CIMComp
EPSRC
Future Composites
Manufacturing Research Hub

Thermoforming of Multi-Axial Advanced Thermoplastic Composite Parts

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Objective

How to press-form complex components from pre-consolidated multi-axial thermoplastic laminates without inducing wrinkles? Forming biaxial pre-consolidated sheets is relatively easy; forming multi-axial sheets without defects is far more challenging!

Methodology

The idea is to lubricate the interface between contacting but non-orthogonally orientated pair of plies. For example, in a 6-ply layup:
0/90/+45/-45/90/0,
one would expect significant relative motion at the interface indicated by '/' when forming doubly curved geometries; a potent source of wrinkling defects (see Figure 1) when press forming pre-consolidated sheets.

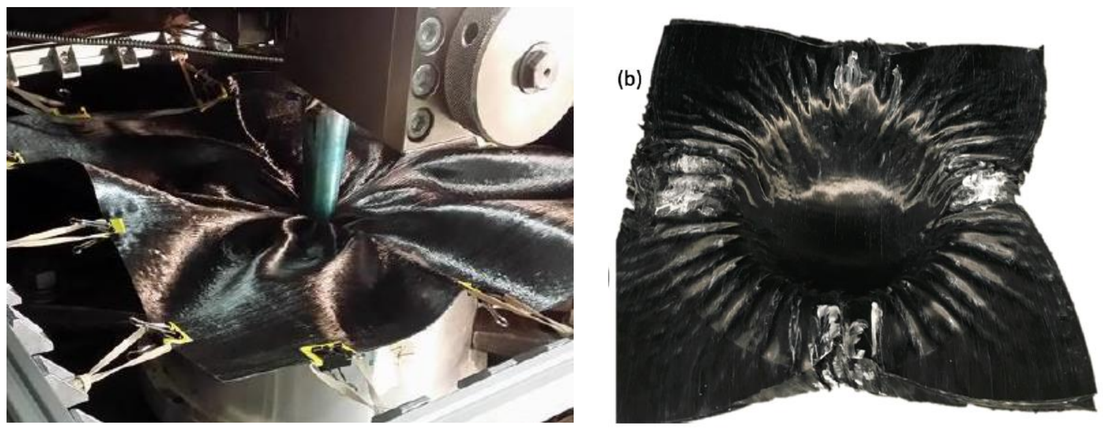

Figure 1. Wrinkling of composite prepreg sheets during forming

Molten metal will provide lubrication (see Figure 2). The metal will have a melt temperature close to that of the matrix phase (e.g tin T_m=235°C, nylon T_m =223°C). The aim will be to squeeze the metal out of the laminate during the press-forming process, facilitated by the low viscosity and high surface tension of the molten metal.

Figure 2. Molten tin

The metal will be heated using induction heating enabling the laminate to be heated from the inside. Segmented tooling and an automated multi-step press will be used to create a pressure-driven squeeze flow starting at the centre of the sheet and moving outwards.

A novel, high temperature deep-draw 'wrinkle-o-meter' (see Figure 3: room temperature version) will be designed and manufactured to accurately measure the change in wrinkling behaviour resulting from the introduction of molten metal in the laminate.

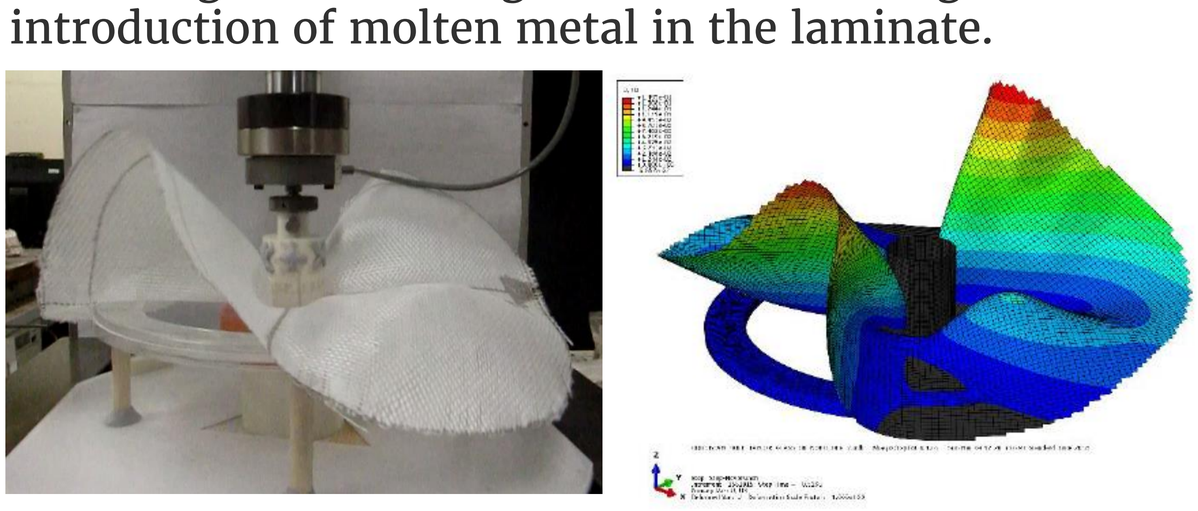

Figure 3. Low temperature deep-draw wrinkle-o-meter for fabrics and corresponding finite element simulation.

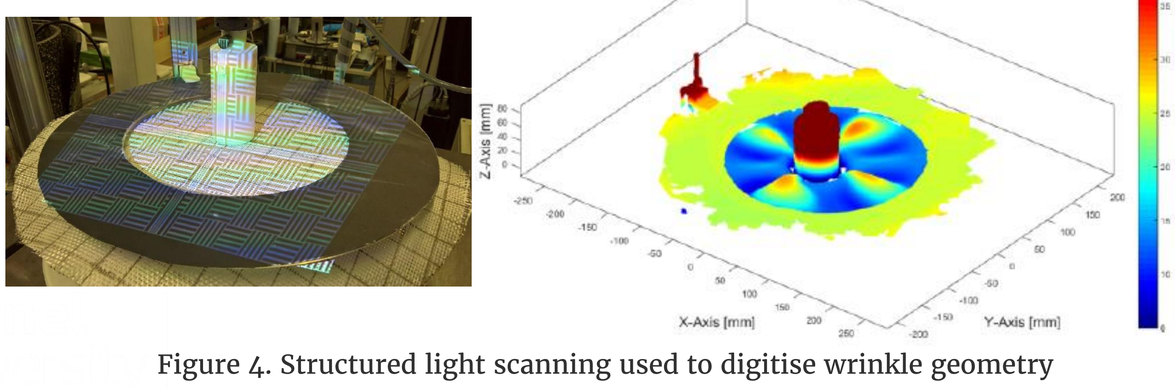

Figure 4. Structured light scanning used to digitise wrinkle geometry

Progress to date

- Preliminary room temperature experiments on the wrinkling mechanics of lubricated prepregs have been conducted
- A collaboration with Induction Coil Solutions has been instigated and will provide access to expertise and essential induction heating technology
- A room-temperature version of the deep-draw wrinkle-o-meter has been implemented and tested (see Figure 4)

Key findings

- Reduction of inter-ply friction via lubrication does reduce wrinkling
- The deep-draw wrinkle-o-meter combined with structured light scanning is potentially a powerful new tool in understanding wrinkling mechanics

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