Course ES-2
Composite Laminate Analysis

Course Summary

This course provides the backbone designing and analyzing composites with a thorough understanding of classical laminate plate theory and failure criteria. The ES-2 course is perfect for engineers who did not take composite course during their university education, or who recognize that their university courses were too theoretical and did not provide enough practical understanding. ES-2 goes well beyond university level composite courses by using mechanical property data for modern composite materials that are currently available and evaluating these materials on existing composite configurations. The course is 80% analysis and 20% hands-on. The shop work involves manufacturing unidirectional and woven fabric panels at the lamina and laminate level as well as loading test coupons to failure. The course performs the analysis with a highly evolved Excel spreadsheet. Additionally, it introduces the students to composite analysis using FEA. ES-2 is a prerequisite for ES-3 and ES-4, unless the students have an extensive background with laminate analysis through their past work experience or university education. ES-2 is also recommended as an intermediate prerequisite between ER-1 and ER-2 for engineers performing repairs and modification who have access to load data.

Introduction

Mathematical skills in matrix algebra and basic calculus are utilized. Participants without a thorough knowledge in composite materials or any analysis experience are strongly encouraged to take our Repair Analysis and Substantiation course as a prerequisite. Engineers involved in the design and repair of composite structures are often required to analyze and develop a unique lamination sequence. This requires an understanding of the relationships between materials and their effects on the properties of the composite laminate. Students will develop and perform stress, strain and stiffness analysis using Laminated Plate Theory, as well as fabricate and perform structural testing on composite laminates. The mechanical testing will be compared with the computer analytical predictions. This course will enable the engineer to determine the mechanical behavior of a laminated fiber-reinforced structure by understanding the interaction between the fiber and the matrix and the effects of the stacking sequence on a laminate. The class requires only a basic understanding of engineering loads, moments and deformations. The generalized stress-strain relationships for homogenous, isotropic materials are used to develop the stiffness and strength for an orthotropic, fiber-reinforced composite. The course develops all of the necessary equations to understand the effects of resin content, fiber volume and material density. The analysis unfolds into lamination theory to study the results of lamination sequence and the requirements for ply orientation. Simple computer programs are developed and used to demonstrate the effects of different configurations of the ABD matrix on the mechanical properties of a complete composite laminate. Failure criteria are applied to
the composite laminate to finalize the design process.
Key Lecture Topics:

- Axis and coordinate systems for both the material and laminate.
- Basic engineering loads, moments and deformations.
- Stress and strain relationships.
- Composite material properties.
- Constitutive equation based on the stiffness and compliance matrices.
- Off-axis, in-plane and transverse loading.
- Interpretation of the A, B and D matrices.
- ABD matrix effects on the physical properties for various lamination sequences.
- Computer laminate analysis using the ABD matrix.
- Laminate failure criteria.

Workshop Exercises:

- Direct application of micro-mechanics and macro-mechanics brought from the theoretical classroom environment.
- Computer design and simulation.
- Wet layup and prepreg composite laminate fabrication.
- Structural testing to failure; comparison between actual and theoretical calculations and analysis.
### Course Benefits

Attendees will learn how to develop and perform stress, strain and stiffness analysis using Laminated Plate Theory and to perform structural testing/validation on composite laminates.

### Prerequisites

ES-1 (Formerly E-1) Composite Essentials for Engineers & Managers course, or

ER-1 Aerospace Repair Analysis & Substantiation, or

M-1/R-1 Advanced Composite Fabrication & Damage Repair - Phase 1, or

Equivalent experience with composite materials and processes.

### Teaching Method

Active classroom lecture and workshop exercises

### CEU

3.6