RIGID TOOLING FOR OPTICAL 3D WETTING PERMEABILITY MEASUREMENTS

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Introduction
A simple method for through-thickness permeability characterization is by point-infusion into the top of a stack of material as presented along with a solution for the flow geometry at the point the resin reaches the bottom of the mould [1]. This method requires little specialized tooling and produces measurements for all three components of the diagonalized permeability tensor in one test. More recent work has simplified the solution for the three unknown fabric permeability components from such a test [2]. Complications exist with this method in comparison with more common 1D saturated flow cells for K_{zz} measurement. These include 1) the compressibility under a vacuum bag, 2) the flow singularity of point-infusion, and 3) capillary pressure effects.
This paper presents a new adaptation of the point-infusion method using rigid tooling comprising thick transparent acrylic sheets for both the top and bottom of the mould. Thus, a hybrid between standard 2D radial testing and 3D point infusion is employed. This method eliminates the complications associated with the thickness gradients under a vacuum bag.

Materials
Both vacuum bag tooling and rigid tooling were used to evaluate the permeability of two fabrics: a carbon biax non-crimped fabric (NCF) (VectorPly C-BX 1800 +/-45° 580 gsm) and a fiberglass biax NCF (JB Martin TG-15-N, 518 gsm, PPG rovings). Fabric samples were cut at 150 x 150 mm. In the bag tests, the carbon was compressed to full vacuum (differential ~860 mbar) to about 61% fibre volume content; the glass to 50% (wet thickness measured during the test).
Two thick acrylic plates (300 x 300 x 80 mm) were machined with 6 mm diameter holes in the top plate, for both inlet and vent lines (Figure 1). The rigid tool's cavity thickness was set by thickness spacers to the same thickness as the wetted height of the vacuum bag infusions, to achieve the same fibre volume contents.

Results
Figure 2 shows all the permeability measurements. Tests done under a vacuum bag are labelled "B1…" and rigid tooling "R1…" As seen, the scatter in the bag testing for the carbon samples is much higher than, and encompass the rigid tooling results. The glass samples show a different story; the scatter is similar, but rigid tooling results are higher than bag results.
This is demonstrated again in Figure 3, with error bars denoting standard error. The rigid tool seems to have achieved much better precision, dropping the standard error from 30% to about 10% for both materials despite having one less sample (4 instead of 5).
The higher results for glass are suspected to be due to the error associated with bag testing of highly compliant materials: it is difficult to know at what height to place the inlet tube. Once the bag is sealed around the tube, vacuum is applied and the compliant, thick glass stack

compresses to a significant degree. If the tube was placed high, then a gap between the bag and the fabric could theoretically result in high flow by the inlet, although the vacuum is thought to mitigate this by pulling the tube down. To prevent this, the tube was pushed farther down than with other materials before locking in place, which is may add more compression by the inlet than elsewhere.

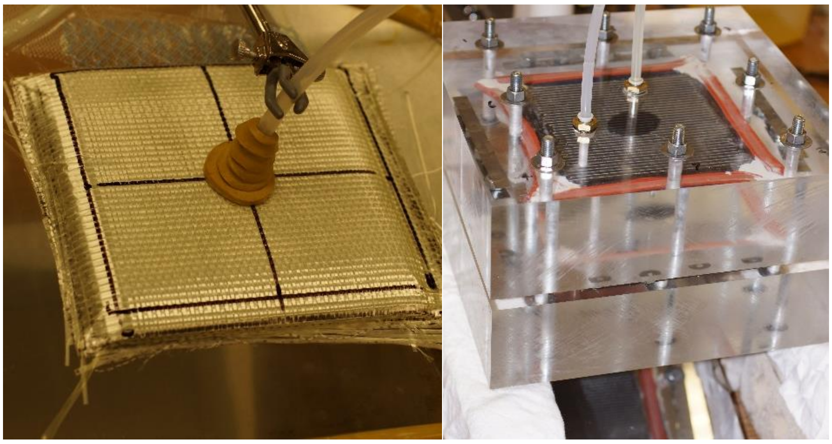

Figure 1: *Permeability measurement tools: vacuum bag (left) and rigid (right).*

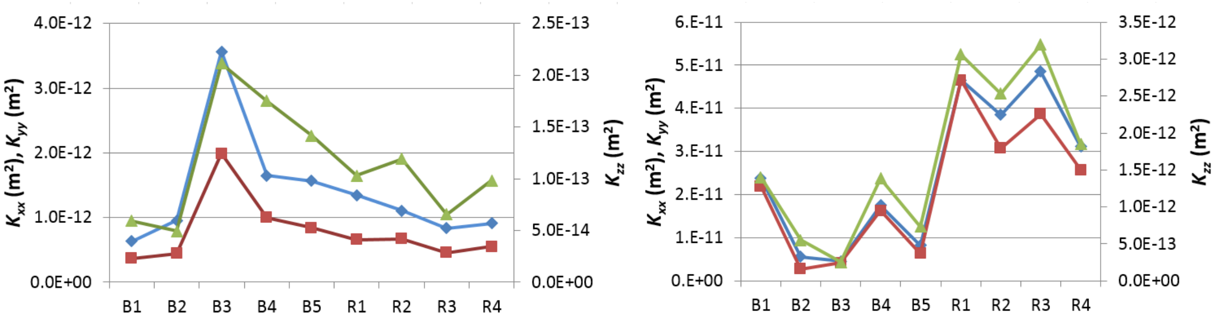

Figure 2: *Permeability measurements for carbon (left) and glass (right):* ♦ = K_{xx}, ■ = K_{yy}, ▲ = K_{zz}.

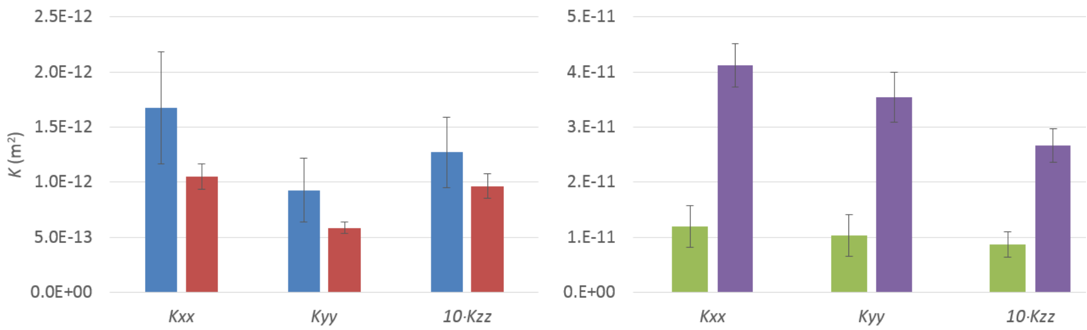

Figure 3: *Permeability measurements for carbon (left) and glass (right): bag tool = left column of each pair, rigid tool = right.*

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References

[1] P.B. Nedanov, S.G. Advani, A Method to Determine 3D Permeability of Fibrous Reinforcements, In: *Journal of Composite Materials*, 36(2):241–54, 2002

[2] A. George, A. Pickett, J. Sirtautas, K. Drechsler, Optimization of 3D wetting permeability measurements, In: *Flow Processes in Composite Materials, Auckland, NZ*, pages 18 – 25, 2012