Course E-9/M-9

Cure Management & Process Control for Composites: In and Out of Autoclave

Course Summary

This course is designed as an overview of the fundamentals of composite processing from a Material State Management (MSM™) perspective and how this can be used to reduce costs while improving quality and performance.

Data from two new instruments will be demonstrated including sensors within the laminate without the need for a thermocouple lead penetrating the vacuum bag and near measurement of the viscoelastic state of the prepreg for acceptance and shelf-life determination. The change in viscoelastic state as it is cured will also be demonstrated and a new approach to shelf-life management will be discussed.

This course has been designed to provide a fundamental understanding of the properties critical to procurement, storage, and cure of composites with the goal of teaching how and why procurement specifications, storage requirements and cure cycles were developed in the past and to demonstrate new tools that can lower cost while improving quality of the product.

Introduction

Over five days, this course will proceed from legacy processing based on control of the temperature history of the part to the point of production controls based on the state of the material. It is intended to instruct the student in both the science and the methods for composite processing. For those wishing to attend for three days and only interested in greater knowledge of material state within current design specifications; these topics will be concentrated in the period Monday thru Wednesday. For those whose interests are in methods to expand the design envelope, the period Wednesday thru Friday will demonstrate emerging material state cure methods not available in the past but deemed sound for implementation into new industry specifications.

Emerging technologies are focused in two areas. The first (Monday-Wednesday) is to provide better understand how the current process-based methods such as temperature, pressure, and vacuum that exist in current specifications ensure the material state limits of the product are not exceeded. The second (Wednesday-Friday) is demonstrate how process optimization can be achieved within legacy specifications, using this data to develop newer specifications that more accurately control degassing, consolidation and cure based on the changes in material state.

The goal of this course is to educate and demonstrate that better methods than those being used, a.) are possible, and b.) can be implemented at all stages of composite processing with simple changes in the approach, controls and instrumentation that are commercial off the shelf.

The course will review the state of the art and demonstrate the tools required for implementation. Discussion periods will be held that focus on specific interest raised by the students and hands-on training will be provided using the tools required for implementation.

There has been, for many years, discussions regarding model-based curing using processing science. The goal is to help move this technology from discussion to implementation by demonstrating the tools not available at the time many of the existing process procedures were developed.

The students in this course will be introduced to new methods to determine the material state and how these can be used to improve performance, reduce scrap, lengthen out-time, and optimize processing.

The first three days of class will focus on ‘hands on’ training creating cure “profiles” for computer-based management of time, temperature, pressure, and vacuum. A short introduction to Material State Management (MSM TM) will also be provided. Days three through five will illustrate the uses of advanced systems to monitor cure state using cure profiles developed earlier. Day three will include both legacy and emerging technology. The final half day will be used to review and for discussion.

Outcome, Days 1-3: Upon completion, the students will have prepared a cure profile and simulated both the process equipment and the state of cure during the process. They will be able to differentiate the cure profile of the processing equipment from the cure profile observed by the part. They will witness a part layup with an internal temperature sensor that is measure by a magnetic field over the bag rather than using a thermocouple lead. They will also witness linking to a remote viscoelastic cure measurement sensor

Outcome, Days 3-5: For those not attending days 1-2 a brief recap of the profile purpose and preparation will be given. Upon completion, students should be able to evaluate cure state data and prepare meaningful test plans to determine the effectiveness of a given cure cycle to achieve a desired viscoelastic state. Student will be familiar with ASTM D7750-12, *Standard Test Method for Cure Behavior of Thermosetting Resins by Dynamic Mechanical Procedures using an Encapsulated Specimen Rheometer* and the viscoelastic interpretation of both the final cure state described in CMH17 and partial cure status based on viscoelastic properties.

Discussion Period, Day 5 Discussions will focus on how to use the technology pending specification change and to identify critical steps to specification development based on the demonstrated technology.

Topics

Key Lecture Topics:

- Emerging technologies within the legacy framework
- Material State Management (MSM™) Overview
- Legacy cure cycles; history and limitations.
- Computer advancements & process control software.
- Process management using viscoelastic models.
- Advanced microwire sensors.
- Industry definitions and terminology for emerging systems.
- Thermoset “cure” definition.
- Introduction to ASTM D7750-12, Standard Test Method for Cure Behavior of Thermosetting Resins by Dynamic Mechanical Procedures using an Encapsulated Specimen Rheometer
- CMH17 and cure (glass transition temperature (Tg) measurement methods)
- Heat transfer & temperature distribution
- Viscoelasticity and pressure gradients

Workshop Exercises:

- Prepare computer-based cure profiles setting target values limits and triggers
- Conduct cure process and viscoelastic simulations
- Software training to view and interpret cure control actions
- Software training to compare actual viscoelastic cure from database
- Observe prepare a composite laminate with advanced sensors in place.
- Observe cure with real-time viscoelastic feedback from an encapsulated sample rheometer.
- Observe and discuss the viscoelastic state of prepreg laminate during cure.
- Produce and review QA reports and compare to existing cures.
- Prepare a hypothetical specification based on material state.

Course Benefits

Upon course completion the student should be familiar with the methods and applications sufficient to assess applicability to their own needs, support disposition of discrepant parts, and to engage in further development of materials and processing within their own organizations.

Prerequisites

Familiarity with composite manufacturing, design, or certification is required. The M-1/R-1 or ES-1 courses are suggested for those seeking prerequisite knowledge if necessary. At a minimum the student should be familiar with prepreg materials, layup, vacuum bagging, and curing of composites.

Teaching Method

Active classroom lecture and workshop exercises: 50% Theory and 50% Practical

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