Course ER-1
Aerospace Repair Analysis and Substantiation

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 structures. The 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 tools 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 a mandatory prerequisite for the ER-2 Advanced Aerospace Repair Analysis and Substantiation course, where ER-2 provides advanced composite repair analysis techniques that are applicable to primary structures.

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, the repair must be individually analyzed and substantiated to show that it is airworthy. Equally important, the materials and processes for the repair design must be thoroughly substantiated to correspond with analysis methods and material data.

ER-1 does not have a prerequisite. It is intended to provide commercial and military aircraft repair engineers 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 the original laminate coupons cut from the test panel, performing a composite repair utilizing standard aerospace repair procedures, and mechanically testing coupons cut from the repair. The ER-1 course information is optimal for repairs developed for surface panels, engine nacelles, wing-to-body fairings, landing gear doors, etc. and is intended to allow engineers to present analysis and data acceptable to the administrator for obtaining regulatory approval for composite repairs.

ER-1 provides attendees with the necessary skills to analyze the stiffness and load carrying capability of both the original composite laminate and the proposed composite repair configuration. The analysis presents laminate plate theory in full detail and is performed with a computer spreadsheet to expedite the calculations. Following the stiffness analysis, the course presents strength calculations based on common industry failure criteria methods to validate that the repair has restored the load carrying capability of the original laminate. 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-scarf, up-side-down wedding cake, right-side-up wedding cake, cocured external doublers, and precured bonded 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 repair & bonded 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 civilian aerospace 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.

Topics

Key Lecture Topics:

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

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 hands-on experience and skills, but is not necessary.

Teaching Method

Active classroom lecture and workshop exercises

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