Analysis of Laminated Composite Structures AE/ME 6284

Purpose of the course and its significance for your engineering education:

The course will elucidate the formulation, solution, and application of problems related to design of composite and sandwich structures. These problems are of vital importance in such diverse areas as aerospace, mechanical, marine, biomedical and civil engineering. For example, composite and sandwich construction is used in the fuselage, wings and tails of modern planes, superstructures and radar enclosures of naval ships are often built using sandwich structures and elements of buildings are constructed using sandwich panels to provide both thermal insulation and structural efficiency. The tendon-to-bone insertion site and arterial walls represent examples of natural composite material investigated in biomechanics.

The purpose of the course is to prepare engineers to solve practical problems associated with design of composite structures. In addition, the course provides the necessary theoretical foundations for researchers working with such structures. After the completion of the course you should be able to design composite structures, perform a preliminary analysis using available solutions, understand manuals of software used in design of composite structures, prepare the input and analyze the output from a FEA analysis, and assess the applicability and limitations of finite element packages and theories referred to in the corresponding manuals. The emphasis in the course is on the concepts and their applications.

Subjects:

The course covers both material and structure-oriented aspects of composites. In the following description, the subjects included in each chapter do not necessarily coincide with the titles of the paragraphs in the viewgraphs.

Chapter 1: Review of Basic Concepts
1. Orthotropic and isotropic engineering constants
2. Specially and generally orthotropic laminae
3. Strength of a lamina (strength criteria)

Chapter 2: Miscellaneous Aspects of Analysis of Laminated Structures
1. Strength of composite beams
2. Review of stiffness of various laminates and their advantages
3. Large aspect ratio plates bending in cylindrical surface (cylindrical bending)
4. Application of inverse laminate equations
5. Extended discussion of hygrothermal stresses
6. Review of interlaminar stresses
7. Review of micromechanics of progressive failure

Chapter 3: Laminate bolted and bonded joints

Chapter 4: Analysis of Discontinuous Fiber-Reinforced Composites: Engineering Approach
1. Types of short-fiber (discontinuous) composites
2. Stress transfer and stiffness of aligned and random-oriented short fiber composites
3. Strength of short-fiber composites
4. Fatigue of short-fiber composites

Chapter 5: Foundations of Micromechanics of Composite Materials
1. General principles
2. Representative volume element and representative unit cell
3. Fundamental micromechanics equations
4. Representative models used in micromechanics (self-consistent, Mori-Tanaka, composite cylinder assemblage, etc.)

Chapter 6: Micromechanical Approach to Strength of a Lamina
1. Longitudinal tension and compression
2. Transverse tension and compression
3. In-plane shear

Chapter 7: Sandwich structures
1. Introduction to sandwich structures
2. Governing equations
3. Boundary conditions for a sandwich plate
4. Static analysis of sandwich plates of composite materials
5. Applicability of the first order shear deformation theory (FSDT)
6. Experiments on sandwich panels: verification of theoretical models
7. Buckling of sandwich plates
8. Sandwich or laminated plates subjected to dynamic loads
9. Free vibrations of sandwich plates
10. Response of a sandwich plate subjected to a dynamic lateral load
11. Local buckling of sandwich panels
12. Buckling of Honeycomb Core Sandwich Panels Subjected to In-Plane Compressive Loads – Design Formulae
14. Joints in sandwich structures
15. Fatigue properties of sandwich core materials

Chapter 8: Selected Topics of Composite Material Structures (optional – subject will be specified prior to the fall semester).

References:

The course is based on a large number of references. A unique textbook covering all subjects considered in the course does not exist. Instead, the students receive copies of all viewgraphs discussed in the class (they will be uploaded to Canvas prior to the Fall semester). These slides represent a comprehensive review of all materials that will be considered. The chapters of the course are supplied with relevant references that may be used for a deeper
insight in the corresponding subject. However, the viewgraphs are sufficient to understand and successfully complete the course.

Several textbooks that are relevant to the material considered in the course are listed below. Additional references are referred to as needed.


**Projects:**

This is a 400-level course and the students must illustrate that they are capable of solving practical problems. Accordingly, standard homework assignments and tests will be
replaced with four projects, each of them resembling typical problems in industry or exploring a particular issue related to mechanics of composites. The student has to work on the project during several weeks and submit a report with the solution. The report should resemble a typical report in industry, i.e. it must be typed, written in a clear and logical language, demonstrate all relevant mathematical equations and contain all necessary references. The report should have a section of conclusions outlining the problem, identifying important tendencies (effects of various design variables) and providing practical recommendations for design of the component.

The students will send their reports to the professor (upload reports on Canvas) and they will be contacted by phone or e-mail, if there are any questions that should be clarified.

These are individual projects, i.e. everybody must submit an independent report.

Grading policy:

Each project corresponds to 25% of the final grade.
Final grade: A = 85-100
B = 70-85
C = 55-70

Important note: The policy of Professor Birman is based on his experience with industry. If a project is not finished or if it contains mistakes, the engineer responsible for this work is required to correct it and submit a satisfactory project. Accordingly, if your project is incorrect, we will discuss the source of the mistake and you will have the opportunity to resubmit the correct design. While this may involve additional effort, on the positive side, this usually results in a high grade for most projects (this is a much nicer outcome than that in industry where if you make too many mistakes, you can find yourself in a less desirable situation looking for another job).

Instructor:

Professor Victor Birman works in the areas of composite material structures, smart structures, biomechanics, buckling and dynamics. He published over 300 research papers in archival journals, book chapters and conference proceedings. Prof. Birman has cooperated with the Air Force, Air Force Office of Scientific Research, Army Research Office, Office of Naval Research, Department of Transportation, Missou, Missouri Department of Transportation, Navy, National Institutes of Health, NASA, and industry. He serves as Associate Editor of several journals and as a reviewer for over 25 journals, several publishing companies and agencies. Professor Birman is a Fellow of the American Society of Mechanical Engineers and Associate Fellow of the American Institute of Aeronautics and Astronautics.
The monograph of Dr. Birman “Plate Structures” was published by Springer in July 2011. He is also a co-author of the book “Structural Interfaces and Attachments in Biology” that was published by Springer in 2012 (these are not required books for the course).