Darcy-based viscosity measurement for fast curing resin systems

D. Becker[1*], P. Mitschang[1]

[1] *Institut fuer Verbundwerkstoffe GmbH, Erwin-Schroedinger-Strasse, Geb. 58, 67663*
*Corresponding author (david.becker@ivw.uni-kl.de)

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Introduction

The demand for shorter cycle times in processes such as Resin Transfer Molding (RTM) has forced up the development of highly reactive resin systems. Some resin systems can reach complete curing in less than one minute. Simultaneously, knowledge about the resin processing characteristics, especially the time- and temperature-dependent viscosity, is essential for the process design. But, given the extremely fast reaction of highly reactive resin systems, the limitations of conventional viscosity measurement approaches, such as shear rheometers, are often exceeded. Especially at the beginning of the reaction no values are captured, due to mixing and application procedures.

Objectives

The target of the presented study was to develop and validate an approach specifically designed for an RTM-related viscosity measurement. The approach is based on the law of Darcy which is commonly known as the basis for the measurement of textile permeability. The basic idea is to virtually invert a permeability measurement: instead of using reference fluid to measure the unknown permeability of a porous structure, a porous structure of known permeability is used in order to measure the unknown resin viscosity. To calculate the time-dependent viscosity development based on experimental data of flow velocity, injection pressure, and permeability a Darcy-based algorithm has to be developed. The resulting viscosity data can then for instance serve as input for Liquid Composite Molding (LCM) simulations. The idea is illustrated in Figure 1.

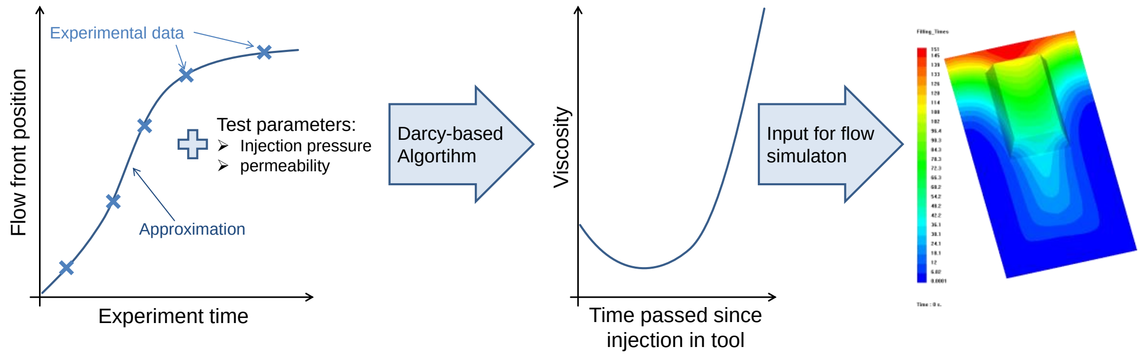

Figure 1: *Calculation of the time-dependent viscosity of resin injected in to the tool based on the experimental data and possible usage of result for LCM simulation.*

Experimental Set-up & Validation Methods

To validate the approach a prototype system was built-up (Figure 2, left) which provides a one-dimensional flow and flow front progression monitoring via capacitive sensors. The system can be heated to different temperatures, just like an RTM-tool. As reference porous structure micro glass spheres were chosen (Figure 2, middle), because they are non-deformable and are quasi-homogeneous. Also, the permeability can be adjusted to be in the range of textiles (e.g. ~3E-11 m² at a diameter of 0.25 mm). A further advantage is that the glass spheres provide single-scale porosity, which leads to a sharp flow front. Experiments proof the homogeneous impregnation of the pore space (Figure 2, right).

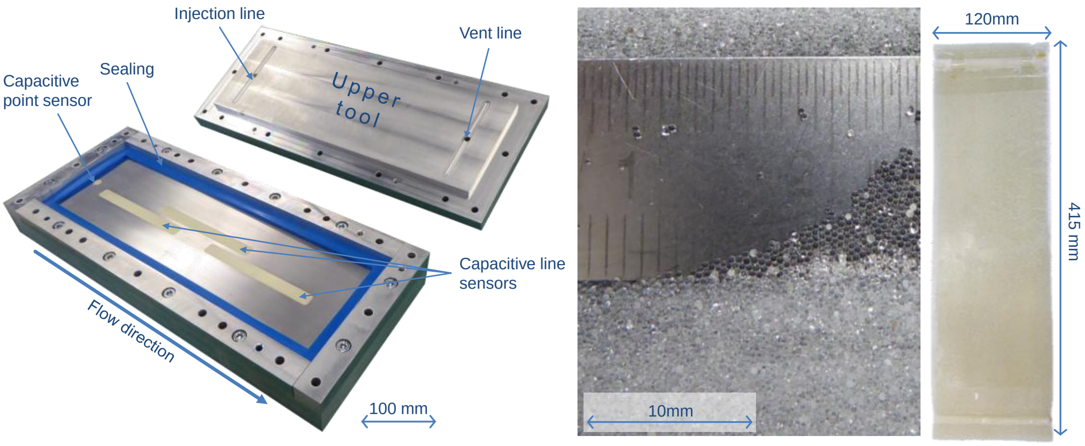

Figure 2: *The 1D-CapaVisco system used for the RTM-oriented viscosity measurement (left), micro-glass spheres as positioned in cavity before (middle) and after infiltration (right).*

In a first step the algorithm was validated, by performing 1D-flow simulations and using the resulting flow front progression as input for the developed algorithm. Then the viscosity development calculated by the algorithm was compared with the input of the flow simulation. In a second step real-life experiments were performed, by injecting a fast-curing resin system in the prototype system via an RTM injection system. Injection pressure, tool and resin temperature were varied.

Results & Outlook

The validation of the algorithm via flow simulation proofed mathematical correctness of the algorithm. Yet, the algorithm had to be extended by strategies for coping with inaccuracies in flow front movement. The real-life experiments proof the basic functionality of the principle but also revealed potential for improvement. In this context further research will focus on flow front detection strategy (sensor placement), heating strategy and automation.

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