Production Control Effect on Composite Material Quality and Stability

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Production Control Effect on Composite Material Quality and Stability

- Motivation and Key Issues
  - Quality control tests on prepreg or lamina (i.e. receiving inspection or acceptance tests) may not always detect material defects
  - Material suppliers (e.g. fiber, resin, prepregger, etc.) and part fabricators need to have an understanding of each others' roles and responsibilities
- Objectives
  - Develop essential information on the nature of the controls required at various producer levels to assure the continuation of stable and reliable composite raw material for aerospace usage
    - Develop and clarify requirements
  - Provide guidance to NASA's National Center for Advance Materials Performance (NCAMP)
- Approach
  - LET'S GET EVERYONE TOGETHER!
  - Try things out in NCAMP
  - Document what works and what doesn't

FAA Sponsored Project Information

- Principal Investigators & Researchers
  - John Tomblin & Yeow Ng
- FAA Technical Monitor
  - Curtis Davies
- Other FAA Personnel Involved
  - Larry Ilcewicz, Peter Shyprykevich, Lester Cheng, Evangelina Kostopoulos, and David Ostrodka
- Industry Participation
  - 38 Aircraft Companies & Tier-1 Suppliers
  - 15 Material Suppliers
- Other Partners
  - CMH-17 (formerly MIL-17), SAE P-17, SAE PRI Nadcap, SAE PRI QPL, ASTM D30
  - University of British Columbia and Center for Nondestructive Evaluation at Iowa State University

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PREPREG KEY CHARACTERISTICS

Task:
Identify prepreg key characteristics that have significant influence on structural properties.

Issues:

Prepreg manufacturing parameters which are closely monitored and controlled may not always be those which significantly affect composite structural properties.

All properties of a material batch cannot be tested to assure that prepreg is consistent and can yield finished composite parts with predictable properties.

An efficient quality program must focus on process control and the most important end-product properties.

Initial draft being developed by John Adelmann, Sikorsky (retired)

PREPREG KEY CHARACTERISTICS

Approach:

- List prepreg process variables, constituent and prepreg properties, and cured laminate properties by category.
- Propose probable cause-and-effect relationships between lower level and higher level process variables and material characteristics.
- Reduce the list of lower level properties and variables to those which most significantly affect structural performance.

PREPREG KEY CHARACTERISTICS

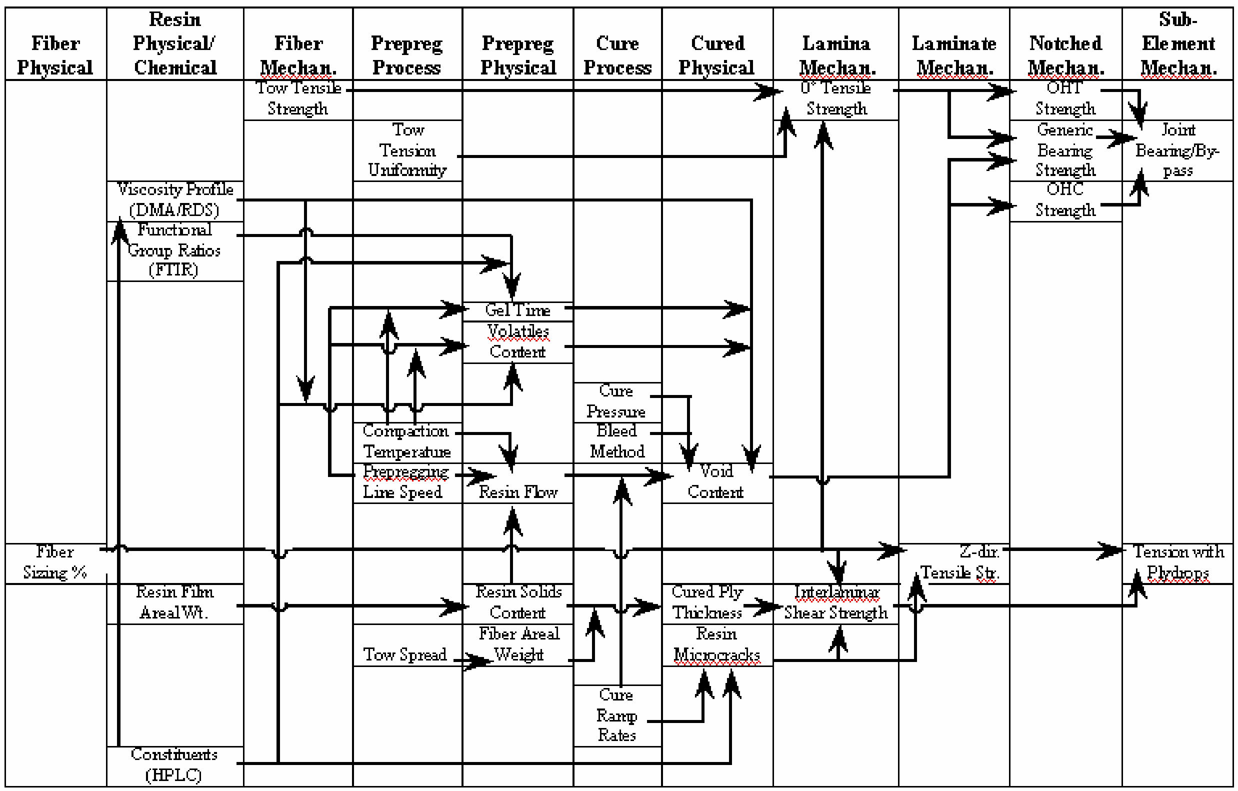
Status:

- 66 properties, process parameters, and characteristics were identified in 11 categories:
  - Fiber physical characteristics
  - Resin physical/chemical properties
  - Fiber mechanical properties
  - Prepreg manufacturing parameters
  - Prepreg physical properties
  - Prepreg processing (cure) parameters
  - Cured laminate physical properties
  - Lamina mechanical properties
  - Unnotched laminate mechanical properties
  - Notched laminate mechanical properties
  - Sub-element mechanical properties

Status (continued):

- Cause-and-effect relationships were proposed:

Table 2
Characteristics Affecting Notched Laminate and Sub-element Structural Properties



PREPREG KEY CHARACTERISTICS

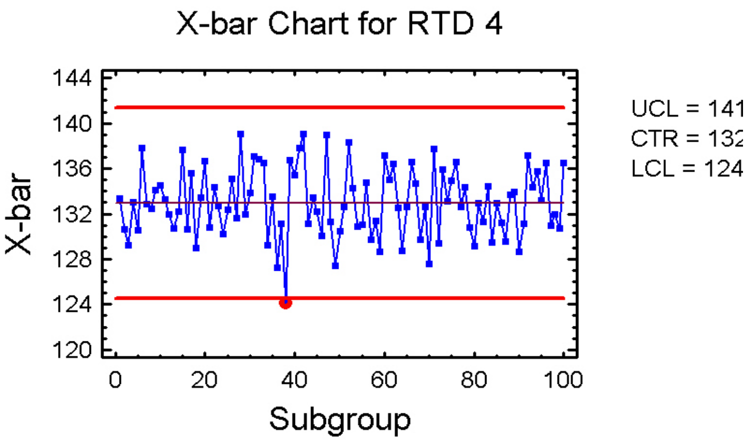
Status (continued):

- Characteristics that most significantly affect structural performance appear to be those which influence:
  - Laminate (part) void content
  - Laminate (part) microcracking
  - Fiber direction tensile/compressive properties
  - Fiber alignment
  - Cured ply thickness
  - State of cure (glass transition temperature)
- 26 such characteristics were identified, 12 of which are under the direct control of the material suppliers (the other 14 are controlled by the part fabricator).

Material Property Monitoring

- Partnering with material suppliers and aircraft companies to monitor material property variations over time

Control Charts

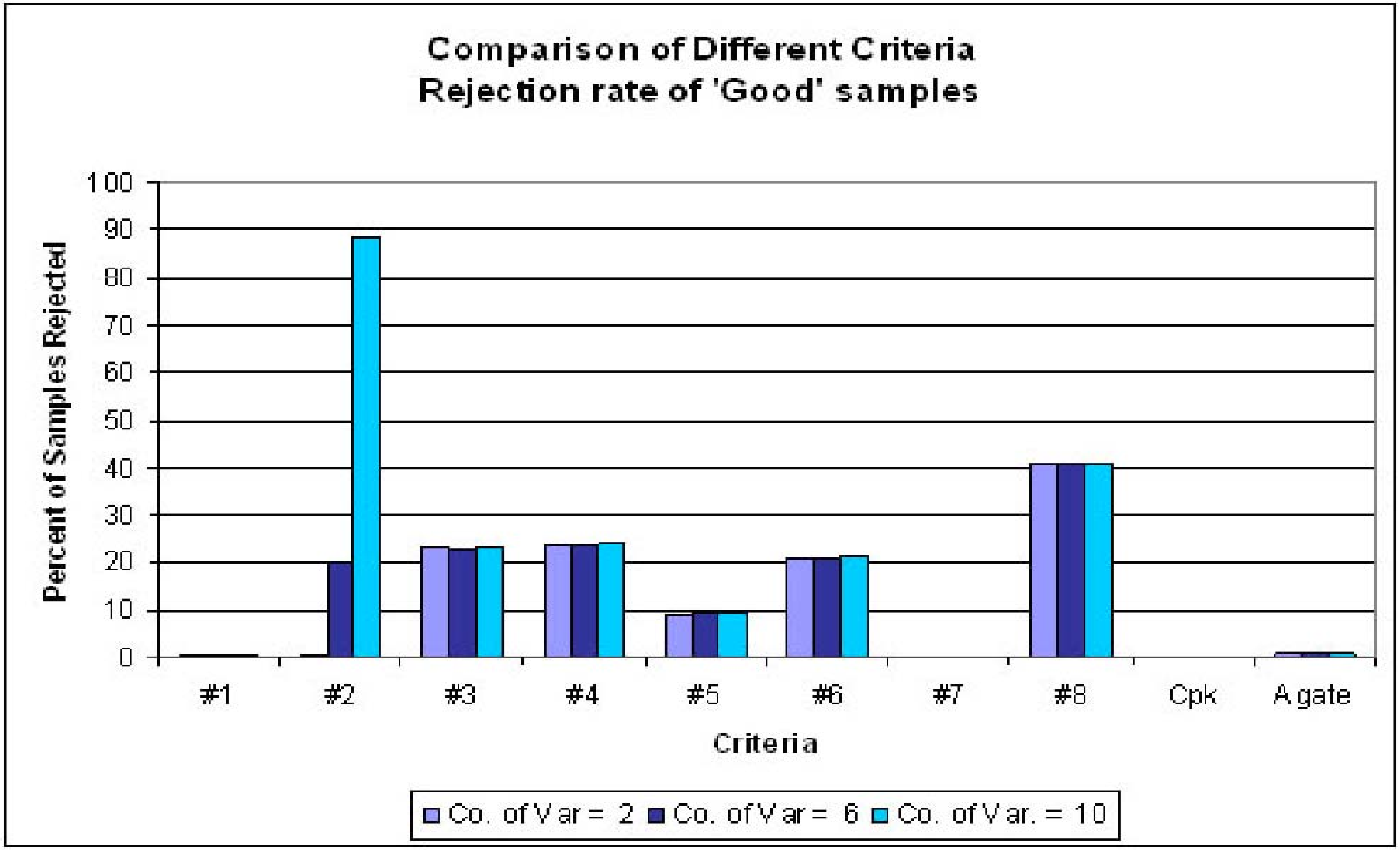


- Everything varies at least a little bit. So how do you tell when you are just experiencing normal variation versus when something out of the ordinary is occurring? Control charts were designed to make that distinction
- As long as all points lie inside the upper and lower control limits, the variation is presumed to be normal or a common cause variation. When a data point falls outside those limits, it's time to look for a reason for the variation
- Two-sided monitoring for all properties including strength

Acceptance Criteria Comparison

- Completed a comparison of various acceptance criteria
  - Earlier methods investigated by Mark Vangel & Scott Reeve
    - Many used A and B-basis values as acceptance thresholds. The numbers used in the comparison were obtained from the basis value simulation program (previous slide)
  - Newer methods include AGATE acceptance criteria and CPK-based criteria
- Includes effects due to retests
- Presentation file available for download at http://www.niar.wichita.edu/coe/ncamp_media.asp

Figure 1: Percentage of good samples rejected



Aerospace grade versus commercial grade

- Commercial grade materials sometimes have lower material variability and costs less
- Define minimum standards for aerospace grade fiber, resin, fabric/braid, and prepreg
  - Material qualification, material specification, process control document, material change management & control, quality control, etc.
  - Level and types of material & process controls needed

Prepreg Aging Effects

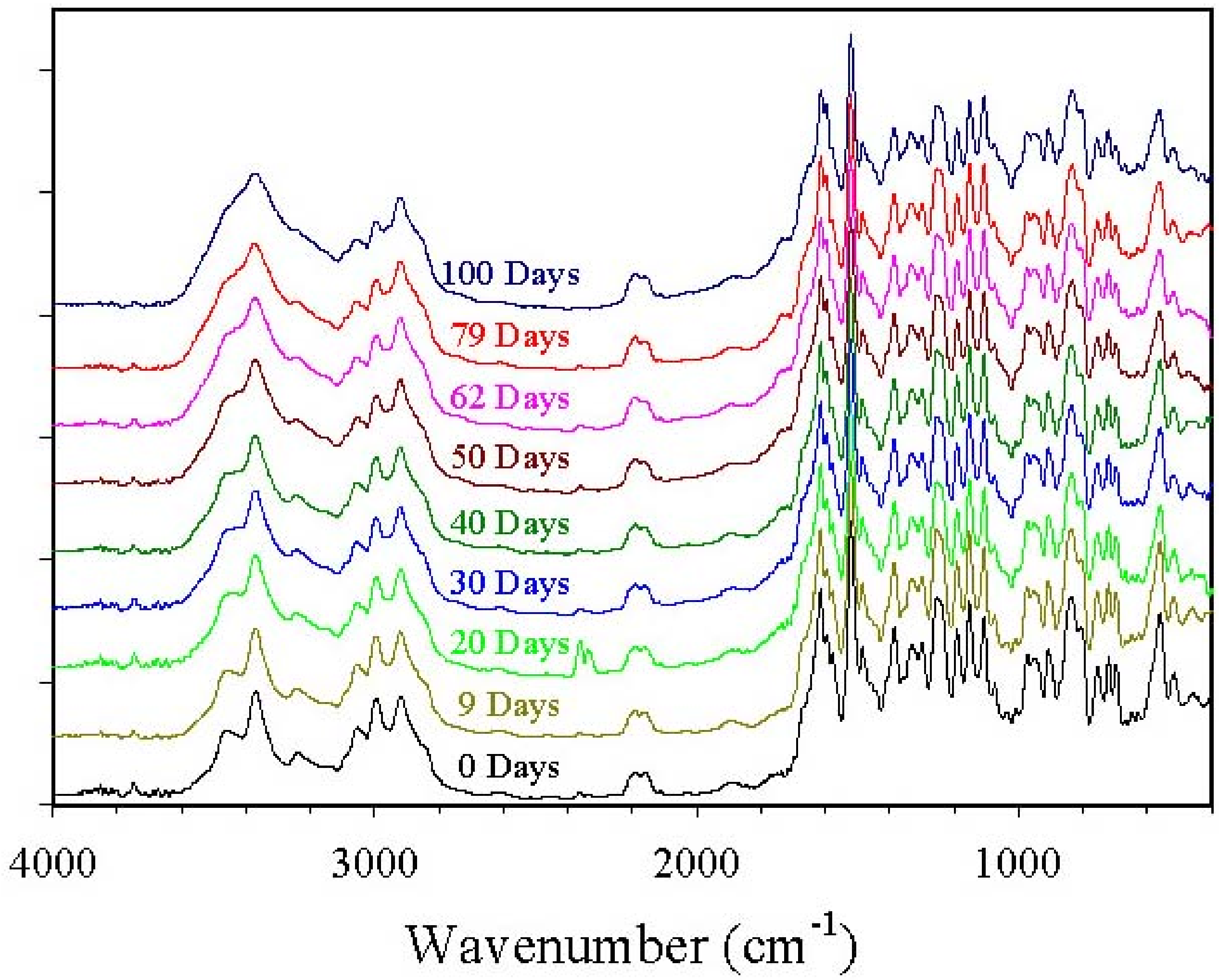
- Collaboration with University of British Columbia, Toray Composites America, Avpro, and Center for Nondestructive Evaluation at Iowa State University
- Prepreg aged at Wichita State University and sent to collaborating partners in dry ice
- Research is still ongoing

Aged prepregs were sent to participating members in dry ice

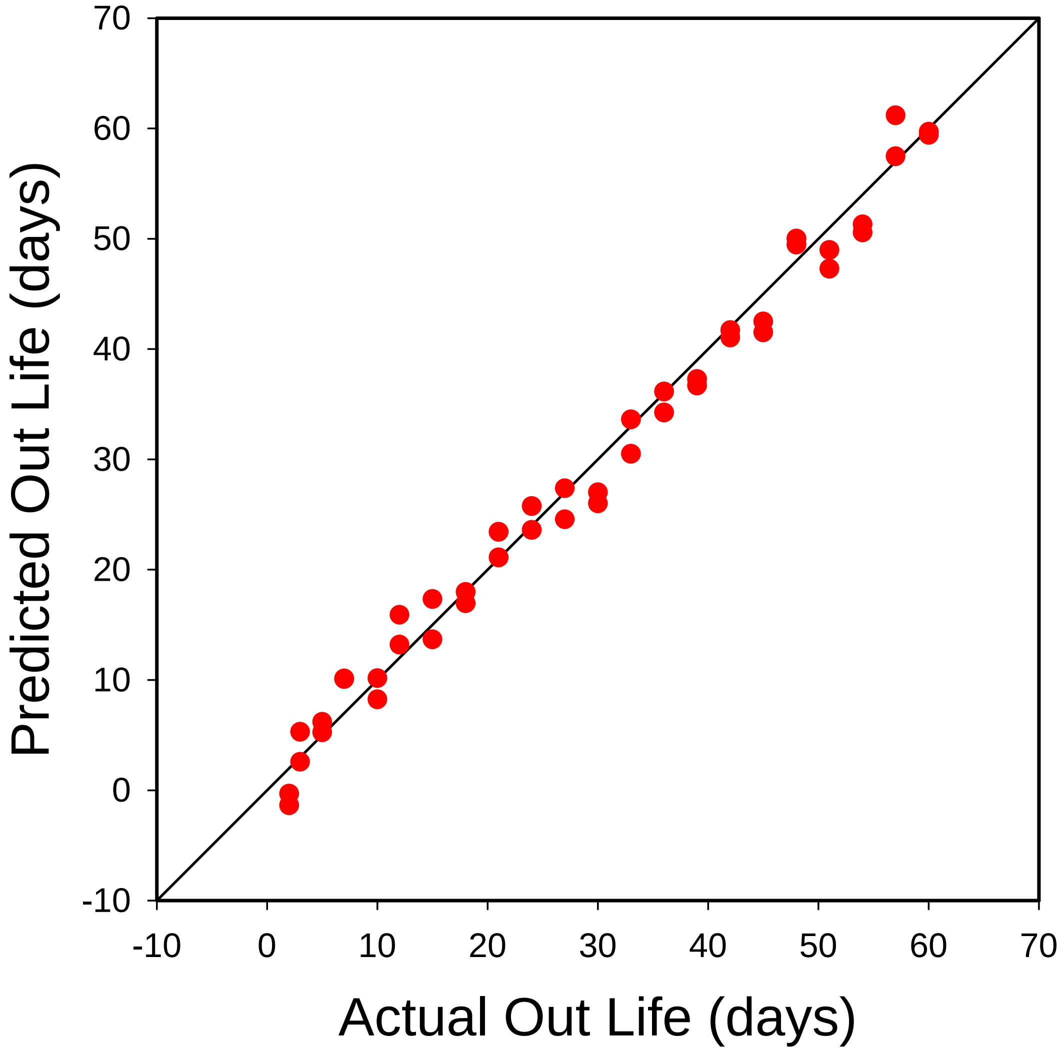
Freezer Storage Time <10°F	Out Time at 70° ± 10°F							
	< 2 day	3 days	5 days	7 days	10 days	12 days	15 days	18 days (Note 1)
See Note 2	✓ ??/1	✓ ??/3	✓ ??/5	✓ ??/7	✓ ??/10	✓ ??/12	✓ ??/15	✓ ??/21

Property	Method/Condition	# Replicates	Members
Short Beam Strength	ASTM D 2344-00, RTD	8	NCAMP
Gel Time	ASTM D3532-99	3	Toray
Tack	NCAMP Test Plan	3	NCAMP
Drape	NCAMP Test Plan	3	NCAMP
HPLC	SACMA SRM 20R-94	2	Toray
DSC	SACMA SRM 25R-94	2	Toray
Photomicrography and void content (and C-scan)	MIL-HDBK-17-1F, sec 6.6.7.3	As needed	NCAMP
Photoacoustic Infrared Spectrum	CNDE Procedures	As needed	CNDE
Tests related to process modeling	As needed	As needed	UBC
APA 2000 or similar tests	As needed	As needed	Avpro

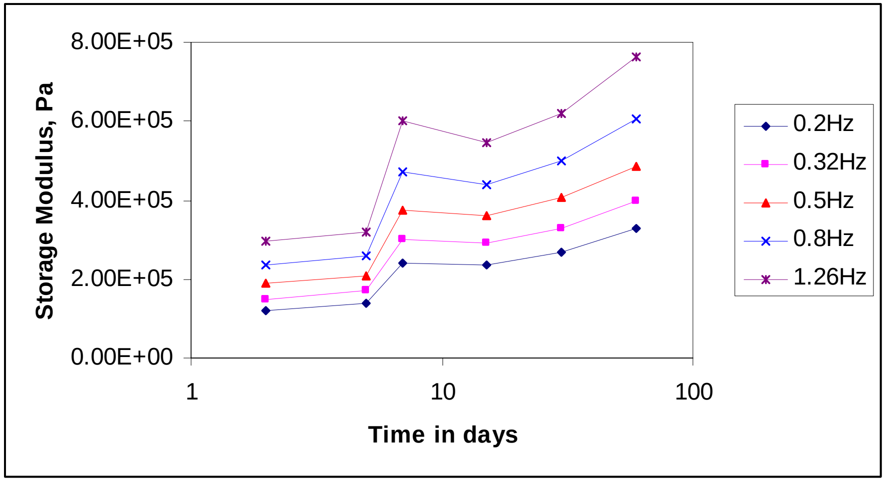
John McClelland and Roger Jones
Center for Nondestructive Evaluation, Iowa State University

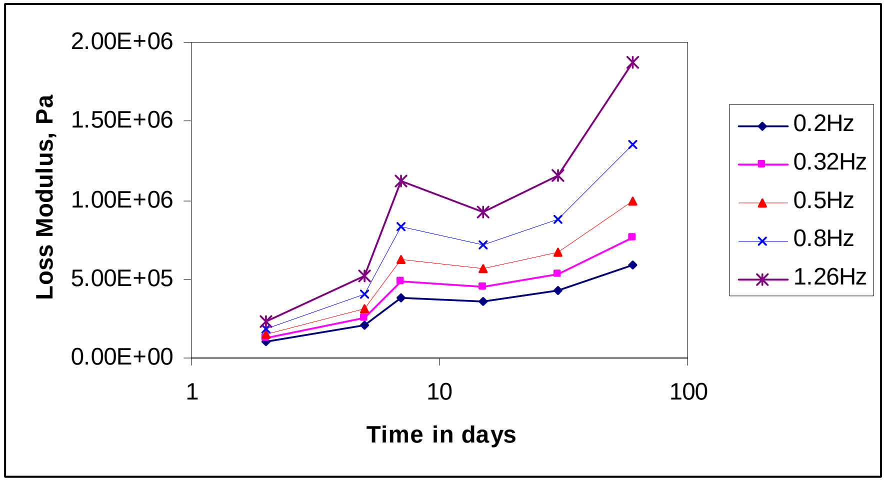


Prediction of Out Life from Photoacoustic Infrared Spectra



Rheometric Dynamic Analyzer (RDA-III), Frequency Sweep





- Experiment performed by Avpro (Tom Rose)
- Preliminary observation: While these graphs do show an upward trend in viscoelastic state, the test data is insufficient to recommend this test method as a means of managing material out time

Investigations of Existing Aerospace Practices

- E-glass chemical compositions per ASTM D578
- Specification for 7781 and other glass styles
- Reliance on supplier quality control system
- Use of higher than measured coefficient of variation
- Use of specifications & process control documents
- Documentation of practices and lesson's learned in NCAMP

E-glass Chemical Composition per ASTM D578

- There are two grades of E-glass per ASTM D578
  - aerospace & printed circuit board grade has 5-10% boric oxide
  - general use grade has 0-10% boric oxide
- Boric oxide makes glass resistant to water and many chemicals (Pyrex & Kimax are borosilicate glass)
- Existing practices do not require E-glass chemical composition certification
- Quality control testing usually does not involve hot/wet testing, so the absence of boric oxide cannot be detected

Specification for 7781 and other glass styles

- AMS-C-9084 is the most common callout for 7781 style, but it does not cover 7781 style
- According to many users, 7781 is assumed to be equal to 181-75DE (a rather cryptic callout)
- ASTM D4029 covers 7781 style but weavers will not certify to it
- Currently determining the feasibility of using AMS 3824

Reliance on supplier quality control system

- Aircraft companies are relying more and more on supplier quality control while reducing purchaser quality control
- First task – Temperature Monitoring Devices
  - investigate the technology of temperature monitoring devices used during shipment of prepreg
  - procedures of using such devices
  - specifications that cover the use and requirements of these devices

Use of higher than measured coefficient of variation (CV)

- Industry sometimes use higher than measured CV to calculate allowables and specification limits
- What are the implications?
  - Material property control
  - Building block approach
- At what point should the actual CV be used?

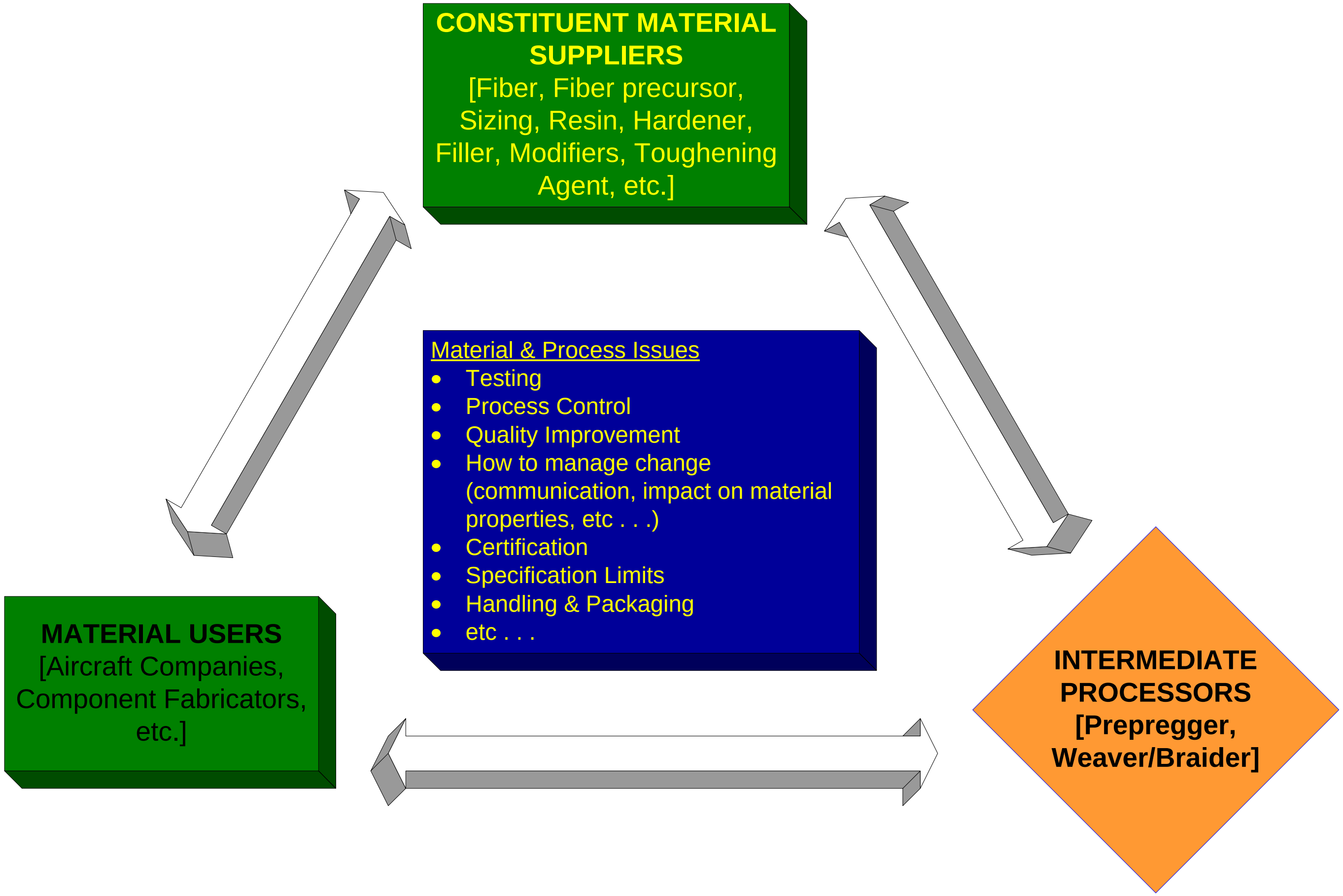
Use of specifications & process control documents (PCD)

- Industry surveys indicated the need to use the following:
  - Carbon fiber material specification & PCD
  - Carbon fiber fabric specification
  - Prepreg material specification & PCD
- Qualifications are through lamina/laminate qualification programs only
- These documents are being developed by NCAMP

Documentation of practices and lesson's learned in NCAMP

- NCAMP offers a practical venue to try things out
- Document NCAMP experiences in the FAA report
  - What works and what doesn't
  - What's required
- The roles and functions of industry organizations
  - CMH-17, SAE PRI, SAE Nadcap, SAE P-17, ASTM D30, NCAMP, etc.
- The roles and functions of material users and various levels of material suppliers

Understanding Each Others' Roles, Requirements, and Responsibilities



Reduce duplicate efforts while maintaining sufficient checks and balances

How all of these fit together?

Industry Organizations
(CMH-17, SAE, Nadcap, PRI, NCAMP, ASTM D30)

Material Specifications

Audit

Process Specifications

Quality Control

Material Change Management

Accreditations

Regulatory Agencies

Material Qualifications

Processing Tolerance Limits

Process Control Documents

Material Compatibility

Qualified Products Listing

A Look Forward

- Benefits to Aviation
  - Provides solution and guidance to the industry
  - Documents lessons learned
  - Ensures a supply of composite materials with stable properties
- Future needs
  - Continue to work with the industry on material & process issues