ASSESSING A COMPLETE CAD SOLUTION FOR THE DESIGN AND USE OF SHORT FIBRE COMPOSITES BY MEANS OF A COMBINATION OF MOLDFLOW AND ABAQUS

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Background

The continued exploitation and uptake of short fibre composites in a range of industrial applications would be greatly enhanced if the designer was able to carry out the complete design process within a computer. This would speed up the design process significantly and allow the materials to be used in a more cost effective, and greener, manner.

In the current design process the scenarios can often be either:

1) Manufacture an expensive mould to check fibre orientation patterns developed and then measure the mechanical properties and check against specification. If this does not meet the required performance, then either modification can be made to the existing mould or a new mould has to be made.

2) Overdesign the part to make sure the required performance can be met. However this might not be the optimum design. More optimal design could allow additional weight saving and if used in an automotive application, reduced fuel consumption. This is particularly evident in fibre reinforced materials where thicker sections can often lead to weaker structures due to fibre orientation.

The ideal, in computer, design process would look like that shown in Figure 1. First design the required component shape in a CAD package (for instance Solidworks), then pass this design to a mould filling simulation programme (for example Moldflow) to produce local fibre orientation predictions (FOD) throughout the part. This local FOD information is then passed to a finite element stress analysis programme (for example ABAQUS) to assess the part's performance against the design specification. This process can then be iterated until an optimum design is reached.

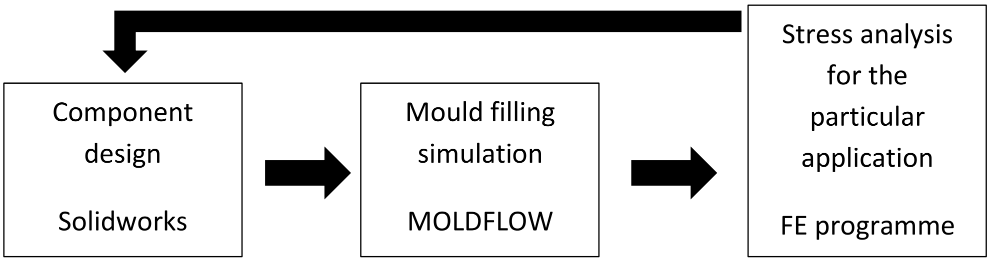

Figure 1: The ideal design scenario

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In this paper we will aim to assess the current state of the art in this process, but with the three steps carried out within the mould filling simulation, in this case using AutoDesk Simulation Moldflow Insights 2016.

Experimental details

Sample geometry

The component chosen for this study was an inverted, centre gated, cup as shown in Figure 2. The component had a height of 28mm and an outer diameter of 95mm. The side walls were 5mm thick and the mould had an insert to allow the top of the cup to be made at different thicknesses of 1, 2 and 4mm. Samples, for comparison with the computer predictions were injection moulded at Bradford using a Rhodia 216 v40 40% wt short glass fibre reinforced nylon 6 and were produced using the manufacturer's moulding conditions. Samples were left to equilibrate for two weeks at room humidity (50%RH) before testing.

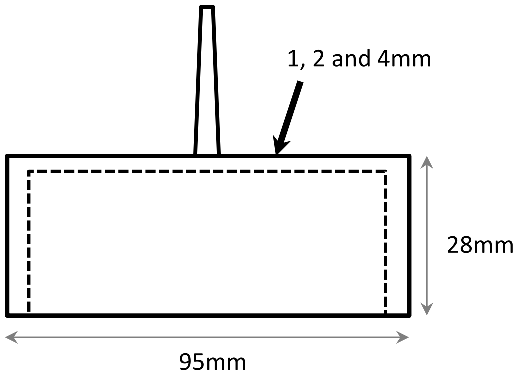

Figure 2: Details of the inverted cup sample

Testing

The test used to compare the experimental measurements and the simulation predictions was a simple compression test as shown in Figure 3. The inverted cup was placed on to a solid metal base, and then a compressive force was applied via the top of the sprue at a downward speed of 4mm/min. A data logger was used to collect the load/time trace for each of the three sample types, allowing force/displacement traces to be determined. The unloading curves were also measured, to ensure that the components were only tested in the elastic range (so no permanent deformation). The simulations also assumed linear elastic behaviour.

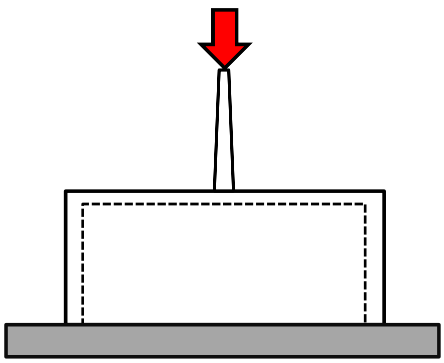

Figure 3: Compression test used to compare model predictions with experimental measurements

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Modelling

Due to the simplicity of both the component shape and the loading condition, the three design steps shown in Figure 1 could, in this case, be all carried out within Moldflow Insights 2016. This is a significant advantage, as the passing of mesh and element information between FE programmes is often a non-trivial issue. In this study a 2 ½ D model was used for the part (termed a mid-plane representation). Here each part of the component is built up of a number of 2D layers: 20 layers were used throughout this study. A typical mesh is shown in Figure 4. As is common with FE studies, mesh refinement studies were carried out to assess any effects.

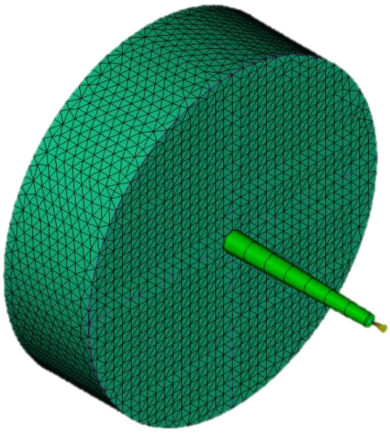

Figure 4: Typical Moldflow mesh

Once the part geometry is established, the key role of the mould filling simulation is to predict the fibre orientation distribution throughout the component. In order to do this there are at least three key questions to answer.

- What is the best fibre orientation model to use?
- What are the best empirical parameters to use for this model?
- What should the inlet orientation be?

In a previous study (and reported at the last ECCM conference in Seville), these three important issues were assessed using a range of injection moulded components (including this inverted cup). The strategy was to find the best combination of these three conditions which would accurately predict the measured FOD (using in-house image analysis facilities [1, 2]) for different component shapes and thicknesses (but using the same fibre reinforced material). The majority of fibre orientation models are based on the seminal work of Jeffery [3] for the rotation of a single, dilute, fibre. Folgar and Tucker [4] modified this to add an interaction coefficient (c_I) to mediate the effect of having a much higher concentration of fibres. Further modifications have come from Moldlfow [5] and the work of Wang et al [6].

The conclusions from this study were as follows.

- The best fibre orientation model for a range of components and thicknesses was the RSC model of Wang [6].
- The optimum empirical parameters for this model were $c_I = 0.006$ and kappa = 0.15.
- The most appropriate inlet condition was transverse orientation in the core region applied at the point of injection.

Figure 6 shows a comparison of the measured and predicted FOD at position D on the top plate of the inverted cup for both a 1mm and 2mm thick sample (see Figure 5 for the analysis position – the same FOD was measured at C and D). It is seen that the combination of these three conditions give an excellent prediction of the FOD.

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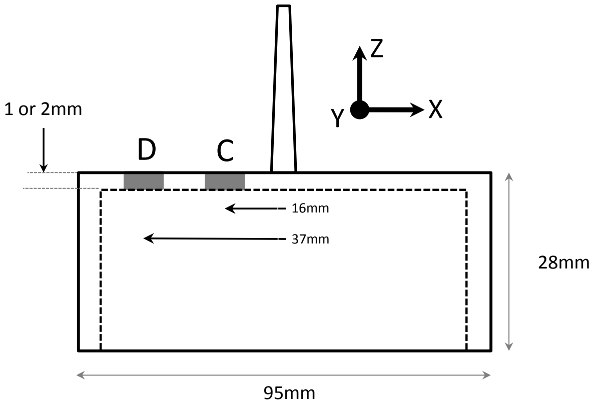

Figure 5: FOD analysis positions

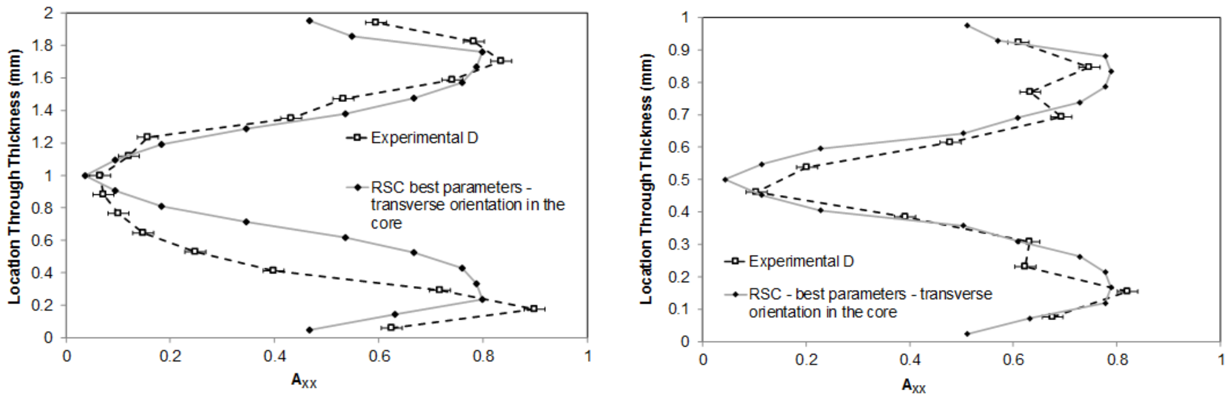

Figure 6: A comparison of model predictions with experimentally measured FOD for optimum conditions for the 1mm and 2mm thick samples.

Moldflow mould filling simulations were carried out using this combination of parameters and model choice, for the three top plate thicknesses. Moldflow was then used to apply a compressive force of 100N to the top of the sprue for each model FOD. Figure 7 shows a typical deformation map, in this case for the 1mm thick top plate.

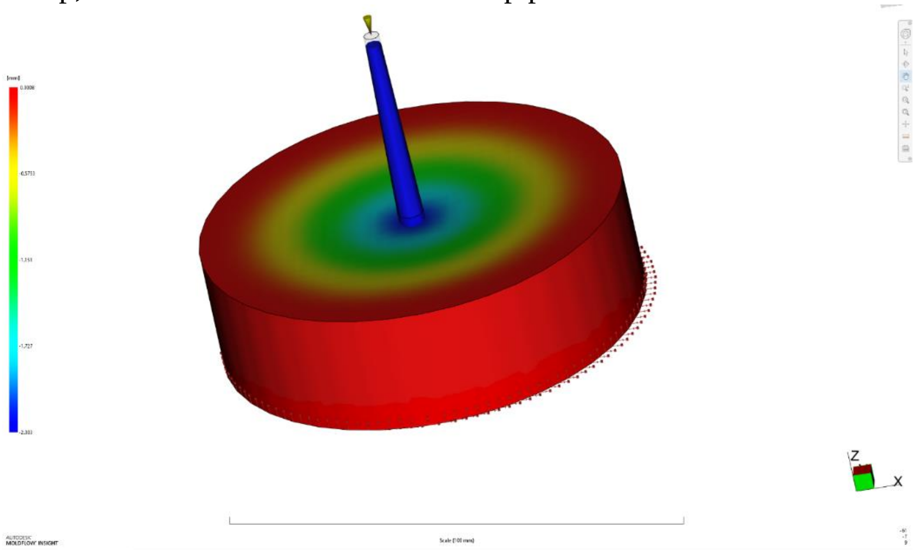

Figure 7: Deformation map for the inverted cup (1mm thick top plate) under a compressive load of 100N

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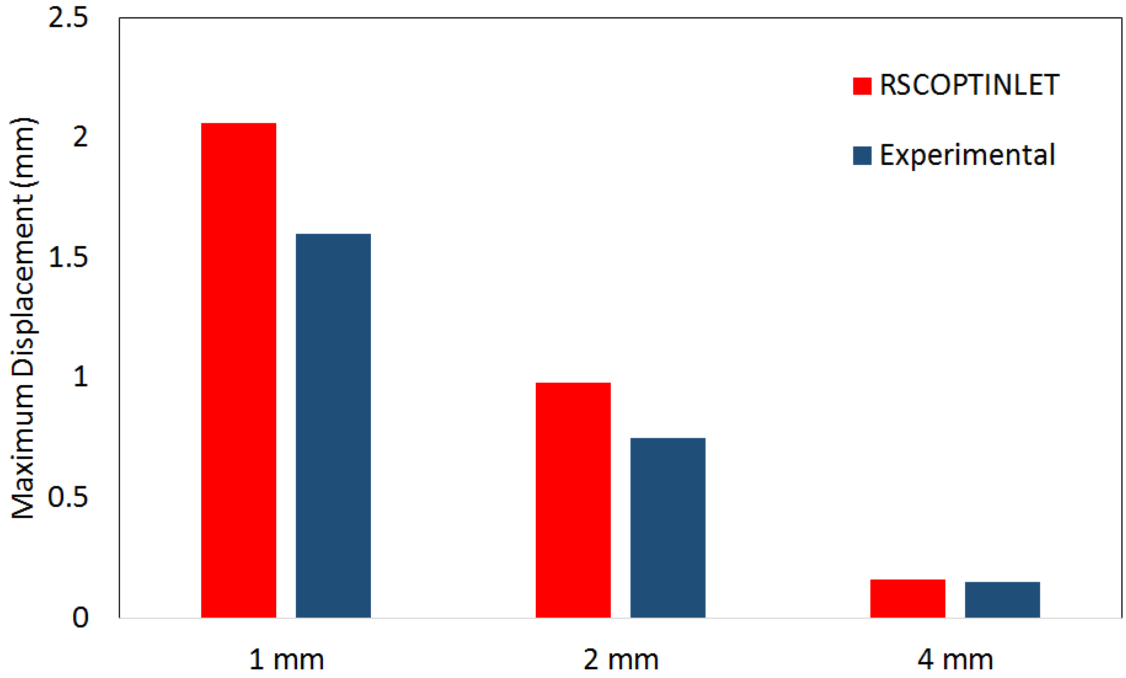
Finally, Figure 8 shows a comparison of the predicted displacement of the sprue, for the three top plate thicknesses, compared to that measured experimentally. It is seen that the agreement is quite good, although the experimentally measured displacement was always lower than predicted. Further work will be carried out to address this difference. Possible reasons could include the method of loading and constraint (in the experimental test the bottom of the cup is allowed to move outwards) and possible differences in water content between the measured component and the properties used from the material database, as it is well know that the water content can affect the properties of nylon.



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