The Effect of Surface Treatment on the Degradation of Composite Adhesives

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The Effect of Surface Treatment on Composite Adhesives

- Motivation and Key Issues
  - Bonded joints contribute to the weight savings of composite materials
  - The degradation of composite adhesives has received less attention than their adherends
- Objective
  - Characterize environmental durability of current bonding practices
  - Develop test methods to accelerate adhesive degradation
- Approach
  - Study adherend conditioning and surface effects
  - Evaluate fracture toughness, shear strength and crack growth

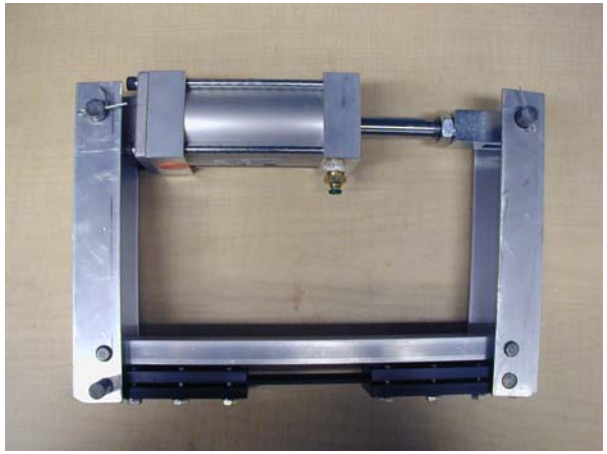
FAA Sponsored Project Information

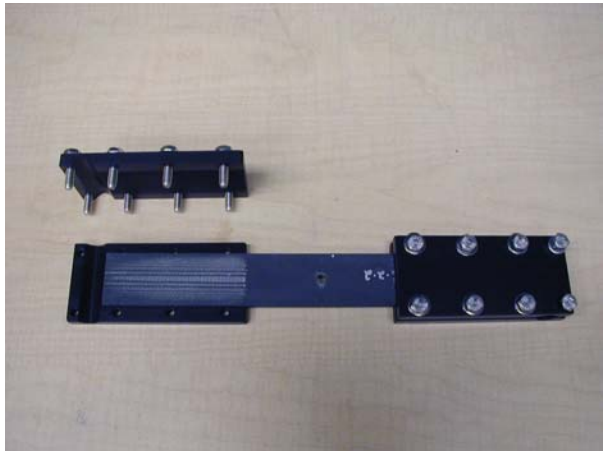
- Principal Investigators & Researchers
  - Lloyd Smith & Prashanti Pothakamuri
- FAA Technical Monitor
  - Peter Shyprykevich
- Other FAA Personnel Involved
  - Curtis Davies, Larry Ilcewicz
- Industry Participation
  - Peter VanVoast (Boeing)
  - Clay George, Chris Praggastis (3M)

Environmental Exposure Facility

- Aggressive environments
  - Redundant safety measures
- Temperature
- Stress
- Time

Environmental Exposure Facility





Durability Study

- Measure fracture toughness and shear strength as a function of surface preparation and exposure duration
- 140F, H_2O, 60% UTS (~3 ksi)
- Saturate coupons before applying load

Coupon/peel ply	0 hrs	2k hrs	4k hrs
DCB/60001	5	5	5
DCB/Nylon	5	5	5
DCB/SRB	5	5	5
WLS/60001	5	5	5
WLS/Nylon	5	5	5
WLS/SRB	5	5	5

Accelerated Degradation Study

- Compare crack growth rates
- 140F, H_2O, wedge

Coupon/peel ply	Unidirectional	Compliant
WC/60001	5	5
WC/Nylon	5	5
WC/SRB	5	5

Effect of Moisture on Co-Bonding

- Pre-cured adherends soaked to 1% moisture content prior to bonding uncured skin
- 140F, H_2O, 1k hrs

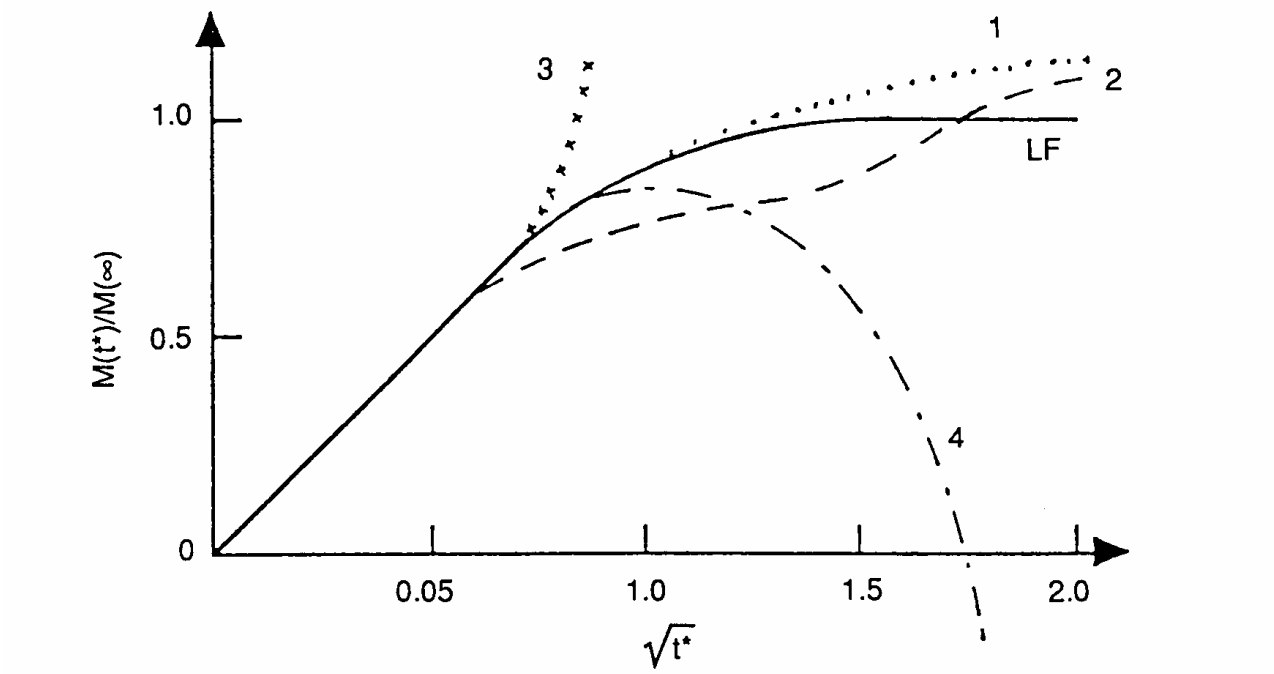
		Creep Stress (ksi)			
Coupon	Process	0	2	3	4
WLS	Dry	3	3	3	3
WLS	Wet	3	0	3	3

Results/Status

- Wet adherends
  - Exposure complete 6/8/05
  - 2 wet coupons at 4 ksi failed during exposure
- Durability study
  - Coupons in saturation
  - Exposure to start 6/15/05, complete 11/28/05
- Accelerated degradation
  - Coupons in fabrication
  - Exposure to start 6/15/05

Modeling Degradation

- Develop approach to describe degradation from simple weight measurements



Mathematical Approach

Fick's Law

$$\frac{\partial c}{\partial t} = D \cdot \frac{\partial^2 c}{\partial z^2}$$

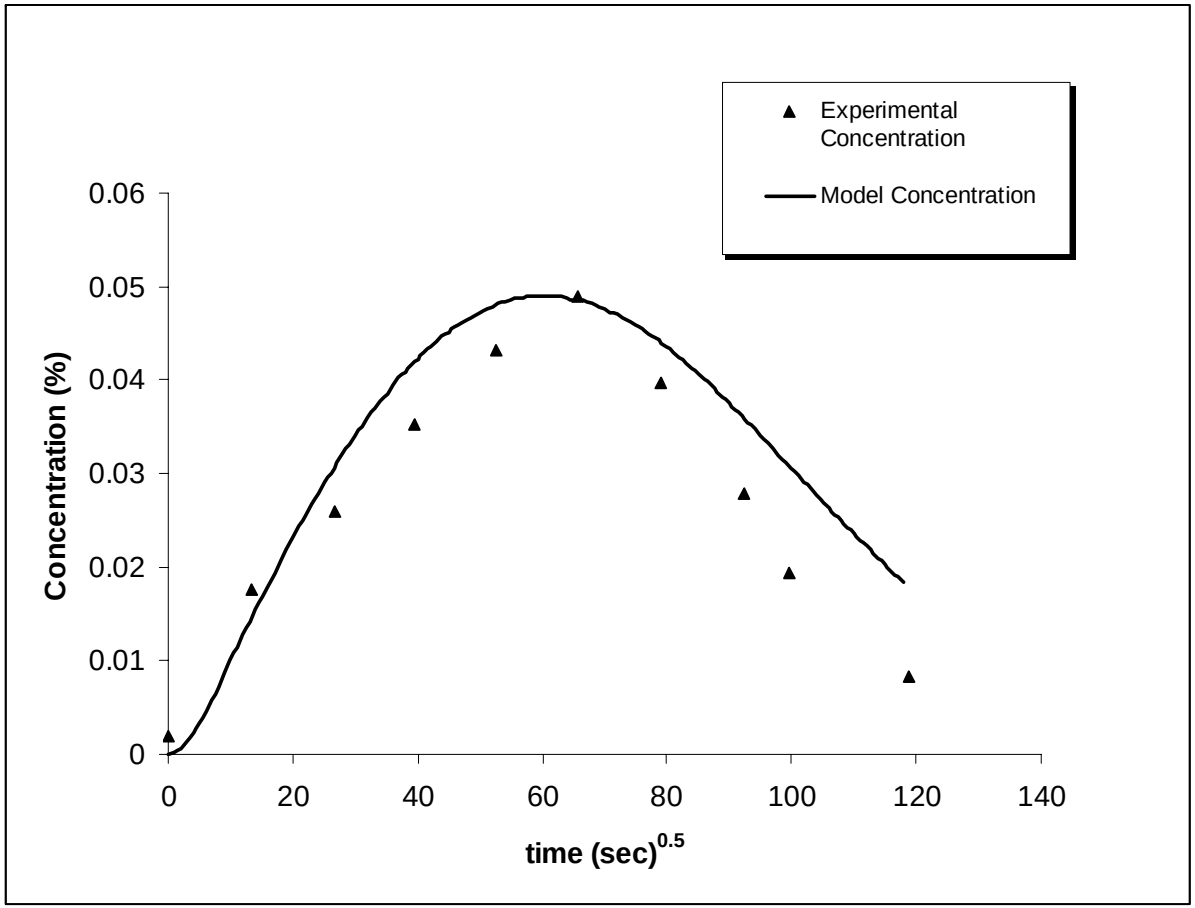
Rate of Reaction

$$-\frac{d[C]}{dt} = k[C]$$

$$C(t,z) = \int_0^t \exp\left(-k(t-\tau)\right) \cdot \left[\frac{dC_o}{d\tau}\right] \cdot d\tau$$

$$\overline{C}(t) = \frac{1}{h}\int_0^h C(t,z) \cdot dz$$

Comparing model to measurements



A Look Forward

- Benefit to Aviation
  - Quantify the effect of surface preparation on degradation
  - Adapt wedge crack coupon for composite adherends & adhesives
- Future needs
  - Characterize degradation of emerging adhesives & processes (e-beam, co-cure, co-bond, etc.)
  - Examine other mechanisms of accelerating degradation (oscillating load)