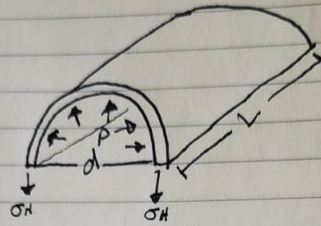


Exam MSX02064 1PM 7/5/2020

Q1) Show hoop stress is  $\sigma_H = \frac{Pd}{2t}$

a)



$$F = P \times A$$

$$= P \times dL = \text{Upwards force}$$

$$F = 2\sigma_H \times tL$$

$$2\sigma_H tL = PdL$$

$$2\sigma_H t = Pd$$

$$\sigma_H = \frac{Pd}{2t}$$

b) Longitudinal stress =  $\sigma_L = \frac{Pd}{4t}$

provided that the ratio between thickness to internal diameter is less than 1/20 it is assumed that hoop and longitudinal stress are constant across wall thickness.

c) 33.5 Psi

Density of seawater =  $1.0250 \text{ g/cm}^3$   
 $= \underline{1.0250 \times 10^{-3} \text{ m}^3/\text{kg} \text{ or } 1025 \text{ Kg/m}^3}$

d)  $P = \rho gh$   ~~$P = 1025 \times 9.81 \times h$~~

$\phi = 4.2 \text{ m}$

thick =  $4.2 \text{ mm}$

$P = 0$

$\sigma_H = 200 \text{ MPa}$

using  $P = \rho gh$

$\sigma_H = \frac{Pd}{2t}$  so  $P = \frac{2\sigma_H t}{d} = \frac{2 \times 200 \times 10^6 \times 4.2 \times 10^{-3}}{4.2}$

so  $\underline{P = 400 \text{ KPa}}$

Safety factor is 2.1

so  $2.1 \times 400 \times 10^3 = 840 \text{ KPa}$

$P = \rho gh = 1025 \times 9.81 \times h$

so  ~~$P = \rho gh$~~   $h = \frac{P}{\rho \times g} = \frac{840 \times 10^3}{1025 \times 9.81}$

depth = 83.54 m

$$e) \quad h = \frac{P}{\rho \times g} = \frac{0.1 \times 10^6}{1025 \times 9.81} =$$

$$0.1 \times 10^6 \approx 840 \times 10^3 \quad 840 \times 10^3 - 0.1 \times 10^6 = 740 \times 10^3$$

$$h = \frac{740 \times 10^3}{1025 \times 9.81} = 73 \quad h = \frac{940 \times 10^3}{1025 \times 9.81} = 93.48 \text{ m}$$

$$f) \quad 0.2 \times 10^6 + 840 \times 10^3 = 1.04 \times 10^6$$

$$h = \frac{P}{\rho \times g} = \frac{1.04 \times 10^6}{1025 \times 9.81} = 103.43 \text{ m}$$

g) There is a benefit to pressurising the inside of the submarine to at higher pressures as the higher you pressurise the inside of the submarine the deeper into the ocean you can go, in an espionage circumstance this is vital as there would be less chance of getting picked up by radar/sonar.

h) The results may change in real life due to ocean salinity changing and that the deeper you go in a submarine the colder it gets, which would add further stress as the materials cool and start to shrink. The other key thing is whether the people operating the submarine would be able to cope with the increased pressure within the submarine as deep sea divers can only be exposed to those high pressures for a certain duration of time it would be the same for the submarine.

## Question 2

a)

1) Define the problem: Needs to be a clear definition of what the problem is. The definition must include what the customer needs are and how it can be solved and Develop a problem Statement, needs to be very broad to encompass all solutions whilst specifically identifying the problems. Criteria for success requires input from Scientists, managers, marketing and manufacturing.

2) Gather Relevant Information: At this stage items such as the following can be considered:

- Is the problem real and it's statement accurate
- Is there really a need for a new solution or has the problem already been solved
- Existing solutions to the problem
- Economic factors governing the solution
- Other factors to consider (Safety, aesthetics, environmental issues, cost)

If someone already has a solution it may not be viable to design your solution.

3) Generate multiple solutions: It is vital that multiple solutions are created perhaps all at different cost points, the following must also be considered:

- must be a creative phase using brainstorming
- A "synthesis" of new ideas to solve the problem at hand
- Design teams should have free reign
- People from different disciplines should be involved as they'd have a different outlook on things

4) Analyse and Select Solution: At this stage in the design process the following ~~are~~ must be done:

- functional analysis
- industrial design/ergonomics
- Mechanical/Strength analysis
- Electrical
- Manufacturing/feasibility
- Product safety and reliability
- Economic and market analysis
- Regulations and standards

The aim here is to select the solution which encompasses as many of these points as possible

5) Testing and implementation of solution: At this point in the design cycle the following must be done:

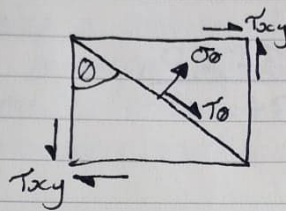
- Prototyping the solution under real world conditions  
This can be ~~done~~ used to correlate with any analytical work carried out in step 4 to increase confidence in the work completed so far
- Documentation - This is relevant if legislative testing is required or if an audit is required to prove what testing was carried out
- Finally apply for patents to protect the design from the competition.

b) FEA could be implemented in every step of the design. For example when the problem is brought to you and you establish what the issue is and what needs to be done to rectify it, FEA could then be used to research the materials being used ~~used~~ already. For example if it was a manufacturer needing to overcome head ~~bolts~~ stretching on their cars, FEA  
Studs

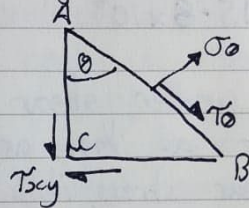
would be used to establish the fault in the existing product. This info can then be used to set the boundaries for any new head stud design such as max forces it should be able to handle, the temperatures it's exposed to. This would narrow down the material selection whereby some designs could be produced these designs would all undergo FEA analysis again to perhaps test the longevity and max yield points, this is ~~is~~ cost effective as it's destructive testing whilst being non-destructive due to it being a simulation. A design may then be chosen based on material cost or ease of manufacturing, and overall the process would have been completed a lot quicker and more ~~cost~~ effectively due to the FEA.

Q4) Show that Direct stress  ~~$\sigma_\theta = \cos \theta \sin \theta = \frac{1}{2} \sin 2\theta$~~

a)  $\sigma_\theta = \tau_{xy} \sin 2\theta$



Free body diagram



Sum of all forces perpendicular to AB are 0

$$AB \sigma_\theta = AC \tau_{xy} \sin \theta + BC \tau_{xy} \cos \theta$$

$$\sigma_\theta = \frac{AC}{AB} \tau_{xy} \sin \theta + \frac{BC}{AB} \tau_{xy} \cos \theta$$

$$\frac{AC}{AB} = \cos \theta \quad \text{and} \quad \frac{BC}{AB} = \sin \theta$$

$$\begin{aligned} \text{so } \sigma_\theta &= \tau_{xy} \sin \theta \cos \theta + \tau_{xy} \sin \theta \cos \theta \\ &= 2 \tau_{xy} \sin \theta \cos \theta \end{aligned}$$

$$\text{due to } \sin \theta \cos \theta = \frac{1}{2} \sin 2\theta$$

$$\sigma_\theta = \tau_{xy} \sin 2\theta$$

b) Direct Stress :  $\sigma_\theta = \tau_{xy} \sin 2\theta$

$\tau_{xy} = 76 \text{ MPa}$   
 $\theta = 51^\circ$

$\sigma_\theta = 76 \times 10^6 \times \sin 102 = \underline{74.34 \text{ MPa}}$   
 $= 74.34 \times 10^6$

c)  $\tau_\theta = -\tau_{xy} \cos 2\theta$

$= -76 \times 10^6 \times \cos 102 = \underline{15.8 \text{ MPa}}$   
 $= 15.8 \times 10^6$

d) An example of a material under shear stress only is wheel nuts on a car as they are tightened. They are being exposed to shear stress, it is common for wheel studs to shear off.

e) It is unlikely as there are other factors that need to be taken into account. For example in the wheel nut scenario there will be some fatigue in the material to a certain extent due to heat and exposure to dirt and water. Generally there is necking on wheel studs and especially head studs where they have been exerted to such constant stress they have stretched.