COMBINED CHARACTERIZATION OF PORE SIZE DISTRIBUTION AND PERMEABILITY IN FIBROUS TEXTILES BY CAPILLARY FLOW POROMETRY

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Introduction

Fibrous reinforcements used in *Liquid Composite Molding* (LCM) processes generally exhibit a dual-scale porous structure that has a direct influence on the resin flow and affects void creation and transport. Previous work showed that Capillary Flow Porometry (CFP) is a promising new technique for fast characterization of the pore size distribution of textile reinforcements [1]. This approach is applied here to study the influence of the flow direction and fiber volume fraction on the pore size distribution. The experiments are also used to measure the air permeability of different fibrous textiles.

Materials and method

A series of tests were conducted using the 3Gz Porometer from Quantachrome Instruments Inc. equipped with the two sample holders of Figure 1. These devices were specially devised to measure the pore size distribution in the in-plane and through-thickness directions with precise control of fiber volume fraction. The test methodology was identical in both configurations. The porous specimen is first soaked with a completely wetting fluid, which is then progressively expelled by applying an increasing air pressure on one side of the sample and recording the corresponding flow rate. This first pressure ramp is called the wet run. Then, a second pressure ramp called the dry run is carried out.

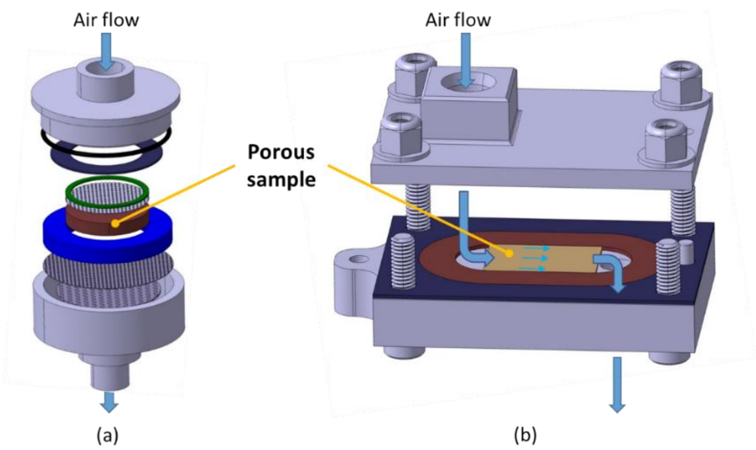

Figure 1: *Sample holders for CFP measurement with fibrous reinforcements: (a) through-thickness; (b) in-plane.*

Determination of pore size distribution

Figure 2a shows typical CFP results obtained with a plain weave glass fiber fabric. Following the standard methodology of CFP, the experimental data were treated assuming an equivalent distribution of parallel cylindrical pores. This gave the pore size distributions of Figure 2b, which provide a quantitative assessment on how the porous structure is affected by compaction. The effective pore size distribution given by CFP when expelling liquid from a saturated fiber bed, much like permeability, depends also on the flow direction. This is not surprising because CFP is a measurement based on a flow process that is influenced by the anisotropic architecture of engineering textiles.

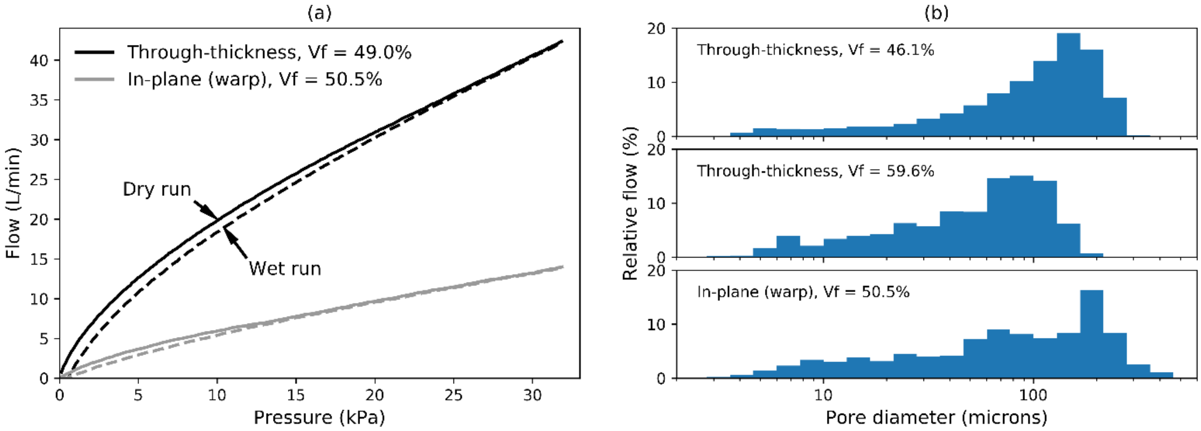

Figure 2: *Typical results from CFP characterization: (a) raw experimental data; (b) pore size distributions.*

Estimation of fabric permeability

The dry run of the CFP experiments can also be used to estimate the air permeability of porous samples. As shown in Figure 2a, a non-linear relationship is observed between the pressure gradient and the flow rate indicating that the classical Darcy's law is not valid under the test conditions of an air flow. Following the approach proposed by Zeng and Grigg [2], the Darcy-Forchheimer equation was considered to take inertial effects into account. Two characteristic parameters denoted x and y were computed from the experiments (see details in [2]) and a linear interpolation was used to determine the air permeability of the porous samples from the intercept on the y-axis (see Figure 3a). Figure 3b compares the air permeability with values obtained by a classical approach based on the filling flow of an incompressible fluid. Both sets of data are described by an exponential model with a shift factor between 2 and 3 between the two results. Knowledge of the shift factor means that CFP could also in the future provide information on the permeability of fibrous reinforcements.

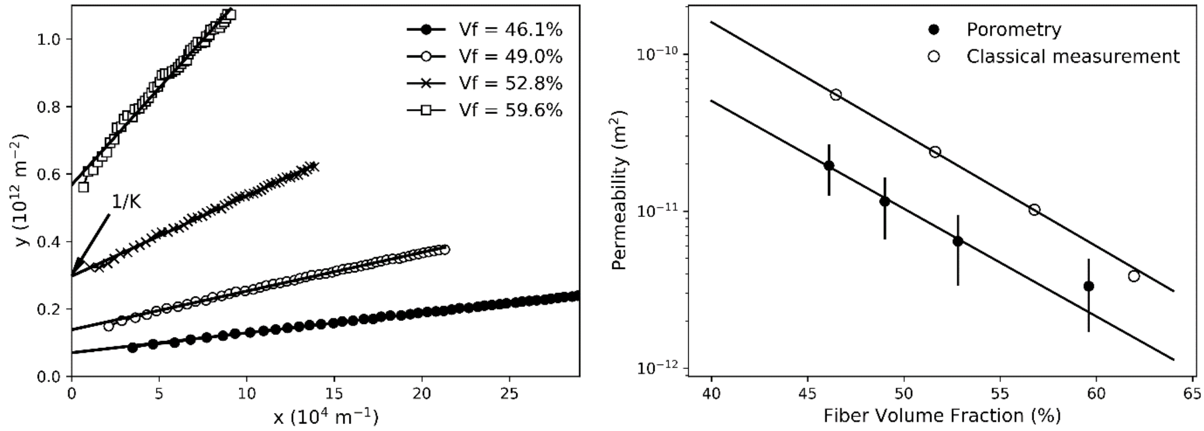

Figure 3: *Analysis of through-thickness permeability: (a) data post-treatment; (b) influence of fiber volume fraction.*

Conclusion

This investigation shows that CFP allows measuring the effective pore size distributions along a flow direction as a function of fiber volume content. In addition, the experiments provide an evaluation on the air permeability of fibrous reinforcements, which could be further corroborated with standard permeability measurements. Hence the information gathered by CFP can complement existing characterisation methods and provide valuable insight on flow processes in composite materials.

References

[1] Bonnard, B., Causse, P., & Trochu, F., Experimental characterization of the pore size distribution in fibrous reinforcements of composite materials. *Journal of Composite Materials*, 51(27): 3807-3818, 2017

[2] Zeng, Z. & Grigg, R., A Criterion for Non-Darcy Flow in Porous Media. *Transport in Porous Media*, 63(1): 57-69, 2006