INVESTIGATING FIBRE ORIENTATION, DISPERSION AND LENGTH REDUCTION IN LONG GLASS FIBRE REINFORCED INJECTION MOULDING

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Abstract

Fibre reinforcement of commodity polymers, such as polypropylene, is a well-established method for the manufacture of components with significantly increased mechanical performance compared to their unfilled counterparts. Glass fibre polymer composites typically incorporate short fibres (250 µm) or long fibres (up to 30 mm in pellet form) within a polymer matrix (PP or Nylon for example). The mechanical properties of any component mounded from these materials is highly dependent on the final fibre orientation, in the case of short and long fibres, alongside fibre length distribution and overall fibre dispersion for the long fibre reinforced materials.

In this paper we investigate fibre orientation, fibre length distribution and fibre dispersion developed within a centre gated disc geometry, Figure 1, both experimentally and, in the cases of fibre orientation and length, through numerical analysis within Autodesk Simulation Moldflow Insights 2016.

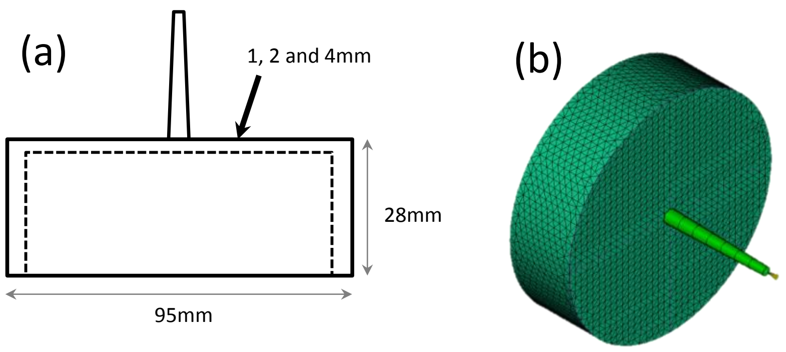

Figure 1: Centre gated disc geometry: a) sample details b) Moldflow mesh

The primary goals of this investigation are:

1. to compare the differences and similarities between short and long fibre orientation developed within the disc region of the sample alongside validation of orientation predictions within AutoDesk Moldflow
2. to evaluate, in the long fibre reinforced case, the fibre length distribution at various locations within the moulding, including the sprue and nozzle sections, and comparisons with predictions from AutoDesk Moldflow
3. to evaluate, in the long fibre reinforced case, the fibre dispersion at various locations within the moulding, including the sprue and nozzle sections

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Fiber Orientation

Samples of 40% wt short glass reinforced nylon 6 were moulded from Rhodia 216 v40 using material suppliers moulding conditions. Following a two week rest period, samples were taken at 2 locations along the flow path on the main central disc, locations C and D in Figure 2, and fibre orientation measured using University of Leeds in-house technique [1, 2].

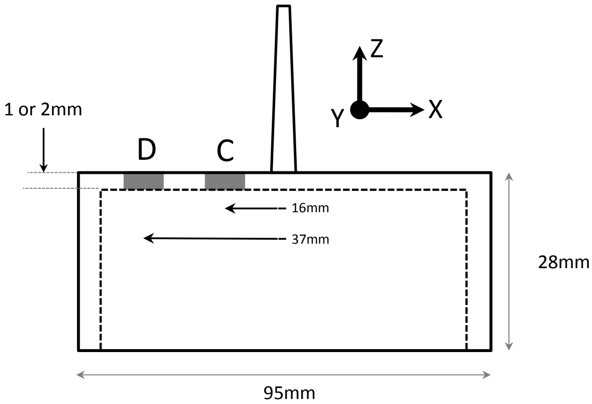

Figure 2: Fibre orientation measurement locations

Fibre orientation predictions within Autodesk Simulations Moldflow Insight 2016 were also conducted, with parameters for orientation models provided by previous work [3]. Fibre orientation predictions, and their effect on predicted mechanical performance, will be more clearly discussed in Dr P Hine's paper 'Assessing a Complete CAD Solution for the Design and Use of Short Fibre Composites'.

A typical fibre orientation prediction comparison for the 1 mm disc is shown in Figure 3 below.

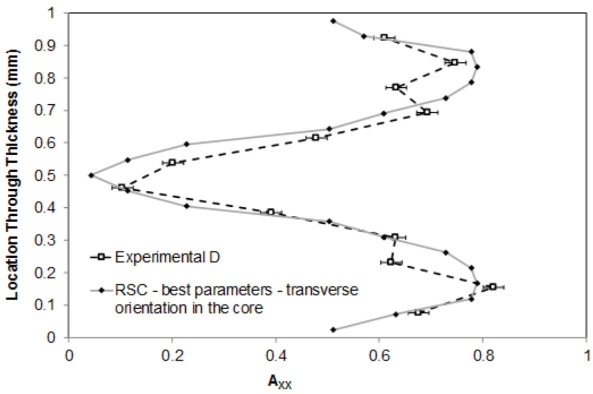

Figure 3: Fibre orientation measurement and predictions within the centre gated disc mounded from short fibre reinforced nylon 6.

Fibre Breakage

In the case of long fibre reinforced materials, the extent of fibre breakage during the injection moulding process has a significant effect on the final mechanical performance of a given component. In order to investigate this effect, fibre length measurements have been taken at specific locations in the centre gated disc. Fibre length predictions within AutoDesk Simulation Moldflow Insights were also conducted, using their inbuilt fibre breakage model, to assess the

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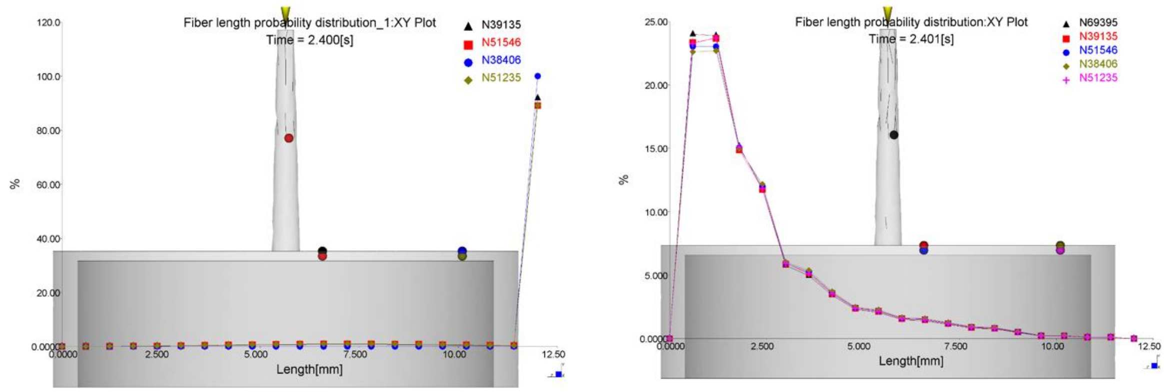
validity of the analyses. Tests were conducted using Sabic Stamax 40% wt long fibre reinforced PP, initial fibre length 12 mm.

Figure 4 shows the fibre length distribution for the 1 thick disc, within the sprue and disc regions, based on the default inlet condition of fibre length 12 mm and when a fibre length distribution based on “air shots” is employed.



Default Inlet Length Distribution Inlet

Figure 4: Fibre length predictions within Autodesk Simulation Moldflow Insights using default and profiled fibre length inlet conditions.

As Figure 4 demonstrates, with the default inlet condition of 12 mm fibre length shows negligible fibre breakage, with fibres within the disc region predominantly unbroken. Predictions using the length distribution inlet condition are more indicative of actual fibre length distributions, as they take account of fibre breakage within the screw component of the injection moulding process.

Fibre Dispersion

As part of the long fibre investigation two different nozzle geometries were examined, as fibre breakage and dispersion of longer fibres has been shown to be highly dependent on the early stages of the injection moulding process [4, 5]. The geometry, shown in Figure 5, includes 3 or 6 mm exit points with a 60 degree inclusive angle at the end of a 10 mm diameter nozzle. An additional ball nosed machined nozzle geometry has also been explored with the same core and exit diameters.

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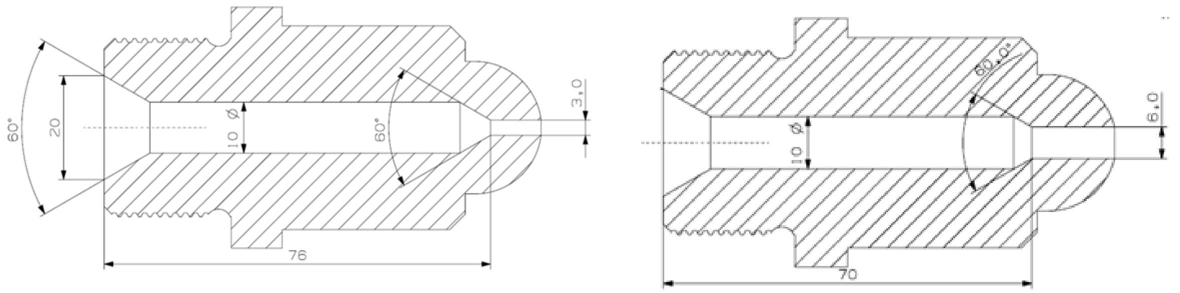
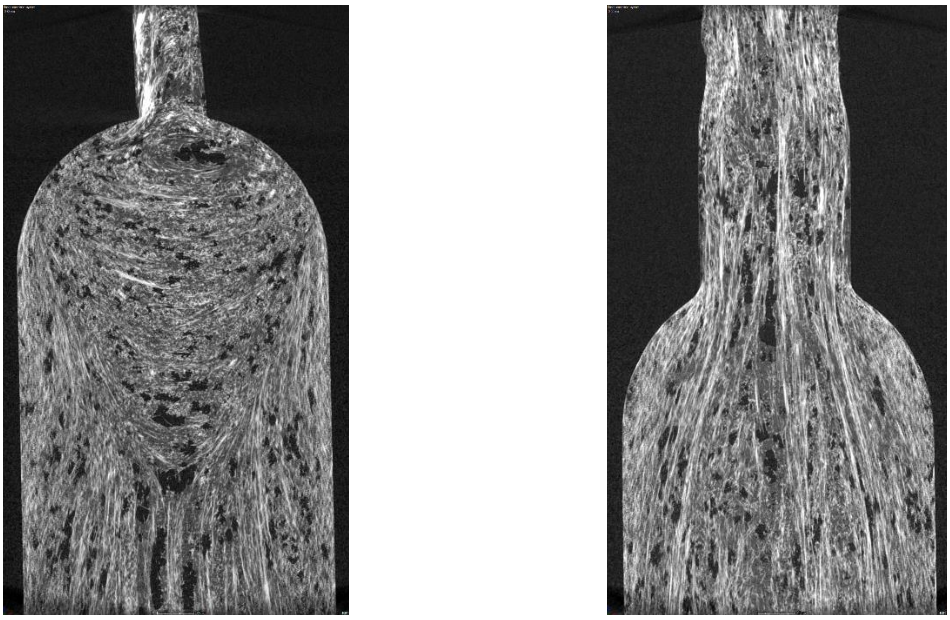


Figure 5: Nozzle geometries for long fibre breakage and dispersion analysis

Micro-CT has been used to visualise the fibre dispersion within the component, sprue and nozzles. Here the effect of decreased exit diameter in the nozzle section is clearly demonstrated, with aligned fibres appearing in the 6 mm case and a complex flow shown in the 3 mm, Figure 6.



a) b)

Figure 6: Micro-CT centreline sections of 3 (a) and 6 (b) mm nozzle regions

Further investigation of the CT data also illustrates the history imposed on the fibre orientation and dispersion within both nozzle sections due to the injection moulding process. Figure 7 shows the base of both the 6 amd 3 mm nozzles closest to the injection moulding screw and furthest from the component, with images adjusted so as to highlight clusters of fibres.

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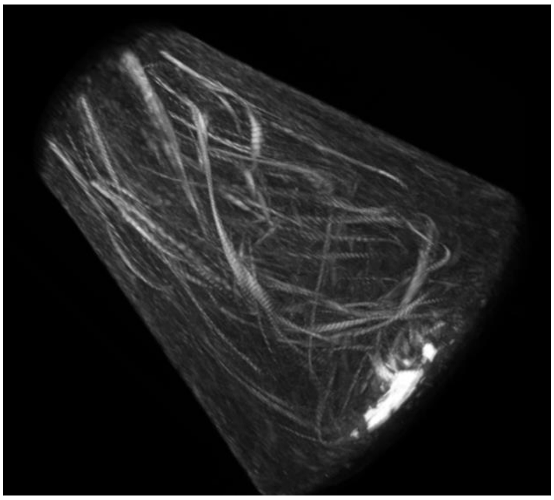

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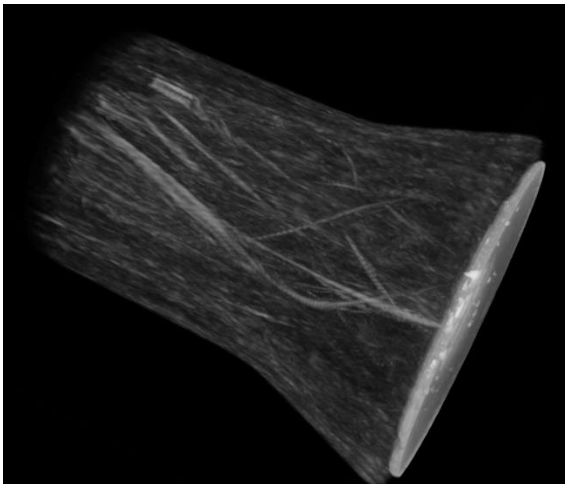

b)

Figure 7: Micro-CT of nozzle base of 3 (a) and 6 (b) mm geometries

In Figure 7, both the 3 and 6 mm nozzle geometries contain fibres with significant bending and rotational configurations within this lower nozzle section. The 3 mm case also appears to demonstrate significantly more clustering of fibres within this region compared to the 6 mm.

Further investigation is currently underway to assess the exit region of the nozzle, alongside the effect of varying fibre content (20, 30 and 40% wt) and exit nozzle geometry (tapered and ball nosed).

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