Emerging Composites

1. Carbon-carbon composites
2. Bio-composites
3. Nano-composites
4. Functionally graded materials (FGMs)

1. Carbon-carbon composites

1) Carbon fibers in a carbon matrix, hence an ultra-high temperature (up to 3300 °C) composite
2) Abrasion resistant
3) Self-lubricating
4) Aircraft brakes, steam and gas turbine engines, heat shields, rocket nozzles, nose cones, etc.
5) Can be machines, drilled, sawed
6) Lightweight

2. Bio-composites

1) By definition, a bio-product is one that is derived from renewable resources, stable in its intended lifetime, and bio-degradable after disposal in composting condition.
2) A bio-composite consists of biofibers and biomatrix, and is expected to be bio-degradable.
3) Biofibers
   - Wood "fibers": short fibers typically, or wood flour
   - Non-wood fibers: kenaf, flax, jute, hemp coir, and sisal (and straw and grass)

   Ranking of non-wood fibers in terms of tensile modulus and tensile strength:
   Flax (about 33% of E-glass's)
   Kenaf
   Hemp
   Sisal
   Jute
   Coir (about 5% of E-glass's)
4) Bio-polymers (Bio-resins)
   Bio-polyester (microbial polyester)
   Soy-based plastics
   Starch plastics

3. Nano-composites

1) Composite filled with nano-sized ($10^{-9}\ m$) particles
2) Platelets and nanotubes
3) Carbon nanotubes (CNTs):
   Young's modulus $\sim 1000\ GPa$
   Tensile strength $>\ 30\ GPa$

   Compared with PAN-based Carbon fibers:
   Young's modulus $250 \sim 550\ GPa$
   Tensile strength $1.9 \sim 6\ GPa$

4) Small amount of nano-particles will provide significant improvement in a variety of properties.
5) Applications:
   Structural components of electronic portable devices
   Auto accessories, both interior and exterior

4. Functionally Graded Materials

- First conceptualized in mid-1980 when a thermal barrier capable of withstanding a surface temperature of 2000 K ($\sim 1727\ ^\circ C$) and a surface temperature gradient of $1000\ K$ ($\sim 727\ ^\circ C$) across a section of less than $10\ mm$ was needed.
- Achieved by varying volume (or weight) fractions gradually over the volume of material.
- FGMs are not homogeneous, nor are they isotropic; in other words, E_x depends on location (x, y, z) and angle θ, for instance.
- Almost ready for commercialization.
- Applications:
  Aerospace: high thermal gradient

Final Exam Review

Chapter 1
Same as midterm (even though the course outline says it's not on the final exam…)

Chapter 2
2.3 Independent mechanical properties vs. Types of materials
e.g. Orthotropic materials, 9 constants
transversely isotropic materials, 5 constants

Chapter 3
3.2 V_f V_m W_f W_m void content
a few fibers + a few matrices + voids
V_f' V_m' V_{fmax} RVE
When an equation in the text is only valid for zero void content
3.3 Isotropic fibers + isotropic matrix
Transversely isotropic fibers + isotropic matrix

Mechanics of materials approach
Halpin-Tsai
Elasticity

3.4 $(\sigma_1^T)_{ult}$: fibers-fail-first
matrix-fails-first
equations to use, the if's
$\left(\sigma_1^C\right)_{ult}$: failure modes
$(\sigma_2^T)_{ult}$ $\left(\sigma_2^C\right)_{ult}$ $(\tau_{12})_{ult}$

Chapter 2 (again)
2.4 $[Q]$, $[S]$
2.5 $[T]$, $[\bar{Q}]$, $[\bar{S}]$
2.6 E_x E_y G_{xy} v_{xy} m_x m_y
Evaluation
Application
e.g. Given any one, find one of the remaining
Global stresses
Global strains
Local stresses
Local strains
Physical meanings of engineering constants (probably m_x and m_y)
2.8 Strength/Failure Theories of a Lamina
Based on local stresses (ε_1, ε_2, γ_{12}) or local strains (σ_1, σ_2, τ_{12})
Max stress – don't' compare well with experimental data, but indicate mode of failure
Max strain – same as above
Tsai-Hill:

- Original
- Modified

Tsai-Wu:

- 3 forms on H_{12}
- Tsai-Hill, Hoffman, von Mises-Hencky (we probably get to pick what we want to use)

Tsai-Hill and Tsai-Wu:

- Compare well with experimental data but don't indicate mode of failure

Chapter 4

4.2 laminate code – shortest possible notation description of a laminate

4.3 $[ABD]$

membrane and bending coupled

membrane and bending uncoupled

Given $[ABD]^{-1}$ and $\begin{Bmatrix} N \\ M \end{Bmatrix}$

$\rightarrow \{\varepsilon^0\}\ \{\kappa\}$

$\rightarrow \{\varepsilon\}_{global}$ at certain location (i.e. ζ)

$\rightarrow \{\sigma\}_{global} \rightarrow$ plots of stresses across the thickness direction

$\rightarrow \{\sigma\}_{global} \rightarrow SR$

4.4 Given $[ABD]^{-1}$

$\rightarrow E_x\ E_y\ \ldots\ E_x^f\ E_y^f\ \ldots$

(Engineering constants of a laminate)

given $[ABD]$

$\rightarrow r_N\ r_M\ r_B$

Chapter 5

5.2 $[ABD]$ matrix when laminate is, for example

1) symmetric

2) quasi-isotropic

3) specially orthotropic

5.3 Progressive failure

FPF, UPF, LPF

Termination criteria

Discount on failed ply (plies)

Chapter 6

6.2 narrow vs. wide beams

Bending moment M (units, signs)

Moment resultant M_x

$E_x^{wide} I$ (to replaced EI [for isotropic beams] for deflection, and slope evaluations)

$E_x^{narrow} I$

Plates: differential elements for $\sum F_y = 0$

differential elements for $\sum M_x = 0;\ \sum M_z = 0$

(g) (h)
essential boundary conditions (satisfied?)
natural boundary conditions (satisfied?)
Given $w_o(x, y) \rightarrow M_x \;\; M_y \;\; M_{xy}$
$[ABD]^{-1}$: given if needed
Beam deflection table given from Shigley's

Emerging Composites
Material from class notes (shouldn't be anything too crazy)