DEFORMATION MECHANISMS IN COMPRESSION MOLDING OF DISCONTINUOUS THERMOPLASTIC COMPOSITES

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Introduction

Compression molding of long discontinuous fiber reinforced thermoplastic composites in the form of chopped tapes also called bulk molding compounds, offer good formability as compared to press formed continuous fiber composites. Complex shapes can be manufactured with high fiber content with compression molding [1], which makes these thermoplastic composite chopped tapes a good candidate for industrial applications. However, in order to manufacture predictable and reproducible products, the essential material behaviour needs to be identified, modelled and characterized. The study of the deformation and flow behaviour of chopped tapes showed that there are still unanswered questions regarding the material behaviour [2].

This work focuses on the identification of the deformation mechanisms that play a role during the compression molding process when the resin is in the molten state. Different experiments were performed to understand the interaction between fluid and fibers during the filling stage of compression molding process. Chopped unidirectional tapes of the thermoplastic composite were used for the experiments in two different molds under different conditions.

Experimental methods

Type 1:

Two access panels (used for accessing a hinge in the rudder of an aircraft) were manufactured with TenCate Cetex® Carbon/Polyphenylene sulphide (C/PPS) TC1100 unidirectional tapes. The objective of this experiment is to observe the deformation behaviour of chopped flakes in high fiber volume fraction with different process settings. The fiber volume fraction (V_f) of the material is 59%. The nominal processing temperature is 330 °C and the polymer has a glass transition temperature (T_g) of 90 °C. The semi-preg tapes were chopped into flakes of length 10 mm and width 6.3 mm. The access panels were consolidated at different pressure (10 bar and 15 bar).

Type 2:

Flake deformations and flow behaviour of chopped flake reinforcements vary significantly in the ribs, as seen in the work done at the University of Twente [1]. Therefore, experiments in a small 60 mm x 60 mm mold with a deep rib were also performed. PES (Polyethersulfone) 48C30L11 material provided by Vaupell was used in this study. The fiber volume fraction (V_f) of the material is 30%. The nominal processing temperature is 360 °C and the polymer has a glass transition temperature (T_g) of 213 °C. To observe flake deformations after full consolidation, silver painted flakes and Glass/PPS flakes were placed on selected locations.

For the qualitative analysis of the experiments, and in order to observe the deformation of flakes, microscopy and specimen milling were used. In the specimen milling, microscopic images were made at different depths through the specimen thickness by removing layer by layer parallel to the surface.

Results

Flake deformations observed during the process are shown in the figure 1. Intra flake shear, in plane deformation of flakes (flake spreading, fiber bending) and fiber matrix separation are the dominant mechanisms. These mechanisms show dependence on geometric parameters like flakes orientation and their contacts with their neighbouring flakes. However, these chopped flakes are distributed manually in the mold so controlling these parameters is not possible. In spite of the difference in volume fraction in both compression molding experiments (access panel and deep rib experiment) the deformations in flakes are similar. Marked flakes in type 2 experiment were identified not only on the surface of the sample but also in the thickness direction. Which showed that the deformation on the surface of the specimen is similar that in thickness directions (figure 1, bottom left), although no-slip boundary condition is observed on the surface of the mold. Increase in deformation of flakes was also observed when there is a change in the geometry e.g. transition from plane section to rib. Flake deformations also show dependence on local flow gradient, which do vary on different locations as observed from the different deformations of the flakes. In specimen milling sample (from type 2 experiment) flake deformations, resin rich area and voids can be seen (figure 1, bottom right). These resin rich spots area and void do tend to increase in the thickness direction of the specimen. The formation of resin rich areas is due to the restriction on the motion of fibers due to their local interaction on fiber level.

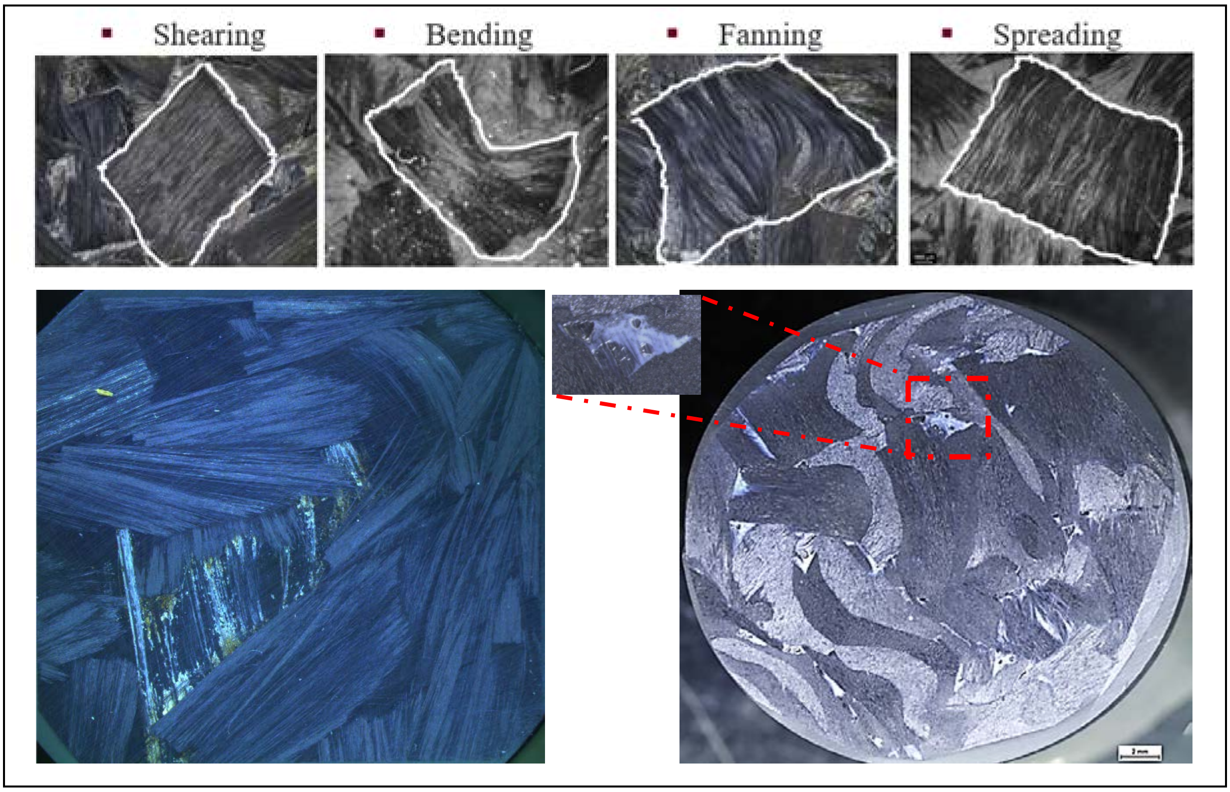

Figure 1:*(Top) Flake deformations observed from the surface microscopy of samples. (Bottom) On left specimen milling sample with marked flake (type 2 experiment) on right sample from type 1 experiment with resin rich spots and voids.*

Future work

Further work on the quantification of the identified deformation mechanisms is in process. These identified mechanisms will be used to develop a mathematical framework which can describe these mechanisms. Furthermore, simulation of the compression molding process of chopped tapes is also a part of the future work.

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