Problem 12-11

Given:

$d = 80.0_{-0.01}\,mm$

$l/d = 1.0$

$b = 80.08^{+0.03}\,mm$

SAE 30 oil

$T_s = 60\,°C$

$W = 3\,kN$

$N = 8\,rev/s$

Find:

T_{ave}, h_o, H_{loss} and Q_s

for minimum clearence assembly.

Solution:

For the minimum clearence assembly

$$c_{min} = \frac{b_{min} - d_{max}}{2} = \frac{80.08 - 80.0}{2} = 0.04\ mm.$$

$$r = \frac{d}{2} = \frac{80}{2} = 40\ mm$$

$$r/c = \frac{40}{0.04} = 1000 \qquad P = \frac{W}{l\,d} = \frac{3000}{(80)^2} = 0.469\ MPa.$$

In order to use graphs we must have μ_{ave} and T_{ave}. We can either assume a "μ" value and find corressponding T and calculate ΔT. Through S find ΔT from graph and compare it with the calculated one.

Or we can assume T_{ave} directly, find corresponding μ and throug S obtain ΔT from the graph. Then compare this with the calculated one. If the discrepancy between them is 0.1 or less the assumed value of T and corresponding μ are average values.

Trial #1 Let $T = 80°C$

From Fig 12-13 the corresponding μ for SAE30 oil

$\mu = 12.5$ mPa-s

$$\Delta T = 2(T_{ave} - T_1) = 2(80-60) = 40°C$$

$$S' = \left(\frac{r}{c}\right)^2\left(\frac{\mu N}{P}\right) = (1000)^2\left(\frac{12.5\times10^{-3}\,(8)}{0.469\times10^6}\right) = 0.2132$$

From Fig. 12-24,

$$\frac{0.12\,\Delta T_c}{P} = 0.349 + 6.0094(0.2132) + 0.0475(0.2132)^2$$
$$= 1.632$$

$$\Delta T = \frac{0.469}{0.12}(1.632) = 6.4°C$$

Discrepancy $= 40 - 6.4 = 33.6°C$.

Trial #2 Let $T = 68°C$

From Fig. 12-13 $\mu = 20$ mPa-s $\Delta T = 2(68-60) = 16°C$

From eqn. 12-7 $S = 0.2132\left(\frac{20}{12.5}\right) = 0.341$

From Fig. 12-24 $\frac{0.12\,\Delta T}{P} = 2.4 \rightarrow \Delta T = (2.4)\,\frac{0.469}{0.12}$

$\Delta T = 9.4°C$

Discrepancy $= 16 - 9.4 = 6.6°C$.

Trial #3 Let $T = 65°C$ $\mu = 21.0$ mPa-s

$\Delta T = 2(65-60) = 10°C$.

$S' = 0.2132\left(\frac{21.0}{12.5}\right) = 0.358$ $\frac{0.12\,\Delta T}{P} = 2.5 \rightarrow \Delta T = 2.5\left(\frac{0.469}{0.12}\right)$

$\Delta T = 9.8°C$

Discrepancy $= 10 - 9.8 = 0.2°C$

It is acceptable!

$$T_{ave.} = T_1 + \frac{\Delta T}{2} = 60 + \frac{10}{2} \rightarrow \boxed{T_{ave} = 65\ °C}$$

$$T_2 = T_{ave} + \frac{\Delta T}{2} = 65 + \frac{10}{2} = 70\ °C$$

$$S = 0.358$$

From Fig. 12-16 $\frac{h_o}{c} = 0.68 \longrightarrow h_o = 0.68(0.04) \longrightarrow$

$$\boxed{h_o = 0.0272\ mm}$$

From Fig. 12-18 $\frac{r}{c}f = 7.5 \longrightarrow f = \frac{7.5}{1000} = 0.0075$

$$T = f\,W\,r = (0.0075)(3000)(40\times10^{-3}) = 0.9\ Nm.$$

$$H_{loss} = 2\pi T N = 2\pi(0.9)(8) \longrightarrow \boxed{H_{loss} = 45.2\ W}$$

From Fig 12-19 $\frac{Q}{rcNl} = 3.8 \longrightarrow Q = (3.8)(40)(0.04)(8)(80)$

$$Q = 3{,}891\ mm^3/s$$

From Fig. 12-20 $\frac{Q_s}{Q} = 0.44$

$$Q_s = 0.44\,Q = 0.44(3{,}891) \longrightarrow \boxed{Q_s = 1{,}712\ mm^3/s}$$

Problem 12.12

Given

This is a self-contained bearing.

SAE 20 oil

$T_s = T_1 = 43\,°C$

$d = 63.5_{-0.025}$ mm

$b = 63.6^{+0.025}$ mm

$N = 1120$ rpm

$W = 5.34$ kN

$\ell = 63.5$ mm

Find:

a) h_o and ϕ

b) ϵ

c) f

d) H_{loss}

e) Q and Q_s

f) P_{max} and $\theta_{P_{max}}$

g) θ_{P_o}

h) T_{ave}

i) T_f

Solution:

Minimum clearence is, $C_{min} = \dfrac{b_{max} - d_{min}}{2} = \dfrac{63.6 - 63.5}{2} = \dfrac{0.1}{2}$

$$C = 0.05$$

$$P = \frac{W}{\ell d} = \frac{5340\ N}{(63.5)(63.5)\,mm^2} = 1.324\ MPa \qquad \frac{\ell}{d} = \frac{63.5}{63.5} = 1.0$$

$$r = \frac{d}{2} = \frac{63.5}{2} = 31.75\,mm$$

$$N = \frac{1120}{60}\,rpm = 18.67\ rev/sec. \qquad r/c = \frac{31.75}{0.05} = 635$$

At this stage, in order to find the required parameters we need to enter the graphs, In order to enter the graph we must have T_{ave} and μ_{ave} (this is a must!), but neither is given.

There are two ways:

1) Assume T_f and find corresponding μ for SAE 20 oil from the Fig 12-13 (the book calculated μ using Table 12-1). Calculate S using eqn. 12-7 and find ΔT_c from Fig. 12-24. Then calculate $T_{ave} = T_1 + \frac{\Delta T}{2}$ and compare this with the assumed T_f. When the difference is 0.1 or less stop the iterations. But this is a long way (The book solved the problem with this way by doing 6 trials which is a time-consuming way).

2) This way is shorter than the first one. Instead of assuming T_f, we directly assume μ and using this value we find S, ΔT_c and T_{ave} by using the same equations. This is first trial. By using the assumed μ and the calculated T_{ave}, we mark a point in Fig. 12-13 above (or below) the SAE 20 line. Then we need to find another point below (or above) the SAE 20 line by assuming second μ according. Once we mark second point below (or above) the SAE 20 line, we connect two points with a line. The intersection point of this line and SAE 20 line will give us μ_{ave} and T_{ave}. With these values we enter to the graphs and find all the parameters with just two trials.

Let first trial be $\mu_{ave_1} = 10$ mPa-s.

Then, $$S = \left(\frac{r}{c}\right)^2 \frac{\mu N}{P} = (635)^2 \frac{10\times10^{-3}\,(18.67)}{1.324\times10^6} = 0.057$$

with this value, from Fig. 12-24 fol $l/d = 1.0$

$$\frac{0.12\ \Delta T_c}{1.324} = 0.349109 + 6.0094(0.057) + 0.047467(0.057)^2$$

$$\Delta T_c = 7.63\ ^\circ C \longrightarrow T_{ave_1} = T_1 + \frac{\Delta T}{2} = 43 + \frac{7.63}{2}$$

$$T_{ave_1} = 46.8\ ^\circ C$$

$\mu_{ave_1} = 10$ mPa-s and $T_{ave_1} = 46.8\ ^\circ C$ values give us a point below the SAE 20 line. Now, we need a point above the SAE 20 line. In order to get a point above the line let 2nd trial be 50 mPa-s.

With $\mu_{ave_2} = 50$ mPa-s

$$S = (635)^2 \frac{50\times10^{-3}(18.67)}{1.324\times10^{6}} = 0.284$$

From Fig. 12-24 for $l/d = 1.0$

$$\frac{0.12\ \Delta T_C}{1.324} = 0.349109 + 6.0094(0.284) + 0.047467(0.284)^2$$

$$\Delta T_C = 22.72\ °C \longrightarrow T_{ave_2} = 43 + \frac{22.72}{2} = 54.4\ °C$$

$\mu_{ave_2} = 50$ mPa-s and $T_{ave_2} = 54.4\,°C$ give us a point above SAE20 line. Connecting these two points gives us an intersection point with SAE 20 line whose coordinates are,

$$\mu_{ave} = 26 \text{ mPa-s} \quad \text{and} \quad T_{ave} = 52\ °C$$

Now, the useful Sommerfeld number is,

$$S = (635)^2 \frac{26\times10^{-3}(18.67)}{1.324\times10^{6}} = 0.148$$

Using this value, the following parameters are obtained.

From Fig. 12-16 $\frac{h_o}{c} = 0.44$ and $\epsilon = 0.56$

From Fig. 12-17 $\phi = 54°$

From Fig. 12-18 $\frac{r}{c} f = 3.6$

From Fig. 12-19 $\frac{Q}{rcNl} = 4.24$

From Fig 12-20 $\frac{Q_s}{Q} = 0.64$

From Fig 12-21 $\frac{P}{P_{max}} = 0.44$

From Fig. 12-22 $\theta_{P_o} = 78°$ and $\theta_{P_{max}} = 18.5°$

Eventually the answers are,

a) $h_o = 0.44(0.05) \longrightarrow \boxed{h_o = 0.022 \text{ mm}}$ and $\boxed{\phi = 54°}$

b) $\epsilon = \frac{e}{c} = 0.56 \longrightarrow e = 0.56(0.05)$ $\boxed{e = 0.028 \text{ mm}}$

c) $f = \frac{c}{r}(3.6) = \frac{0.05}{31.75}(3.6) \longrightarrow \boxed{f = 5.67 \times 10^{-3}}$

d) $T = f \cdot W \cdot r = (0.00567)(5340)(31.75 \times 10^{-3}) = 0.96 \text{ Nm}$

$H_{loss} = 2\pi T N = 2\pi(0.96)(18.67) \rightarrow \boxed{H_{loss} = 112.6 \text{ W}}$

e) $Q = 4.24(31.75)(0.05)(18.67)(63.5) \longrightarrow \boxed{Q = 7{,}980 \text{ mm}^3/s}$

$Q_s = 0.64(7980) \longrightarrow \boxed{Q_s = 5107.2 \text{ mm}^3/s}$

f) $P_{max} = \frac{P}{0.44} = \frac{1.324}{0.44} \longrightarrow \boxed{P_{max} = 3.0 \text{ MPa}}$

$\boxed{\theta_{P_{max}} = 18.5°}$

g) $\boxed{\theta_{P_o} = 78°}$

h) $\boxed{T_{ave} = 52 \text{ °C}}$

i) $T_f = T_i + \Delta T$

$T_f = 43 + 18$

$\boxed{T_f = 61 \text{ °C}}$

$T_{ave} = T_i + \frac{\Delta T}{2}$

$\Delta T = 2(T_{ave} - T_i) = 2(52 - 43)$

$\Delta T = 18 \text{ °C}$