MODELLING THE MOTION OF OBLATE AND PROLATE PARTICLES DURING IMPREGNATION OF DUAL-SCALE FABRICS

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Introduction

When manufacturing fibre reinforced polymer composites using liquid moulding micro and/or nano scale particles may be added to the resin with the purpose to give the final product additional properties. [1] In the fabrics used the fibres are often gathered in bundles and thus relatively large channels are formed in the gaps between the bundles where the impregnating fluid flows. This generally increases the processability but there may be a competition between the flow in the inter bundle channels and the flow in micro channels formed between the fibres in the bundles. At the impregnation flow front a relatively large capillary induced pressure gradient may drive the flow impregnating the bundles. Experiments have, for instance, shown that the flow front in a pressure driven flow is initially leading in the larger channels between the bundles but that the fluid velocity in the bundles will eventually surpass that of the velocity in the channels and thus becoming the leading front. [2] This may for example, lead to void formation and aggregation of particles. [3, 4]

Geometry and Flow Field

The gaps between the bundles in which the particle infused resin flows are represented as a cylindrical channel with a radial capillary driven pressure component calculated for each time step as dependent on the position of the flow front both in the gap, y_g, and in the bundle, y_b.

A rather extensive analysis and usage of relevant processing and material parameters yields that in the first phase of the process the flow front in the gap is leading while the capillary pressure in the bundles creates a radial component to the flow in the area of $y < y_b$. This component will be so large that in the second phase the flow front in the gap start to move backward until the third phase where it is overtaken by the front in bundle and changes direction once more. This process can be seen in Figure 1 where the time scale is crucially dependent on the processing conditions and the material properties.

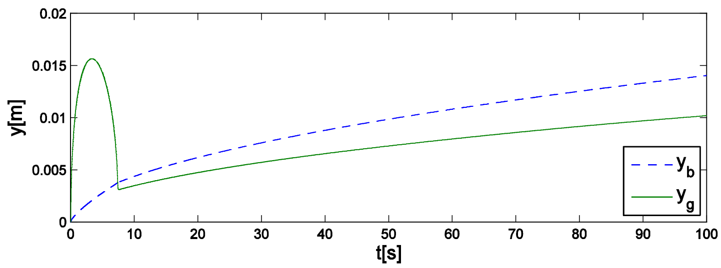


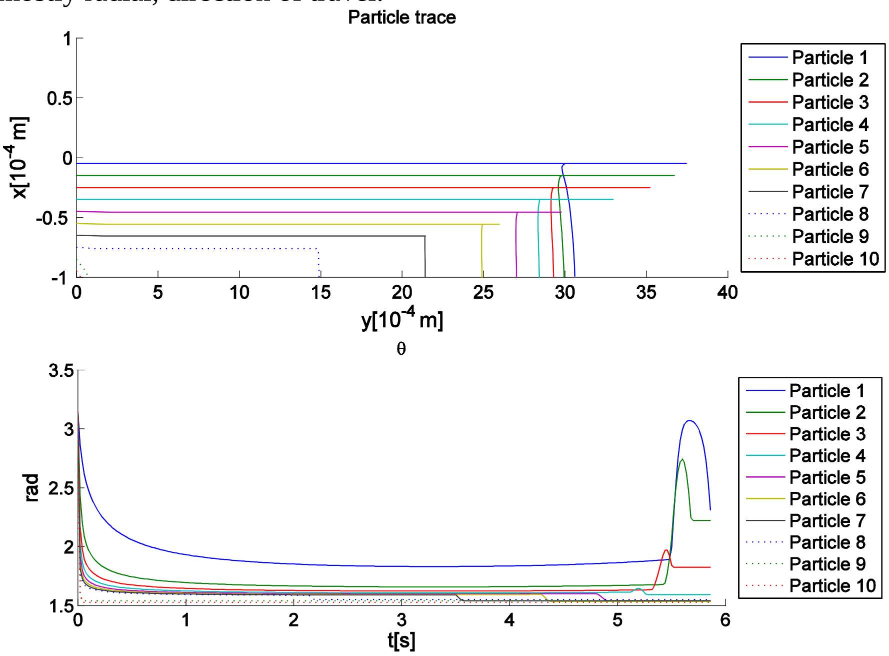
Figure 1: *The development of the flow front both in the gap and in the bundles over time.*

Particles Inserted Into the Resin

The particles in this study are spheroids of prolate, oblate and spherical shape where the hydrodynamic drag force is acting on individual particles [5]. The effects of both Brownian motion and gravity, although small, are included in the study. The effect of varied particle geometry, size and injection time is studied, evaluating both single particles as well as a statistical aggregate on particle deposition in the channel wall.

In Figure 2 (a) ten oblate particles have their starting position along the negative x axis at $t = 0$ and the paths they take in the gap when affected only by the hydrodynamic force are plotted. The particles make quick forward progression in the initial phase when the flow front in the gap progresses rapidly, although not as far as the flow front presented in Figure 1. The particles closest to the centre of the channel reverse their velocity during the flow fronts retardation phase until the flow front in the bundles catches them up. The radial component of the flow in the gap is very large close to the position of the flow front in the bundles so particles are almost instantly sucked to the side of the channel where they fulfil the deposition criteria and stop. Particles that are the closest to the centre of the channel travel furthest due to the parabolic nature of the flow. Particles closest to the channel wall will not experience a reversal in velocity direction since their progression are so slow that the flow front in the bundles catches up to their position before the retardation phase begins and the bundles radial capillary effect transports them to the channel wall.

In Figure 2 (b) the angle θ, which is the angle between each particles normal vector and the y axis of the channel is plotted as a function of time for the same particles. As seen the oblates rotate slowly with the flow field at different timescales dependant on their radial position. If continued undisturbed these particles would be seen to rotate in Jeffery orbits. In phase two of the flow this rotation is reversed, which can most easily be seen by observing Particle 1 at around the four second mark. Then as the flow front in the bundles overtakes them the particles rotate rapidly to align themselves with their new, mostly radial, direction of travel.



(a)

(b)

Figure 2: (a)*The trace left by ten oblate particles released at t=0 and evenly distributed along the negative x axis.***(b)** *The angle between the normal vector of the particles and the y axis as a function of time*

Acknowledgements

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