Course Summary

This course is designed for degree-qualified aerospace and mechanical engineers or persons having practical experience in strength of materials calculations who are responsible for the design analysis and substantiation of repairs to secondary structure and lightly loaded primary structures. This course is an entry level course and provides classroom lecture on composite materials, processes, and manufacturing with a focus on repair techniques and repair analysis. The hands-on shop work involves manufacturing test panels, damaging the panels, performing repairs, and mechanically testing coupons from both the original and repaired panels. The mechanical characteristics of the original and repaired panels are validated with analysis using an Excel spreadsheet, which has become one of the most recognized analysis training tool in the industry. Many students come from aircraft operators involved with commercial, business, general aviation, and military aviation, but the course is also applicable for engineers involved in original design who need to consider the design for maintainability and supportability of composite structures. The ER-1 course is also a mandatory prerequisite for the ER-2 Advanced Aerospace Repair Analysis and Substantiation course.

Introduction

In the aerospace world, composite repairs are most often performed in accordance with approved repair instructions. When the damage size falls outside the scope of these instructions, then the repair has to be individually analyzed and engineered for the specific structure. Just as important, the materials and processes for the repair design have to be thoroughly substantiated to correspond with analysis methods and material data.

ER-1 was developed with no firm prerequisite to provide commercial and military aircraft “repair” engineers with a fundamental understanding of composite materials & processes (40%), composite analysis (40%), and hands-on (20%). This course teaches laminate stiffness analysis, laminate strength analysis, and analysis of the bonded joint. This understanding is reinforced throughout the week with the students fabricating and curing a test panel, mechanically testing coupons cut from the test panel, performing a composite repair utilizing standard aerospace repair procedures, and mechanically testing the repair. The ER-1 course information is optimal for repairs developed for surface panels, flight controls, wing-to-body fairings, landing gear doors, etc, and is designed to allow engineers to present analysis and “data acceptable to the administrator” for obtaining regulatory approval for composite repairs.

This course will provide attendees with the necessary skills in analyzing the stiffness and load carrying capability of both the original composite laminate and the proposed composite repair. The
analysis equations are presented in complete detail, the is performed with a computer spreadsheet to expedite the calculation. This course also reviews the basis of strength calculations in composite materials and discusses several common “failure criteria” methods widely used in the industry. Computer analysis is combined with hands-on coupon fabrication and repair testing for comparison.

Students will learn how to determine the type of repair required, analyze load transfer across the repair joints, determine the type of repair joints required (i.e.: taper-scarfed, stepped, bonded doublers, bolted doublers, etc.), and prepare the specific repair instructions.

The hands-on exercises manufacture a test panel from prepreg carbon fiber woven fabric and unidirectional material. The panels are vacuum bagged and cured as they would in a manufacturing environment. Both prepreg and wet layup composite repairs are performed by the class with different joint configurations, and cured with field-level repair techniques. Verification is performed on the last day of the course, when the repairs are cut into coupons and mechanically tested. The final verification is when the repairs are analyzed and compared with the coupon test results.

An important portion of the course is devoted to repair documentation and validation techniques, and the types of information needed to substantiate the repair to regulatory authorities. While the emphasis in this area will be on substantiation to meet FAA requirements, the same types of data and support documentation would be needed for military applications, spacecraft applications, or for repairs done for the requirements of other regulatory agencies.
Key Lecture Topics:

- Overview of composite and adhesive bonding technologies.
- Composite material categories: reinforcement fibers, weave style, resin systems, adhesives, core materials, etc.
- Original and repair material differences: Prepregs -v- wet layup resins, woven fabric -v- uni, cores materials -v- potting compounds, film adhesives -v- paste adhesive, material substitution options, etc.
- Material and Process Specification categories applicable to the original laminate.
- Repair processing: cure cycles, vacuum bagging, oven curing, autoclave curing, hot bonders and heat blankets, etc.
- Co-cured and pre-cured techniques for both wet layup and prepreg repairs.
- Use and application of the structural repair manual (SRM).
- Documentation and repair substantiation techniques.
- Effects of low impact, medium impact, and high impact damage.
- Material properties/allowable data.
- Strength and Stiffness analysis for both the original and repair laminate.
- Repair analysis techniques.
- Repair scarf joints and bonded doubler repairs.
- Original and repair laminate testing techniques.

Workshop Exercises:

- Hands-on computer analysis of both the original laminate and the repair using simple Excel spreadsheets.
- Analysis performed on unique repair scenarios as well as on typical structural repair manual (SRM) repairs to determine stiffness margins and strength margins of safety.
- Hand layup, vacuum bagging, and curing prepreg carbon fiber laminates
- Repair of a damaged composite panel using scarfing techniques, laying up the repair, vacuum bagging, and field-level curing the repair to help to give the engineers an appreciation for the subtleties involved in obtaining a high-quality repair.
- Test coupons are made from both the original laminate and repaired laminates and mechanically tested to determine the strength and stiffness of each.
- Manufacturing drawings are utilized with the final repair analysis exercise to experience a real world engineering application of the techniques covered in the course.
Course Benefits

Attendees will gain knowledge in repair analysis and substantiation to meet FAA requirements, as well as the same types of data and support documentation that would be needed for military applications, spacecraft applications, or for repairs done under the supervision of other regulatory agencies.

Prerequisites

No prerequisites are required. The course is intended for degreed aerospace, mechanical, and materials engineers. The M-1/R-1 or the ES-1 course may be taken prior to provide a more in-depth introduction to composite materials.

Teaching Method

Active classroom lecture and workshop exercises

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