Mansoura University
Faculty of Engineering
Special Programs(BME&MTE)

Fall Term 2014/2015
Stress Analysis (PDE 281)
Final Exam. Jan. 2015

Problem # 1

1. Thin-walled pressure vessels are subjected to plane stress condition. (✓)
2. Circular rods under torsion are considered a uni-axial stress condition. (✗)
3. Thermal stresses **always** occur upon heating mechanical components. (✗)
4. Maximum normal stress failure theory is suitable for ductile materials. (✗)
5. Stress analysis using **Finite Element Method** is suitable for mechanical Components with complicated geometries. (✓)
6. Brittle coating method is based on the theory of light. (✗)
7. Transmission polariscopes are used for real mechanical components. (✗)
8. Stress and strain measurements are confined to **free surfaces.** (✓)
9. Long members having small cross-sections may buckle when subjected to Compressive loads which exceed the critical values. (✓)
10. The principal stresses are independent on the X-Y-Z coordinate system. (✓)

Problem # 2

Given: $\sigma_{xx}= \sigma_{yy}= \sigma_{zz}= 0$, $\tau_{xy}= \tau_{yz}= \tau_{xz}= 80$ Mpa

Solution:

c) $I_1= \sigma_{xx}+ \sigma_{yy}+ \sigma_{zz}= \mathbf{0}$

$I_2= \sigma_{xx}\sigma_{yy}+ \sigma_{xx}\sigma_{zz}+\sigma_{yy}\sigma_{zz}- \tau_{xy}^2- \tau_{yz}^2- \tau_{xz}^2 = -3(80)^2= \mathbf{-19200}$

$I_3= \sigma_{xx}\sigma_{yy}\sigma_{zz}- \sigma_{xx}\tau_{yz}^2- \sigma_{yy}\tau_{xz}^2- \sigma_{zz}\tau_{xy}^2+2\tau_{xy}\tau_{yz}\tau_{xz}=2(80)^3= \mathbf{1024000}$

a) $\boldsymbol{\sigma^3- I_1\sigma^2+I_2\sigma-I_3= 0}$

$\sigma^3- 0*\sigma^2-19200*\sigma+1024000= 0$

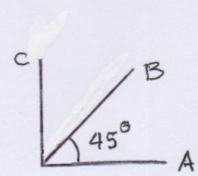
$\sigma_1=$ 160 **Mpa**

$\sigma_2=$ -80 **Mpa**

$\sigma_3=$ -80 **Mpa**

b) $\tau_{max}=\frac{\sigma 1-\sigma_3}{2}=$ 120 **Mpa**

Problem # 3



Given: E= 210 Gpa, μ=0.28,

$\varepsilon_A=400*10^{-6}$, $\varepsilon_B=300*10^{-6}$, $\varepsilon_C=-100*10^{-6}$

Solution:

1) $\varepsilon_{1,2}=0.5(\varepsilon_A+\varepsilon_C)\pm 0.5((\varepsilon_A-\varepsilon_C)^2+(2\varepsilon_B-\varepsilon_A-\varepsilon_C)^2)^{0.5}$

$\varepsilon_{1,2}=0.5(400-100)\pm 0.5((400+100)^2+(2*300-400+100)^2)^{0.5}$

ε_1=441.5 micron

ε_2=-141.5 micron

2) $\boldsymbol{\sigma_1}=E(\varepsilon_1+\mu\varepsilon_2)/(1-\mu^2)$

$=\frac{210*10^3*(441.5\ \ -0.28*141.5\ \ )*10^{-6}}{1-0.28^2}$

=91.5 Mpa

$\boldsymbol{\sigma_2}=E(\varepsilon_2+\mu\varepsilon_1)/(1-\mu^2)$

$=\frac{210*10^3*(-141.5\ \ +0.28*441.5\ \ )*10^{-6}}{1-0.28^2}$

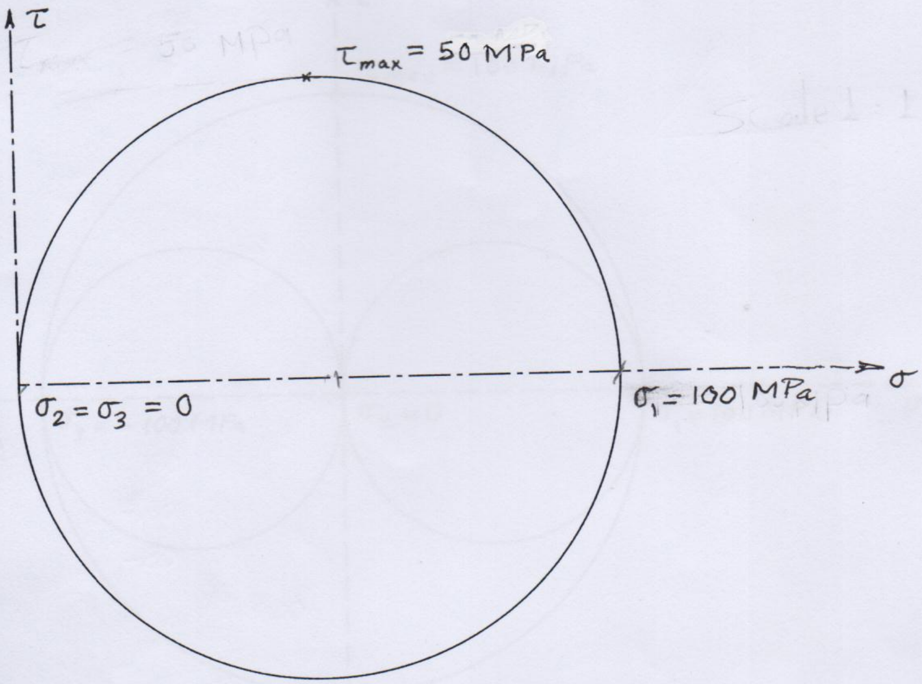
=-4.0 Mpa

3) $\boldsymbol{\gamma_{max}}=(\varepsilon_1-\varepsilon_2)=441.5476+141.5476$

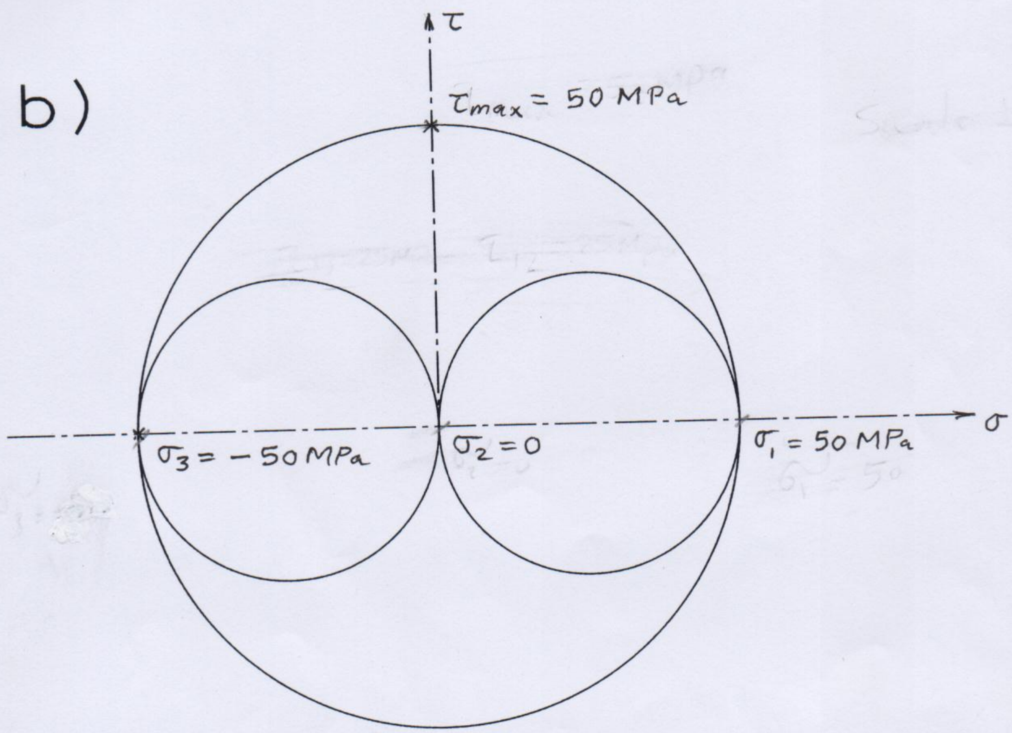
=583 micron

Problem#4

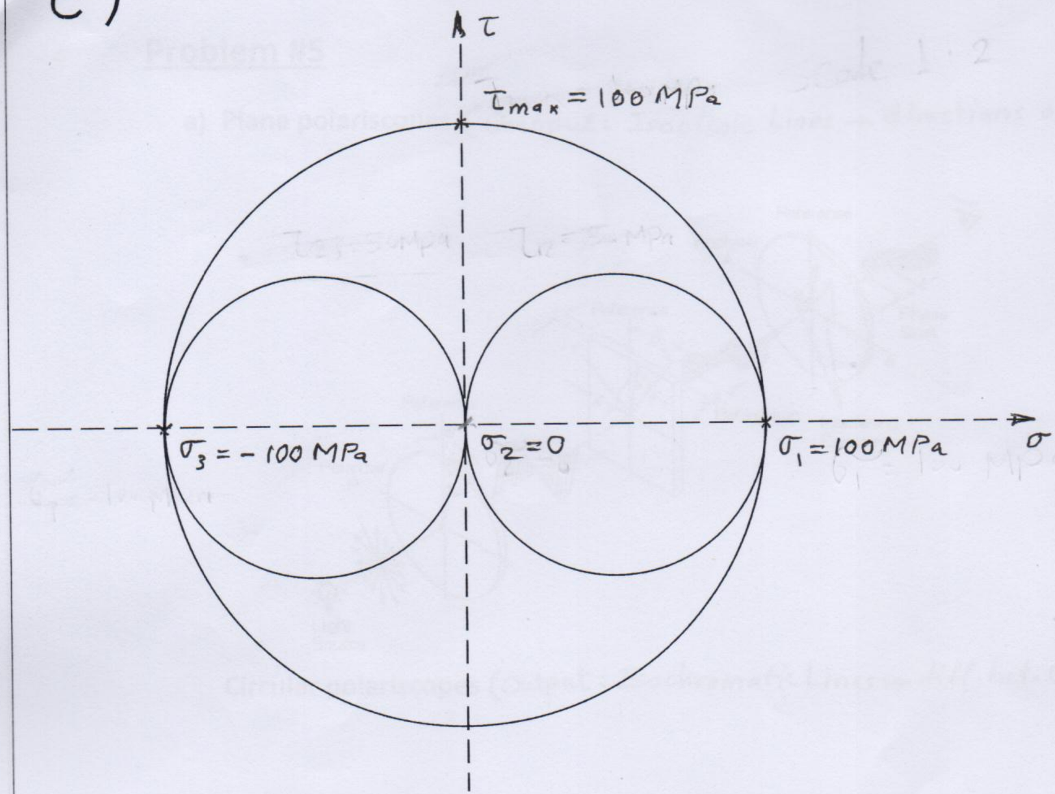
a)


τ
$\tau_{max} = 50$ MPa
σ
$\sigma_2 = \sigma_3 = 0$
$\sigma_1 = 100$ MPa

b)

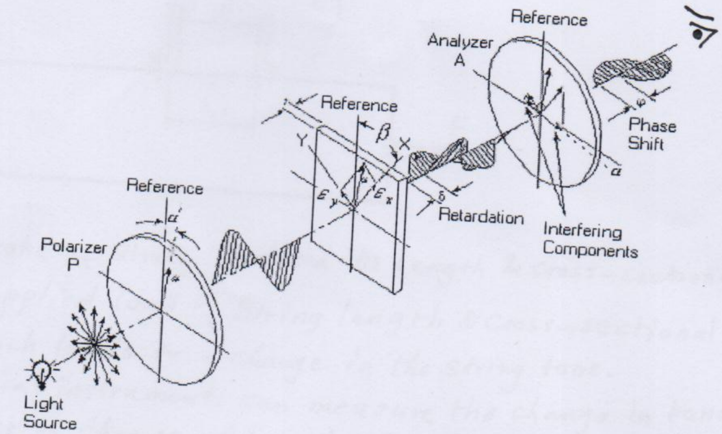

τ
$\tau_{max} = 50$ MPa
σ
$\sigma_3 = -50$ MPa
$\sigma_2 = 0$
$\sigma_1 = 50$ MPa

c)

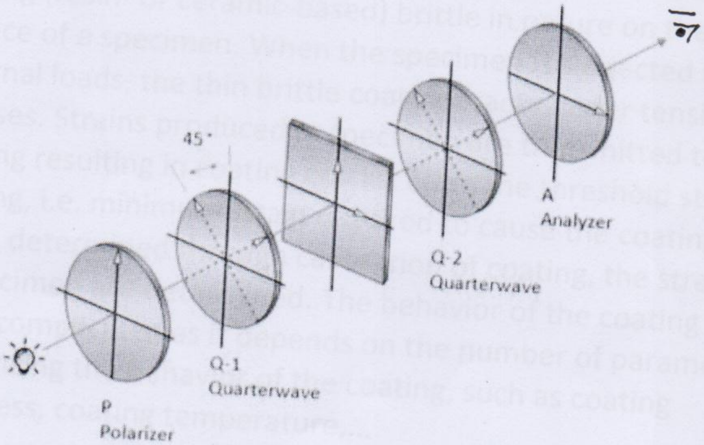


Problem #5

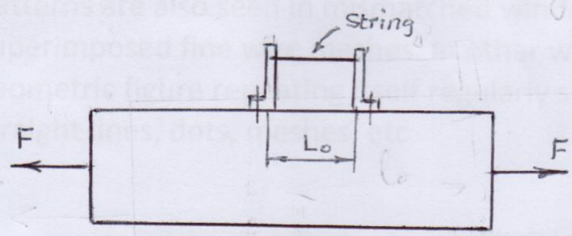
a) Plane polariscopes (Output: Isoclinic Lines → directions of σ_1 & σ_2)



Circular polariscopes (Output: Isochromatic Lines ⇒ diff. bet. $\sigma_1 - \sigma_2$)



b) Acoustical method



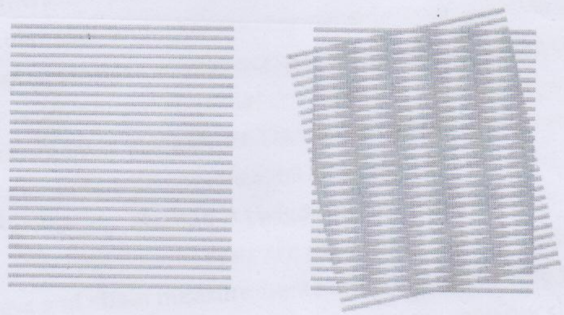
a) Original tone of String is related its length & cross-sectional area.
b) Due to applied load F, String length & cross-sectional area which leads to a change in the string tone.
c) Accoustical instruments can measure the change in tone and convert it to change of length ΔL.
d) Strain $\epsilon = \Delta L / L_o$ & Stress $\sigma = E\epsilon$

Brittle Coating Method

The principle of stress analysis involves the adherence of a thin coating (resin- or ceramic-based) brittle in nature on the surface of a specimen. When the specimen is subjected to external loads, the thin brittle coating cracks under tensile stresses. Strains produced in specimen are transmitted to the coating resulting in coating cracks. From the threshold strain of coating, i.e. minimum strain required to cause the coating to crack, determined through calibration of coating, the stresses in specimen are determined. The behavior of the coating is quite complicated as it depends on the number of parameters influencing the behavior of the coating, such as coating thickness, coating temperature,...

Moire Fringes Technique

Moire is a French word and its meaning is watered silk, which is a common optical phenomenon being observed daily if a fold of silk or any other finely woven fabric is allowed to slip on another fold and viewed against a light background simmering zig-zag patterns, localized between two folds of fabric. Such patterns are also seen in mismatched window blinds or superimposed fine wire meshes. In other words, whenever a geometric figure repeating itself regularly such as a set of straight lines, dots, meshes, etc.

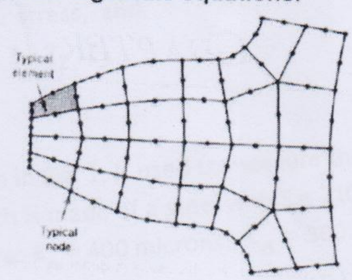


Finite element method

FEM: Method for numerical solution of field problems.

Description

- **FEM cuts a structure into several elements (pieces of the structure).**
- **Then reconnects elements at "nodes" as if nodes were pins or drops of glue that hold elements together.**
- **This process results in a set of simultaneous algebraic equations.**



El-Mansoura University
Faculty of Engineering
Special Programs(BME & MTE)
Time allowed: Two hrs.

Fall Term 2014/15
Stress Analysis (PDE 281)
Final Exam. Jan. 2015
Total Marks (50 Pts.)

Solve All Problems. Equation Sheet is provided

Problem # 1: (10 points)

Mark (√) or (X) the following statements:

1. Thin-walled pressure vessels are subjected to plane stress condition. ( )
2. Circular rods under torsion are considered a uni-axial stress condition. ( )
3. Thermal stresses **always** occur upon heating mechanical components. ( )
4. Maximum normal stress failure theory is suitable for ductile materials. ( )
5. Stress analysis using **Finite Element Method** is suitable for mechanical Components with complicated geometries. ( )
6. Brittle coating method is based on the theory of light. ( )
7. Transmission polariscopes are used for real mechanical components. ( )
8. Stress and strain measurements are confined to **free surfaces.** ( )
9. Long members having small cross-sections may buckle when subjected to Compressive loads which exceed the critical values. ( )
10. The principal stresses are independent on the X-Y-Z coordinate system. ( )

Problem # 2: (10 points)

At a point on a stressed member, the applied stresses are found to be:

$\sigma_{xx} = \sigma_{yy} = \sigma_{zz} = 0$, and the shear stresses on all surfaces are equal 80 MPa.

Calculate the following:

(a) The principal stresses σ_1 , σ_2 , σ_3

(b) The largest maximum shear stress, and

(c) The three stress invariants I_1 , I_2 , I_3

Problem # 3: (10 points)

A Rectangular Strain Rosette, shown in Fig. 1, is used to measure the strains at a point located on a component which is made of a steel with E = 210 GPa and μ = 0.28. The measured strains are: ϵ_A = 400 microns, ϵ_B = 300 microns, ϵ_C = −100 microns. Calculate:

1) The principal strains, ϵ_1 & ϵ_2, in microns,
2) The principal stresses, σ_1 & σ_2 , in MPa,
3) The maximum shear **strain** at the point, γ_{max} .

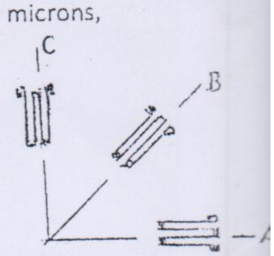


Fig. 1

Problem # 4: (10 points)

It is required to **accurately draw** a Mohr's stress circles for each of the following stress conditions, and show the magnitude of all the principal stresses and maximum shear stresses:

1. $\sigma_{xx} = 100$ MPa, $\sigma_{yy} = \sigma_{zz} = 0$ & all shear stresses τ_{xy}, τ_{yz}, τ_{zx} are zero
2. $\sigma_{xx} = \sigma_{yy} = \sigma_{zz} = 0$, $\tau_{xy} = 50$MPa, $\tau_{yz} = \tau_{zx} = 0$
3. $\sigma_{xx} = -\sigma_{yy} = 100$ MPa, $\sigma_{zz} = \tau_{xy} = \tau_{yz} = \tau_{zx} = 0$

Problem # 5: (10 points)

(a) Draw a **neat sketch** of the components of **plane** and **circular polariscopes.** What is the output of each setting?.

(b) Write a short note on each of the following stress analysis techniques: Acoustical method, Brittle coating method, Moire method, Finite element method.

Support your answer with accurate sketches.

With my best wishes, Prof. Dr. M. Shabara