Course E-9/M-9

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

Course Summary

The course is designed to introduce new technology to a wide range of composites personnel including material & process engineers, inspectors, technicians, QA personnel, and process equipment operators.

This course has been designed to demonstrate engineering, certification, and manufacturing methods for implementation of available technologies both within limits of existing process specifications and to enable greater use of these technologies in future designs.

Introduction

Over five days, this course will proceed from legacy processing platforms to more recent model based process control. 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 with interests limited to manufacturing 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 features not yet included in current industry specifications.

Emerging technologies are focused in two areas.The first is limited to better means to measure and manage the parameters – such as temperature, pressure, and vacuum – that exist in current specifications.The second is to better model and manage material state and thereby to implement better control and process optimization within legacy specifications and to develop newer specifications that more accurately control degassing, consolidation and cure as the material changes state.

To effectively implement Material State Management^{TM} (MSM^{TM}) based control will require collaboration between those writing specifications and those interpreting and implementing the specification. Each of these tasks become more easily achieved if the material state is known and critical properties can then be managed. Broadly speaking a large goal of this course is to educate and demonstrate that better methods than those currently being used by a large portion of the industry are possible, and can be implemented at all stages of composite processing to give great benefit to manufacturers.

The course will review the state of the art and demonstrate recent advances in technology. A discussion period will be held on the challenges of implementing material state management. Hands

on training will be provided for basic tools required for implementation.

There has been, for many years, discussions regarding model based curing, processing science and material state management. Although there has been significant progress in equipment and software to augment existing processes, the methods for measuring and managing the materials remains essentially unchanged. This course is designed to address these issues.

The students in this course will be introduced to new methods for viscoelastic property measurement, cure model development, internal laminate and bondline temperature sensing and how these influence cost and performance factors such as material out-time, heat rate, soak time, and other variables during 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™) 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 cure state of the material through cure. They will be able to differentiate the cure profile of the processing equipment and the cure profile observed by the part. They will witness a part layup with an internal temperature sensor, and location of sensors in the trim area and external to the autoclave.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 most effectively 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. 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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