COUPLING THE FORMATION, MOVEMENT, DISPERSION AND EFFECTS OF VOIDS IN RESIN INFUSION

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Introduction

Despite their promised advantages, industry has been slow to adopt composite materials for high performance structural applications. Less costly process methods such as resin infusion (RI) are being developed for many high-performance applications, but require significant amounts of optimization, in time and money, to achieve satisfactory mechanical properties. Minimization of voids is the focus of such RI optimization. This requires understanding of the formation, movement, dispersion, and effects of such voids. An approach to coupling these areas of study is demonstrated here. Two laminates were produced by resin transfer moulding with an aerospace-grade carbon uni-directional weave and Hexcel RTM-6 epoxy resin for the demonstration.

Void Formation

Much recent research has been devoted to relate the flow velocity during resin infusion to the amount of voids created by mechanical entrapment at the flow front [1]. Theoretical *a priori* models and experimental *in situ* methods with various means to measure bubble formation at the flow front have been developed in attempts to ascertain this optimal velocity. But it remains inherently difficult, especially with opaque carbon fibres, to model the void formation at the flow front. An attempt at back-calculation of the void formation from the final cumulative amount of voids is made assuming that the formed voids all stay in the cured laminate (infusions were purposefully ended before reaching the mould's vent).

Void Movement and Dispersion

There exists a large gap between the areas of void formation and the mechanical effects: the movement/dissolution of the voids after formation and up through cure when the voids are frozen into place. Various studies have focused on individual phenomena through fluid mechanics. In this study, attempts are being made to apply void movement and entrapment/splitting/escape models developed in [2]. The number and size of voids is approximated along recent bubble shape experimentation [3]. The rising pressure causes all bubbles to shrink (Ideal Gas Law) and dissolve into the resin (Henry's Law).

Such predictions require better detailed metrics for dispersion, size, and aspect ratio of the bubbles to finally work its way into shear, fracture and fracture mechanics [4]. An example is shown in Figure 1, a micrograph of cross-sections voids near the flow front, thresholded to put all voids in black. The "stringiness" in the x-direction (along the tows) can be seen, which is thought to predict to crack propagation. Nearest neighbour and 2-point correlation functions measure the "clumpiness" and directionality of the void clusters.

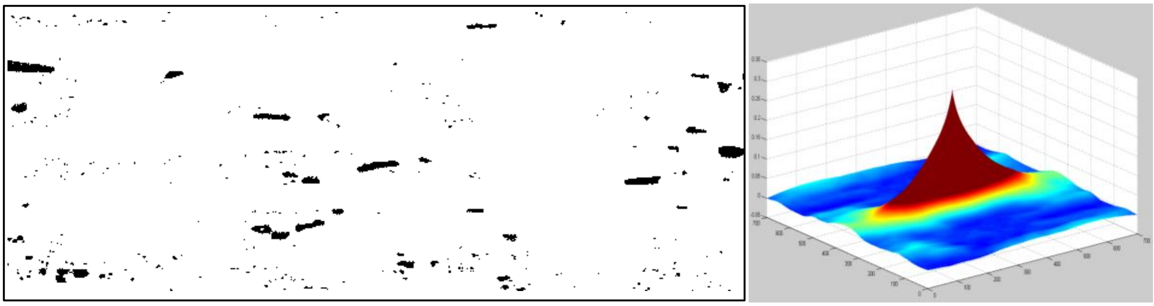

Figure 1: *Thresholded micrograph of voids (left), 2-point correlation showing density and directionality of void clusters.*

To better measure full field void concentrations, ultrasound transmission is being developed to relate this to c-scan attenuation with promising results.

Mechanical Effects of Voids

Previous literature on the correlation of mechanical properties with the local void content has dealt mostly with prepreg materials, while very few published results are available for resin infusion processing. The importance of local testing was seen in interlaminar shear-strength (ILSS) results. Averaging results across a thin row of samples parallel to the flow direction would be expected to result in homogenous data as the flow velocity should be the same in the y-direction for x-direction 1D flow. Irregular binder concentrations are expected to have caused y-direction variation in flow, which suggested that these results be further separated into columns on the laminate surface. Only then does the correlation become clear (Figure 2).

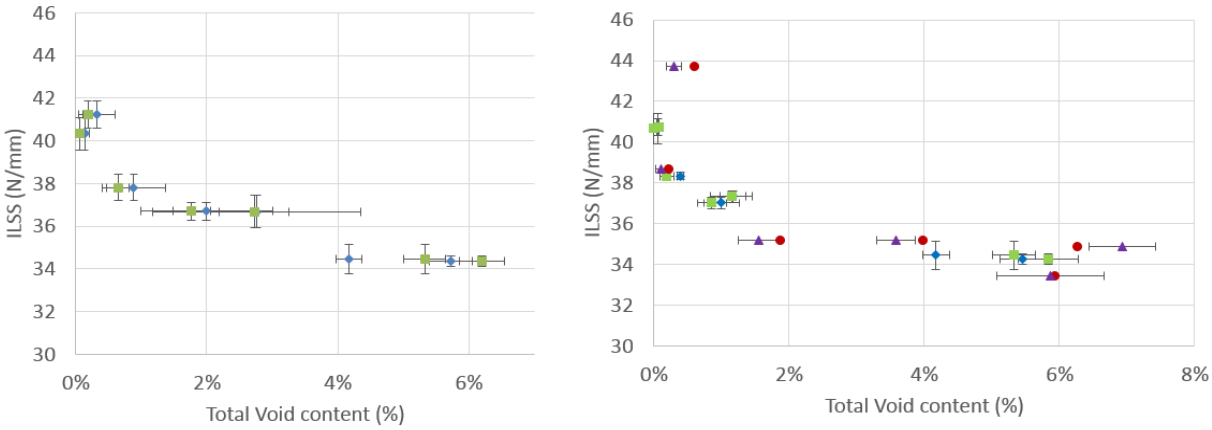

Figure 2: *Local measured void content vs. ILSS, averaged across rows (left) and further split into columns (right).*

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