Chapter 1

Sliding Contact Bearings

McKee's equation, $\mu = \left[\frac{33.25}{10^8} \times \frac{Zn}{p} \times \frac{d}{c}\right] + k$

μ – Coefficient of friction

Z – Absolute or dynamic viscosity of oil, $N\text{-}s/m^2$ or kg/m-s

n – Speed of journal, rpm

p – Bearing pressure, N/mm^2

d – Diameter of journal, mm

c – Diametral clearance, mm

k – 0.002

Sommerfeld number, $S = \frac{Zn}{60 \times 10^6 p}\left(\frac{d}{c}\right)^2$ (Refer Table 1.1)

$$p = \frac{W}{ld}$$

W – Load acting on the journal, N

l – Length of journal, mm

Heat generated in the bearing, $H_g = \mu WV$ watts

V – Sliding velocity of journal, m/s

Heat dissipated by the bearing, $H_d = CA\,(t_b - t_a)$ watts where

C – Heat dissipation coefficient

= 140 to 420 $W/m^2/^oC$ (still air)

= 490 to 1400 $W/m^2/^oC$ (well ventilated bearings)

A – Projected area ($l \times d$) in m^2

t_b – Temperature of bearing surface, ^oC

$$t_b = \frac{t_o + t_a}{2}$$

t_o – Temperature of oil, ^oC

t_a – Atmospheric temperature (temperature of surrounding air), ^oC

Mass of oil required to carry away the heat generated, $m = \frac{H_g}{C_p \Delta t_o}$ kg/s

where

C_p – Specific heat of oil

= 1840 to 2100 $J/kg/^oC$

Δt_o – Difference between outlet and inlet temperatures of oil, ^oC

Critical pressure (i.e., minimum operating pressure)

$$p_c = \frac{Zn}{4.75 \times 10^6}\left(\frac{d}{c}\right)^2\left(\frac{l}{l+d}\right) \text{ N/mm}^2$$

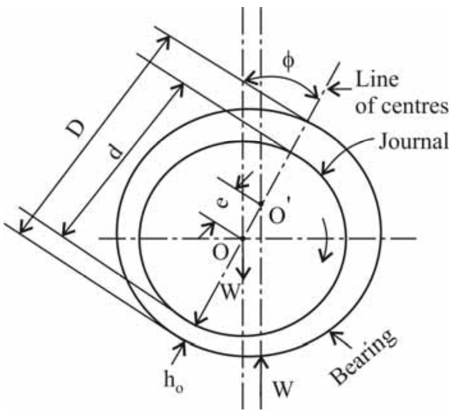

Fig. 1.1 Geometric relations for a journal bearing

Diametral clearance, $c = D - d$

Diametral clearance ratio, $c_r = \frac{c}{d}$ ($\simeq$ 0.001 usually)

Eccentricity, $e = \frac{c}{2} - h_o$

Minimum film thickness, $h_o = \frac{c}{2} - e = \frac{c}{2}(1 - \in)$

Eccentricity factor or attitude, $\in = \frac{2e}{c} = 1 - \frac{2h_o}{c}$

Dimensionless performance parameters:

$\frac{\mu d}{c}$ – Coefficient of friction variable

$\frac{4q}{dcn'l}$ – Flow variable

$\frac{q_s}{q}$ – Flow ratio

$\frac{p}{p_{max}}$ – Pressure ratio

$\frac{\rho C_p \Delta t_o}{p}$ – Temperature rise variable

where

q – Oil flow through the bearing, mm^3/s

q_s – Axial flow of oil (or) side leakage, mm^3/s

n' – Speed of journal in rps

p_{max} – Maximum bearing pressure, N/mm^2

ρ – Density of oil = 900 kg/m^3

$\rho C_p = 142 \times 10^4$ N/m^2 ^oC

ϕ – Attitude angle

Table 1.1 Dimensionless performance parameters for full journal bearings with side flow

$\frac{l}{d}$	$\in$	$\frac{2h_o}{c}$	S	ϕ	$\mu\frac{d}{c}$	$\frac{4q}{dcn'l}$	$\frac{q_s}{q}$	$\frac{\rho C_p \Delta t_o}{p}$	$\frac{p}{p_{max}}$
∞	0	1.0	∞	70.92	∞	π	0	∞	-
	0.1	0.9	0.240	69.10	4.80	3.03	0	19.9	0.826
	0.2	0.8	0.123	67.26	2.57	2.83	0	11.4	0.814
	0.4	0.6	0.0626	61.94	1.52	2.26	0	8.47	0.764
	0.6	0.4	0.0389	54.31	1.20	1.56	0	9.73	0.667
	0.8	0.2	0.021	42.22	0.961	0.760	0	15.9	0.495
	0.9	0.1	0.0115	31.62	0.756	0.411	0	23.1	0.358
	0.97	0.03	-	-	-	-	0	-	-
	1.0	0	0	0	0	0	0	∞	0
1	0	1.0	∞	85	∞	π	0	∞	-
	0.1	0.9	1.33	79.5	26.4	3.37	0.150	106	0.540
	0.2	0.8	0.631	74.02	12.8	3.59	0.280	52.1	0.529
	0.4	0.6	0.264	63.10	5.79	3.99	0.497	24.3	0.484
	0.6	0.4	0.121	50.58	3.22	4.33	0.680	14.2	0.415
	0.8	0.2	0.0446	36.24	1.70	4.62	0.842	8.00	0.313
	0.9	0.1	0.0188	26.45	1.05	4.74	0.919	5.16	0.247
	0.97	0.03	0.00474	15.47	0.514	4.82	0.973	2.61	0.152
	1.0	0	0	0	0	-	1.0	0	0
0.5	0	1.0	∞	88.5	∞	π	0	∞	-
	0.1	0.9	4.31	81.62	85.6	3.43	0.173	343.0	0.523
	0.2	0.8	2.03	74.94	40.9	3.72	0.318	164.0	0.506
	0.4	0.6	0.779	61.45	17.0	4.29	0.552	68.6	0.441
	0.6	0.4	0.319	48.14	8.10	4.85	0.730	33.0	0.365
	0.8	0.2	0.0923	33.31	3.26	5.41	0.874	13.4	0.267
	0.9	0.1	0.0313	23.66	1.60	5.69	0.939	6.66	0.206
	0.97	0.03	0.00609	13.75	0.610	5.88	0.980	2.56	0.126
	1.0	0	0	0	0	-	1.0	0	0
0.25	0.0	1.0	∞	89.5	∞	π	0	∞	-
	0.1	0.9	16.2	82.31	322.0	3.45	0.180	1287.0	0.515
	0.2	0.8	7.57	75.18	153.0	3.76	0.330	611.0	0.489
	0.4	0.6	2.83	60.86	61.1	4.37	0.567	245.0	0.415
	0.6	0.4	1.07	46.72	26.7	4.99	0.746	107.0	0.334
	0.8	0.2	0.261	31.04	8.80	5.60	0.884	35.4	0.240
	0.9	0.1	0.0736	21.85	3.50	5.91	0.945	14.1	0.180
	0.97	0.03	0.0101	12.22	0.922	6.12	0.984	3.73	0.108
	1.0	0	0	0	0	-	1.0	0	0

Table 1.2 Design practices for journal bearings

Machinery	Bearing	$\frac{l}{d}$	Allowable bearing pressure, p N/mm^2	Absolute viscosity of lubricant, Z N-s/m^2	$\left(\frac{Zn}{p}\right)_{min}$
Stationary High Speed Steam Engines	Main Crank Pin Wrist Pin	1.5 –3.0 0.9–1.5 1.3–1.7	1.75 4.2 4.6	0.015 0.03 0.025	3.56 0.85 0.71
Gas and Oil Engines (Four Stroke)	Main Crank Pin Wrist Pin	0.6 –2.0 0.6–1.5 1.5–2.0	4.9–8.4 10.8–12.6 12.5–15.4	0.02–0.065	2.85 1.42 0.71
Gas and Oil Engines (Two Stroke)	Main Crank Pin Wrist Pin	0.6 –2.0 0.6–1.5 1.5–2.2	3.5–12.5 7–10.5 8.4–12.5	0.02–0.065	3.56 1.7 1.42
Aircraft and Automobile Engines	Main Crank Pin Wrist Pin	0.8–1.8 0.7–1.4 1.5–2.2	5.6–11.9 10.5–24.5 16.1–35	0.008	2.13 1.42 1.14
Reciprocating Compressors and Pumps	Main Crank Pin Wrist Pin	1.0–2.2 0.9–1.7 1.5–2.0	1.75 4.2 7.0	0.03 –0.08	4.27 2.85 1.42
Centrifugal Pumps, Motors and Generators	Rotor	1.0–2.0	0.7-1.4	0.025	28.45
Machine Tools	Main	1.0–4.0	2.1	0.04	0.14
Steam Turbines	Main	1.0–2.0	0.7–2.0	0.002–0.016	14.22
Railway Cars	Axle	1.9	3.5	0.1	7.11
Marine Steam Engines	Main Crank Pin Wrist Pin	0.7–1.5 0.7–1.2 1.2–1.7	3.5 4.2 10.5	0.03 0.04 0.03	2.85 2.13 1.42
Transmissions	Light, Fixed	2–3	0.18	0.025	14.22
Gyroscopes	Rotor	–	6.0	0.03	7.82
Shafting	Self Aligning Heavy	2.5–4 2–3	1.1 1.1	0.06 0.06	4.27 4.27
Cotton Mills	Spindle	–	0.007	0.002	14.24
Punching and Shearing Machines	Main Crank Pin	1–2 1–2	28.0 56.0	0.1 0.1	– –
Rolling Mills	Main	1–1.5	21.0	0.05	1.42

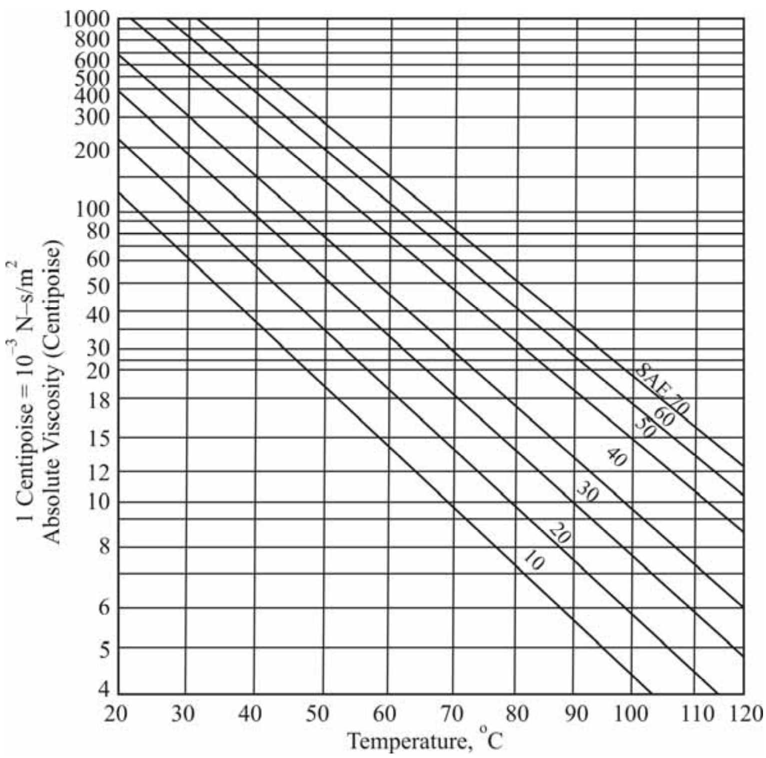

Fig. 1.2 Average absolute viscosities versus temperature