AN EXPERIMENTAL STUDY ON THE INFLUENCE OF FLOW CHANNEL GEOMETRY ON THE FLOW FRONT PROGRESSION IN RESIN TRANSFER MOULDING

C, Kracke.[1]; B. Staudt.[1]; S. Bickerton[2]; P. Mitschang[3]

[1]*BMW Group, Ohmstraße 2 84030 Landshut, Germany*
[2]*Centre for Advanced Composite Materials, University of Auckland, Private bag 92019; 1142 Auckland, New Zealand*
[3]*Institut für Verbundwerkstoffe GmbH, Erwin-Schrödinger-Straße, Gebäude 58; 67663 Kaiserslautern, Germany*
*Corresponding author (Christoph.Kracke@bmw.de)

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Introduction

Automotive composite manufacturing requires cost effective, fast and stable processes. Resin Transfer Moulding (RTM) in combination with automation offers those benefits. This work focuses on the resin distribution system consisting of flow channels integrated into the tool. Flow channels across the part surface reduce the longest distance the fluid has to travel through the preform. Those flow channels offer high potential to reduce the flow resistance and improve the stability of the RTM-process. In practice, the distribution system is often divided into many different branches and the associated flow channels have different cross section sizes. In [1] different injection gate forms have been investigated, with the result that the length of the flow channel is particularly important. An influence of the flow channel cross section shape on the injection time has not been proven. In [2] optimal cross section shapes for heated flow channels in injection moulds are discussed. In this work the optimal solution is a full circular channel shape. For applications, where the flow channel is only applied to one tool half, the optimal solution is a parabolic shape. The targeted application of flow channels and their interaction with the textile in the RTM-process has yet to be investigated.

Objectives

In this work different flow channel cross section area sizes and shapes (Fig. 1 experiment 1) and the manipulation of the flow front progression through a changing flow channel cross section size are investigated (Fig. 1 experiment 3). Also the density of the flow channels and the corresponding length of those flow channels is varied (Fig.1 experiment 2). Two different textiles (carbon fibre non crimped fibre textile and a random fibre glass fibre textile) are used to show interactions between the flow channel cross section area size and the permeability of the textile.

Experimental Setup

For the experiments a completely transparent mould was used, which allows the continuous monitoring of the flow front on both sides by the use of two cameras (schematic on the left side in Fig. 1). The fluid was injected with a constant pressure of 3 Bar. Some deflection of the glass plate was noted depending on the injection pressure and position in the mould. The injection pressure distribution itself was dependent on the flow channel set up. The cavity height of 2.1 mm increased by values between 0.1 mm (near the circumferential clamping) and 0.39 mm (worst case for the centre of the mould). The pressure and fluid distribution was simulated using PAM RTM and results compared with the deformation for different positons of the mould and the flow front progression during the experiments. The influence of the glass plate deflection was considered for the final result interpretation.

A sunflower oil was used as a substitute fluid in the experiments instead of an epoxy resin (58.7 mPa s at 23.4°C compared to an average epoxy resin viscosity during injection 62 mPa s at 80°C). The recorded flow front images were analysed using Matlab to determine flow front length and fluid covered area. The tool halves could be switched easily, one tool half had integrated pressure sensors. Vacuum was applied outside the circumferential clamping area.

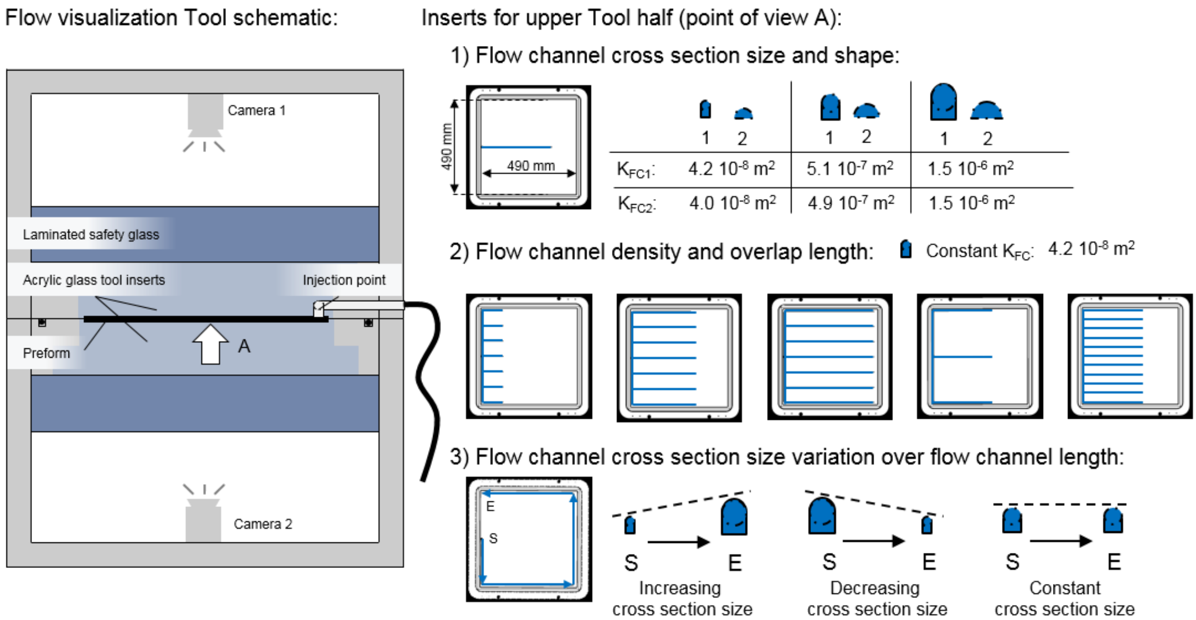

Figure 1: *Left side: Schematic of the transparent flow visualization tool. Right side: Overview of the design of experiments. 1) Variation of flow channel cross section size and shape, 2) Variation of flow channel density and length, 3) Flow channel cross section size variation over the flow channel length.*

Results

In the first series of experiments an influence of the cross section shape and size is observed. The injection time converges with an increasing flow channel cross section size. The parabolic flow channel shape has a significant shorter injection time for the small flow channel permeability (K_{FC}: 4.2 10^{-8} m^2) compared to the semicircle flow channel shape. The two other flow channel sizes, show no effect of the flow channel shape. While for the two larger cross sections a parallel flow front is observed, the small flow channels show an angle between the flow front and flow channel edge. This is similar to the investigated influence of not intended flow channels (race-tracking) in [3]. The angle leads to an improved filling behaviour for the second series of experiments, since a “V” shaped flow front between the flow channels avoids air entrapments, compared to a “U” shaped flow front for larger cross sections. In the third series of experiments the increasing cross section leads to longer injection times. The small cross section at the start acts like a throttle for the rest of the flow channel. Therefore, the increasing flow channel cross section size has no effect in this case. The decreasing and constant cross section size lead to shorter injection times, which are similar to each other. The results of the experiments are an important basis for the dimensioning and arrangement of the flow channel distribution system in RTM tools.

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