PROBLEM 7.46 | THE BAR SHOWN IS MACHINED FROM STEEL WITH $S_y = 420$ MPa AND $S_U = 570$ MPa. THE AXIAL FORCE F IS COMPLETELY REVERSING. ESTIMATE THE VALUE OF THE FORCE AMPLITUDE WHICH WILL CAUSE FAILURE AT 100,000 CYCLES.

GIVEN:

1). MACHINED STEEL BAR
2. $S_y = 420$ MPa, $S_U = 560$ MPa
3. 20mm DIA HOLE IN SECTION OF WIDTH 60 mm
4. RADII OF TRANSITION FROM 60 mm TO 40 mm WIDTH IS 4mm
5. THICKNESS OF BAR 6 mm
6. LOADING IS COMPLETE REVERSING.

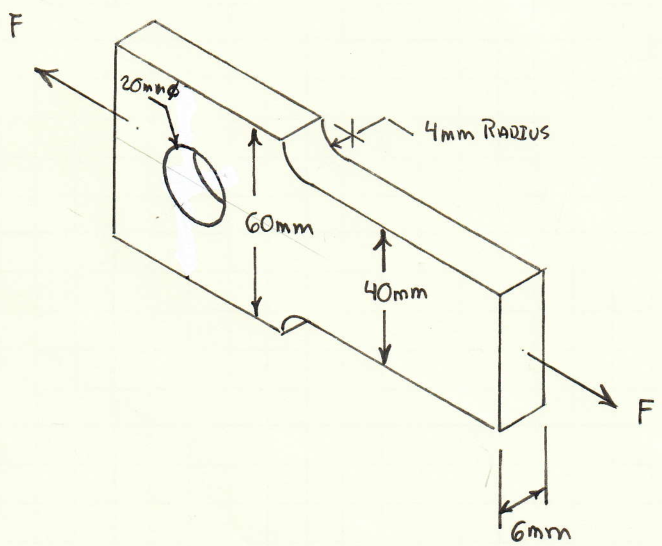
ASSUMPTIONS:

1. LINEAR ELASTIC RESPONSE

FIND:

1. VALUE OF THE AMPLITUDE CORRESPONDING TO A LIFE OF 100,000 CYCLES.

FIGURE:



SOLUTION:

THE AVERAGE STRESS IN THE TWO SECTIONS OF THE BAR ARE

$$\sigma_{60mm} = \frac{F}{(0.06m)(.006m)} = 2.778(10^3)\frac{1}{m^2}\cdot F \quad (1)$$

$$\sigma_{40mm} = \frac{F}{(0.04m)(0.006m)} = 4.167(10^3)\frac{1}{m^2}\cdot F \quad (2)$$

THE AVERAGE STRESS THROUGH THE CENTER OF THE HOLE IN THE 60mm SECTION OF THE BAR.

$$\sigma_{60mm,H} = \frac{F}{(0.06m - 0.02m)(.006m)} = 4.167(10^3)\frac{1}{m^2}\cdot F \quad (3)$$

NOTE THAT THE AVERAGE STRESS AT THE HOLE AND THE AVERAGE STRESS IN THE 40mm WIDTH SECTION OF THE BAR ARE THE SAME AND ARE THE LOCATIONS OF THE MAXIMUM <u>AVERAGE</u> STRESSES IN THE BAR. THEREFORE, THE REMAINDER OF THIS PROBLEM WILL FOCUS ON THESE STRESSES.

NOW THE S-N CURVE NEEDS TO BE CALCULATED. THE FIRST POINT ON THE S-N CURVE IS GIVEN BY

$$0.9\cdot S_{UT} = 0.9\cdot(560\,MPa) = \underline{\underline{504\,MPa \;@\; 10^3\,\text{CYCLES}}} \quad (4)$$

THE SECOND POINT IS S_e @ 10^6 cycles. THE VALUE OF S_e FOR THIS BAR MUST NOW BE CALCULATED. FROM LECTURE 15

$$S_e' = 0.5\cdot S_{UT} = 0.5(560\,MPa) = 280\,MPa$$

$$S_e = k_a\cdot k_b\cdot k_c\cdot k_d\cdot k_e\cdot k_f\cdot S_e' = 0.75\cdot 0.85\cdot 0.4902\cdot 280\,MPa = \underline{\underline{87.5\,MPa}}$$

Lec 15, Pg 17 → $k_a = 0.75$ (MACHINED FINISH)

k_b = SIZE EFFECT = 0.85

$k_c = 1$ Reliability

$k_d = 1$ Temperature

$k_e = 1/K_{f,H} = 1/2.04 = \underline{0.4902}$ $\quad 1/K_{f,R} = 1/1.88 = 0.532$

- $K_{T,H}$ = THEORETICAL STRESS CONCENTRATION FACTOR FOR HOLE $d/w = 20mm/60mm = 1/3 = .333$
  $= 2.3$ (APP F.1)

  $K_{f,H}$ = FATIGUE STRENGTH REDUCTION FACTOR FOR HOLE
  $= 1 + q(K_t - 1) = 1 + 0.8(2.3-1) = 2.04$
  - q = NOTCH SENSITIVITY = .8 (Lec 15 pg 22)

- $K_{T,R} = 2.1$
  - $D/d = 60/40 = 3/2 = 1.5$, $r/d = 4/40 = 1/10 = .1$ (APP F.2)

  $K_{f,R} = 1 + q(K_T - 1) = 1 + .8(2.1-1) = 1.88$
  - $q = .8$ (Lec 15 pg 22)

NOW THE PARAMETERS OF THE S-N CURVE CAN BE CALCULATED

$$m = \frac{1}{3}\cdot \log \frac{0.9\cdot S_{UT}}{S_e} = \frac{1}{3}\log\frac{0.9(560\,\text{MPa})}{87.5\,\text{MPa}} = 0.2535$$

$$b = \log \frac{(0.9\,S_{UT})^2}{S_e} = \log \frac{(0.9\cdot 560\,\text{MPa})^2}{87.5\,\text{MPa}} = 3.464\ \log\text{MPa}$$

GIVEN $N = 100{,}000$ cycles

$$S_f = \frac{10^b}{N^m} = \frac{10^{3.464\,\log\text{MPa}}}{(100{,}000)^{0.2535}} = \frac{10^{3.464}\,10^{\log\text{MPa}}}{(100{,}000)^{0.2535}} = 157.2\,\text{MPa}$$

FROM (2) & (3)

$$4.167(10^3)\tfrac{1}{m^2}\cdot F = 157.2\,\text{MPa} \Rightarrow \boxed{F = 37.7\,\text{kN}}$$

SUMMARY:

USING THE TABLES IN THE LECTURE NOTES REQUIRES A CONVERSION FROM METRIC TO ENGLISH.

WHEN CONSTRUCTING THE SN DIAGRAM IT IS IMPORTANT TO REMEMBER THAT THE ENDURANCE LIMIT GIVEN BY THE RULES OF THUMB ~~MOST~~ ARE FOR THE IDEAL SPECIMEN AND MUST BE CORRECTED FOR THE SPECIMEN UNDER CONSIDERATION.