ANALYSIS AND SIMULATION OF DRY-SPOT BEHAVIOR IN LIQUID COMPOSITE MOLDING

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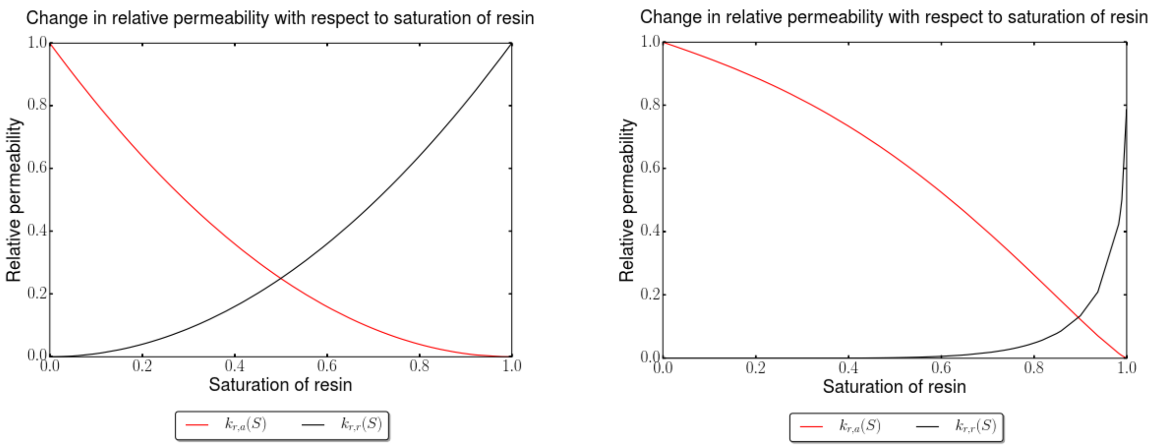
Introduction

Due to industrial automation of liquid composite molding processes and increasing geometrical complexity of composite components, dry-spots from flow front junctions have become increasingly difficult to avoid. Experiments show that formation of a dry-spot in an early stage of an injection process does not necessarily lead to scrap parts. Therefore, simulation-based predictions of dry-spots are no sufficient condition for identification of unsuitable injection strategies. [1] Consequently this paper presents first results of numerical simulation of dry-spot dynamics in LCM process.

Relative permeability models

Due to the low flow velocities and porous nature of the fiber, two-phase simulation of air-resin system is based on the pressure-saturation approach formulated using Darcy's law. The relative permeability model takes into account the influence on the flow of each phase in the presence of the other phase. It therefore depends on the saturation of the resin phase as seen in Figure 1.



(a) Brooks and Corey model

(b) Van Genuchten model

Figure 1: *An example of variation in relative permeability curves for two models*

With the priority to study the decrease in unsaturated area (dry-spot) and the rate in which it is saturated (filled with resin), the regime of interest for relative permeability curve is considered to be filled initially with air completely. Then resin displaces air. Two models to calculate relative permeability, which take the effective saturation for calculating the relative permeability of air and resin, are of interest. Firstly, a power law constitutive model or Brooks and Corey model [2]. Secondly, Van Genuchten model [3].

Modification based on air-fraction parameter

The introduction of an air-fraction scalar term and the modification of the pressure equation provide an additional term apart from the empirical term associated with relative permeability model, to optimize the simulation. The foremost interest is to improve the results using an optimized air-fraction term which relates to the amount of mobile air entrapped in a system suggested by Gascón, L. et al [4]. This additional parameter implementation, along with the assumptions that total velocity is approximately equal to the velocity of resin and velocity of mobile air is equal to the velocity of resin, was considered to modify the pressure and saturation equation.

Results

Numerical investigations showed that the user-defined relative permeability values (maximum attainable relative permeability of each phase and power coefficient value) associated with the relative permeability models have a high influence on the numerical simulation. The choice of the best relative permeability model and the optimization of the parameters based on simulation condition is a necessity for approximating the experimental results.

The numerical simulation with Van Genuchten relative permeability model [3] showed considerably good agreement with the experimental results for lower power coefficient values. Whereas, the Brooks and Corey model [2], which happens to be computationally faster, did not match experimental results.

With a view to possibly improve the simulation results of a computationally faster relative permeability model, the pressure-saturation equations modified with the air-fraction term [4] showed good relation between approximating experimental observation and low computational cost, as seen in Figure 2. The air-fraction term enables a better control on the simulation.

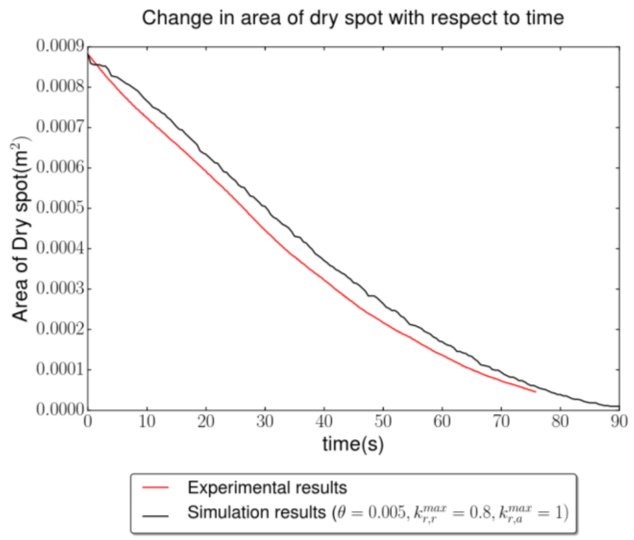


Figure 2: *Comparison of simulations results with experiment*

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