Name.....Student I.D.....

Department of Mining and Materials Engineering

Faculty of Engineering

Prince of Songkla University

Mid-term Exam for Semester: 1 Academic Year: 2011

Date: August 7, 2011 Time: 9.00-12.00

Subject: 237-502 Adv. Mat. Proc. and Mat. Selection Room: S203

Instructions

1. There are 3 problem sets. Please do all of them. Write your answers in the space provided.
2. Textbook and course notes are not allowed.
3. Dictionary and calculator are allowed.
4. This mid-term exam is accounted for 25 % of total grade of this course.

Asst. Prof. Dr. Thawatchai Plookphol

Problem No.	Full Score (points)	Student's Score (points)
1.	30	
2.	20	
3.	50	
Total	100	

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<u>Problem 1</u> Explain the followings:

1.1 Three basic stages in design process (15 points)

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1.2 Materials property chart (5 points)

1.3 Performance matrix *P* (5 points)

1.4 Material index, *M* (5 points)

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Problem 2 Material index for a cheap, stiff column (20 points)

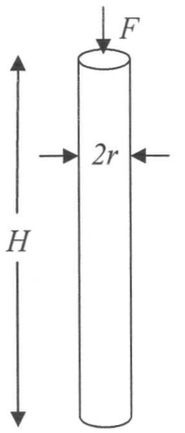

Figure 2

Columns support compressive loads: the legs of a table; the pillars of the Parthenon. Derive the index for selecting materials for the cheapest cylindrical column of specified, H, that will safe support a load F without buckling elastically. You will need the equation at with a slender column buckles. It is

$$F_{crit} = \frac{n^2 \pi^2 EI}{H^2}$$

where n is a constant that depends on the end constraints and $I = \pi r^4/4 = A^2/4\pi$ is the second moment of area of the column.

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Problem 3 (50 points) Multiple Constraints and Objectives

Trucks rely on compressed air for braking and other power-actuated systems. The air is stored in one or a cluster of cylindrical pressure tanks like that shown in Figure 3.1 (length L, diameter $2R$, hemispherical ends). Most are made of low carbon steel and are heavy.

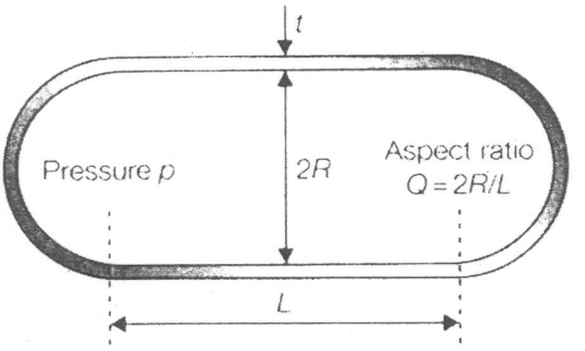

Figure 3.1

The task: to explore the potential of alternative materials for lighter air tanks, recognizing that there must be trade-off between mass and cost—if it is too expensive, the truck owner will not want it even if it is lighter. The following table summarizes the design requirements.

Function	Air cylinder for truck
Constraints	Must not fail by yielding Diameter $2R$ and length L specified, so that the ratio $Q = 2R/L$ is fixed
Objectives	Minimize mass m Minimize materials cost C
Free variables	Wall thickness t Choice of material

3.1 Show that the mass and material cost of the tank relative to one made of low carbon steel are given by

$$\frac{m}{m_0} = \left(\frac{\rho}{\sigma_y}\right)\left(\frac{\sigma_{y,0}}{\rho_0}\right)$$

and

$$\frac{C}{C_0} = \left(\frac{C_m \rho}{\sigma_y}\right)\left(\frac{\sigma_{y,0}}{C_{m,0}\rho_0}\right)$$

where ρ is the density, σ_y is the yield strength, C_m is the cost per kg of the material, and the subscript 0 indicates values for mild steel.

3.2 Explore the trade-off between relative cost and relative mass, considering the replacement of a mild steel tank with one made, first, of low alloy steel, second, one made of

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filament-wound CFRP, using the material properties in the table below. Define a relative penalty function:

$$Z^* = \alpha^* \frac{m}{m_0} + \frac{C}{C_0}$$

where α^* is a relative exchange constant, and evaluate Z^* for $\alpha^* = 1$ and for $\alpha^* = 100$.

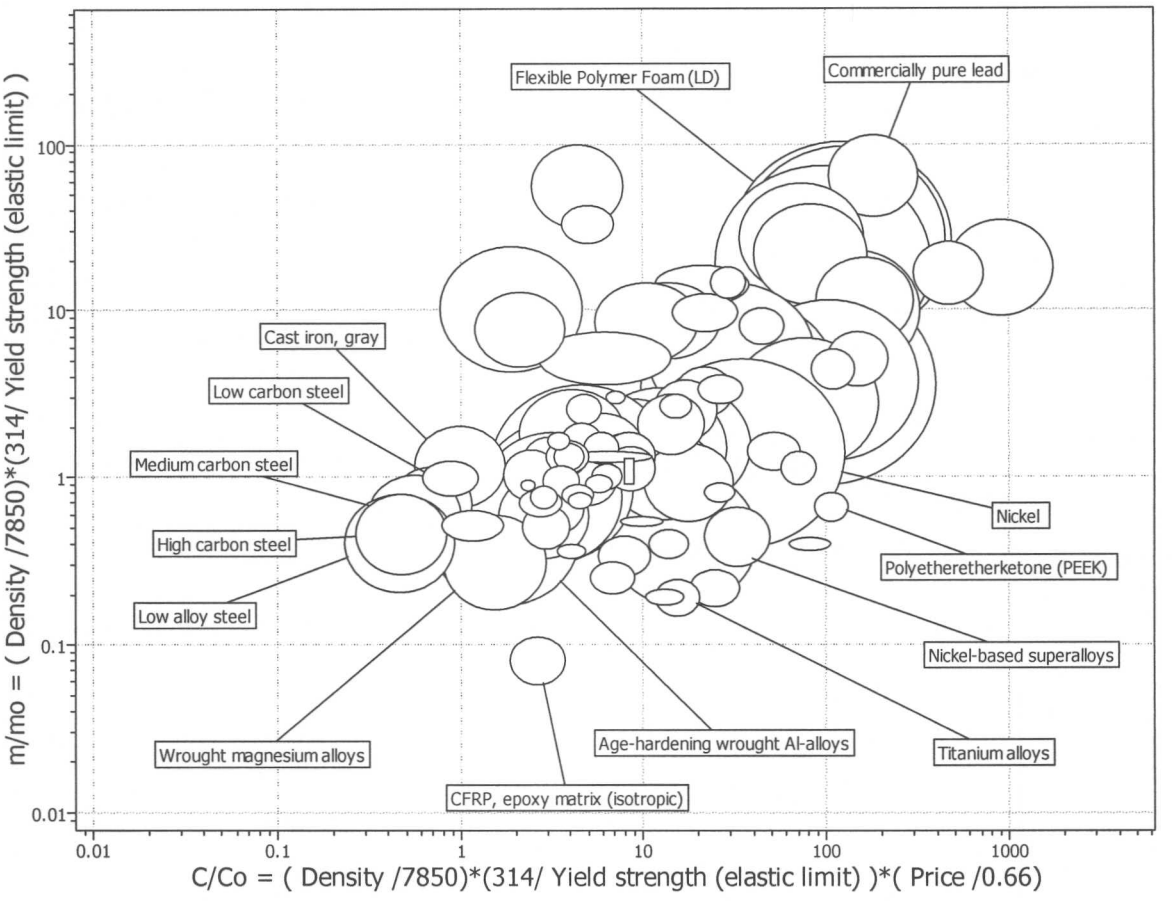

Figure 3.2

Material	Density ρ (kg/m^3)	Yield Strength σ_y (MPa)	Price per kg C_m ($/kg)
Mild steel	7850	314	0.66
Low alloy steel	7850	775	0.85
CFRP	1550	760	42.1

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3.3 Figure 3.2, and the chart below it, shows the axes of m/m_0 and C/C_0. Mild steel (here labeled "low carbon steel") lies at the coordinates (1, 1). Sketch a trade-off surface and plot contours of Z^* that are approximately tangent to the trade-off surface for $\alpha^* = \mathbf{1}$ and for $\alpha^* = \mathbf{100}$. What selections do these suggest?

Hint:

For thin-walled pressure vessel

$$\sigma_{hoop} = \frac{pR}{t}$$

$$V_{cs} = 2\pi RLt$$

$$V_{hs} = 2\pi R^2 t$$

where p is the internal pressure

R is the radius of the vessel

L is the length

t is the thickness of wall

V_{cs} is the volume of the cylindrical shell

V_{hs} is the volume of the hemispherical shell.

Yielding will occur when

$$\sigma_{hoop} \geq \sigma_y .$$

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