FLOW FRONT MONITORING AND PERMEABILITY ANALYSIS OF PNEUMATICALLY SPLICED WOVEN FABRICS

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Abstract

Pneumatic splicing is a method that was historically developed for the textile industry, enabling the joining of separate bobbin ends during knitting/weaving processes. The process involves overlapping two yarns and placing them into a specially designed chamber, where upon releasing high-pressure blast of air, counter-rotating vortices entangle and intermingle the fibre bundles to form a permanent mechanical joint. Davidson et al. (2021, 2024) investigated the mechanical properties of pneumatically spliced engineering fibres including carbon, glass, and basalt. Their findings revealed the strength of these spliced joints could achieve ~70-80% of the virgin fibre strength, where in their investigations, 12k carbon fibre tows exhibited the best relative performances. Pneumatic splicing also facilitates the remanufacturing of discontinuous fibre waste generated during manufacturing processes, potentially facilitating the production of quasi-continuous yarns that can be rewoven into fabrics.

Vacuum Assisted Resin Transfer Moulding (VARTM) is a widely used method for manufacturing composites. To date there has not been published work on VARTM of fabrics containing spliced joints. Spliced joints are highly entangled, containing double the fibres of the virgin yarns at the overlap regions. The influence of the geometry of the spliced joint and increased fibre density impact on flow front and resin permeability, has not been characterised. The aim of this work is to investigate the effect of the presence of spliced joints on the flow front and permeability of a 2x2 twill 12k carbon fibre fabric. 2x2 twill 12k carbon fibre fabrics including splices were manufactured at the using a Dornier loom, as detailed in Figure 1. Splice joints were placed 200mm from the edge of the fabric, 80mm apart in the vertical direction and ~300mm apart in the horizontal. The spliced joints were manufactured using an Airbond model 701. The spliced overlap length was approximately 20 mm, where pulses were fired starting in the centre of the overlap, and the number of pulses fired varied between 3 and 8 such that the constituent tows could no longer be pulled apart by hand.

The in-plane permeability of fabrics containing and excluding splices were determined using a radial infusion method with constant inlet pressure. This method has the inlet port at the centre of the fabric, with the resin inlet pressure controlled by a constant vacuum, resulting in a radial flow front. The radial infusion methodology measures the permeability in different directions for anisotropic materials. The flow front of anisotropic materials are typically elliptical or irregular, with the major axis of the ellipse aligning with the direction of higher permeability as seen in Figure 2(b). Two analyses were performed with the spliced joints being (1) transverse to the flow and (2) in line with the flow. For the experimental setup, a single ply of the woven

fabric was cut to 405 x 405mm and sandwiched between 2 glass plates. Flow front monitoring was performed using a 12MP Raspberry Pi camera positioned beneath the glass panels, as seen in Figure 2(a). The flow front was tracked using a Python script to analyse the video recording, and the permeability was then calculated using Darcy's Law, as outline by Sharma et al. (2010).

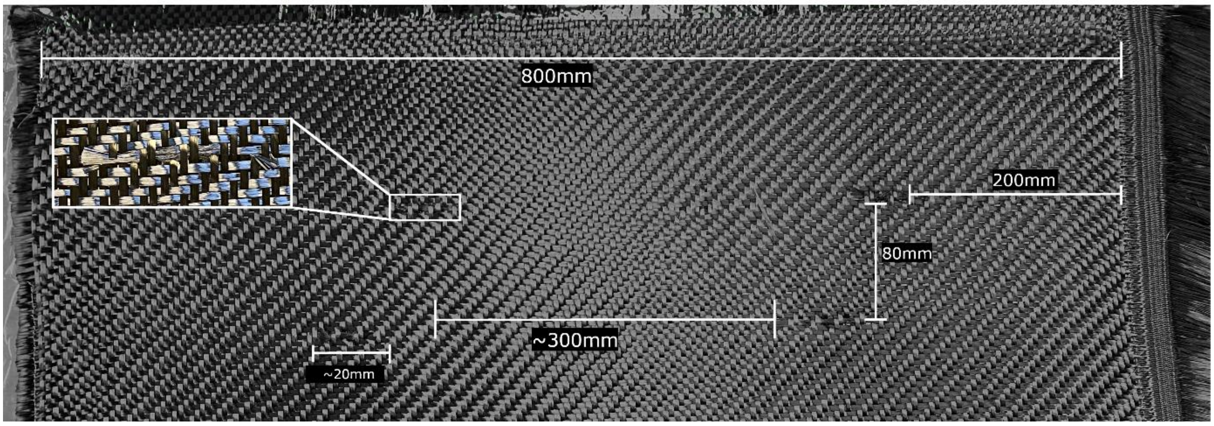
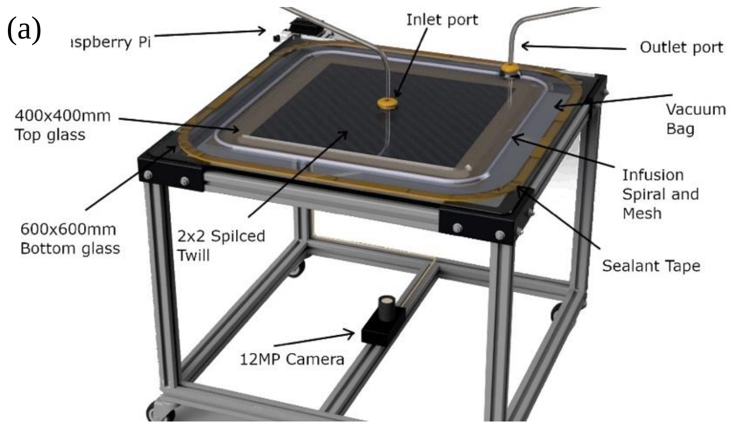


Figure 1. 2x2 twill 12k carbon fibre woven fabric with pneumatically spliced joints



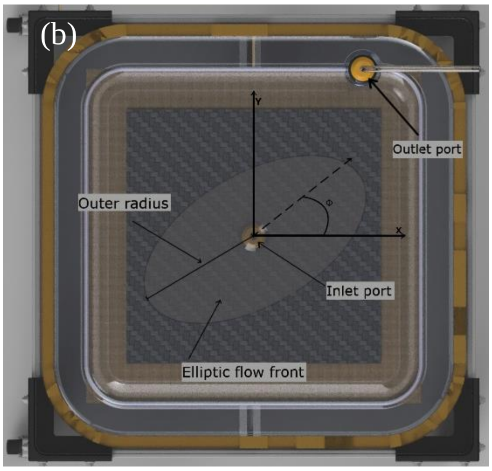


Figure 2. (a) Schematic of VARTM apparatus (b) elliptical flow front schematic

The results indicate that spliced regions in woven sheets have minimal impact on both the flow front shape and the permeability of the fabric. The presence of spliced joint had some effect on the flow front, where resin flow appeared to be constricted by the increased quantity of fibre and entanglement in joint. Further research is necessary to understand the impact of increasing the number of splices within a ply on permeability and flow front of the fabric, the effects of spliced joints in both the weft and warp directions, and the implications of spliced regions within thicker, more complex laminates