14.10 M12 x 1.25 CLASS 9.8
85% PROOF PRE-LOAD
5cm THICK ALUMINUM SANDWICH
FIND $N_{sf}$, $N_{sy}$ & $N_{ss}$
GIVEN 20 kN (PEAK) FLUCTUATING LOAD

PRE-LOAD

$$F_i = .85 S_p A_t = .85(650\,MPa)(92.07\,mm^2)(1E{-}6\,m^2/mm^2) = 50.869\,kN$$

$S_p$ (TABLE 14-7) = 650 MPa
$A_t$ (TABLE 14-2) = 92.07 mm²

BOLT & JOINT STIFFNESS

$$K_b = \frac{\pi d^2 E_b}{4\ell} = \frac{\pi(.012m)^2\,207\,GPa}{4(.05m)} = 4.6822 \times 10^8\ N/m$$

$$K_m = \frac{2\pi d^2 E_m}{\ell} = \frac{2\pi(.012m)^2\,71.7\,GPa}{(.05m)} = 12.974 \times 10^8\ N/m$$

LOAD ON BOLT DUE TO 20 kN EXTERNAL LOAD

$$P_b = P\frac{K_b}{K_m + K_b} = \frac{20kN\,(4.6822)}{(4.6822 + 12.974)} = 5.307\,kN$$

TOTAL LOAD ON BOLT

$$F_b = P_b + F_i = 5.307 + 50.869\,kN = 56.173\,kN$$

FACTOR OF SAFETY IN YIELD, $N_{sy}$

$$N_{sy} = \frac{S_y}{\sigma_{bolt,max}} = \frac{S_y A_t}{F_b} = \frac{720\,MPa(92.07\,mm^2)(1E{-}6\,\frac{m^2}{mm^2})}{56.173\,kN} = 1.18$$

$S_y$ (TABLE 14-7) = 720 MPa

## BOLT STRESSES

$$P_{max} = 20\,kN$$

$$P_{min} = 0$$

$$P_{alt} = \frac{P_{max} - P_{min}}{2} = 10\,kN$$

$$P_{mean} = \frac{P_{min} + P_{max}}{2} = 10\,kN$$

$$\sigma_{min} = \frac{k_b}{k_b + k_m} P_{min} + \frac{F_i}{A_t} = \frac{F_i}{A_t} = \frac{50.869\,kN}{(92.07\,mm^2)(1E\text{-}6\ m^2/mm^2)} = 553\,MPa$$

$$\sigma_{max} = \frac{k_b}{k_b + k_m} \frac{P_{max}}{A_t} + \frac{F_i}{A_t} = \frac{F_b}{A_t} = \frac{56.173\,kN}{92.07\,mm^2(1E\text{-}6\ m^2/mm^2)} = 610\,MPa$$

$$\sigma_{MEAN} = \frac{k_b}{k_b + k_m} \frac{P_{MEAN}}{A_t} + \frac{F_i}{A_t} = \frac{.2652(10\,kN) + 50.869\,kN}{92.07\,mm^2(1E\text{-}6\ m^2/mm^2)} = 581\,MPa$$

$$\sigma_{alt} = \frac{k_b}{k_b + k_m} \frac{P_{alt}}{A_t} = \frac{.2652(10\,kN)}{92.07\,mm^2(1E\text{-}6\ m^2/mm^2)} = 28.8\,MPa$$

## FACTOR OF SAFETY IN FATIGUE

$$N_{SF} = S_e \cdot \frac{S_{ult} - \sigma_{min}}{[S_e \cdot (\sigma_{MEAN} - \sigma_{min})] + S_{ult} \cdot \sigma_{alt}}$$

$$S_e = .5 S_{ut} \cdot C_{LOAD} C_{SIZE} C_{SURF} \cdot \frac{1}{K_F}$$

$$= .5(900\,MPa)(.7)(.93)(.48)\frac{1}{3}$$

$$= 46.9\,MPa$$

$$N_{SF} = 46.9 \frac{900 - 553}{46.9(581 - 553) + 900 \cdot 28.8} = 0.60$$ (JOINT FAILS IN FATIGUE)

## FACTOR OF SAFETY IN JOINT SEPARATION

$F_m = 0$ ; FIND $P_o$ SUCH THAT $F_m = 0$

$$N_{sep} = \frac{P_o}{P} = \frac{F_i(k_b + k_m)}{k_m} \cdot \frac{1}{P} = \frac{50.869\,kN(4.6822 + 12.974)}{12.974} \cdot \frac{1}{20\,kN} = 3.46$$

NOTE: FOS ARE DIFFERENT FROM TEXT DUE TO EFFECTIVE CYLINDER METHOD.