5 – 15)	525	525 – 700	0.9	3.7

BELTS

Table (4): Selection of V – Belt according to power and speed

Power (KW)	Small Sheave speed (rpm)				
	1800	1500	1200	900	700
0 – 1	**A**	**A**	**A**	**A**	**A**
1 – 3.75	**A or B**	**A or B**	**A or B**	**A or B**	**A or B**
3.75 – 7.5	**A or B**	**B**	**B**	**B**	**B or C**
7.5 – 11	**B**	**B or C**	**B or C**	**B or C**	**C**
11 – 15	**B or C**	**C**	**C**	**C**	**C**
15 – 22	**C**	**C**	**C**	**C**	**C**
22 – 30	**C**	**C or D**	**C or D**	**C or D**	**D**
30 – 45	**C or D**	**C or D**	**C or D**	**C or D**	**D**
45 – 56	**C or D**	**C or D**	**C or D**	**D**	**D or E**
56 – 75	**C or D**	**D**	**D**	**D**	**D or E**
75 – 93	**---**	**---**	**D**	**D**	**D or E**
93 – 150	**---**	**---**	**D**	**D or E**	**D or E**
150 – 300	**---**	**---**	**---**	**E**	

Table (5): Power per V-belt

Type	**Power / belt (KW/ belt)**	**Limit**
A	$= V\left[\frac{0.3313}{V^{0.09}} - \frac{14.47}{kd} - 0.000077V^2\right]$	**Kd ≤ 127**
B	$= V\left[\frac{0.583}{V^{0.09}} - \frac{36.65}{kd} - 0.000133V^2\right]$	**Kd ≤ 178**
C	$= V\left[\frac{1.082}{V^{0.09}} - \frac{100.6}{kd} - 0.000237V^2\right]$	**Kd ≤ 305**
D	$= V\left[\frac{2.31}{V^{0.09}} - \frac{350}{kd} - 0.00048V^2\right]$	**Kd ≤ 432**
E	$= V\left[\frac{3.38}{V^{0.09}} - \frac{664}{kd} - 0.00069V^2\right]$	**Kd ≤ 710**

k = 1 $\theta = 180^o$

k = 0.8 $\theta = 120^o$

spur Gears

Table 28.1. Standard proportions of gear systems.

S. No.	*Particulars*	*$14\frac{1}{2}°$ composite or full depth involute system*	*20° full depth involute system*	*20° stub involute system*
1.	Addendum	1*m*	1*m*	0.8 *m*
2.	Dedendum	1.25 *m*	1.25 *m*	1 *m*
3.	Working depth	2 *m*	2 *m*	1.60 *m*
4.	Minimum total depth	2.25 *m*	2.25 *m*	1.80 *m*
5.	Tooth thickness	1.5708 *m*	1.5708 *m*	1.5708 *m*
6.	Minimum clearance	0.25 *m*	0.25 *m*	0.2 *m*
7.	Fillet radius at root	0.4 *m*	0.4 *m*	0.4 *m*

Table 28.2. Minimum number of teeth on the pinion in order to avoid interference.

S. No.	*Systems of gear teeth*	*Minimum number of teeth on the pinion*
1.	$14\frac{1}{2}°$ Composite	12
2.	$14\frac{1}{2}°$ Full depth involute	32
3.	20° Full depth involute	18
4.	20° Stub involute	14

Table 28.3. Properties of commonly used gear materials.

Material (1)	*Condition* (2)	*Brinell hardness number* (3)	*Minimum tensile strength (N/mm²)* (4)
Malleable cast iron			
(*a*) White heart castings, Grade B	—	217 max.	280
(*b*) Black heart castings, Grade B	—	149 max.	320
Cast iron			
(*a*) Grade 20	As cast	179 min.	200
(*b*) Grade 25	As cast	197 min.	250
(*c*) Grade 35	As cast	207 min.	250
(*d*) Grade 35	Heat treated	300 min.	350
Cast steel	—	145	550
Carbon steel			
(*a*) 0.3% carbon	Normalised	143	500
(*b*) 0.3% carbon	Hardened and tempered	152	600
(*c*) 0.4% carbon	Normalised	152	580
(*d*) 0.4% carbon	Hardened and tempered	179	600
(*e*) 0.35% carbon	Normalised	201	720
(*f*) 0.55% carbon	Hardened and tempered	223	700

spur Gears

Table 28.3. Properties of commonly used gear materials. (continued)

Material (1)	*Condition* (2)	*Brinell hardness number* (3)	*Minimum tensile strength* (N/mm^2) (4)
Carbon chromium steel			
(*a*) 0.4% carbon	Hardened and tempered	229	800
(*b*) 0.55% carbon	"	225	900
Carbon manganese steel			
(*a*) 0.27% carbon	Hardened and tempered	170	600
(*b*) 0.37% carbon	"	201	700
Manganese molybdenum steel			
(*a*) 35 Mn 2 Mo 28	Hardened and tempered	201	700
(*b*) 35 Mn 2 Mo 45	"	229	800
Chromium molybdenum steel			
(*a*) 40 Cr 1 Mo 28	Hardened and tempered	201	700
(*b*) 40 Cr 1 Mo 60	"	248	900

Table 28.3. Properties of commonly used gear materials. (continued)

(1)	(2)	(3)	(4)
Nickel steel			
40 Ni 3	"	229	800
Nickel chromium steel			
30 Ni 4 Cr 1	"	444	1540
Nickel chromium molybdenum steel			
40 Ni 2 Cr 1 Mo 28	Hardness and tempered	255	900
Surface hardened steel			
(*a*) 0.4% carbon steel	—	145 (core) 460 (case)	551
(*b*) 0.55% carbon steel	—	200 (core) 520 (case)	708
(*c*) 0.55% carbon chromium steel	—	250 (core) 500 (case)	866
(*d*) 1% chromium steel	—	500 (case)	708
(*e*) 3% nickel steel	—	200 (core) 300 (case)	708
Case hardened steel			
(*a*) 0.12 to 0.22% carbon	—	650 (case)	504
(*b*) 3% nickel	—	200 (core) 600 (case)	708
(*c*) 5% nickel steel	—	250 (core) 600 (case)	866
Phosphor bronze castings	Sand cast Chill cast Centrifugal cast	60 min. 70 min. 90	160 240 260

spur Gears

Lewis form factor

$$y = 0.124 - \frac{0.684}{T}, \text{ for } 14\tfrac{1}{2}^\circ \text{ composite and full depth involute system.}$$

$$y = 0.154 - \frac{0.912}{T}, \text{ for } 20^\circ \text{ full depth involute system.}$$

$$y = 0.175 - \frac{0.841}{T}, \text{ for } 20^\circ \text{ stub system.}$$

The values of the velocity factor (C_v) are given as follows :

$$C_v = \frac{3}{3+v}, \text{ for ordinary cut gears operating at velocities upto 12.5 m / s.}$$

$$= \frac{4.5}{4.5+v}, \text{ for carefully cut gears operating at velocities upto 12.5 m/s.}$$

$$= \frac{6}{6+v}, \text{ for very accurately cut and ground metallic gears operating at velocities upto 20 m / s.}$$

$$= \frac{0.75}{0.75+\sqrt{v}}, \text{ for precision gears cut with high accuracy and operating at velocities upto 20 m / s.}$$

$$= \left(\frac{0.75}{1+v}\right) + 0.25, \text{ for non-metallic gears.}$$

Table 28.4. Values of allowable static stress.

Material	*Allowable static stress (σ_o) MPa or N/mm²*
Cast iron, ordinary	56
Cast iron, medium grade	70
Cast iron, highest grade	105
Cast steel, untreated	140
Cast steel, heat treated	196
Forged carbon steel-case hardened	126
Forged carbon steel-untreated	140 to 210
Forged carbon steel-heat treated	210 to 245
Alloy steel-case hardened	350
Alloy steel-heat treated	455 to 472
Phosphor bronze	84
Non-metallic materials	
Rawhide, fabroil	42
Bakellite, Micarta, Celoron	56

spur Gears

Table 28.5. Values of deformation factor (*C*).

Material		Involute tooth form	Values of deformation factor (C) in N-mm				
			Tooth error in action (e) in mm				
Pinion	Gear		0.01	0.02	0.04	0.06	0.08
Cast iron	Cast iron	$14\frac{1}{2}°$	55	110	220	330	440
Steel	Cast iron		76	152	304	456	608
Steel	Steel		110	220	440	660	880
Cast iron	Cast iron	20° full depth	57	114	228	342	456
Steel	Cast iron		79	158	316	474	632
Steel	Steel		114	228	456	684	912
Cast iron	Cast iron	20° stub	59	118	236	354	472
Steel	Cast iron		81	162	324	486	648
Steel	Steel		119	238	476	714	952

The value of *C* in N/mm may be determined by using the following relation :

$$C = \frac{K.e}{\frac{1}{E_P} + \frac{1}{E_G}}$$

K = A factor depending upon the form of the teeth.
= 0.107, for $14\frac{1}{2}°$ full depth involute system.
= 0.111, for 20° full depth involute system.
= 0.115 for 20° stub system.
E_P = Young's modulus for the material of the pinion in N/mm^2.
E_G = Young's modulus for the material of gear in N/mm^2.
e = Tooth error action in mm.

Table 28.6. Values of maximum allowable tooth error in action (e) verses pitch line velocity, for well cut commercial gears.

Pitch line velocity (v) m/s	Tooth error in action (e) mm	Pitch line velocity (v) m/s	Tooth error in action (e) mm	Pitch line velocity (v) m/s	Tooth error in action (e) mm
1.25	0.0925	8.75	0.0425	16.25	0.0200
2.5	0.0800	10	0.0375	17.5	0.0175
3.75	0.0700	11.25	0.0325	20	0.0150
5	0.0600	12.5	0.0300	22.5	0.0150
6.25	0.0525	13.75	0.0250	25 and over	0.0125
7.5	0.0475	15	0.0225		

spur Gears

Table 28.7. Values of tooth error in action (*e*) verses module.

Module (m) in mm	*Tooth error in action (e) in mm*		
	First class commercial gears	*Carefully cut gears*	*Precision gears*
Upto 4	0.051	0.025	0.0125
5	0.055	0.028	0.015
6	0.065	0.032	0.017
7	0.071	0.035	0.0186
8	0.078	0.0386	0.0198
9	0.085	0.042	0.021
10	0.089	0.0445	0.023
12	0.097	0.0487	0.0243
14	0.104	0.052	0.028
16	0.110	0.055	0.030
18	0.114	0.058	0.032
20	0.117	0.059	0.033

Table 28.8. Values of flexural endurance limit.

Material of pinion and gear	*Brinell hardness number (B.H.N.)*	*Flexural endurance limit (σ_e) in MPa*
Grey cast iron	160	84
Semi-steel	200	126
Phosphor bronze	100	168
Steel	150	252
	200	350
	240	420
	280	490
	300	525
	320	560
	350	595
	360	630
	400 and above	700

For safety, against tooth breakage, the static tooth load (W_S) should be greater than the dynamic load (W_D). Buckingham suggests the following relationship between W_S and W_D.

For steady loads, $W_S \geq 1.25\ W_D$

For pulsating loads, $W_S \geq 1.35\ W_D$

For shock loads, $W_S \geq 1.5\ W_D$

Note : For steel, the flexural endurance limit (σ_e) may be obtained by using the following relation :

$$\sigma_e = 1.75 \times \text{B.H.N. (in MPa)}$$

Buckingham equation, For The maximum or the limiting load for satisfactory wear of gear teeth,

$$W_w = D_p.b.Q.K$$

where W_w = Maximum or limiting load for wear in newtons,

D_p = Pitch circle diameter of the pinion in mm,

b = Face width of the pinion in mm,

Q = Ratio factor

$$= \frac{2 \times V.R.}{V.R. + 1} = \frac{2T_G}{T_G + T_P}, \text{ for external gears}$$

$$= \frac{2 \times V.R.}{V.R. - 1} = \frac{2T_G}{T_G - T_P}, \text{ for internal gears.}$$

$V.R.$ = Velocity ratio = T_G / T_P,

K = Load-stress factor (also known as material combination factor) in N/mm^2.

The load stress factor depends upon the maximum fatigue limit of compressive stress, the pressure angle and the modulus of elasticity of the materials of the gears. According to Buckingham, the load stress factor is given by the following relation :

$$K = \frac{(\sigma_{es})^2 \sin\phi}{1.4}\left(\frac{1}{E_P} + \frac{1}{E_G}\right)$$

where σ_{es} = Surface endurance limit in MPa or N/mm^2,

ϕ = Pressure angle,

E_P = Young's modulus for the material of the pinion in N/mm^2, and

E_G = Young's modulus for the material of the gear in N/mm^2.

The values of surface endurance limit (σ_{es}) are given in the following table.

Table 28.9. Values of surface endurance limit.

Material of pinion and gear	*Brinell hardness number (B.H.N.)*	*Surface endurance limit (σ_{es}) in N/mm^2*
Grey cast iron	160	630
Semi-steel	200	630
Phosphor bronze	100	630
Steel	150	350
	200	490
	240	616
	280	721
	300	770
	320	826
	350	910
	400	1050

spur Gears

The recommended series of modules in Indian Standard are 1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12, 16, 20, 25, 32, 40 and 50.

The modules 1.125, 1.375, 1.75, 2.25, 2.75, 3.5, 4.5,5.5, 7, 9, 11, 14, 18, 22, 28, 36 and 45 are of second choice.

Table 28.10. Values of service factor.

Type of load	*Type of service*		
	Intermittent or 3 hours per day	*8-10 hours per day*	*Continuous 24 hours per day*
Steady	0.8	1.00	1.25
Light shock	1.00	1.25	1.54
Medium shock	1.25	1.54	1.80
Heavy shock	1.54	1.80	2.00

Note : The above values for service factor are for enclosed well lubricated gears. In case of non-enclosed and grease lubricated gears, the values given in the above table should be divided by 0.65.

Helical Gears

$$C_v = \frac{6}{6+v}, \text{ for peripheral velocities from 5 m / s to 10 m / s.}$$

$$= \frac{15}{15+v}, \text{ for peripheral velocities from 10 m / s to 20 m / s.}$$

$$= \frac{0.75}{0.75+\sqrt{v}}, \text{ for peripheral velocities greater than 20 m / s.}$$

$$= \frac{0.75}{1+v} + 0.25, \text{ for non-metallic gears.}$$

The dynamic tooth load on the helical gears is given by

$$W_D = W_T + \frac{21\,v\,(b.C\cos^2\alpha + W_T)\cos\alpha}{21\,v + \sqrt{b.C\cos^2\alpha + W_T}}$$

where v, b and C have usual meanings as in spur gears

The static tooth load or endurance strength of the tooth is given by

$$W_S = \sigma_e . b . \pi\, m . y'$$

Helical Gears

The maximum or limiting wear tooth load for helical gears is given by

$$W_w = \frac{D_P . b . Q . K}{\cos^2 \alpha}$$

where D_P, b, Q and K have usual meanings as in spur gears

In this case $K = \frac{(\sigma_{es})^2 \sin \phi_N}{1.4} \left[\frac{1}{E_P} + \frac{1}{E_G} \right]$

were ϕ_N = Normal pressure angle

Bevel Gears

Proportions for Bevel Gear

The proportions for the bevel gears may be taken as follows :

1. Addendum, $a = 1\ m$
2. Dedendum, $d = 1.2\ m$
3. Clearance $= 0.2\ m$
4. Working depth $= 2\ m$
5. Thickness of tooth $= 1.5708\ m$

where m is the module.

Strength of Bevel Gears

$$W_T = (\sigma_o \times C_v)\, b . \pi\, m . y' \left(\frac{L - b}{L} \right)$$

where σ_o = Allowable static stress,

C_v = Velocity factor,

$= \frac{3}{3 + v}$, for teeth cut by form cutters,

$= \frac{6}{6 + v}$, for teeth generated with precision machines,

v = Peripheral speed in m / s,

b = Face width,

m = Module,

y' = Tooth form factor (or Lewis factor) for the equivalent number of teeth,

L = Slant height of pitch cone (or cone distance),

$$= \sqrt{\left(\frac{D_G}{2} \right)^2 + \left(\frac{D_P}{2} \right)^2}$$

Bevel Gears

$$W_S = \sigma_e . b . \pi \, m . y' \left(\frac{L - b}{L} \right)$$

The value of flexural endurance limit (σ_e) may be taken from Table 28.8, in spur gears.

The maximum or limiting load for wear for bevel gears is given by

$$W_w = \frac{D_P . b . Q . K}{\cos \theta_{P1}}$$

where D_P, b, Q and K have usual meanings as discussed in spur gears except that Q is based on formative or equivalent number of teeth, such that

$$Q = \frac{2 \, T_{EG}}{T_{EG} + T_{EP}}$$

Sliding Contact Bearings

Table 26.2. Absolute viscosity of commonly used lubricating oils.

S. No.	Type of oil	Absolute viscosity in kg / m-s at temperature in °C					
		30	35	40	45	50	55
1.	SAE 10	0.05	0.036	0.027	0.0245	0.021	0.017
2.	SAE 20	0.069	0.055	0.042	0.034	0.027	0.023
3.	SAE 30	0.13	0.10	0.078	0.057	0.048	0.040
4.	SAE 40	0.21	0.17	0.12	0.096	0.78	0.06
5.	SAE 50	0.30	0.25	0.20	0.17	0.12	0.09
6.	SAE 60	0.45	0.32	0.27	0.20	0.16	0.12
7.	SAE 70	1.0	0.69	0.45	0.31	0.21	0.165

S. No.	Type of oil	Absolute viscosity in kg / m-s at temperature in °C					
		60	65	70	75	80	90
1.	SAE 10	0.014	0.012	0.011	0.009	0.008	0.005
2.	SAE 20	0.020	0.017	0.014	0.011	0.010	0.0075
3.	SAE 30	0.034	0.027	0.022	0.019	0.016	0.010
4.	SAE 40	0.046	0.04	0.034	0.027	0.022	0.013
5.	SAE 50	0.076	0.06	0.05	0.038	0.034	0.020
6.	SAE 60	0.09	0.072	0.057	0.046	0.040	0.025
7.	SAE 70	0.12	0.087	0.067	0.052	0.043	0.033

Sliding Contact Bearings

Table 26.3. Design values for journal bearings.

Machinery	Bearing	Maximum bearing pressure (p) in N/mm²	Operating values			
			Absolute Viscosity (Z) in kg/m-s	ZN/p Z in kg/m-s p in N/mm²	$\frac{c}{d}$	$\frac{l}{d}$
Automobile and air-craft engines	Main Crank pin Wrist pin	5.6 – 12 10.5 – 24.5 16 – 35	0.007 0.008 0.008	2.1 1.4 1.12	—	0.8 – 1.8 0.7 – 1.4 1.5 – 2.2
Four stroke-Gas and oil engines	Main Crank pin Wrist pin	5 – 8.5 9.8 – 12.6 12.6 – 15.4	0.02 0.04 0.065	2.8 1.4 0.7	0.001	0.6 – 2 0.6 – 1.5 1.5 – 2
Two stroke-Gas and oil engines	Main Crank pin Wrist pin	3.5 – 5.6 7 – 10.5 8.4 – 12.6	0.02 0.04 0.065	3.5 1.8 1.4	0.001	0.6 – 2 0.6 – 1.5 1.5 – 2
Marine steam engines	Main Crank pin Wrist pin	3.5 4.2 10.5	0.03 0.04 0.05	2.8 2.1 1.4	0.001	0.7 – 1.5 0.7 – 1.2 1.2 – 1.7
Stationary, slow speed steam engines	Main Crank pin Wrist pin	2.8 10.5 12.6	0.06 0.08 0.06	2.8 0.84 0.7	0.001	1 – 2 0.9 – 1.3 1.2 – 1.5
Stationary, high speed steam engine	Main Crank pin Wrist pin	1.75 4.2 12.6	0.015 0.030 0.025	3.5 0.84 0.7	0.001	1.5 – 3 0.9 – 1.5 13 – 1.7
Reciprocating pumps and compressors	Main Crank pin Wrist pin	1.75 4.2 7.0	0.03 0.05 0.08	4.2 2.8 1.4	0.001	1 – 2.2 0.9 – 1.7 1.5 – 2.0
Steam locomotives	Driving axle Crank pin Wrist pin	3.85 14 28	0.10 0.04 0.03	4.2 0.7 0.7	0.001	1.6 – 1.8 0.7 – 1.1 0.8 – 1.3

Machinery	Bearing	Maximum bearing pressure (p) in N/mm²	Operating values			
			Absolute Viscosity (Z) in kg/m-s	ZN/p Z in kg/m-s p in N/mm²	$\frac{c}{d}$	$\frac{l}{d}$
Railway cars	Axle	3.5	0.1	7	0.001	1.8 – 2
Steam turbines	Main	0.7 – 2	0.002 – 0.016	14	0.001	1 – 2
Generators, motors, centrifugal pumps	Rotor	0.7 – 1.4	0.025	28	0.0013	1 – 2
Transmission shafts	Light, fixed Self -aligning Heavy	0.175 1.05 1.05	0.025- 0.060	7 2.1 2.1	0.001	2 – 3 2.5 – 4 2– 3
Machine tools	Main	2.1	0.04	0.14	0.001	1–4
Punching and shearing machines	Main Crank pin	28 56	0.10	—	0.001	1–2
Rolling Mills	Main	21	0.05	1.4	0.0015	1–1.5

Sliding Contact Bearings

Density of lubricants at any temperature

$$\rho_t = \rho_{15.5} - 0.000\,657\ t$$

<u>Coefficient of friction for journal bearings ,</u>

$$\mu = \frac{33}{10^8}\left(\frac{ZN}{p}\right)\left(\frac{d}{c}\right) + k$$ (when Z is in kg / m-s and *p* is in N / mm^2)

where *k* = Factor to correct for end leakage. It depends upon the ratio of length to the diameter of the bearing (*i.e. l / d*).
= 0.002 for *l / d* ratios of 0.75 to 2.8.

<u>Critical Pressure of the Journal Bearing</u>

$$p = \frac{ZN}{4.75\times10^6}\left(\frac{d}{c}\right)^2\left(\frac{l}{d+l}\right)\ N/mm^2$$ ...(when Z is in kg / m-s)

$$sommerfeld\ number = \frac{ZN}{p}\left(\frac{d}{c}\right)^2 = 14.3\times10^6$$