FLOW AND FILTRATION BEHAVIOUR OF BOEHMITE NANOPARTICLE-FILLED MATRIX SYSTEMS IN RTM PROCESS

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1. Introduction

Liquid composite moulding (LCM) processes display various advantages for the manufacture of fiber-reinforced plastics compared to their prepreg-based counterpart. These advantages include lower cost and better suitability for complex-curved structures. Using nanoparticle filled matrix systems in LCM processes shows a promising route to increase the performance by reducing resin shrinkage and increasing its toughness while keeping the advantages of LCM processes.

The matrix flow behavior and textile permeability properties are the most critical factors in LCM processes. The application of nanoparticles in the matrix may influence its flow behavior and permeability of the preform significantly due to the increased interaction between the fibers, matrix systems and particles — even in some cases leading to filtration of the particles along the flow length.

In this paper, the flow behavior of a nanoparticle filled matrix system is investigated. The focus lies on investigating and correlating the filament distance distribution of the preform to the flow behavior of the particle-filled suspension in the preform.

2. Materials

The matrix used for the experiment is epoxy resin with corresponding hardener and accelerator (Epoxy: LY 556, Hardener: HY917, Accelerator: DY070) from Huntsman Advanced Materials (Switzerland) GmbH. A quasi-unidirectional carbon-fiber textile (Style 796) from Fa. ECC which has an average areal weight of 270 g/m^2 (warp/0 °direction: 400 tex carbon fiber, weft/90 °direction: 34 tex glass fiber for stabilization). Boehmite nanaoparticles (primary particle size of 20nm) are dispersed into the epoxy matrix by 40 wt%, to produce masterbatches in the institute for particle technology- TU Braunschweig. The x10%, x50% and x90% valued of dispersed particle size within the produced masterbatch is separately 81 nm, 104 nm and 134nm. For the injection experiments, the masterbatch is diluted to 5 wt% of particle concentration with a planetary mixing machine (Thinky Mixer ARV-310).

3. Methodologies

Filament distance distribution characterization: Considering the flow behaviour of the particle-filled epoxy system in the textile, it is quite critical to understand the porous structure of the fibrous preform, to analyse the particle flow and filtration mechanism in the porous textile structure. Considering the stochastically distributed filaments in a laminate cross section, Nearest Neighbour Distance (NND) and Neighbour Distance (ND) was systematically characterized. For the calculation, a custom software with image fuzzy recognition and related algorithm was developed to accurately detect each filament and their distance in a laminate cross section.

Injection process & filtering effect characterization: a special RTM-tool was developed which enables the withdraw of fluid samples, depending on the flow length and time, directly during the injection. Injection experiments were carried out with different FVF (40%, 50%, 60%) parallel to fiber directions. Fluid boehmite/epoxy samples were taken out directly from the RTM tool by different flow length and time, and the particle concentration was measured by Thermal Gravimetric Analysis (TGA).

4. Results and discussion

4.1 Filament distance distribution vs. FVF

According to the results of NNCD in figure 1, it could be shown that the average value of the smallest distance between the filaments is around 0.138 um at FVF of 30%. It stays almost constant until FVF 55%, and begins to decrease remarkably from FVF 55%, until 0.00426 um by FVF 70%. This changing trend indicates a critical phase transition in the textile porous structure: as the FVF is low, the textiles show a dual-scale porous structure. With the increase of the compaction, the macro-pores begin to vanish, so the porous structure of the textiles becomes more homogenous, resulting at the end a quasi-single-scale porous structure.

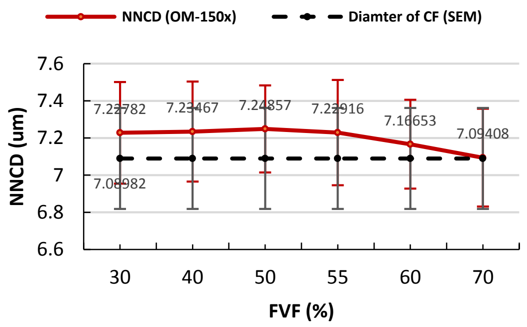

Figure 1: *NNCD vs. FVF*

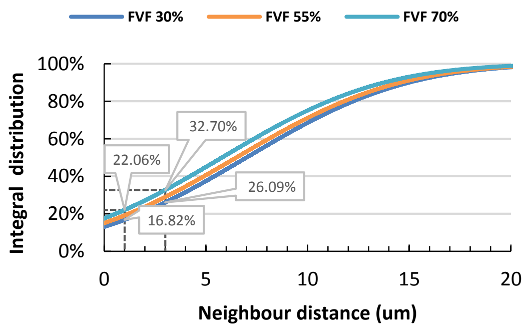

Figure 2: *Neighbour distance distribution vs. FVF*

4.2 Particle filtration vs. FVF

According to the filtration of the particles, as shown in the figure 3 below, it could be found that the retention is rather small by FVF 40% and 50%, however, by 60%, a severe filtration phenomenon could be observed- about 78% of the particle are filtered at a flow length of 100 mm.

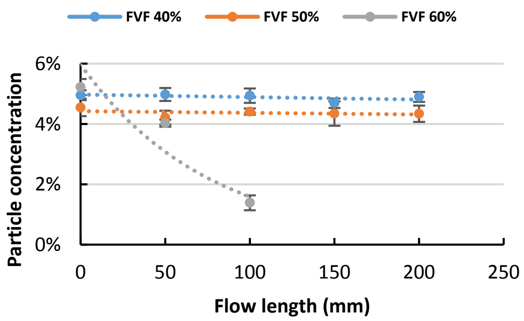

Figure 3: *Particle concentration along flow length by different FVF*

5. Conclusion

Combining the results of NNCD and filtration, it could be assumed that significant change in the filtration behaviour is directly related to the critical FVF as described earlier. Below the critical FVF, in this case 55%, where the impregnation is dominated by dual-scale flow, the filtration seems negligible as particles could mainly flow between the macro-channels between the rovings. However, above this critical FVF by which the macro-channels disappear, only leaving micro-channels between the filaments, a remarkable filtration was observed which could severely influence the impregnation.

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