

EM 4133/6133 Mechanics of Composite Structures

Spring 2009

(Subject to change)

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Assessment

Based on the student's performance in the following activities

1. Problem Sets **25%**
 - About 8
 - Typically out on Wednesday due following Wednesday
 - Late Policy — All homework must be done
 - Computer problem (EM 6133 only) counts as two problem sets
2. Design problem **15%**
3. Review Article **5%**
4. In-class Test #1 **15%**
5. In-class Test #2 **15%**
6. Final Exam **(25%)**

Catalog Data

Mechanics of Composite Materials. (3) (Prerequisites: EM 3213 and MA 3253).
Three hours lecture. Stress, strain, constitutive relations for anisotropic material, lamina properties, laminate properties, composite beams and plates.

Prerequisites by Topic

- Concepts of stress, strain, and mechanics of materials
- Ability to solve ordinary homogeneous differential equations with constant coefficients
- Ability to differentiate and integrate multivariable functions

Class Schedule

Tuesday: 18:00 – 20:50, Room Simrall 106.

Expectations

The objective of this course is to provide a minimum level of literacy in the field of composite structures. Students who successfully complete the course should be able to read, understand, and comment on papers in the open literature. Students should have a grasp of the fundamental techniques used to analyze composite structures and an introduction into the current concerns posed by the scientific community.

Course Objectives

1. To familiarize students with the basic concepts and characteristics of fiber-reinforced composite materials.
2. To discuss the micromechanical and macromechanical characteristics of composite lamina.
3. To examine the constitutive relationship for a composite laminate and its use in the classical lamination theory.
4. To develop an understanding of the through-thickness stress and strain variations in composite laminate and the effect of ply pattern on laminate characteristics.
5. To examine failure theories for fiber-reinforced composite laminates.
6. To apply classical lamination theory to the analysis and design of structures made of laminated fiber-reinforced composite materials.

Performance Criteria

Outcome 1: Demonstrate a fundamental understanding of:

- 1.1 the definition, characteristics, and behavior of composite materials
- 1.2 the commonly used fabrication techniques for composite materials
- 1.3 the stress-strain relations for an anisotropic lamina and the hygrothermal effects

Outcome 2: Demonstrate the ability to:

- 2.1 calculate engineering constants from constituent properties
- 2.2 calculate the components of compliance and the stiffness matrices for a lamina at an arbitrary orientation

- 2.3 calculate the lamina stress and strain components due to mechanical and hygrothermal loading
- 2.4 calculate the stiffness and strength properties of a lamina based on the properties of constituent materials
- 2.5 calculate the components of laminate extensional, coupling, and bending stiffness matrices
- 2.6 calculate the midplane strains and curvatures based on force and moment resultants and visa versa
- 2.7 calculate through-the-thickness stress and strain distributions
- 2.8 calculate effective in-plane engineering properties of a laminate
- 2.9 apply a specific failure criterion for the analysis of a composite laminate
- 2.10 analyze and design laminated structures with classical boundary conditions

Outcome 3: Demonstrate the ability to:

- 3.1 submit assignments as technical reports with clear and concise statements explaining each solution step
- 3.2 properly interpret and discuss the solution outcome

Grading Scale

$90 \leq A \leq 100$; $80 \leq B < 90$; $70 \leq C < 80$; $60 \leq D < 70$; $0 \leq F \leq 60$

Attendance Policy

It is important for students to attend every lecture, as many topics will be discussed in only one period. Attendance will be checked in every lecture period. For a student with only 1 invalid absence, the lowest problem set score will be removed.

Make-up Test Policy

No make-up tests will be given in this course. If a test is missed for a valid reason, with prior notification and consent of the instructor, the average of the other test and the final exam will be used as the grade for the missed test. If a test is missed for an invalid reason, a grade of zero will be given to that test.

Recommended Text

Robert M. Jones, Mechanics of Composite Materials, 2nd Edition, Taylor & Francis, PA, 1999.

Other References

1. Michael W. Hyer, Stress Analysis of Fiber-Reinforced Composite Materials, McGraw-Hill, New York, New York, 1998.
2. Derek Hull, An Introduction to Composite Materials, Cambridge University Press, London, 1981.

3. Handbook of Composites, George Lubin, ed., Van Nostrand Reinhold Company, Inc., New York, 1982.
4. Engineered Materials Handbook, Volume 1: Composites, ASM International Handbook Committee, Metals Park, Ohio, 1987.
5. Mel M. Schwartz, Composite Materials Handbook, McGraw-Hill Book Company, New York, 1984.
6. Stephen W. Tsai and H. Thomas Hahn, Introduction to Composite Materials, Technomic Publishing Co., Inc., Westport, Connecticut, 1980.
7. J. R. Vinson and R. L. Sierakowski, The Behavior of Structures Composed of Composite Materials, Martinus Nijhoff Publishers, Boston, Massachusetts, 1986.
8. A. Brent Strong, Fundamentals of Composite Manufacturing: Materials, Methods, and Applications, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.
9. Brian C. Hoskin and Alan A. Baker, eds., Composite Materials for Aircraft Structures, American Institute of Aeronautics and Astronautics, Inc., New York, 1986.
10. James M. Whitney, Structural Analysis of Laminated Anisotropic Plates, Technomic Publishing Co., Inc., Westport, Connecticut, 1987.
11. Bhagwan D. Agarwal and Lawrence J. Broutman, Analysis and Performance of Fiber Composites, 2nd Edition, John Wiley & Sons, Inc. New York, New York, 1990.

Journals

- *AIAA Journal* — Structures, stability, dynamics; Analytical models, some experimental
- *Journal of Composite Materials* — Fracture, failure; Analytical models
- *Journal of Applied Mechanics* — Mathematical models, little or no experiments
- ASTM STP's — Concentrate on one topic: fracture/failure; NDI; fatigue, etc.

Week	Date	Material	Jones
1	1/13	Inventory; Course Intro/Overview; What is a composite; History	1.1, 1.2, 1.3
2	1/20	Constituents; Applications/Manufacturing aspects; Advantages and disadvantages; Intro to tensor/engineering notation; Role of the matrix; Cylinder model; Shear lag mode (1-D)	1.4, 1.5
3	1/27	Shear lag mode (2-D); Load sharing; Probabilistic nature of failure; Weibull distribution; Intro to micromechanics; Mechanics of materials	3.1, 3.2
4	2/3	Generalized micromechanics; Elasticity approach; Generalized Hooke's Law; Compliance/Stiffness	3.3, 2.1, 2.2, 2.3
5	2/10	Longitudinal/Transverse modulus; Poisson's ratio; reciprocity; Shear modulus; Short-fiber composites	
6	2/17	Compliance matrix; Unidirectional ply values; Elasticity; Extensional shear coupling; Coefficients of mutual influence	2.4-2.7
7	2/24	Tensor transformation (2-D); Mohr's circle; 3-D transformation; Laminate and ply axes; Laminate shorthand; \mathbf{A} matrix; \mathbf{A}^{-1}	4.1, 4.2
8	3/3	Examples of ply stress & strain in laminate & ply axes; Stress concentration at a hole, isotropic and orthotropic; Orthotropic case ply-by-ply	4.3, 6.4
9	3/10	Introduction to failure concepts; Introduction to unidirectional failure criteria; In-Class Test #1	3.5, 4.5
10	3/17	Spring Break (No class)	
11	3/24	Ply-by-ply failure analysis; Example of failure analysis, Post-first-ply failure	
12	3/31	Bending equations; \mathbf{D} ; \mathbf{D}^{-1} ; Bending example; Bending and buckling of laminated plates; Energy formulation; Orthotropic case	5
13	4/7	Bending-stretching coupling; \mathbf{B} matrix; Example of an unsymmetric case; Thermal strains; Existence; C.T.E.; Induced thermal stress resultants; Thermally induced stresses and bending; Ply thermal strains	
14	4/14	Student presentations	
15	4/21	In-class Test #2; Fabrication concerns; Thermal strains example; Moisture effects; Limitations of CLPT; Edge effects; Interlaminar stresses; Review	4.6