The Effect of Surface Treatment on The Degradation of Composite Adhesives

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The Effect of Surface Treatment on The Degradation of Composite Adhesives

- Motivation and Key Issues
  - Commercial composite aircraft use surface preparations such as peel ply and abrasive techniques for bonding primary structure
  - Critical parameters which dictate the durability of the adhesive bond are
    - Adherend surface quality
    - Pre-bond and post bond moisture effects
    - Service loads
- Objective
  - Quantify how surface preparation techniques affect the integrity of adhesive bonds
  - Investigate test methods that may accelerate environmental degradation

The Effect of Surface Treatment on The Degradation of Composite Adhesives

- Approach
  - ➢ To Study surface preparation effects
    - Compare relative degradation in 140°F water
      - ❖Crack growth
      - ❖Residual strength
      - ❖Failure mode
  - ➢ Accelerate degradation methods
    - Specimens stressed while immersed in water at 140°F during standardized tests
    - Creep and fatigue tests
  - ➢ Material
    - Boeing 8-276 form 3 laminates
  - ➢ Adhesive Type
    - 3M AF555

FAA Sponsored Project Information

- Principal Investigators & Researchers
  - Lloyd Smith
  - Prashanti Pothakamuri
- FAA Technical Monitor
  - Peter Shyprykevich
- Other FAA Personnel Involved
  - Curt Davies
- Industry Participation
  - Boeing: Peter VanVoast

Summary of past work

- Part I : Moisture sensitivity
  - Residual shear strength decreased with increasing creep load.
  - 3M AF555 showed little sensitivity to adherend moisture content
  - Predominantly adherend failure
- Part II : Peel ply
- a) lap shear test
  - Polyester
    - Highest strength
    - Adherend and cohesive failure
  - SRB and nylon
    - Lower strength
    - Adhesion failure (also observed by Flinn et al.)
  - Moisture increased substrate failure
    - Motivated further study involving CILS and shear modulus coupons

Summary of past work

- b) DCB test
  - Polyester : Higher G_{IC}
    : Adherend failure
  - SRB and nylon : Lower G_{IC}
    : Adhesion failure
- c) Wedge crack
  - SRB : High initial crack growth
    : Comparable crack growth under exposure
    : Does not clearly describe observed lower durability

- Part III : Abrasive techniques
  - Grit blast : Lower G_{IC} (GB caused damage to the substrate)
    : Adherend failure
  - Sanded, peel ply : Higher G_{IC}
    : Cohesive failure

Work done

- Task 1 : CILS and IPS tests
- Task 2 : Creep and fatigue tests on DCB specimens
- Task 3 : Wedge crack tests on different adherend thicknesses

Task 1: CILS and IPS tests

- Motivation – Adherend failure modes were dominated in the creep rupture tests and adherend moisture study in polyester bonds
- Aim – To find the effects of moisture on the compression interlaminar strengths and in-plane shear strengths of the composite BMS 8 -276
- Approach - CILS and IPS specimens were soaked to various moisture levels in water at 160 °F and tested

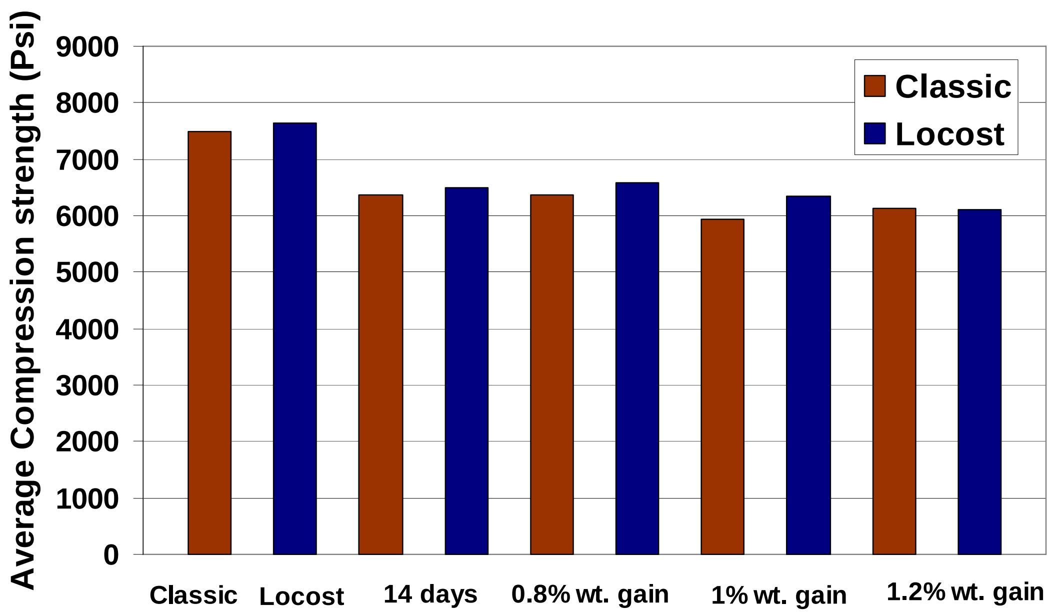
CILS and IPS tests -Test matrix

Exposure limit	*CILS Number of specimens*	*IPS Number of specimens*
6 days immersion	**5 - Classic** **5 – Low cost**	**5 - Classic** **5 – Low cost**
2 weeks immersion	**-**	**5 - Classic** **5 – Low cost**
0.8 % weight gain	**5 - Classic** **5 – Low cost**	**-**
1% weight gain	**5 - Classic** **5 – Low cost**	**5 - Classic** **5 – Low cost**
1.2% weight gain	**5 - Classic** **5 – Low cost**	**5 - Classic** **5 – Low cost**
Equilibrium weight gain	**5 - Classic** **5 – Low cost**	**5 - Classic** **5 – Low cost**

<u>Test temperatures</u>

- CILS at 180 °F
- IPS at RT

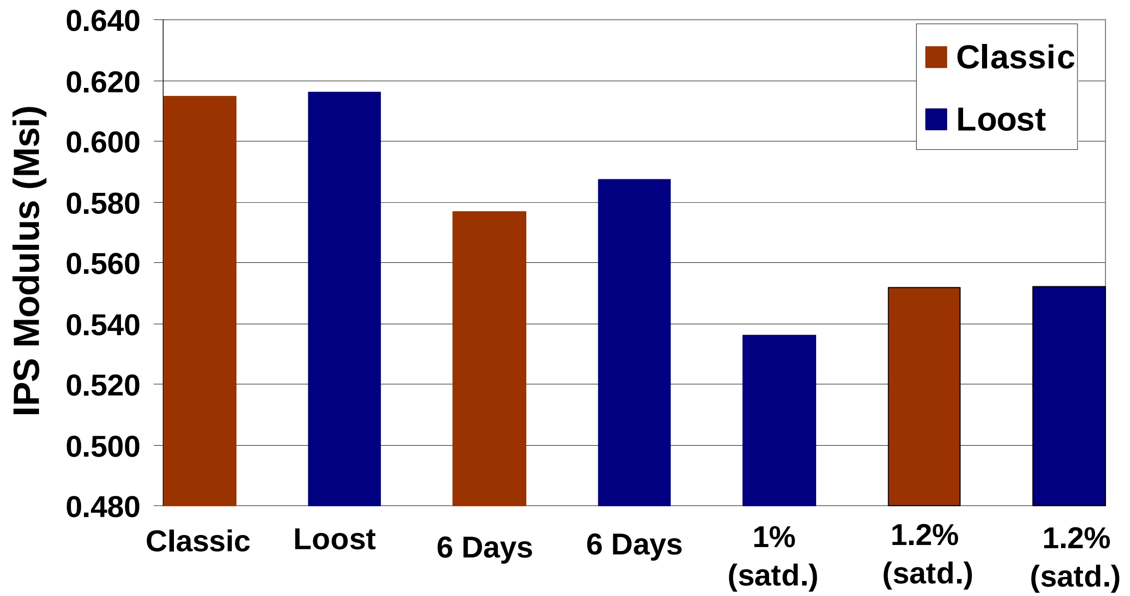
CILS and IPS tests - CILS results



<u>Moistur effects on CILS strengths</u>

• 6 days exposure	:	15% decrease	- Classic type
		20% decrease	- Low cost type
• 14 days - 1.2% wt. gain	:	5% decrease	- Classic type
		5-8% decrease	- Low cost type

CILS and IPS tests - IPS results



Moisture effects on IPS modulus

• 6 days exposure :	5% decrease	- Classic type
	6% decrease	- Low cost type
• 1 - 1.2% wt. gain :	5% decrease	- Classic type
	5-8% decrease	- Low cost type

Task 2: Creep and Fatigue tests

- Motivation: Necessity to determine better surface preparation by measuring crack growths of bonds under in-situ conditions

- Aim: Evaluate the effects of various abrasive surface preparations on the crack growth of the composite-adhesive bonds by using an accelerated method for degradation.

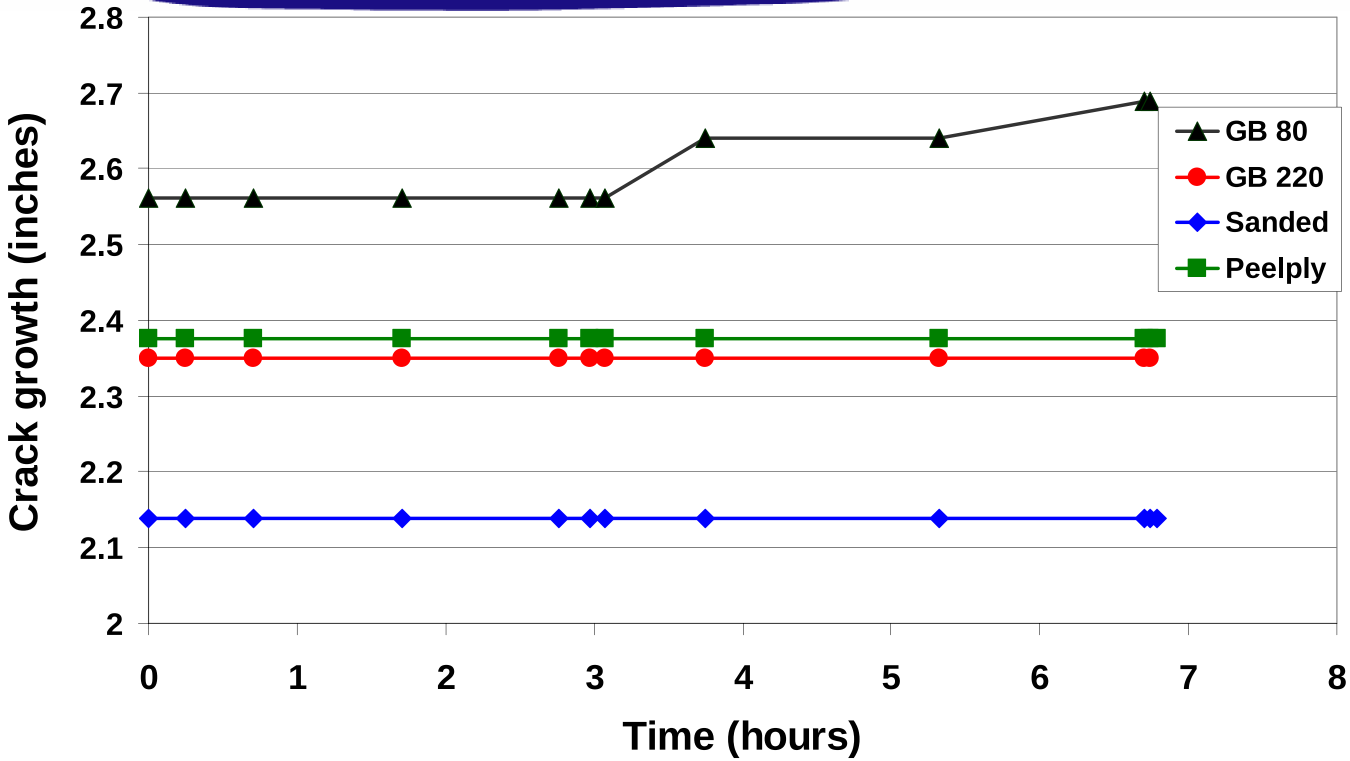
- Approach: Stress (creep and fatigue) was applied on DCB specimens while exposed to environments (140 °F, water). This was the technique used to accelerate degradation

Creep and fatigue tests -Test Matrix

Type of specimen	*140 ºF Water immersion*			*-65 ºF in air*	*No exposure, No load (Baseline)*	*Total coupons*
	Creep load	*Fatigue load *1*	*Fatigue load (9.5 lbs)*2*	*Fatigue load*		
Peel ply	**2**	**10**	**8**	**10**	**5**	**35**
Sanded	**2**	**10**	**9**	**10**	**5**	**36**
Grit blast 1	**2**	**10**	**8**	**10**	**5**	**35**
Grit blast 2	**2**	**10**	**9**	**10**	**5**	**36**

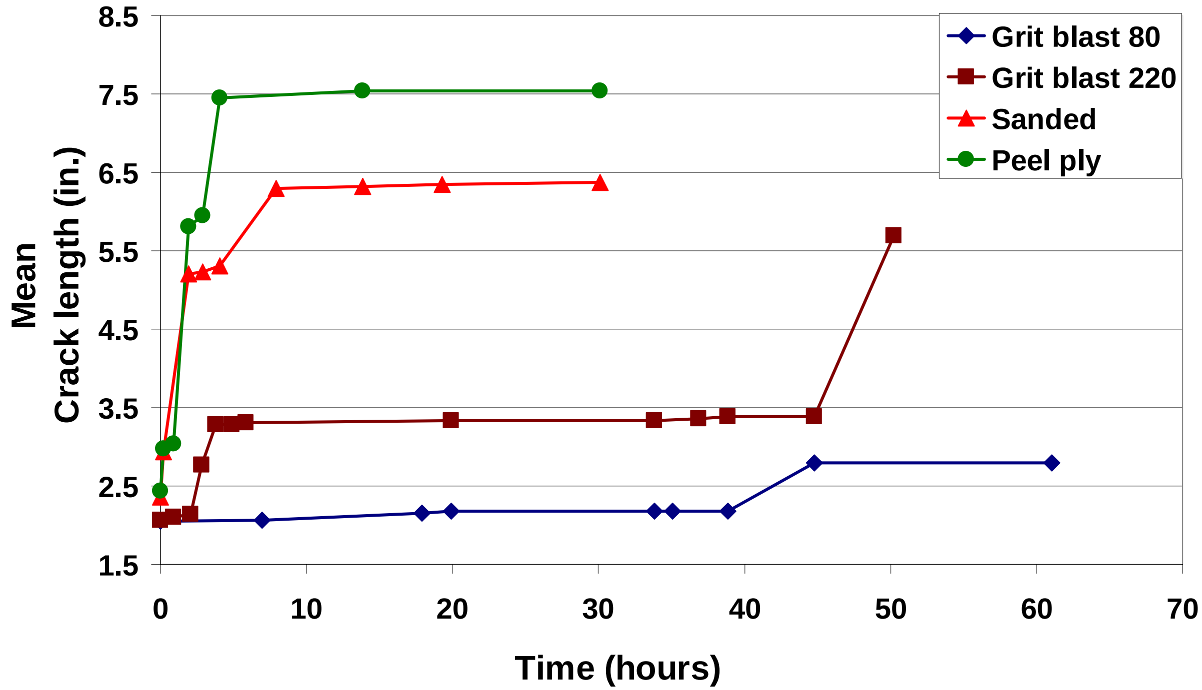
1. **Coupons dried in oven at 160 °F**
2. ***1Applied load = 90% G_{IC}**
3. ***2Applied 9.5 lbs on all specimens**
4. **Crack growth measured daily for 100 hours, weekly for up to 4000 hours**
5. **G_{IC} may be measured at the conclusion of the test.**
6. **For -65 ºF a load of 50% of the load applied at 140 ºF is applied.**

Creep and fatigue tests - Creep results



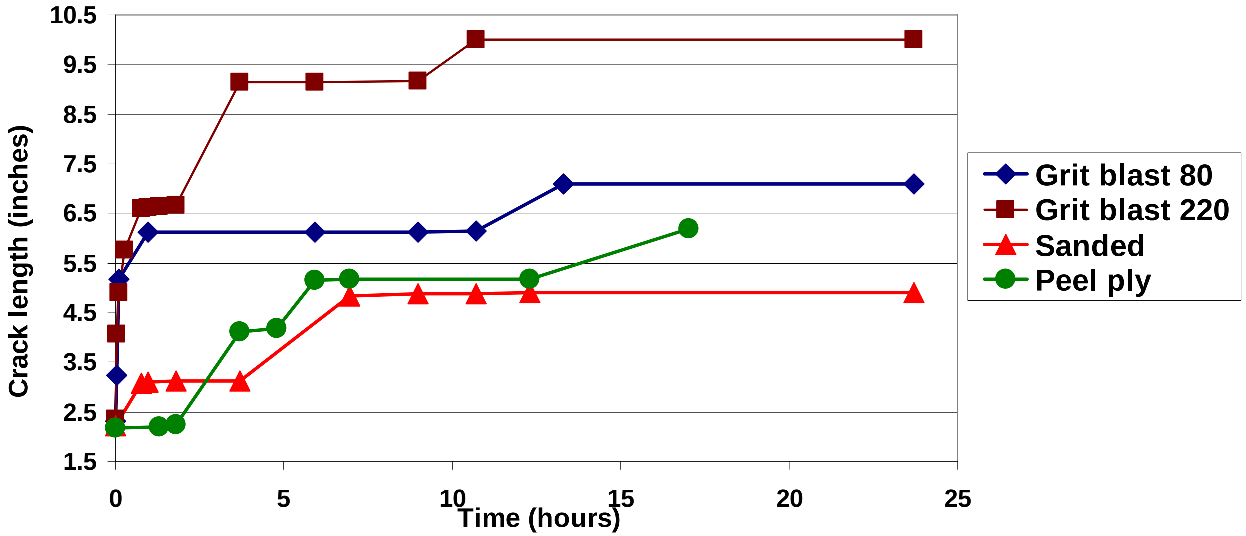
- Applied creep load of 90% G_{IC} on the respective specimen.
- Very little crack growth for GB 80 specimens
- No accelerated degradation (crack growth) under creep load

Creep and fatigue tests - Fatigue (90% G_{IC}) results



- Applied 90% of fracture load (lbs)
  - GB 80 – 6.2, GB 220 – 8.4, Peel ply – 9.8, Sanded – 10.3
- Could not correlate crack growth to bond quality due to differences in load values

Creep and fatigue tests - Fatigue (9.5 lbs) results

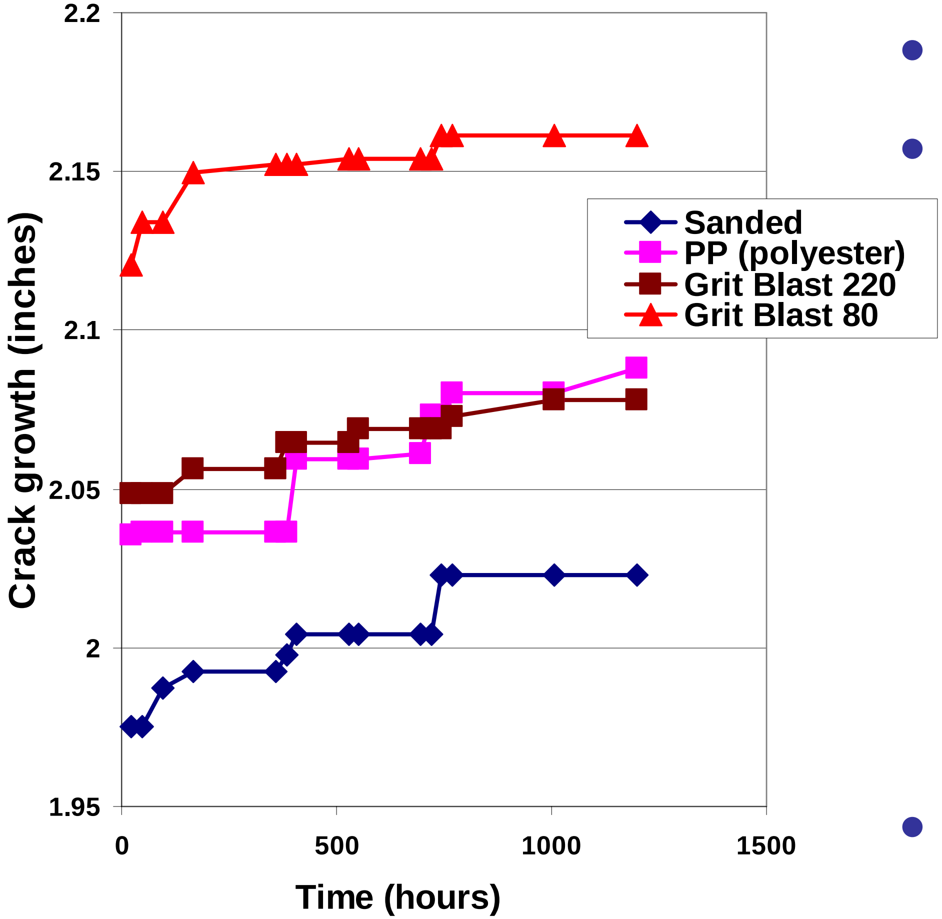


- Applied 9.5 lbs on all the DCB specimens
- Accelerated degradation to differentiate surface preparations
- After 550 hours (23 days) of exposure:
  - 100% of GB-220, 60% of GB-80, 40% of PP and 30 % of Sanded specimens failed
- Slopes of GB 80 and 220 are higher compared to PP and sanded which implies higher crack growth with time
- Sanded better bonds with slower crack growth

Creep and fatigue tests
Fatigue(9.5 lbs) Failure modes

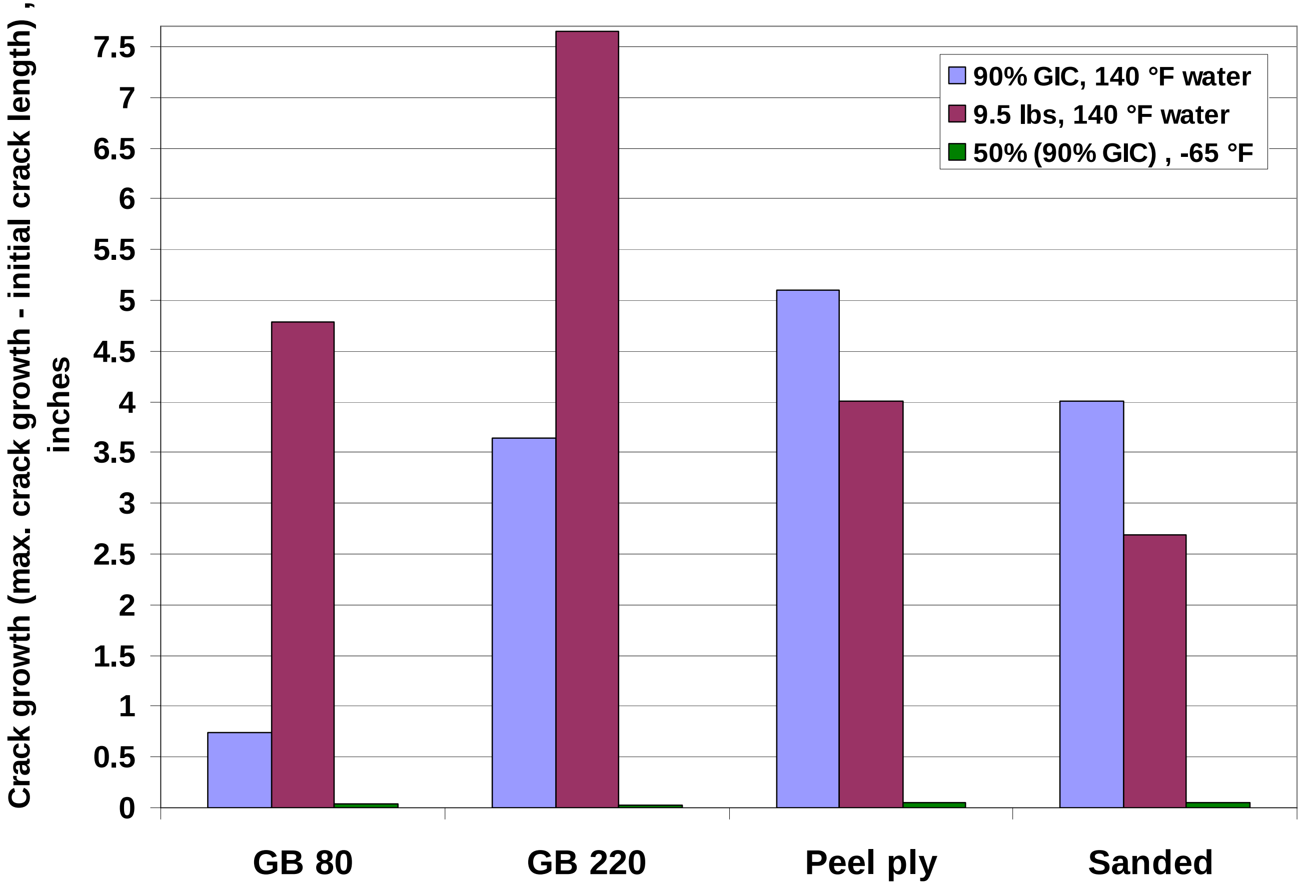
- Sanded – 80% cohesive
- Peel ply - 50% adherend, 50% cohesive
- GB 220 - 60% cohesive, 40% adherend
- GB 80 - 100% adherend

Creep and fatigue tests - Fatigue (-65 °F) results



- - 65 °F, Exposure temp.
- As G_{IC} of DCB bonds increase with temperature, 50% of the loads applied at 140 °F were applied
  - GB-80 - 3.1 lbs
  - GB-220 - 4.2 lbs
  - PP - 4.9 lbs
  - Sanded - 5.15 lbs.
- Crack growth did not correlate to bond quality

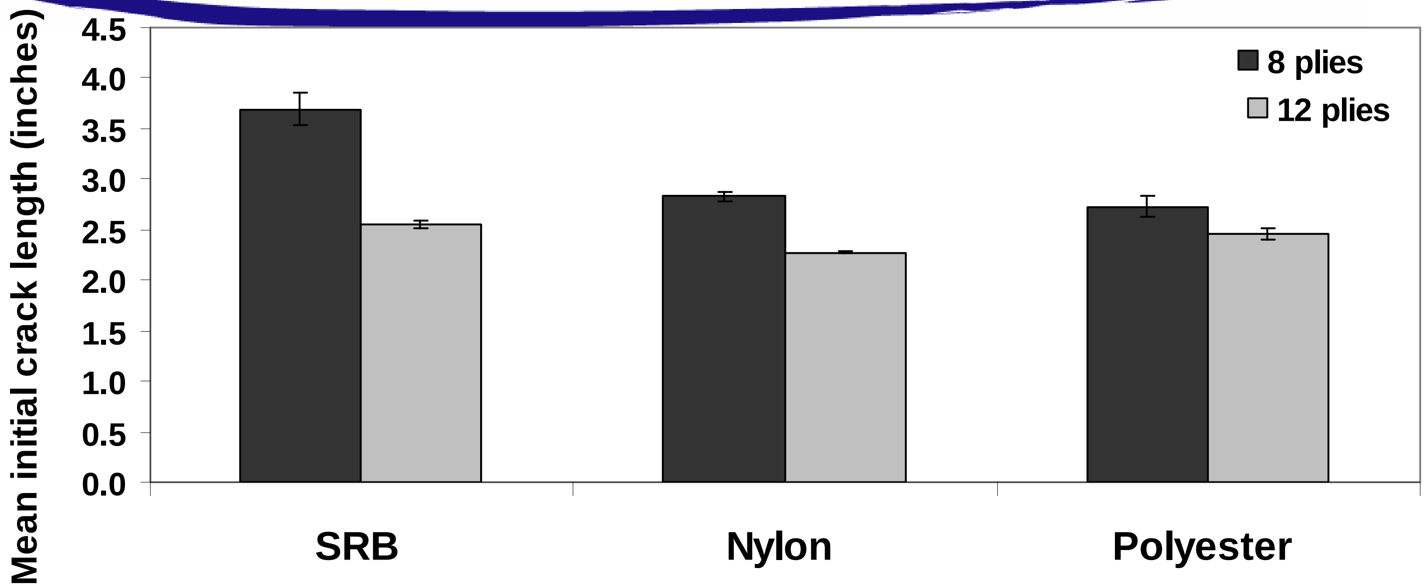
Fatigue results



Task 3: Wedge crack tests

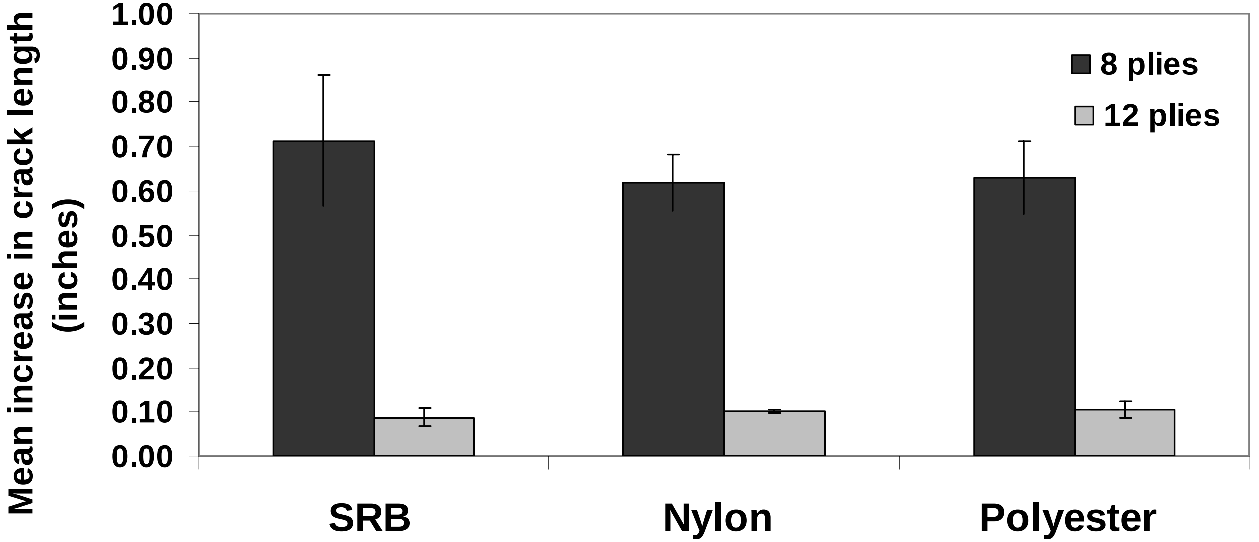
- Motivation: To implement aluminum wedge test technique which was successful in differentiating surface preparations for aluminum adherends
- Aim: To attempt a range of fracture toughness by varying the adherend thicknesses of WC specimens in order to determine better surface preparations of the bonds
- Approach: Wedge specimens of varied adherend thicknesses (8,12 plies) were made and wedge tests at 140 °F in water were done.

Wedge crack tests
Results



- In thin specimens, mean initial crack length for SRB is 23% and 26% higher compared to nylon and polyester respectively.
- Mean initial crack length is same for nylon and polyester in both cases
- Mean initial crack length for thicker (12 plies) is lower than thin specimens
- Mean initial crack length for thick specimens is almost the same in SRB, nylon and polyester peel ply specimens.

Wedge crack tests
Results



- SRB shows little (11-13)% mean crack growth compared to nylon and polyester in the thin specimens
- In thick specimens, no significant mean crack growth in all specimens. (does not differentiate surface preparations)
- In thin specimens, crack growth does not differentiate between nylon and polyester surface preparations clearly

Summary

- Task1 : CILS and IPS
  - Moisture has 15-20% decrease in the interlaminar shear strengths while less effects (5-8% decrease) in in-plane shear strengths on BMS 8-276 composite
  - Classic and low cost type BMS 8 276 composite had similar interlaminar shear and in-plane shear strength values at all moisture levels.
- Task 2: Creep and Fatigue tests
  - Creep tests
    - Did not observe accelerated degradation in the crack growth under creep load
  - Fatigue tests- Achieved accelerated degradation
  - under 90% G_{IC} loads, could not correlate crack growth to bond quality of the respective specimens
  - Under 9.5 lbs, could differentiate surface preparations which correlated to bond quality
  - Sanded resulted better bonds followed by polyester peel ply with the lowest crack growth and better failure modes
  - At -65 °F exposures, crack growth could not differentiate the bonds. It might be due the lower load values
  - Grit blasted specimens had higher crack growths and adherend failures (due to the harsher effects of grit blasting on the adherend, which made weaker bonds).

Summary

- Task 3: Wedge crack tests
  - In thick specimens mean initial crack length is low and further crack growths under exposure are significantly lower compared to thin
    - Thin adherends (8 plies)
      - SRB : Noticeable initial crack length and further crack growth under exposure
      - Crack growth does not differentiate nylon to polyester surface preparation clearly
    - Thick adherends (12 plies)
      - Does not differentiate bond quality with thick adherend for all surface preparations.
      - Unsuccessful in differentiating surface preparations of the bonds. It might be benevolent to use different wedge dimensions for thick adherend WC specimens

A Look Forward

- Benefit to Aviation
  - Better understanding of moisture, peel ply, abrasive technique effects on the bond integrity.
  - Greater confidence in adhesive bonds
  - Guide development of QA methods for surface prep.
- Future needs
  - Moisture effects on the composite substrate integrity
  - Application to other composite systems and adhesives
  - Durability of differing joint designs