EFFICIENT METHOD TO CHARACTERIZE TEXTILE PERMEABILITY AS A FUNCTION OF FIBER VOLUME CONTENT WITH A SINGLE UNIDIRECTIONAL INJECTION EXPERIMENT

C. Di Fratta*, F. Klunker, P. Ermanni

Laboratory of Composite Materials and Adaptive Structures, ETH Zürich, Leonhardstrasse 27, 8092, Zürich, Switzerland.
**Corresponding author's e-mail: claudiodifratta@mavt.ethz.ch*

Keywords: *Permeability, Fabrics/Textiles, Liquid Composite Molding (LCM), Measurement Methods, Resin Flow, Resin Transfer Molding (RTM).*

Introduction

The characteristic stage of Liquid Composite Molding (LCM) technologies, such as Resin Transfer Molding (RTM) and its variants, is represented by the resin injection or infusion into a cavity with a fibrous preform. The resin flow is governed by process conditions, mold geometry and material properties [1, 2]. Concerning the latter, a key influencing parameter is the textile permeability. Accurate permeability characterization allows trustworthy prediction of cavity filling times and simulation of flow patterns, which can improve LCM process design and reduce development times [1, 3].

Textile permeability is generally a direction-dependent property and varies strongly with the fiber volume content (FVC). Permeability characterization has been a matter of intensive research in the last decades and several approaches have been outlined [4]. They can be classified according to the type of flow established through the fibrous preform: fully saturated or partially saturated (commonly referred to as unsaturated). A further classification stems from the test direction; for example, it is usual to distinguish between radial and unidirectional experiments in case of in-plane permeability measurements. Although a standard procedure is still missing to date, recent efforts by the scientific community have led to agreed guidelines for unidirectional unsaturated permeability measurements, used in an international benchmark exercise [3]. The majority of the procedures proposed for permeability measurements rely on experiments performed at a given FVC. Since a minimum of three experiments in each direction at each FVC is recommended, numerous material samples and time-consuming tests are typically needed for a full characterization.

The present work investigates a novel method for unsaturated permeability characterization as a function of FVC in a single test. This method, which relies on a simple experimental set-up with only two sensors, allows improving the measurement efficiency and reducing efforts, times and costs of a complete permeability characterization.

Methodology

The methodology is based on a single unidirectional experiment, in which a preform with different FVC sections is impregnated. The experiment can be carried out in the same experimental set-up described in the benchmark exercise [3], with the simple addition of a second pressure transducer embedded in the mold. An algorithm was developed to elaborate the pressure data from the inlet sensor and the cavity sensor, in order to

reconstruct the textile permeability distribution in real time during the impregnation. Therefore, the evaluation time after the test to extract full permeability curves is virtually equal to zero. Another major advantage of this approach is that the permeability can be assessed in conditions similar to the real industrial environment (e.g., elevated injection pressures, flow rates and fiber volume contents), because no visual flow-front observations are required and, thus, a rigid metal mold can be used. Furthermore, the methodology is independent from the adopted injection technique (i.e., constant flow rate or constant injection pressure) and from any information regarding the spatial variation of FVC. It is applicable also in case of continuous changes of fiber volume content along the preform.

Experimental results

The methodology has been validated through series of tests with random mat and woven fabrics. Preforms with three sections of different FVC were impregnated and the permeability of the various sections determined. An example of the resulting permeability distribution is depicted in Figure 1. The obtained results were consistent with permeability values calculated following the guidelines for the benchmark exercise [3], indicating that accurate permeability characterization can be achieved for both kinds of textiles.

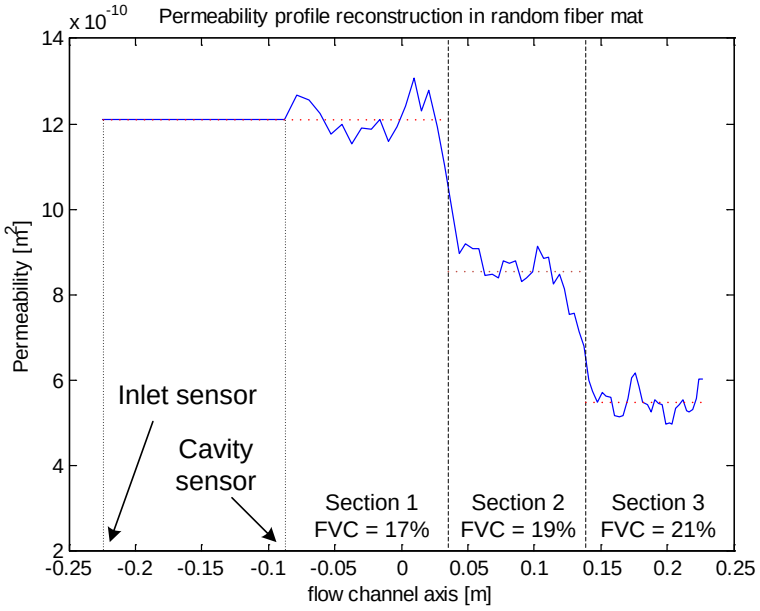

Figure 1: *Permeability reconstruction during the impregnation of a random fiber mat preform with three FVC sections.*

Acknowledgements

Grigorios Koutsoukis and Daniel Filipovic are acknowledged for their support in the experimental validation of the methodology. The authors thank also Prof. Dr. François Trochu from École Polytechnique de Montréal for his precious collaboration to the work.

References

[1] P. Ermanni, C. Di Fratta, F. Trochu, Molding: Liquid Composite Molding (LCM), In: *Wiley Encyclopedia of Composites*, Editors: L. Nicolais, A. Borzacchiello, Publisher: John Wiley & Sons, Inc., pages 1884-1894 , 2012

[2] C. Di Fratta, F. Klunker, P. Ermanni, A methodology for flow-front estimation in LCM processes based on pressure sensors, *Composites Part A: Applied Science and Manufacturing*, 47:1-11, 2013

[3] N. Vernet et al., Experimental determination of the permeability of engineering textiles: Benchmark II, *Composites Part A: Applied Science and Manufacturing*, 61:172-184, 2014

[4] S. Sharma, D.A. Siniger, Permeability measurement methods in porous media of fiber reinforced composites, *Applied Mechanics Reviews*, 62(2):020802 (19 pages), 2010