



Possible ways to improve wettability and fiber-matrix adhesion of natural fiber (Jute) suitable for biocomposite applications

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Centre for Material and Fiber Innovation (CMFI)

The Centre was opened in 2005 to integrate research on to four major areas such as metals, textiles, composites and polymer, and materials for biomedical application at Deakin.

- Post Doctoral & Senior Fellows – 20-25
- Support Staff (inc technicians) – 11
- PhD students – 50





Composite Group at CMFI



Research focus:

- Out of Autoclave Processing
- Carbon Fibre based composites
- Advanced Melding
- Nano and Biocomposites



Brief Outlines

- Overall Scenario
- Research background
 - ✓ Why "Jute" ?
 - ✓ Traditional Jute based products
 - ✓ Present Market Situation
 - ✓ Diversified Application
 - ✓ Key Challenges and Solutions
 - ✓ What and why "Quickstep"?
- S1,S2,S3 Experimental, Results and Summary
- Findings
- Ongoing study





Overall Strategies

- **S.1** Biocomposite parts manufacturing through Australia Patented Quickstep™ process followed by HLU---changes in degree of cure, fracture surface and fracture-mechanical behavior of composites compared to HLU
- **S.2** parts manufacturing through combined atmospheric Helium plasma and Quickstep™ process---changes in fracture-mechanical behavior compared to HLU and Quickstep
- **S.3** parts manufacturing through Vacuum Assisted Resin Infusion---changes in fracture-mechanical behavior compared to HLU, Quickstep and P+Q



Research background

Why “Jute”?

Table 1. Comparative properties of Jute fibres (L25)

Properties/Contents	Jute	Hemp	Flax	E-glass
Cellulose/Hemicellulose/Lignin (%)	61/14/12	70/18/4	71/19/2	-----
Density	1.3	1.39	1.50	2.5
Specific strength	331	496	230	800
Specific stiffness	10	9.35	8.66	28
Cost, USD/Kg	0.30	2.10	200	3.25
%Elongation at Break, Eb	1.16	1.6	2.7	2.5

Advantages

- Renewable 4 times a year.
- Friendly in processing, takes less energy when production.
- It doesn't emit CO₂ during thermal recycling.

Source: Mohanty, A. K.; Misra, M.; Hinrichen., G. *Macromol. Mater. Eng.* 2000, 276/277, 1-24





Traditional Jute based products

Jute Yarn



Jute Rope



Jute Hessian



Jute CBC

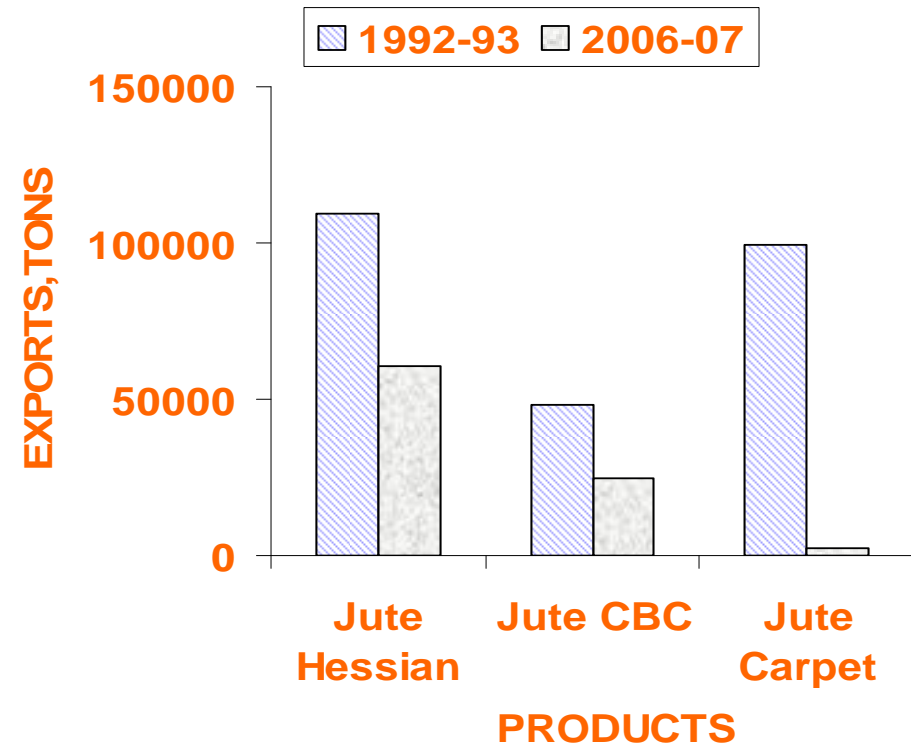
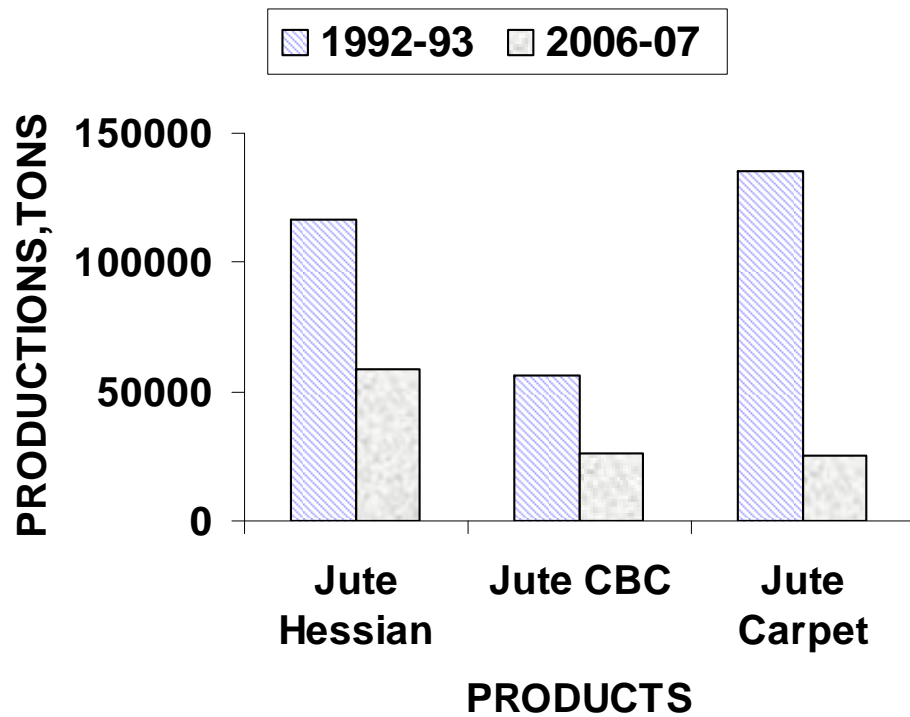


Jute Carpet





Present Market Situation of world jute based products



Source: Gordon Mackie, One day workshop on "A Road map for the Jute Industry", 6th July, Hotel Sheraton, Dhaka, Bangladesh.



Diversified Application

Fashionable bags



Furniture



Disaster shelter



Highway barrier



Highway Sound Barrier (TOMEI EXPRESSWAY)

Corrugated sheets



Automotive components

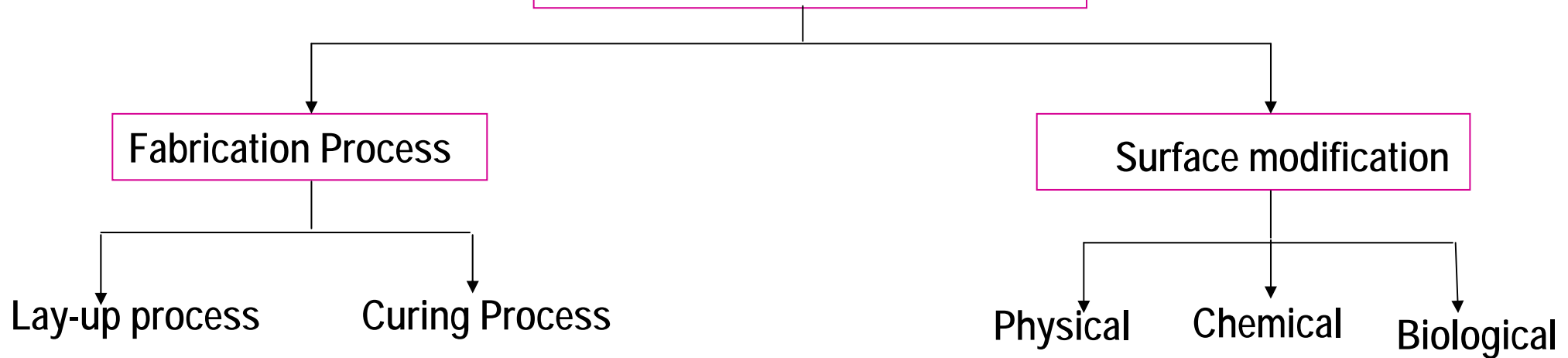




Key Challenges and Solutions

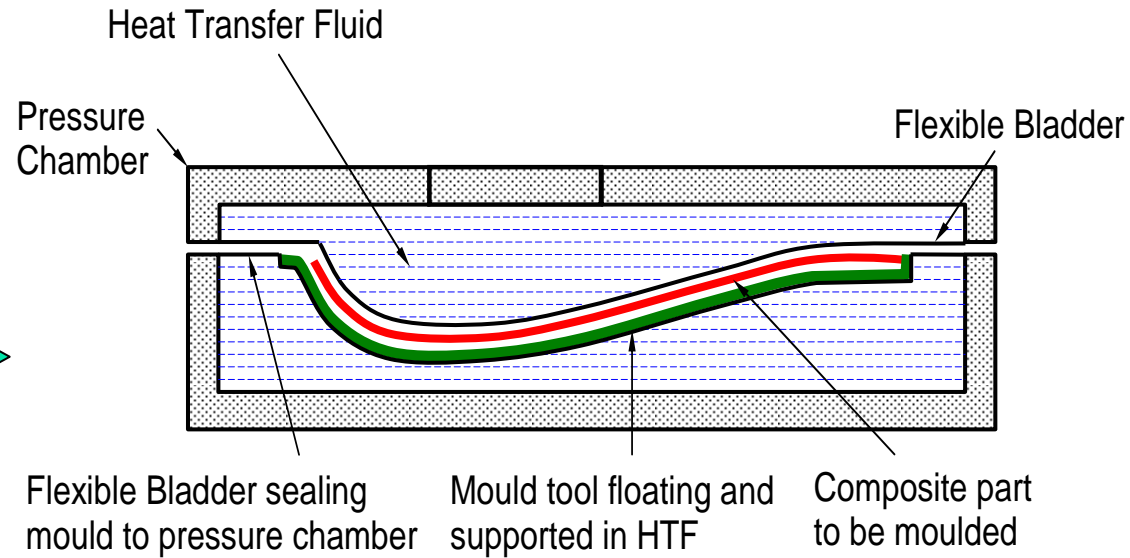
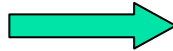
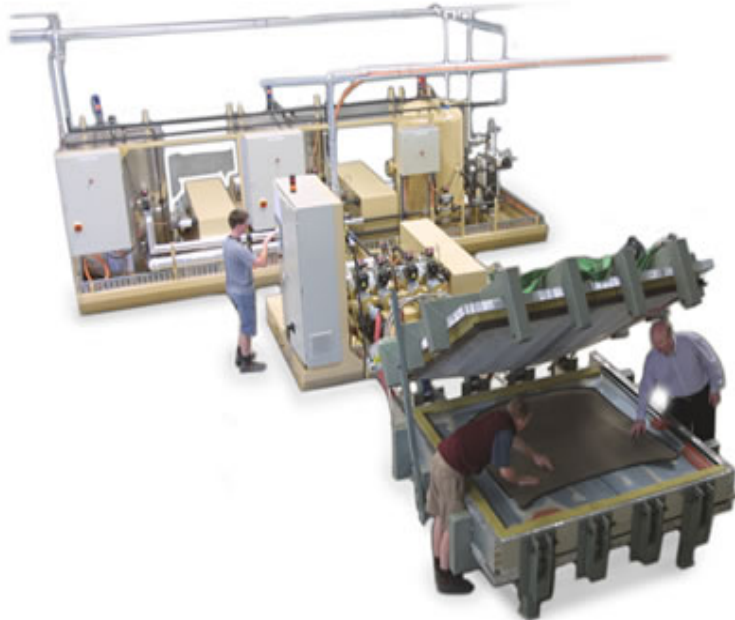
- ❖ High styrene emissions
- ❖ Poor fiber-matrix adhesion.
- ❖ Durability Problems

Possible Solutions





What and why "Quickstep"?



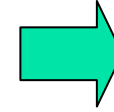
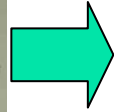
"Quickstep™"?

- Better heat control, higher energy absorption.
- Low resin viscosity/large processing window after the rapid heating rates.
- Faster cycle times.

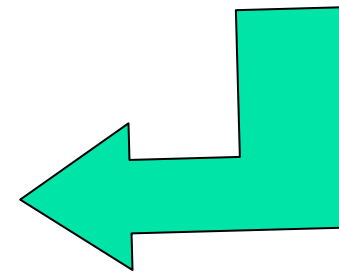
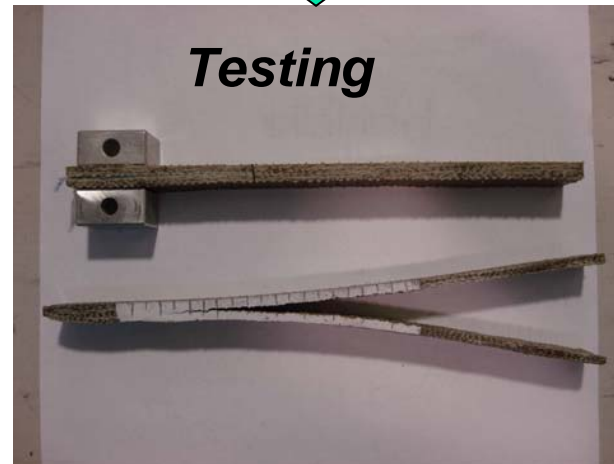
Source: 2008 Quickstep Global Technology Exchange - Perth, Western Australia



S1: Experimental Composites: HLU, Quickstep



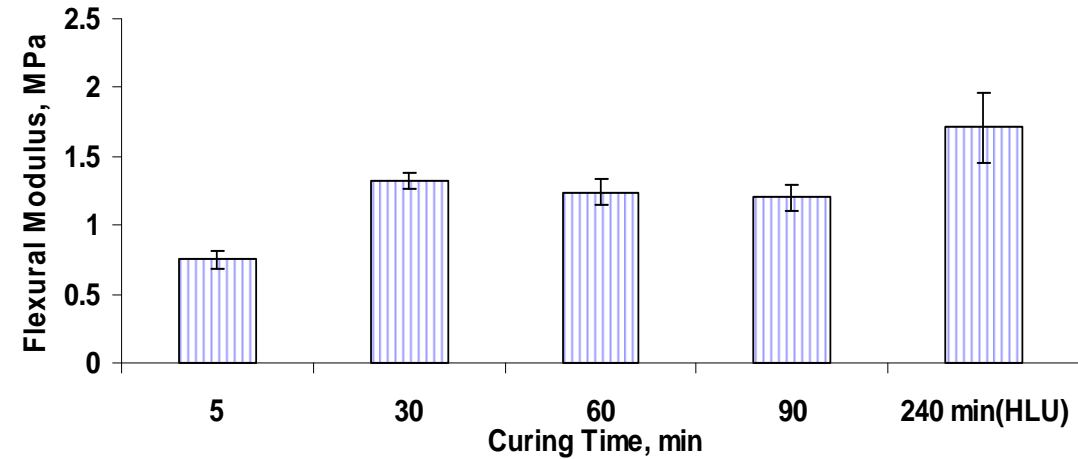
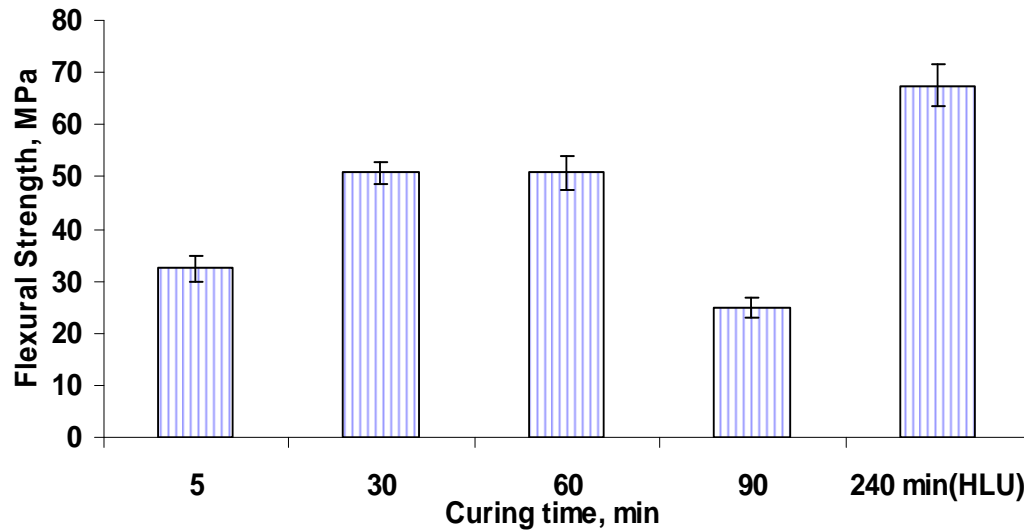
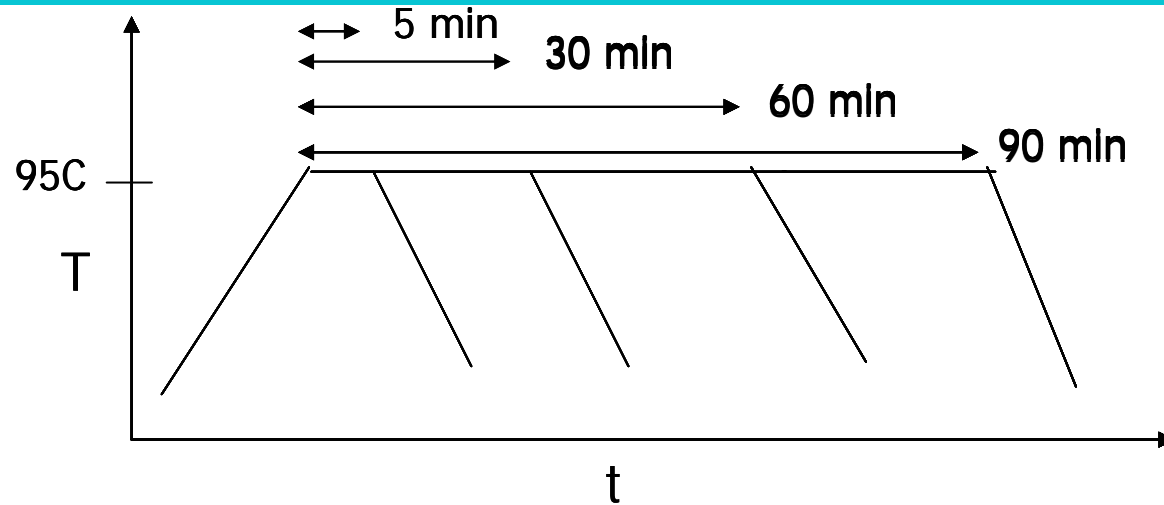
HLU ↓



Quickstep

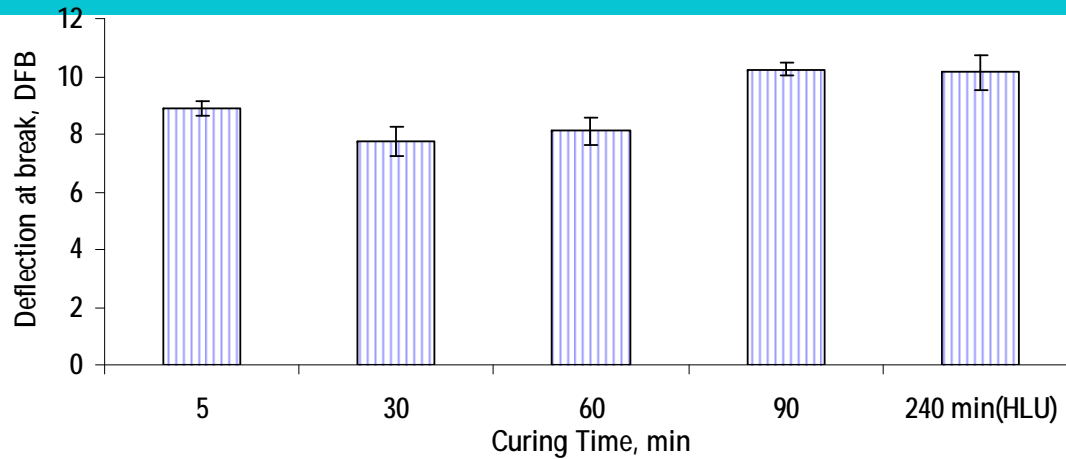


S1 Results: Optimisation of dwell/curing time: FS and FM

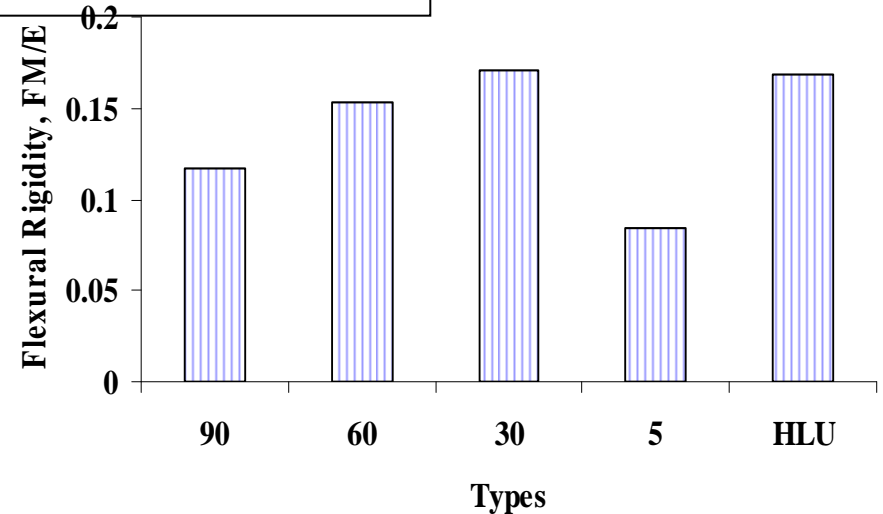
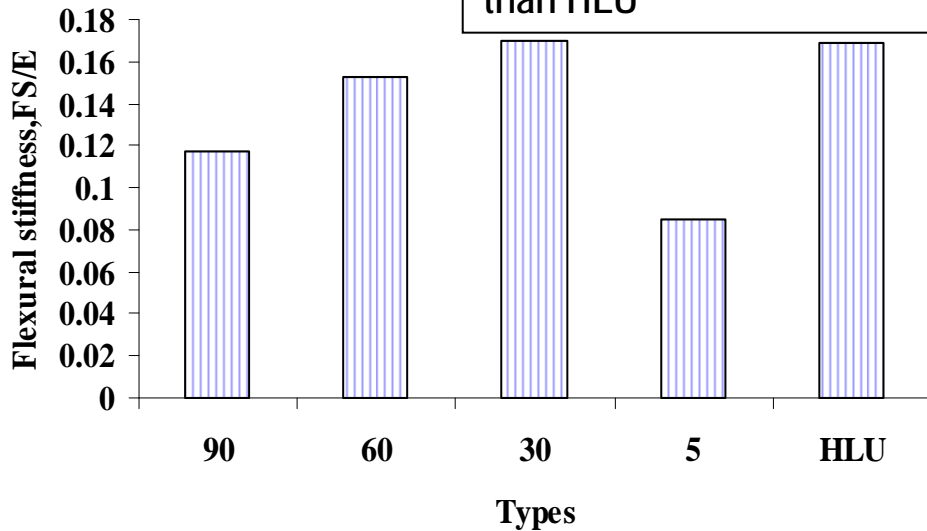




Optimisation of dwell time :DFB, Stiffness and rigidity



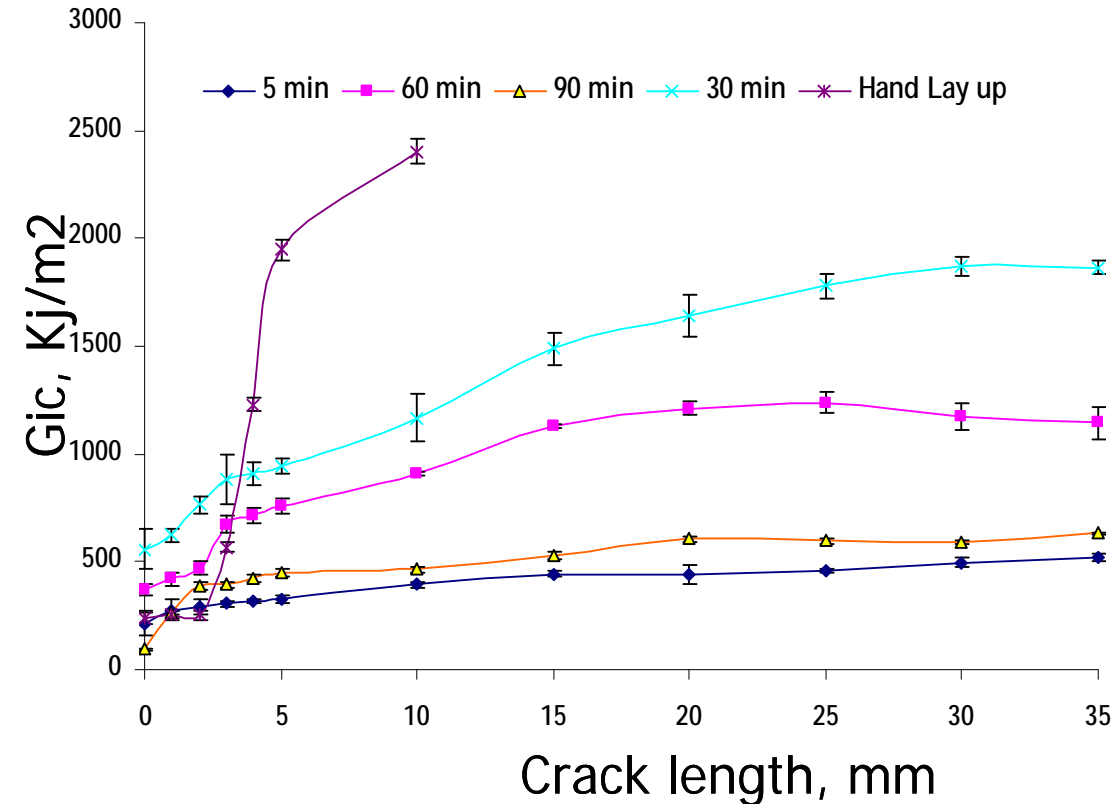
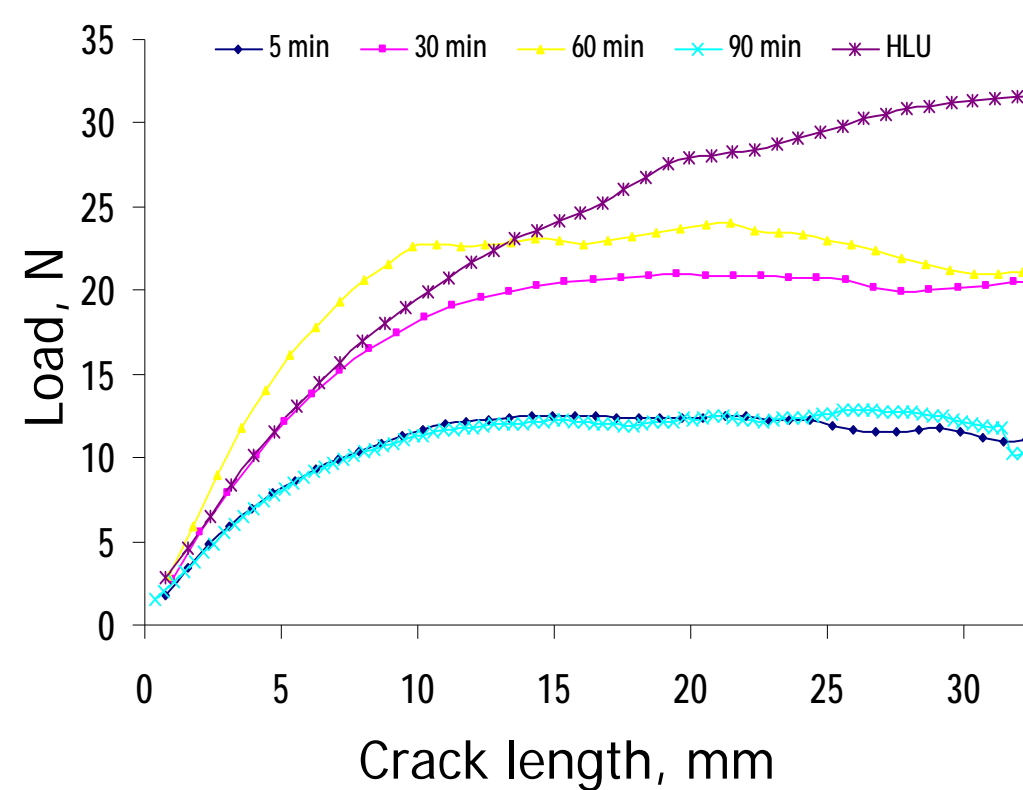
DFB minimum with similar Stiffness and rigidity for 30 min than HLU





S1 Results

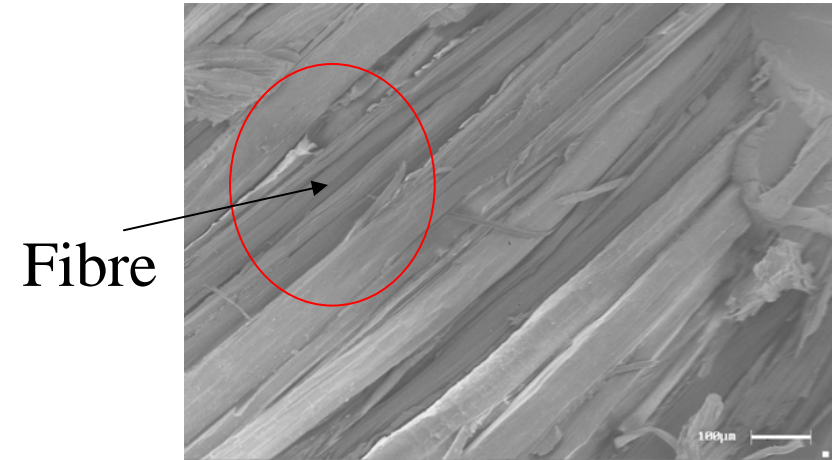
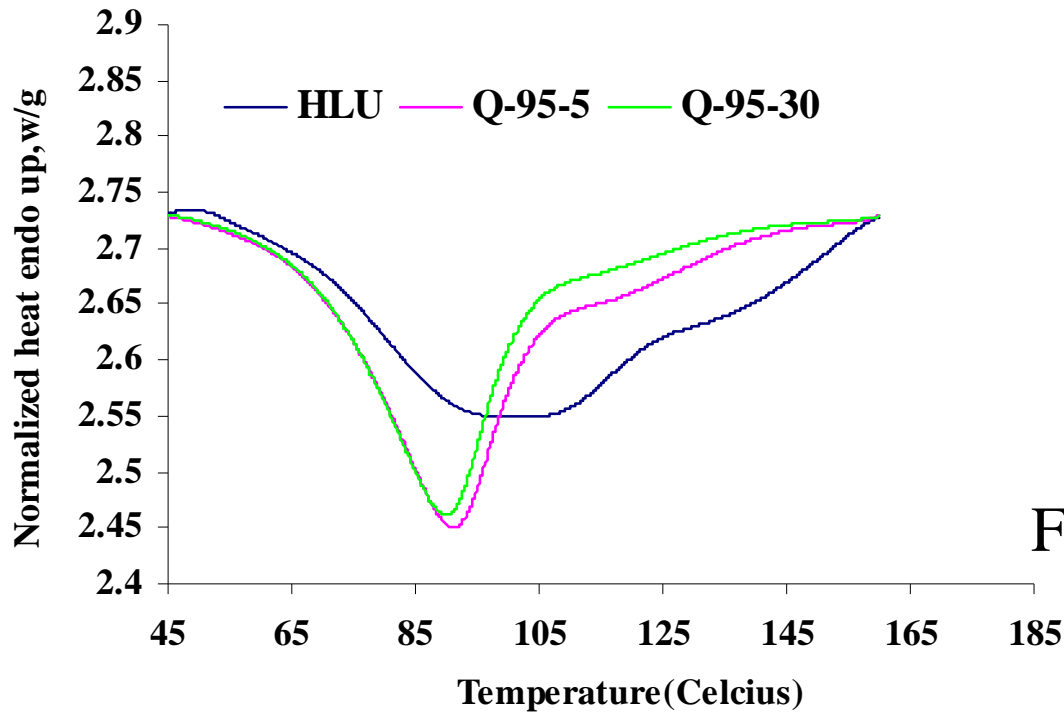
Mode-I delamination fracture toughness



Higher G_{Ic} -propagation/ Load capacity for HLU, 30 min best for among quickstep
HLU failed in a tension under brittle failure whereas Q failed in a CT mode under ductile manner
Crack propagation stopped at 10 mm for extensive fiber bridging and low FM adhesion

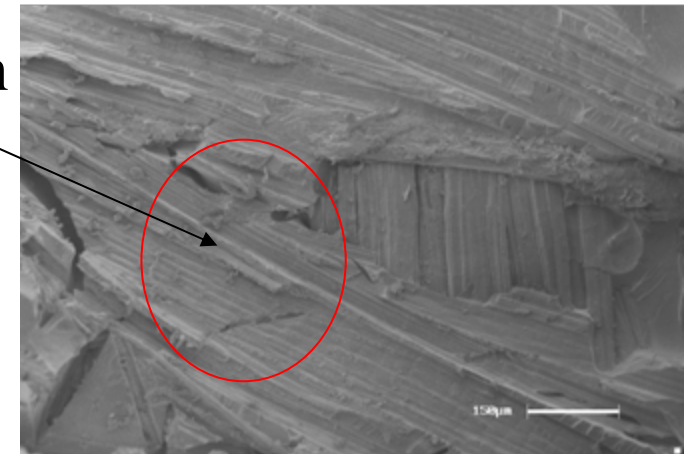


Why? Surface Morphology and Degree of Cure



HLU

Fibre+Resin



Quickstep

DC (24 hr):30 min,87%>5 min,84%>HLU,65%



S1 Findings

Quickstep:

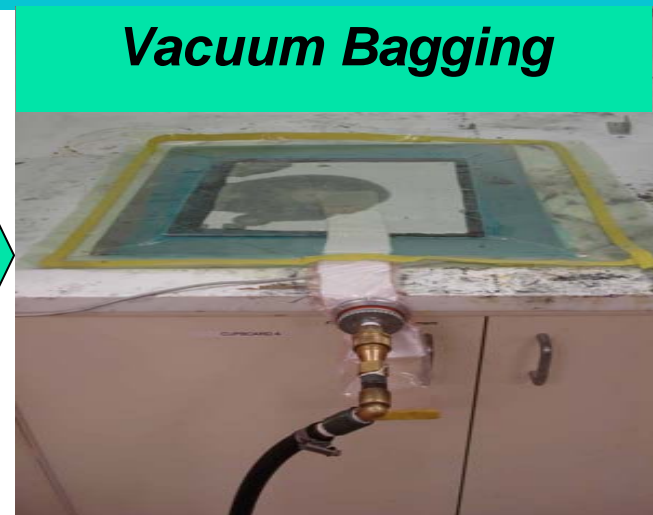
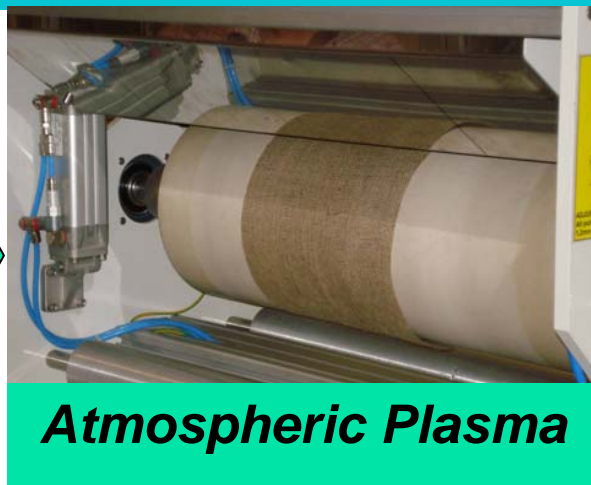
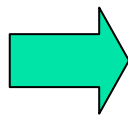
- Lower scattering/SD in results.
- Q-95/30 selected as a best for S2, Cure cycle time reduced from 4hrs to 30 mins
- Better resin dispersion/fiber wetting and higher degree of curing confers moderate fracture toughness and similar stiffness/rigidity
- lower in delamination fracture toughness value with higher energy absorption

HLU

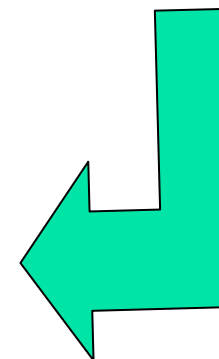
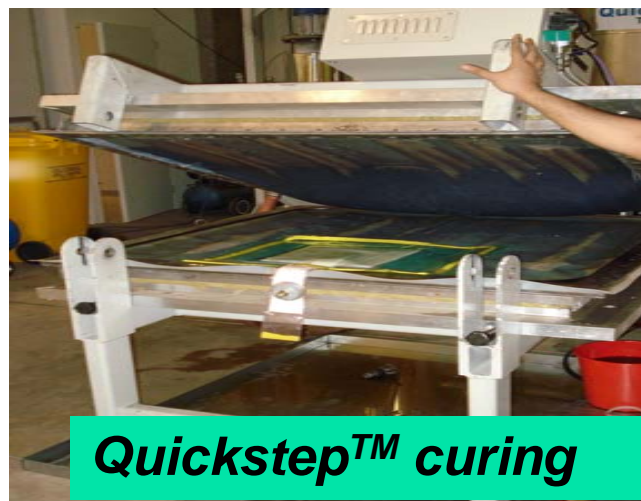
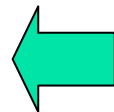
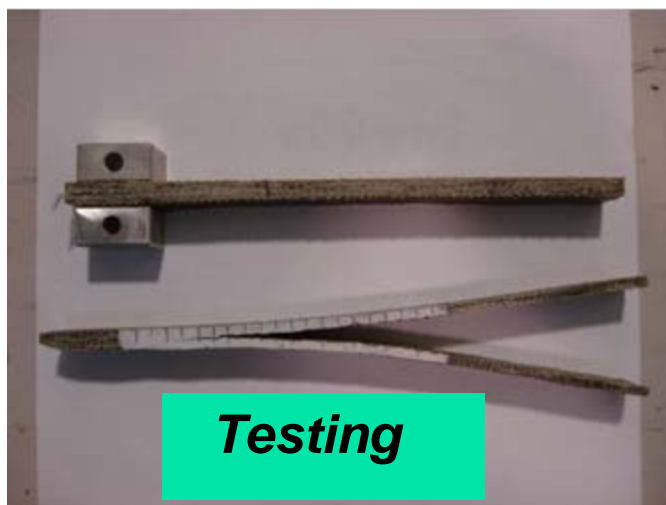
- Higher scattering/SD in results
- Failure mode: Both tensile and compression
- Extensive fiber bridging than fiber-matrix adhesion



Modified Experimental S-2

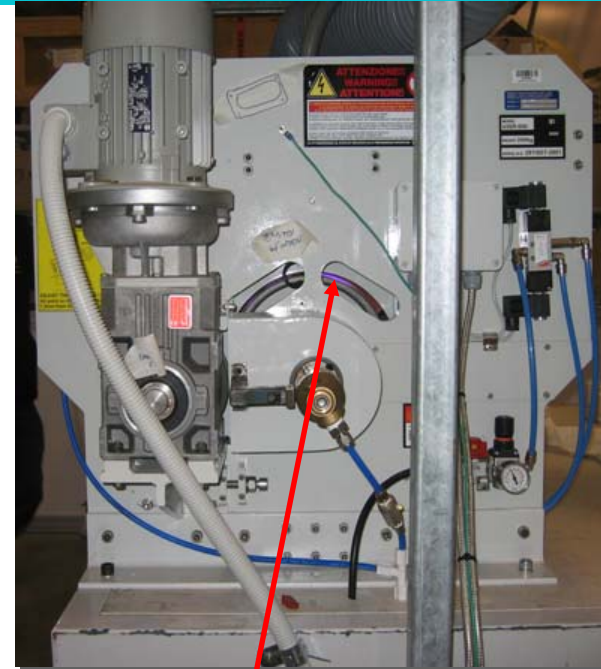
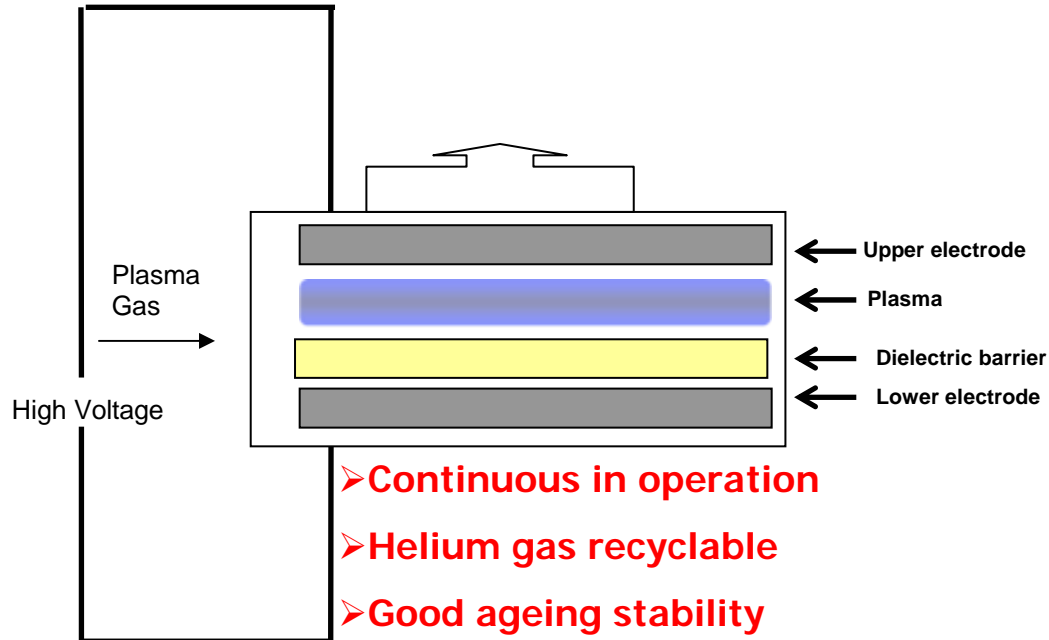


Modified Experimental----S-2





Atmospheric Plasma Unit at Deakin



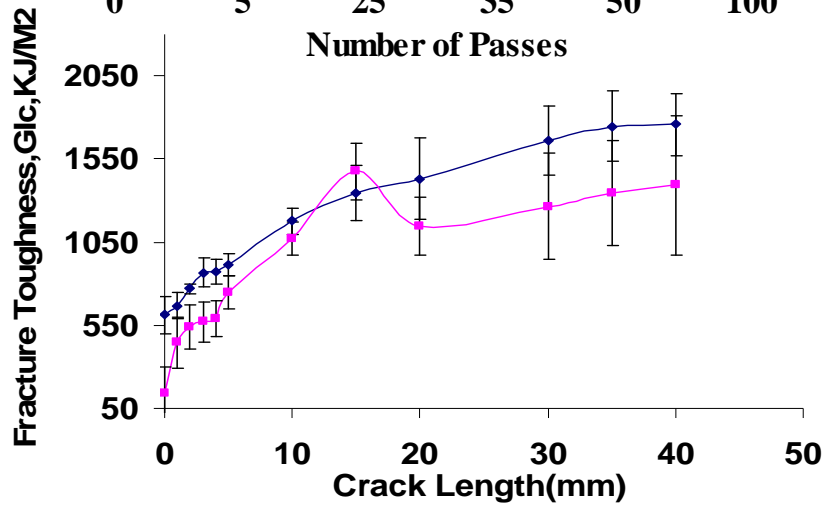
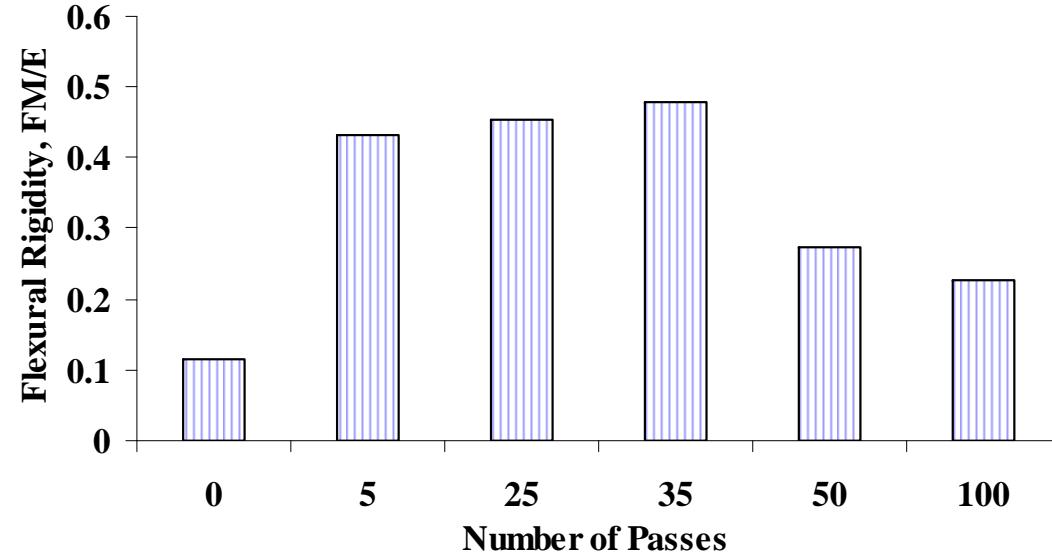
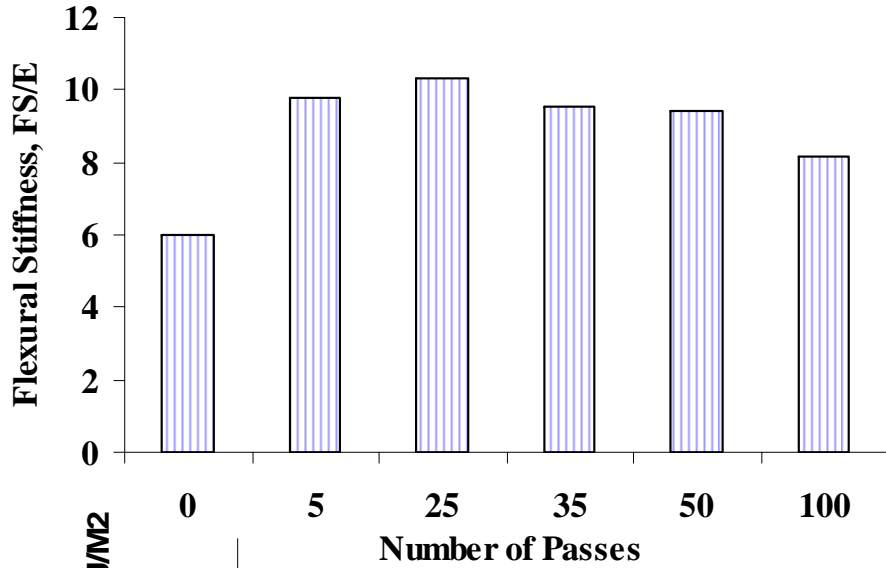
Plasma generated using helium in air





S2 Results

Flexural Stiffness, Rigidity and Fracture toughness



◆ Untreated ■ Helium treated(35P)

Sample	Glc-Int	Glc-Prop	FS, MPa	FM, GPa
Quickstep	428	1747	52	1.4
P+Q	142	1474	80	3.8



S2 Summary

Improved flexural behaviour with a little sacrifice in delamination fracture toughness.

Food for thought:S3

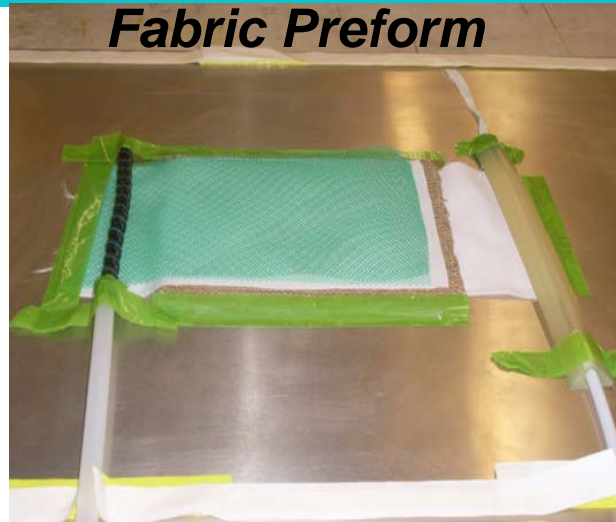
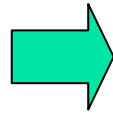
- Styrene emission is still a severe problems for polyester users from environmental and safety aspect.
- Problem solve through Vacuum Assisted Resin Infusion:S3



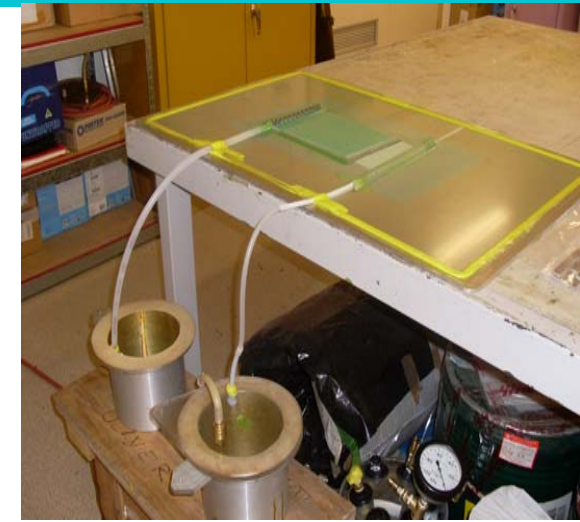
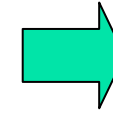
S3: Manufacturing through Vacuum Assisted Resin Infusion



Cutting

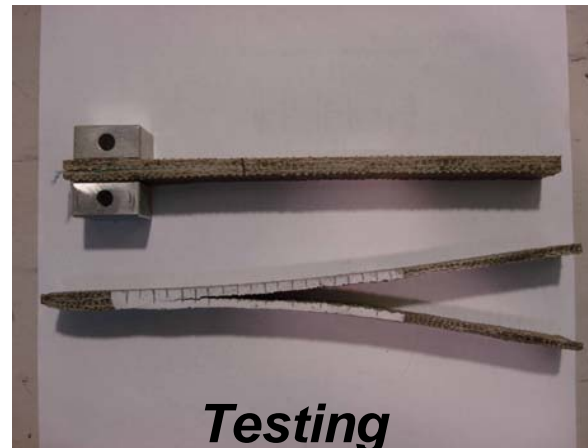


Fabric Preform

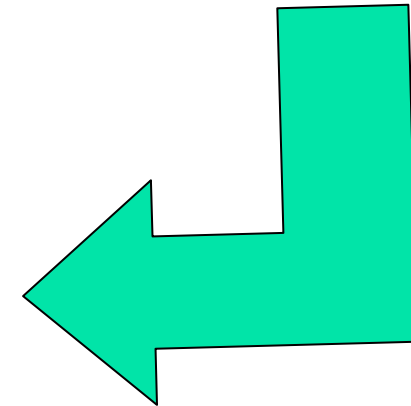


Resin Infusion

Modified Experimental S-3



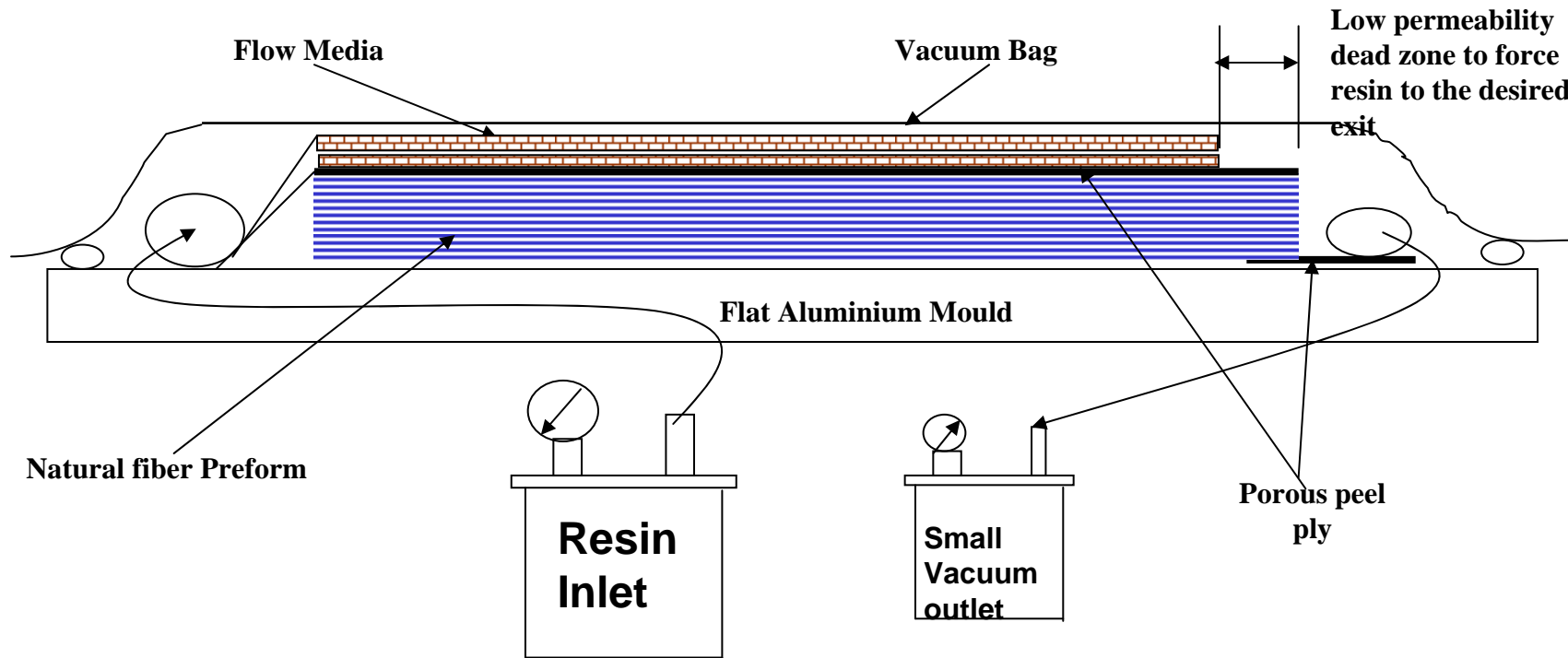
Testing





Modified Experimental S-3

- Why "Infusion"?
- Higher FVF, 40-42%
 - Lowest styrene emission,
 - Less labor intensive

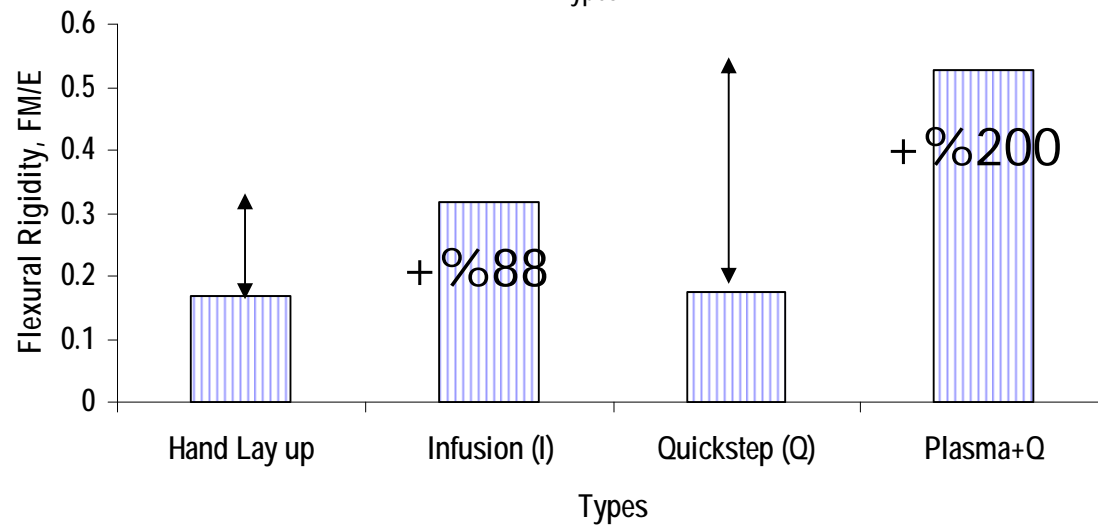
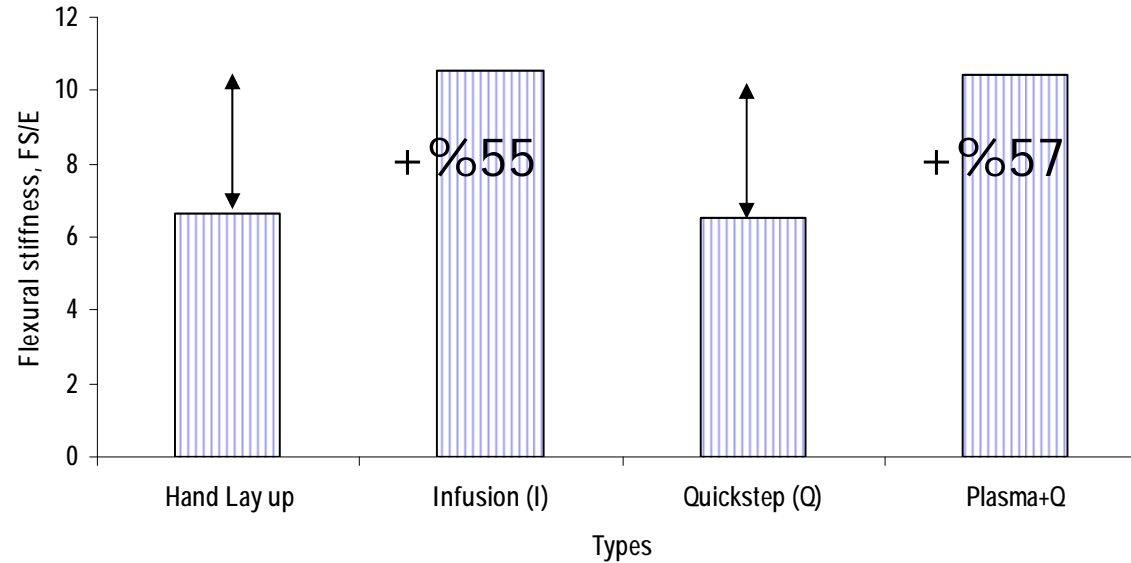


Schematic of Vacuum Assisted Resin Infusion



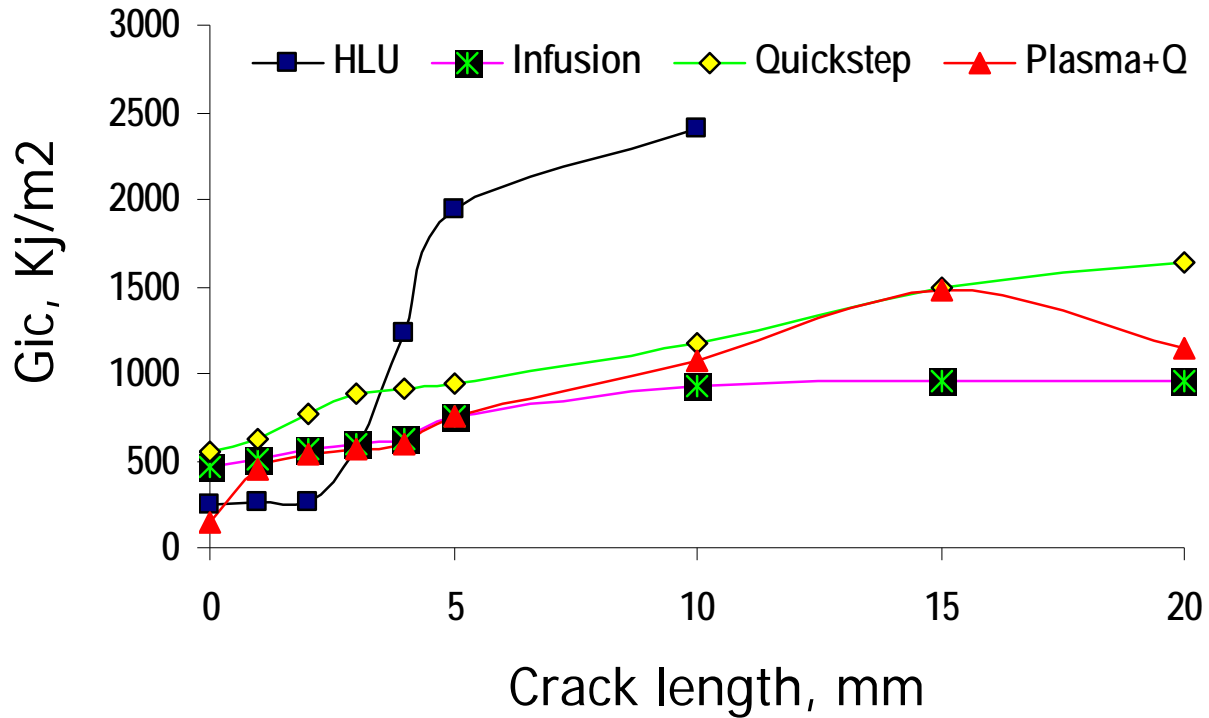
S3 Results

Flexural Stiffness and Rigidity





S3: Mode-I delamination fracture toughness



Higher G_{ic} -propagation= HLU>Q>P+Q>Infusion
Energy absorption=Q>P+Q>Infusion>HLU



S3 Results

Manufacturing Process Comparison

Types of process	Tooling cost	Labor cost	Quality	H&S Concern
Quickstep™	High	High	Variable	Liquid
Hand Lay-up (HLU)	Low	High	Not Reproducible	Risky
Infusion	Intermediate	Low	Reproducible	Very friendly

Curing Process	Curing Time	Mech. Prop.	Heating media
Quickstep™	Very low	Good	Liquid
Hand Lay-up (HLU)	Long	Good	Air
Infusion	Moderate	Very good	Air

Points calculated : HLU:1, Quickstep:2, Infusion:4, P+Q:3

S3 Summary

Changing in infiltration process/Infusion shows best mechanical behaviour and moderate delamination fracture toughness, It is also safe and suitable for commercial applications.

Findings

S 1

Quickstep has found as a potential addition to HLU

S2

Use of atmospheric helium plasma prior to Quickstep can be used to enhance stiffness/rigidity

S3

Infusion ensures safe processing environment with higher flexural and moderate fracture toughness.

Ongoing study

- ✓ Infusion query?
- ✓ Quickstep+ Infusion?
- ✓ Plasma + Infusion?
- ✓ Durability study?

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- ❖ Deakin University, Australia, MST authority, and AEWCCentre, University of Maine, Maine, USA.
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- ❖ Robert Pow, AFM
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- ❖ Claudia Garschke and Mandy heering

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Thank you, Any Question??