Course ES-3
Design of Composite Structures

Course Summary

ES-3 has been developed specifically for engineers, to provide a thorough understanding of the configuration of composite details and components to meet the design requirements for structural applications. The course discusses the requirements for designing both assembled and co-cured/co-bonded structure using solid laminates, sandwich panels, stiffened structure, panel edge bands, ply drop-offs, and panel field areas. The course also addresses the requirements for assembling composite structures using both bonded and mechanically fastened joints and utilizes extremely robust bonded and bolted joint analysis techniques. Analysis is performed to evaluate panel buckling and vibration. Additionally, ES-3 provides an understanding of environmental knockdowns, BVID, allowable damage limits (ADLs), and repair-induced stress concentrations to determine design values to meet static and Damage Tolerance requirements for both primary and secondary structure. This course performs analysis with both traditional hand calculations, using MS Excel and MathCAD, and FEA, using Femap/NASTRAN.

Introduction

The composite design process must follow the highly touted *Building Block* approach that starts at the lamina level and progress through the laminate, element, detail, and subcomponent levels before achieving the final component level. Designing composite structures involves understanding the interaction of the laminate with the structural configuration. A composite component will seldom ever be constant thickness with the same laminate throughout. Instead, a single composite component is typically configured with solid laminate regions, sandwich panel regions, mechanically fastened edge bands, bonded joint regions, and free edges. Each region needs to be specifically designed for its unique purpose and special considerations must be applied to transition from one region to the next. The tailoring of structural properties through lamination and fiber orientation are discussed in relationship to strength of materials issues and load/deformation response. The design development of composite structure is based on design outcomes at each level and how fiber/resin systems and ply orientation is determined to achieve these design outcomes. This course will cover the design requirements of many basic structural elements and details using both simplified and robust analysis procedures. Detailed stress analysis will be discussed with respect to design detail such as joints, structural stiffening against instability, access holes, and other structural discontinuities. Other aspects of the course to be covered include environmental and longevity aspects, component quality, and in-service support issues. Regulator requirements are presented to achieve both Design Limit Load (DLL) and Design Ultimate Load (DUL) to achieve both static strength and Damage Tolerance requirements. Several design case studies are undertaken during the course on classroom computers. These case studies will be used to reinforce the lectures.

Topics

Key Lecture Topics:

- Composite design process
- Operational and environmental requirements.
- Structural applications and design requirements.
- A review of ply and laminate material properties.
- Composite plates and shells.
- Interlaminar stresses.
- Structural elements.
- Design of composite structures.
- Composite sandwich structures.
- Bonded and bolted joint design.
- Ply drop-off and build-up.
- Stress concentrations.
- Design effects evaluated with finite element analysis (FEA).
- Design implications of defects, BVID, and allowable damage.
- Damage and damage tolerance – a review of damage mechanisms, damage growth, durability, and damage resistance in composite structures is discussed with the aim of improving the appropriate application of composite materials and determining the design, manufacturing, inspection, and maintenance requirements.
- An approach to designing composite components – in the design and development of composite structures and components there are several steps that need to be followed to produce an efficient and effective structure. These steps will be overviewed to consider what the engineer is attempting to achieve.
- Structural behavior of composite components – the configuration of a laminated composite structure will affect its overall structural performance. The implications and influences of ply orientation, stacking sequence, and symmetry are discussed in this section.
- Issues with structural detail (holes, joints, etc.) – the detailed geometric features of composite structure have a wide and different effect on the structural performance of composite components. Here these effects are reviewed to provide a better understanding of the unique behavior and stress issues for composite structures.
- Structural applications – a review of primary, secondary, and tertiary structural applications of composite materials.

Workshop Exercises:

- Determination of design requirements of a basic structural element, stress analysis for the design, and fabrication of the structural element.
- Destructive testing of the structural elements, and comparison to design calculations.
- Determination of both strength and deformation performance properties via structural analysis.
- Manufacture the structural elements in teams with small variation of the ply configuration.
- Each design team tests their structure to destruction and compares the test results against design analysis calculations.

Course Benefits

Attendees will gain knowledge and experience in the design of advanced composite structures.

Prerequisites

ES-2 Composite Laminate Analysis course or equivalent engineering experience with laminate analysis.

Teaching Method

Active classroom lecture and workshop exercises

CEU

3.6