جامعة بيرزيت

BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Department of Mechanical and Mechatronics Engineering

ENME 435: Machine Design 1– First Exam	Student Name:_________
Date of Examination: 28.10.2019	Time duration: 90 minutes
Instructor: Dr. Rashad Mustafa	Total Marks: 100%

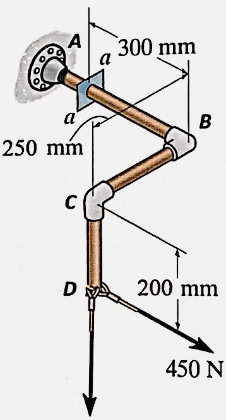
The pipe assembly is fixed at ***A***. The rod has a diameter of 25 mm and made of A-36 steel. Please answer the following questions:

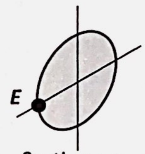
☑ **Question 1:** Please, determine the state of stress at point ***E*** on the cross section of the rod at section a-a. (25P)

☑ **Question 2:** Please, determine and draw the principal stress and maximum in-plane shear stress at Point ***E*** on the cross section of the pipe at section a-a. (15P)

☐ **Question 3:** Please determine the total elastic strain energy that can be stored in the rod **A-B**. The distance between **A-B** is 400 mm. Neglect the shearing strain energy. (20P)

Question 4: Please, determine the factor of safety for the above given material for all applicable theory. (20P)



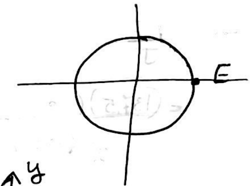


Section a-a

Question 5: What diameter should be used for the shaft **(A-B)** in order to get a factor of safety **10**, if the rod **A-B** is to be made of Cast Iron Alloys –ASTM A-197. Consider please for this calculation only an axial tension force of **55 *kN*** applied on the A-B member. (20P)

Q1 :-

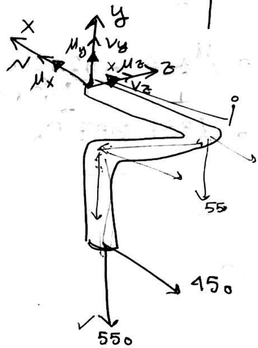
$d = 25mm$



$\Sigma F_y = 0$

$V_y - 550 = 0$

$V_y = 550\ N$ ✓



$\Sigma F_z = 0$

$V_z = 0$

$\Sigma F_x = 0$

$N - 450 = 0$

$N = 450$

Moments

$\Sigma M_x = 0$: $M_x - (550)(0.25) = 0$

$M_x = 137.5\ N.m$ ✓

$\Sigma M_y = 0$: $(450)(0.25) + M_y = 0$

$M_y = -112.5\ N.m$

$\Sigma M_z = 0$: $M_z + (0.3)(550) - (450)(0.2) = 0$

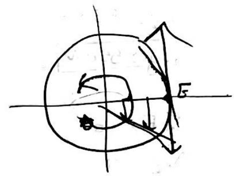
$M_z = -75\ N.m$

Stresses we have at E : τ_{xy} ($=0$), τ_x, σ_N, σ_y, σ_z ($=0$)

$\sigma_N = \frac{N}{A} = \frac{450}{\frac{\pi}{4}(0.025)^2} = +917197.45\ Pa$ (Tension)

$$\tau_x = \frac{Tc}{J}$$

$$= \frac{(137.5)(0.0125)}{\frac{\pi}{2}(0.0125)^4} = 44840764.33$$



$$\sigma_y = \frac{M_y z}{I} = \frac{(112.5)(0.0125)}{1.9165\times10^{-8}}$$

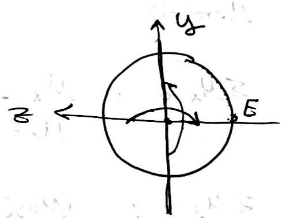
$$= 73375945.7 \text{ Pa}$$

$$I = \frac{\pi}{4}(R)^4$$

$$= \frac{\pi}{4}(0.0125)^4$$

$$= 1.9165\times10^{-8}$$

$$\sigma_z = 0$$

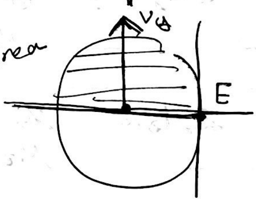


$$\tau_{xy} = \frac{VQ}{Ib}$$

$$= \frac{(550)(\bar{y}A)}{I\,b}$$

$$= \frac{(550)\left(\frac{(4)(0.0125)}{3\pi}\right)\left(\frac{1}{2}\pi(0.0125)^2\right)}{1.9165\times10^{-8}\times 0.025}$$

$$= 1494695.191 = 1.495\text{ MPa}$$



• So we have three stresses

σ_y, τ_x, σ_N

$\sigma = +73.4\text{ MPa} + 0.9179\text{ MPa}$

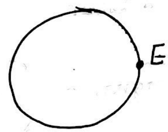
$\boxed{\sigma = 74.29\text{ MPa}}$ Tension

$\tau_1 = 44840764.33 \Rightarrow \boxed{\tau = 44.84\text{ MPa}}$

$\tau_{tot} = 44.84 + 1.495 = 46.335\text{ MPa}$ ↓

$= 46.335\text{ MPa}$

Q2 :-



$\tau_{xy} = 46.335 \downarrow$ (neg)

$\sigma_x = 74.29$ MPa

$\sigma_y = 0$

Now :-

~~Max~~ the principal stresses :-

σ_1, σ_2

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{74.29}{2} \pm \sqrt{\left(\frac{74.29}{2}\right)^2 + (46.335)^2}$$

$\sigma_{1,2} = 37.145 \pm 59.386$

$\sigma_1 = 96.53$

$\sigma_2 = -22.241$

Now we find θ_p :-

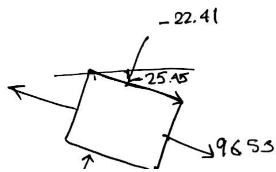
$$\tan 2\theta_p = \frac{\tau_{xy}}{\left(\frac{\sigma_x - \sigma_y}{2}\right)} = \frac{-46.335}{\frac{74.29}{2}}$$

$2\theta_p = -50.9$

$\boxed{\theta_p = -25.45}$

$$\sigma_x' = \frac{74.29}{2} + \frac{74.29}{2}\cos(-50.9) + (-46.335)\sin(-50.9)$$

$\sigma_x' = 96.54 \longrightarrow$ so element



Max shear:-

$$\tau_{xymax} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$= 59.39 \ MPa$

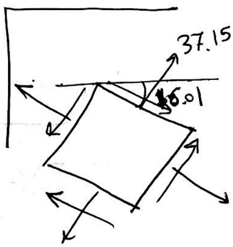
$\sigma_{avg} = 37.15 \ MPa$

We need θ_s:-

$$\tan 2\theta_s = \frac{-\left(\frac{\sigma_x - \sigma_y}{2}\right)}{\tau_{xy}}$$

$2\theta_s = -32.03$

$\theta_s = -16.01$



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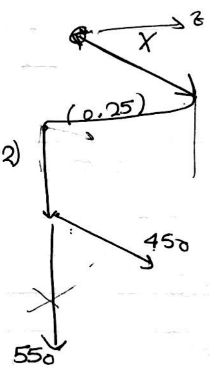
To find U_{AB}:-

$U_{AB} = U_N + U_{M_y}$

$= \frac{N^2 L}{2AE} + \int_0^{400} \frac{M^2}{2EI} dx$

$= \frac{(450)^2(0.4)}{(2)(0.025)^2\frac{\pi}{4}(200\times10^9)} + \int_0^{400} \frac{(137.5)^2 dx}{2(200\times10^9)\times1.9165\times10^{-8}} + \frac{(112.5)^2 dx}{} + \int \frac{(90-550x)^2 dx}{}$

$= 4.127\times10^{-4} J + \int$



$M_x = (0.25)(550) = \boxed{137.5}$

$M_z + (550)(x) - (450)(0.2) = 0$

$\boxed{M_z = 90 - 550x}$

$M_y + (450)(0.25) = 0$

$\boxed{M_y = -112.5}$

$\frac{T^2}{2GJ}$

1.3

$\frac{(0.4)(137.5)^2}{(2)75\times10^9\times\frac{\pi}{2}(0.0125)^4}$

$= 4.127\times10^{-4} + 0.4 \left(\frac{(137.5)^2 + (112.5)^2}{7666}\right) + \int_0^{400} \frac{(90)^2 - 49500x + 302500x^2}{7666}$

0.4226

$= 4.127\times10^{-4} + \frac{1646.9}{1.00} + \frac{(8100)(0.4) - (49500)\frac{x^2}{2}\Big]^{0.4}}{7666} + \frac{302500\frac{x^3}{3}\Big]^{0.4}}{7666}$

0.5165

0.126

$= 2.717 J$