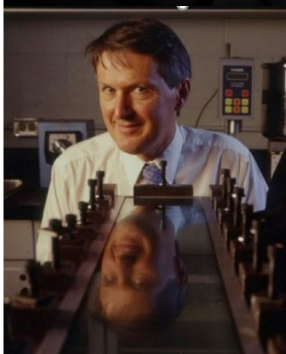


FRANÇOIS TROCHU-POLYTECHNIQUE MONTREAL

LIQUID COMPOSITE MOLDING

THE STORY OF PERMEABILITY IN "LIQUID COMPOSITE MOLDING" (LCM) HOW TO DEVISE AND VALIDATE PROCESS SIMULATION SOFTWARE?

April 14, 2022 at 11:00 AM US Eastern Daylight Time

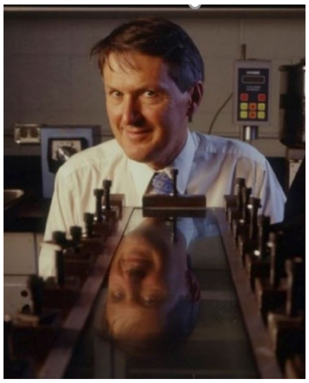
ABSTRACT

Permeability characterizes the capability of establishing a fluid flow through a porous medium. This lecture aims to present a summary on the state-of-the-art knowledge on permeability in LCM together with a discussion on open questions. The Story of Permeability in Liquid Composite Molding (LCM) started in 1986 when Professor Gauvin[1], among other investigators, began using Darcy's law to model Resin Transfer Molding (RTM). Since these early investigations, a large number of research papers were published on permeability in LCM. Several benchmark exercises were also conducted over the years to devise a common way to measure this key parameter for LCM process simulation. Although results from a large number of academic and industrial laboratories have become closer, some questions still remain.

Among the difficulties encountered, the first one was connected with the definition of permeability. What kind of permeability should be considered to model LCM? Saturated permeability as defined in Darcy's law or unsaturated process permeability as introduced in LCM? A second problem arises from the intrinsic material variability of fibrous reinforcements. Finally, how do we measure permeability? In fact, the LCM specific process variant considered plays an important role on how permeability should be measured. The design of the testing device and the processing of experimental data are also key factors to obtain reproducible results. Most investigators conducted different kinds of experiments to measure permeability, which explains why results may vary so much. Note that some researchers even attempted to predict permeability by computer simulation, although without convincing success yet. This lecture will discuss all these factors and present the concept of "process permeability" introduced to validate computer simulations of mold filling in LCM.

In fact, the predictive capability of permeability in LCM is closely connected with computer simulation. Successful experimental procedures will be exposed and discussed to measure the 1D and 2D in-plane and through-thickness permeability in rigid molds. In the case of Vacuum Assisted Resin Infusion (VARI), the concept of "flexible permeability" for direct infusion without a distribution medium will be described and validated. Finally, a new characterization approach based on a single experiment combining permeability and preform expansion will be presented to predict mold filling and thickness variations in VARI. In the case of indirect infusion with a distribution medium, the concept of "apparent permeability" will be introduced. For validation purposes, simulation results obtained with measured permeability will be systematically compared to experiment for each LCM process variant considered. The conclusion will sum up the current research issues on permeability and the principles guiding the definition and measure of this key parameter.

1: Gauvin, R. and Chibani, M., "The Modelling of Mold Filling in Resin Transfer Molding" International Polymer Processing, vol. 1, no. 1, 1986, pp. 42-46. https://doi.org/10.3139/217.860042



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B I O

Born in Montreal (Quebec), Dr. François Trochu graduated from École Polytechnique, Paris in 1974. With a Master degree in Aerospace Engineering from the University of Texas at Austin in 1975 and a PhD in 1990 from Polytechnique Montreal, he is now Emeritus Professor at Polytechnique Montreal.

With more than 130 papers published in scientific journals and over 100 refereed lectures in international conferences, he has worked mainly in Liquid Composite Molding (LCM), a family of manufacturing processes devised to produce high performance composites by resin injection through fibrous reinforcements.

Member of the scientific board of the Flow Processes in Composite Materials (FPCM) international conference since 1994, he developed the original process simulation software PAM-RTM, which has been commercialized by ESI Group since 2001. With more than 100 industrial and academic users worldwide, it is recognized as a leading computer tool to simulate the fabrication of high performance composites by resin injection.

Professor Trochu held during 14 years a renown Tier I - Canada Research Chair on high performance composites at Polytechnique Montreal and two industrial research chairs of five years with General Motors for automotive applications and Safran in the aerospace field. Applying LCM technology in the automotive and aerospace sectors gave him practical experience and a comprehensive vision of industrial needs.

He contributed recently to the creation of a new concept called “Digital Material Twin” (DMT) to construct, with a controlled accuracy, multiscale geometric models of complex fiber architectures from 3D voxel images obtained by X ray microtomography. This new approach allows analysing the mesoscopic structure of fibrous reinforcements and aims to predict by computer simulation the mechanical and flow properties of high performance composites.