



Composite Structure Engineering Safety Awareness Course

Module 3: Qualification Test Programs

Steve Ward, SWComposites

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Qualification Test Programs

AGENDA

- ◆ Tests
- ◆ Fabrication Trials
- ◆ Batches
- ◆ Liquid Molding
- ◆ Adhesives
- ◆ Test Plan

Qualification Program

- ◆ Specification tests
 - Batch acceptance tests
 - Material characterization
 - Fiber
 - ◆ Often qualified at same time as prepreg
 - Prepreg
- ◆ Structures tests
 - Key properties
- ◆ Fabrication trials

Qualification Program – Resin Tests

Resin Property	Test Method
Density	ASTM D792
Viscosity	TBD
Gel Time	ASTM D2471
IR	ASTM E1252
HPLC (ingredient ratios)	TBD
Cure Kinetics	ASTM E2041, ASTM E2070
Rheology	ASTM E4473

Ref: DOT/FAA/AR-07/3

Qualification Program – Fiber Tests

Fiber Property	Test Condition	Test Method
Form		ASTM E1309
Twist		TBD
Size Content		ASTM D4018
Tensile Modulus	RTD	ASTM D4018
Tensile Strength	RTD	ASTM D4018
Density	RTD	ASTM D3800

Ref: DOT/FAA/AR-07/3

Qualification Program – Prepreg Tests

- ◆ Physical properties
- ◆ Chemical properties
- ◆ Mechanical tests (fiber, laminates)
- ◆ Moisture gain properties
- ◆ Storage life, working life
- ◆ Cure studies
 - Time / temperature / ramp rate / multiple cures
 - Thickness
 - Autoclave, vacuum
 - Co-cure with core

Qualification Program – Uncured Prepreg

Uncured Prepreg Property	Test Condition	Test Method
Fiber Content, areal weight FL1		SACMA SRM 23
Resin Content, % by weight FL1		ASTM D3529 SACMA SRM 23
Insoluble Content		ASTM D3529
Volatile Content, % by weight FL1		ASTM D3530
Flow, % by weight FL1		ASTM D3531 SACMA SRM 22
Gel Time, minutes		ASTM D3532
HPLC (ingredient ratios) FL1		SACMA SRM 20
IR (Ingredients Chemical Signature)	RTD	ASTM E1252
Chemical Reactivity and Degree of Advancement via DSC		ASTM E1356 ASTM D3418 SACMA SRM 25
Tack	RTD	TBD
Drape	RTD	TBD

FL1 - Batch acceptance tests

Ref: DOT/FAA/AR-07/3

Qualification Program – Physical Properties

Cured Laminate Physical Property	Test Condition	Test Method
Cured Ply Thickness FL1		
Fiber Volume, % by volume		ASTM D3171
Resin Content, % by volume		
Void Content, % by volume		ASTM D2734
Laminate Density	RTD	ASTM D792
Glass Transition Temperature, <u>T_g</u> FL2	<ul style="list-style-type: none"> • Dry • Wet (85% RH) 	SACMA SRM 18
Equilibrium Moisture Content	85% Relative Humidity	ASTM D5229
Moisture Absorption	85% Relative Humidity	ASTM D5229
Thermal Induced Microcracking	Cycles over expected range of usage temperatures; fast heat-up spikes, etc.	

FL1 - Batch acceptance test

FL2 - Equivalency baseline database test

Ref: DOT/FAA/AR-07/3

Qualification Program – Lamina Mechanical Tests

Layup FL3	Test Type and Direction	Property	No. of Batches x No. of Panels x No. of Tests/ Batch/Panels			
			Test Temperature/Moisture Condition			
			Lowest Temperature/ Ambient	70F/ Ambient	Highest Temperature/ Ambient	Highest Temperature/ Wet
[0]n	0 Tension ASTM D3039	Modulus		3 x 2 x 3 FL2	1 x 2 x 3	
[0]n FL3	0 Compression ASTM D6641	Modulus		3 x 2 x 3 FL2	1 x 2 x 3	1 x 2 x 3
[90]n FL3	90 Tension ASTM D3039	Ultimate Strength and Modulus		3 x 2 x 3	1 x 2 x 3	3 x 2 x 3
[90]n FL3	90 Compression SACMA SRM 1	Ultimate Strength and Modulus s		3 x 2 x 3	1 x 2 x 3	3 x 2 x 3
[0/90/0/90/0/90/ 0/90/0]	0/90 Tension ASTM D3039	Ultimate Strength and Modulus	3 x 2 x 3	3 x 2 x 3 FL1	3 x 2 x 3	3 x 2 x 3
[90/0]ns FL3	90/0 Compression ASTM D6641	Ultimate Strength and Modulus	3 x 2 x 3	3 x 2 x 3 FL2	3 x 2 x 3 FL1	3 x 2 x 3
[+45/-45]ns FL4	In-plane Shear ASTM D3518	Ultimate Strength and Modulus	3 x 2 x 3	3 x 2 x 3 FL2	3 x 2 x 3	3 x 2 x 3
[0]n FL5	Short Beam Shear ASTM D2344	Ultimate Strength		3 x 2 x 3 FL1		

Ref: DOT/FAA/AR-07/3

Qualification Program – Laminate Tests

Layup FL3	Test Type and Direction	Property	No. of Batches x No. of Panels x No. of Tests/Batch/Panels			
			Test Temperature/Moisture Condition			
			Lowest Temperature/ Ambient	70F/ Ambient	Highest Temperature/ Ambient	Highest Temperature/ Wet
[45/0/-45/90]ns	Open Hole Tension FL3 ASTM D5766	Ultimate Strength	3 x 2 x 3	3 x 2 x 3 FL2	3 x 2 x 3 FL2	3 x 2 x 3
[45/0/-45/90]ns	Open Hole Compression FL3 ASTM D6484	Ultimate Strength		3 x 2 x 3 FL2	3 x 2 x 3 FL2	3 x 2 x 3

FL2 - Equivalency baseline database tests

FL3 - Open hole test configuration: 0.25 inch hole diameter, 1.5 inch width

FL3 – Layups should be selected such that laminate thickness is between 0.100 to 0.150 inch.

Ref: DOT/FAA/AR-07/3

Qualification Program – Batch Acceptance Tests

- ◆ Must have robust test specimens, methods
- ◆ Verify that supplier and purchaser get same values
- ◆ Do not use “wet” tests
- ◆ Focus on critical properties to “monitor” material
 - Purpose is to detect a change
 - Not to determine the full effect of the change
 - Link to key design properties

Qualification Program – Batch Acceptance Tests

- ◆ Recommended in DOT/FAA/AR-07/3 for CFRP tape prepreg
 - Fiber tensile strength and modulus, gm/m
 - Fiber, resin, volatile contents
 - Flow, HPLC
 - Cured thickness
 - RT [0/90] tensile strength and modulus
 - Hot [90/0] compressive strength and modulus
 - RT shear (short beam, CILS)

Qualification Program – Structures tests

- ◆ Laminates
 - Hard, quasi, soft
 - Unnotched, open hole strength
- ◆ Integrate Qualification and Allowables test programs

Qualification Program - Environments

- ◆ Typical for aircraft materials:
 - Cold/ambient
 - Room temp / ambient
 - Hot / ambient
 - Hot / wet
 - ◆ Often several 'hot' temperatures to cover design range

Qualification Program – Fabrication Trials

- ◆ Tack, drape, contour layup
- ◆ Slitting process – AFP, CTLM material
- ◆ Debulk process
- ◆ Sandwich panel core crush, ramps
- ◆ Machining, water jet cutting
- ◆ Drilling, countersinking
- ◆ Painting; paint/finish durability
- ◆ Peel ply compatibility
- ◆ Co-cured, secondary bond adhesive compatibility
- ◆ NDI process, standards

Qualification Test Programs

AGENDA

- ◆ Tests
- ◆ Fabrication Trials
- ◆ **Batches**
- ◆ Liquid Molding
- ◆ Adhesives
- ◆ Test Plan

Qualification Program – Batches

- ◆ Test program to evaluate batch effects, variation
 - Physical, chemical, mechanical properties
 - Fabrication parameters
- ◆ Evaluate
 - Fiber batches
 - Resin batches
 - Prepreg batches
 - ◆ Roll to roll
 - ◆ Within roll – length, width

Qualification Batches – How Many?

- ◆ Why test multiple batches
 - Capture / characterize material variations
 - Detect sensitivity of part fabrication process to material variations
 - Avoid “surprises” in:
 - ◆ Allowables, structures, certification testing
 - ◆ Part fabrication
 - For metals, MMPDS requires 100 data points from 10 heats and lots for A and B-basis values
 - ◆ And composites generally have higher variability, so ???

Qualification Batches – How Many?

- ◆ Traditional 3 batch qualification for composites and adhesives
 - Driven by cost perceptions, not technical rationale
 - Historical basis from secondary structures
- ◆ NOT adequate for primary structure
 - Batches are grouped closely together in time
 - Often are not 3 unique batches
 - ◆ Same fiber precursor, resin raw ingredients
 - ◆ Same prepreg line setup
 - ◆ Many cases only have 2 fiber lots, 2 resin lots
- ◆ Pre-Qual / Qual should include 6 – 10 prepreg batches

Qualification Batches

- ◆ Pan precursor lots
- ◆ Fiber lots
- ◆ Resin mixes, w/ separate raw ingredient lots
- ◆ Prepreg batches
 - Change setup between runs
- ◆ Fabric
 - Separate weaving setups
 - Separate fiber lots for warp and fill yarns

Qualification Batches – Multiple Items

- ◆ Multiple fiber lines (same company)
 - 3 lots, one from each line ← NO
 - 3 lots minimum from 1 line
 - 1 lot minimum from each additional line
- ◆ Multiple fiber sources (different companies)
 - 3 lots, one from each source ← NO
 - 3 lots minimum from each source

Qualification Batches – Multiple Items

- ◆ Multiple tape grades, fabric weaves
 - Treat as separate materials
 - 3 batches minimum per grade or weave
- ◆ Multiple prepreg lines (same company)
 - 3 lots, one from each line ← NO
 - 3 lots minimum from 1 line
 - 1 lot minimum from each additional line
- ◆ Multiple prepreg sources (licensed)
 - Treat as completely separate materials

Qualification Test Programs

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Qualification – Liquid Molding

- ◆ RTM, VATRM, RFI, etc
- ◆ Unique problems relative to prepreg
- ◆ Material specifications and qualification only involves separate fiber/fabric and resin
- ◆ Part fabricator must
 - Have internal “material specification” for combined materials
 - Perform “qualification” using multiple batches of fiber and resin
 - Perform batch tests on cured laminates
 - ◆ Batch panels, witness panels, prolongs

Qualification – Adhesives

- ◆ Two parts, both should be included in specification
- ◆ “Basic” qualification using metal adherends
 - Lap shear, thick adherend shear, peel, flatwise
 - Durability tests (wedge, etc)
 - Characterize adhesive failure modes
 - Use for batch acceptance tests
- ◆ “Application” qualification
 - Representative part adherends and fab process
 - ◆ Surface preparation, cure, etc
 - ◆ Adherend material, ply orientation, core type
 - Stress, fracture toughness type tests

Qualification – Adhesives

- ◆ Qualify each grade (thickness) separately
- ◆ Cure study
 - Similar to prepreg qualification
 - Include high temperatures, long cures, multiple cures
 - ◆ Adhesives often more sensitive
 - Include repair conditions if applicable
- ◆ Environments

Qualification Test Programs

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- ◆ **Test Plan**

Qualification Program

- ◆ If only material qualification, do not need FAA conformity, witnessing
- ◆ If data is to be used for allowables,
 - FAA approved test plan and conformity
 - But are supposed to have a specification and qualified material before allowables testing
 - For joint qualification/allowables test program, need a released draft specification
 - Supplier must provide batch certification test data
 - Purchaser to review data before qual/allowables tests
- ◆ Need to define required material production witnessing (fiber, resin, prepreg), PCD audits, etc
- ◆ Need to define specimen layup, cure, machining, test witnessing

Qualification Test Plan

- ◆ Responsible organizations
- ◆ Witnessing, auditing plan
- ◆ Specific materials, suppliers, sites, PCDs
- ◆ Batches defined
- ◆ Test matrix
- ◆ Test specimens
- ◆ Layup sequences
- ◆ Layup procedures (including storage life, out-times before layup)
- ◆ Cure procedures (including resin injection, etc)
- ◆ Specimen machining
- ◆ Test methods/procedures (see CMH-17 for guidance)
- ◆ Specimen preconditioning (moisture, fluids, etc)

Qualification Test Plan

- ◆ Documentation / data reporting
 - Batch records
 - Batch certification data
 - Layup records / cure records
 - Test specimen conformity (AER)
 - Test witnessing (AER / delegate)
 - Data tables
 - Load-displacement, load-strain curves

Summary

- ◆ Before qualification
 - Understand and document all requirements
 - Have a stable, production ready material
- ◆ Qualification program
 - Material from production scale equipment
 - Adequate number of batches
 - Well defined test specimens and procedures
 - Integrate with allowables program
 - Include fabrication assessments
 - Complete before production part design