Virtual Un-manufacturing of Fibre-steered Preforms for Complex Geometry Composites

CIMComp EPSRC Future Composites Manufacturing Research Hub

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Xiaochuan(Ric) Sun, Wei-Ting Wang, Jonathan Belnoue, ByungChul(Eric) Kim, Stephen Hallett

Aims and Objectives

Automated Fibre Placement (AFP) technology is ideally suited to manufacture structures with simple geometry due to its robustness, speed and repeatability. However AFP is not well-adapted for directly laying up 3D shapes, as the geometry and need for defect free manufacture constrain the head speed, making manufacture time consuming and thus costly. In most cases, complex geometry composites components are designed based on ideal fibre angles, with little or no consideration of the manufacturing processes or constraints involved in delivering them.

This feasibility study took a novel virtual approach to "un-manufacture" these ideal designs for the case of formed composites, so that flat tailored preforms can be created via the continuous tow shearing (CTS) technique, which results in the required ideal fibre architectures after forming (see Fig. 1). The primary manufacturing process envisaged to deliver this is the diaphragm forming of thermoset prepregs deposited using automated deposition. However, it is anticipated that the concept developed will be applicable to textile preforms (including non-crimp fabrics) and thermoplastic prepregs. The objectives of this project is to demonstrate the proof of concept and feasibility of the proposed manufacture processes and to develop numerical tools needed, along with experimental validation.

Work Flow

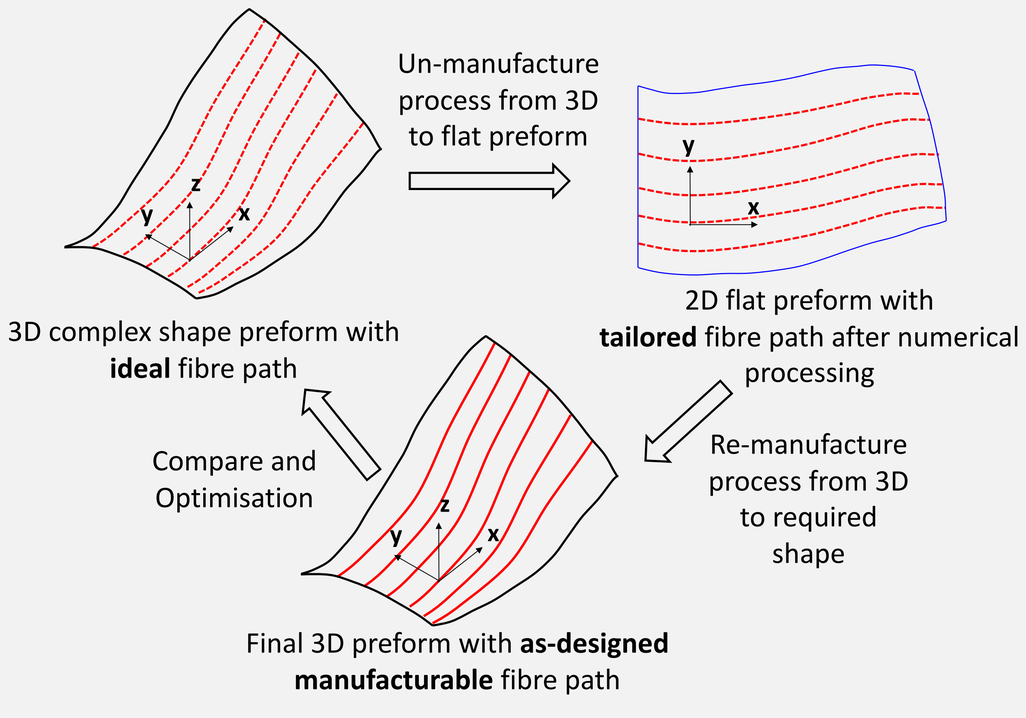

Figure 1. Schematic of the lay-flat and form.

Methodology

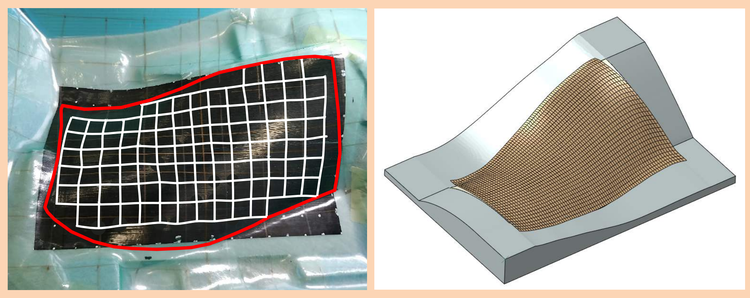

Figure 2. experimental results (left) of forming using UD prepreg with marked grids and model prediction (right) for the re-forming of prepreg tailored fibre path

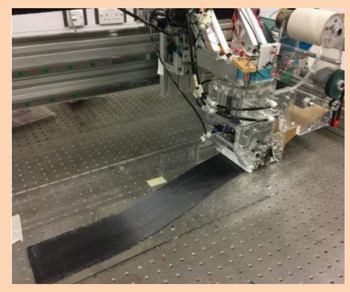

Figure 3. Wide tape CTS machine steering a 100 mm wide unidirectional prepreg tape.

Work packages:

WP1. Numerical modelling of forming and un-forming of steered fibres prepreg stacks on representative complex 3D shape

WP2. Experimental characterisation of prepreg in-plane properties

WP3. Manufacture of technology demonstrator and quality inspection

Numerical Results

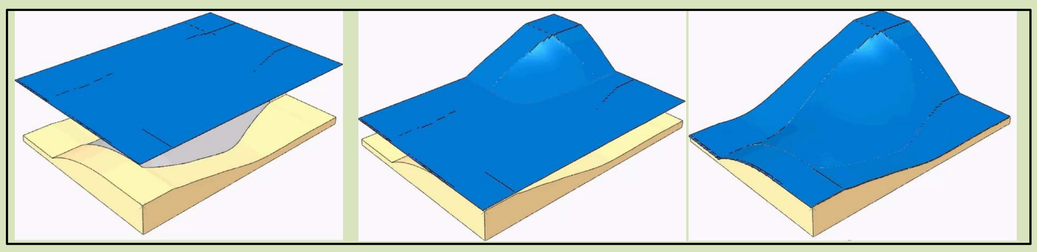

Figure 4. Numerical process modelling of double diaphragm forming (note the part in blue is diaphragm)

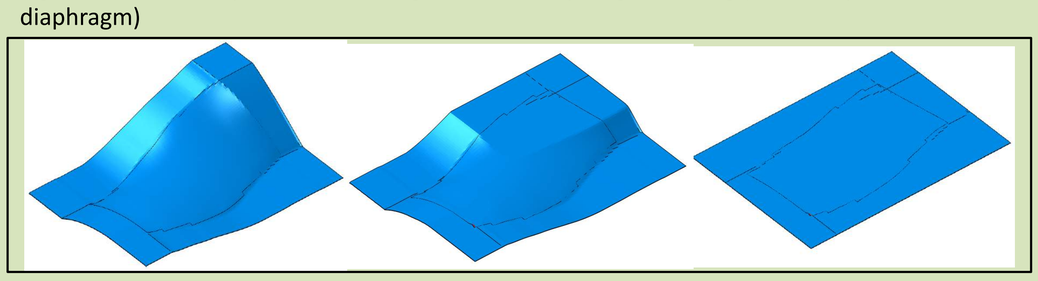

Figure 5. Numerical process modelling of double diaphragm un-forming (note the part in blue is diaphragm, prepreg model is sandwiched between two diaphragm parts)

- Two processes were fully reversible
- 2D flat prepreg with tailored fibre path after post-processing was obtained.
- Fibre path was extracted from prepreg model and passed to manufacture CTS tapes
- 2D flat prepreg model was then put back to forming simulation, the result of which is compared with the ideal fibre path to form a complete optimisation cycle

Experimental Results

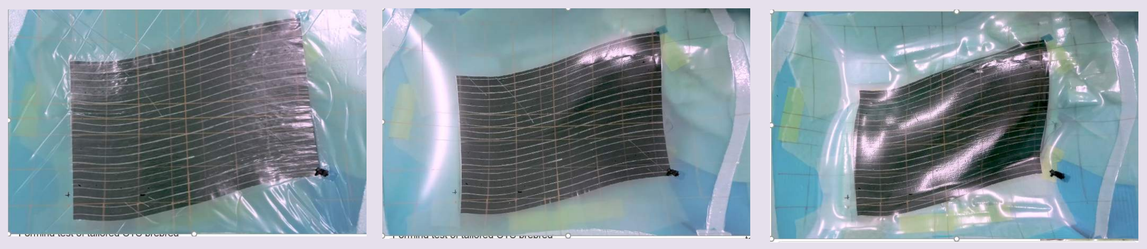

Figure 6. Double diaphragm forming test on tailored CTS prepreg where fibre path was derived from un-forming simulation

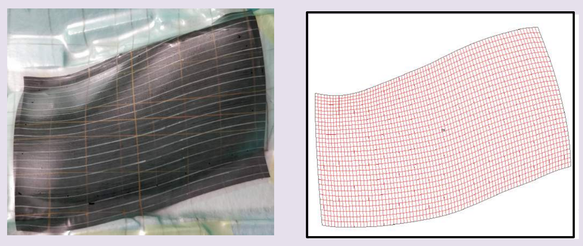

Figure 7. Comparison between Formed tailored CTS prepreg and Reformed preform with tailored fibre path

- Steered fibre tape was made using CTS technique with fibre trajectory derived numerically
- Reformed steered prepreg was found to be similar to modelling results.

Key Findings

- Validated numerical and experimental results demonstrated the feasibility of the proposed manufacture processes which can have lower cost and greater efficiency compared to direct AFP on complex shape
- Steered fibre paths on demonstrator was found to have less wastage and more continuous fibre across the whole part

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