Layer by Layer (LbL) curing Feasibility Study

CIMComp EPSRC Future Composites Manufacturing Research Hub

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Concept / Challenges

- Cure of layers/sub-laminates during deposition

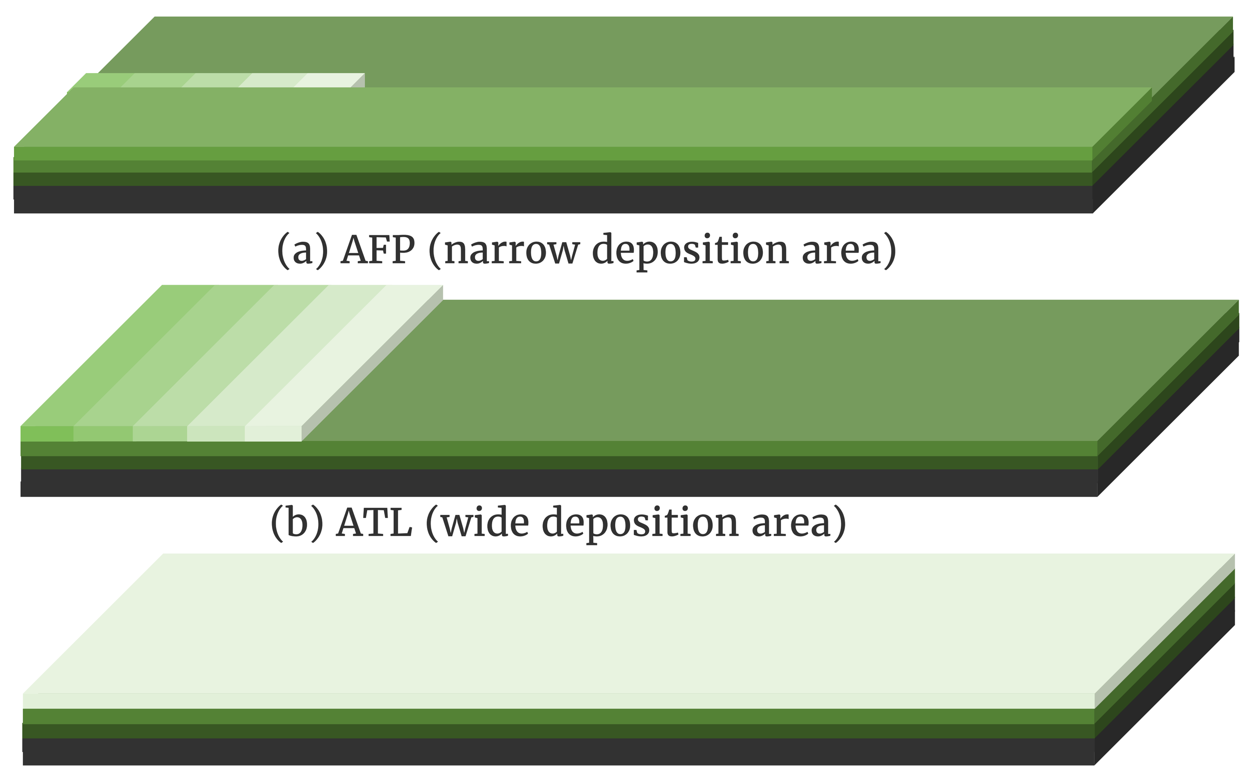


Figure 1. – LbL concept

- Process intensification through acceleration of consolidation and reduction of cure time
- Facilitation of thick and large structure manufacture
- Success hinges on achieving <u>sufficient interlaminar properties</u> across partially cured interfaces and ensuring <u>sufficient consolidation/porosity removal</u>

Objectives

- Development of process (consolidation/cure) simulation
- Assessment of partially pre-cured interface properties
- Process optimisation
- Process implementation and product quality assessment

Materials and Methods

- Demonstration on 913/glass prepreg
- Challenging process window and reactivity – 40 mm case considered
- Coupled 1D ODE viscous compaction solution (DefGen) and 1D FE cure model for process simulation
- Crucifix compaction, DSC and MDSC characterisation
- Partially pre-cured interfaces in press
- ILSS SBS and Mode I DCB testing
- Whole LbL in hydraulic machine
- Microscopy and 33 tensile strength of whole LbL product

Figure 2. – Whole LbL process implementation using a servo-hydraulic machine with heated plates.

Results: Simulation

- Optimised conventional process requires 2 h cure involving 80 ºC overshoot
- Whole LbL process can deliver 40% reduction in cure time with half the overshoot or similar cure times with low overshoot
- Consolidation completed successfully with the LbL process according to simulation
- ATL simulation shows successful consolidation and cure within 20 min of deposition for an 1 m long, 3.5 mm thick plate with no overshoot

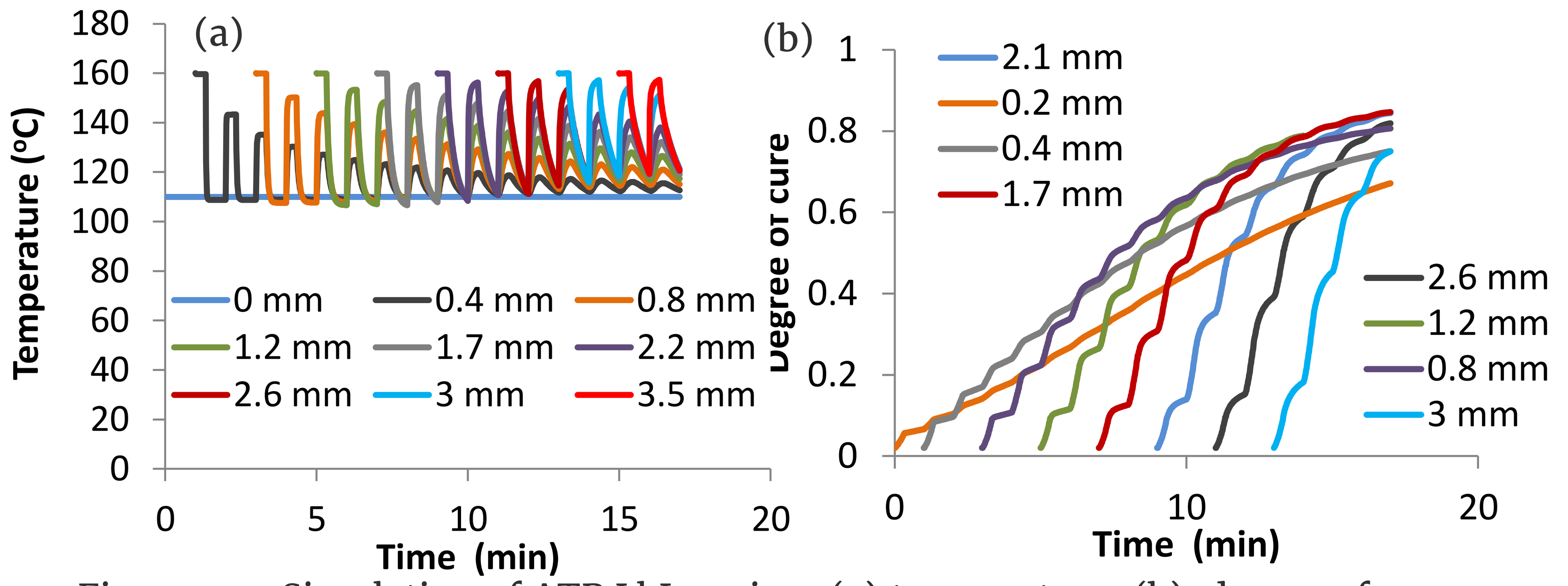
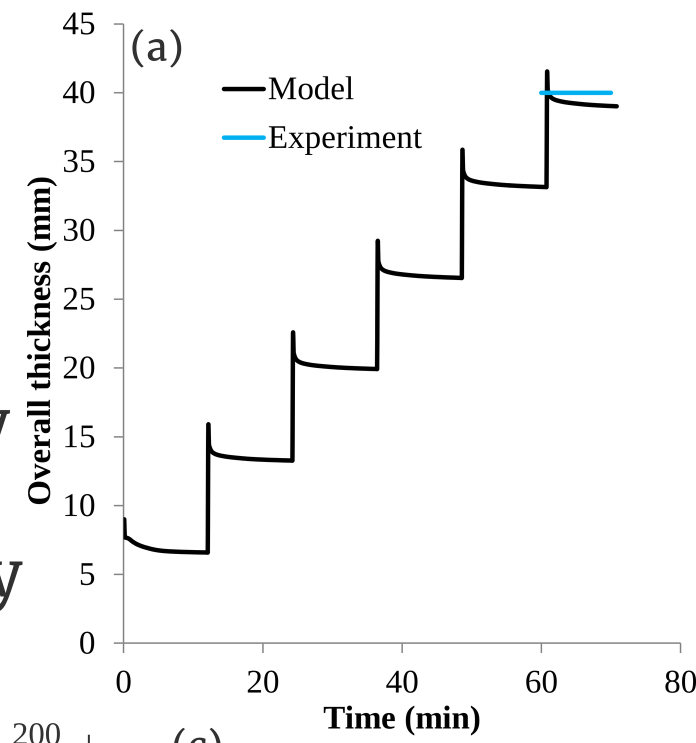


Figure 3. – Simulation of ATP LbL curing: (a) temperature; (b) degree of cure.

Results: Process demo

- Whole layer process successful for 40 mm thick laminate
- 130 ºC cure, 6 sub-laminates
- Simulation follows experiment closely
- Cure within 1 hour
- Process also implemented successfully for single tow compaction



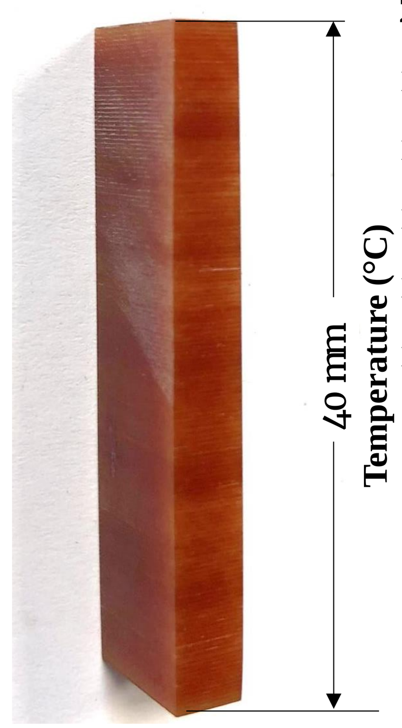


Figure 4. – Section of thick LbL demonstrator.

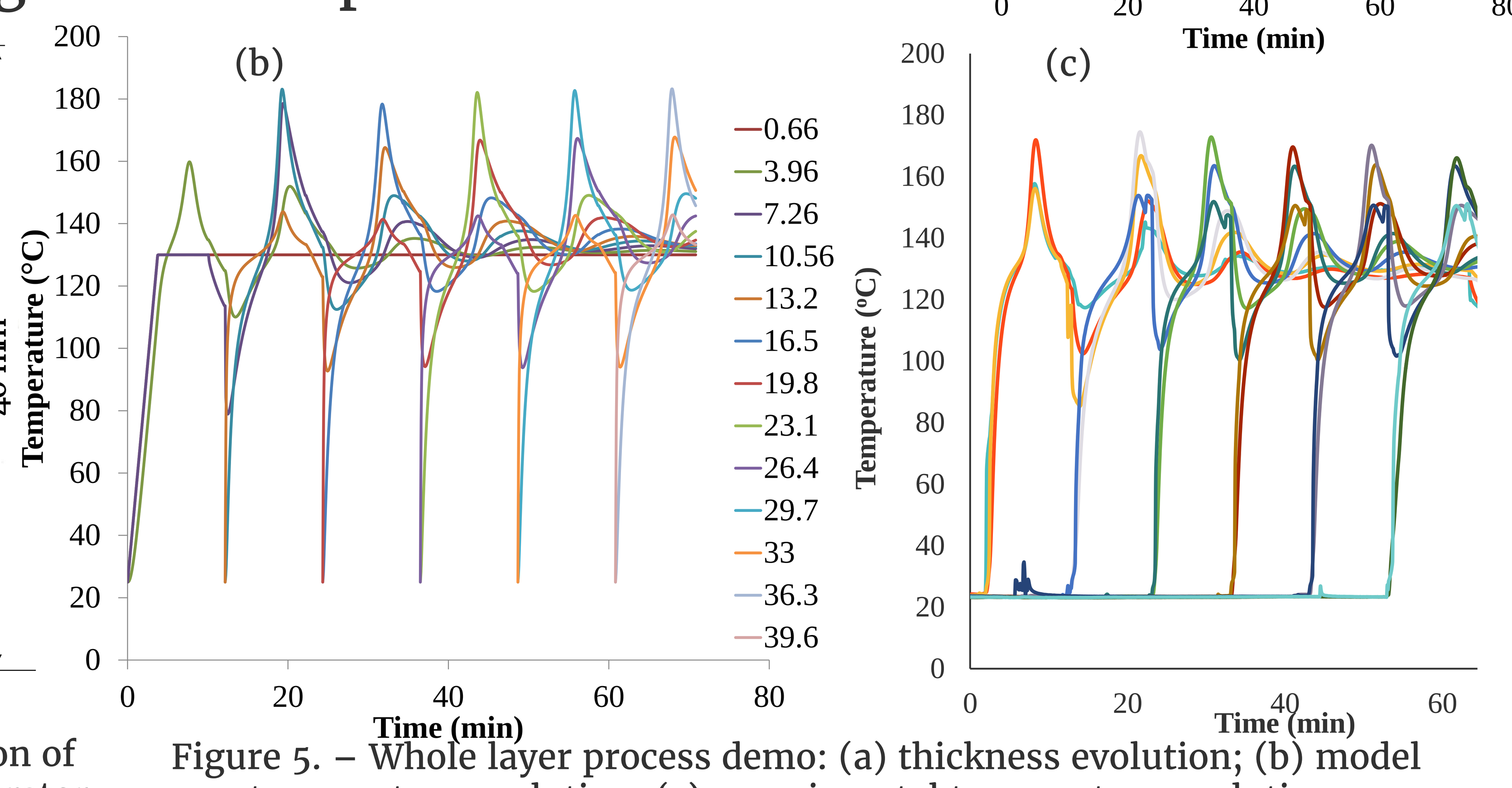


Figure 5. – Whole layer process demo: (a) thickness evolution; (b) model temperature evolution; (c) experimental temperature evolution.

Results: Quality

- No porosity issues in LbL
- Heterogeneous morphology finer in LbL laminates
- Failure initiation at the same level as conventional material
- Interlaminar propagation lower with partial cure due to dominance of fibre bridging in conventional material

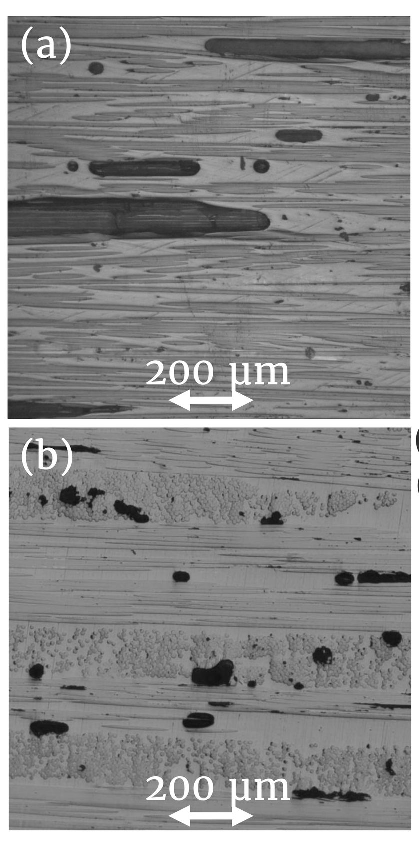


Figure 6. - Microstructure: (a) conventional; (b) LbL material.

Conclusions

- The LbL curing process is feasible
- <u>Cure shortened by 40% in thick laminates</u>
- Sufficient compaction and removal of porosity
- Acceptable mechanical integrity of LbL product

Future

- 3-D/complex geometries
- Implementation in AFP
- Multi-material/hybrid composites processing
- On line through thickness inspection

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