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Gate Positioning and Fiber Orientation Impact on Mechanical Strength in Short Fiber Reinforced Composites: Numerical & Experimental Study

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Introduction

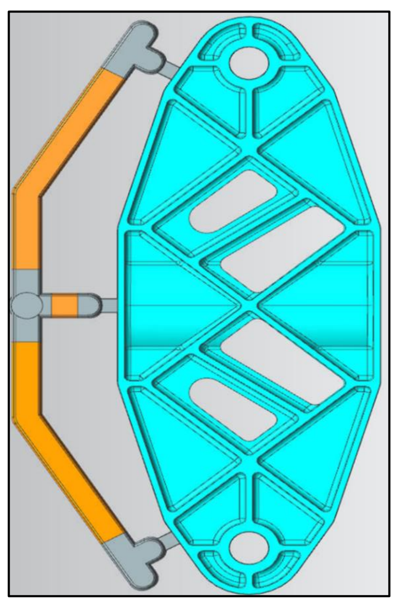
Short fibre reinforced composites show anisotropy leads to considerable variations in stiffness and strength of the component, necessitating precise modeling of local fiber orientation and anisotropic material behavior for accurate stress calculations. The mechanical performance of injection molded SFRP components is significantly influenced by factors such as fiber orientation and gate configuration. The research revolves around a carefully designed fixing plate geometry manufactured from Polyamide with 35% and 50% glass fiber content. This geometry incorporates three different gate configurations to assess their influence on the filling process and resultant fiber orientation, which, in turn, impacts the structural properties of the components. Through integration of experimental testing and integrative simulation workflow, we aim to gain insights into the microstructure and the optimization of critical parameters. The study encompasses a range of loading conditions, including bending and tensile tests (monotonic and cyclic), conducted at different temperatures and humidity levels. Two fiber orientation models such as Folger-Tucker (FT) model, and improved anisotropic rotary diffusion (iARD) model are employed to predict the distribution of fibers in the composite material, and their performance is compared.

Experimental & Numerical Methods

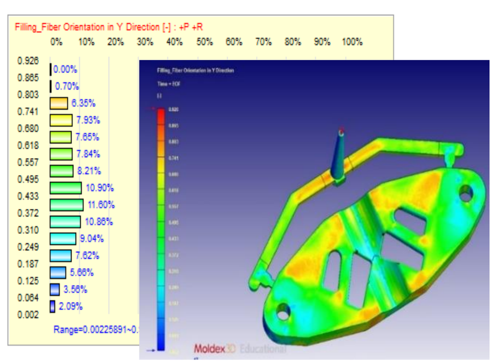
The intricate interplay of anisotropy, loading conditions, and stress states challenges the accuracy of stiffness predictions

CAD - Design → *Process Simulation* → *Fiber Orientation Mapping* → *Material Model Calibration* → *Structural FE Simulation* → *Experimental Test setup*

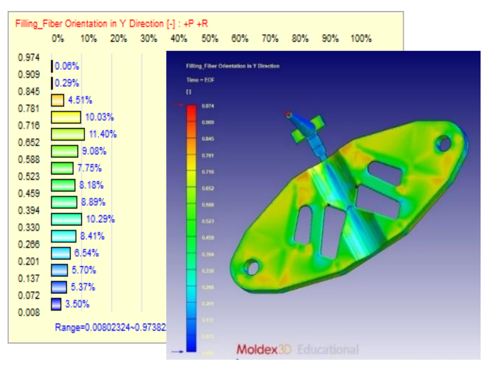
Fixing plate geometry



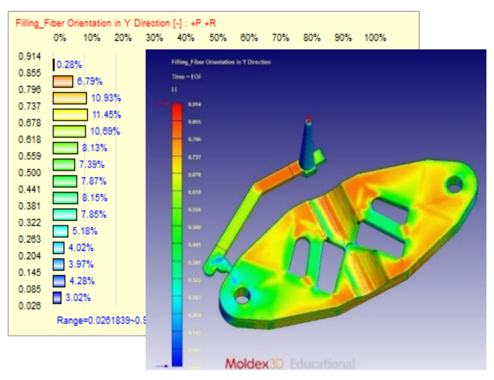
Fiber Orientation in Y direction



Gate 1



Gate 2



Gate 3

Fibre Orientation Models

1. **Folgar Tucker :**

Parameters : Ci = 0.005, RPR = 0.7

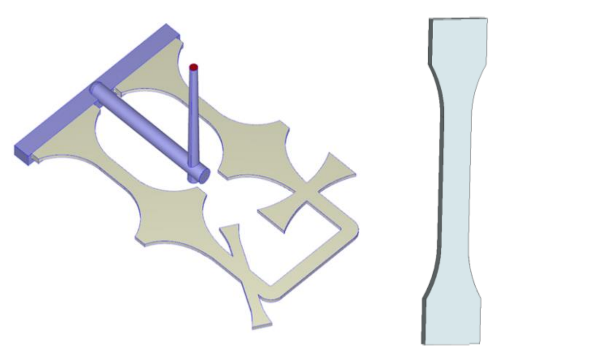
2. **Improved Anisotropic Rotary Diffusion:**

Parameters : Ci = 0.005, Cm = 0.2, RPR=0.7

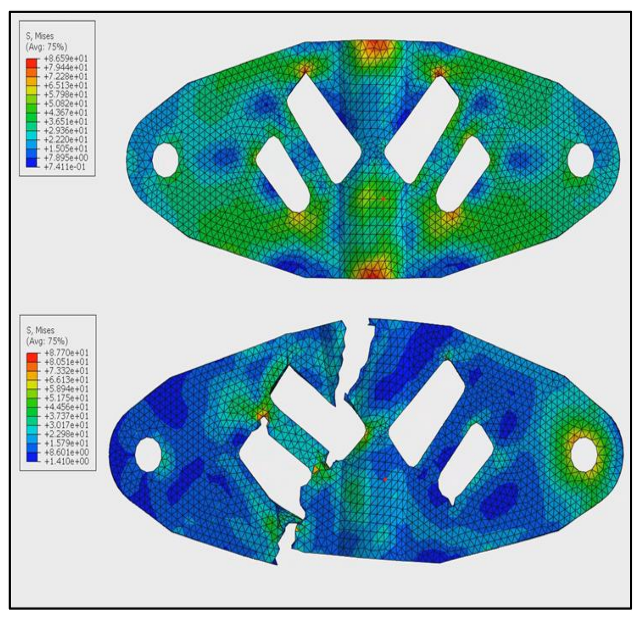
** Ci → Fiber – Fiber Interaction Coefficient

** Cm → Fibre – Matrix Interaction Coefficient

Geometries of standard specimens (a) UD (Fibre Orientation) (b) ISO-527



Structural Simulation

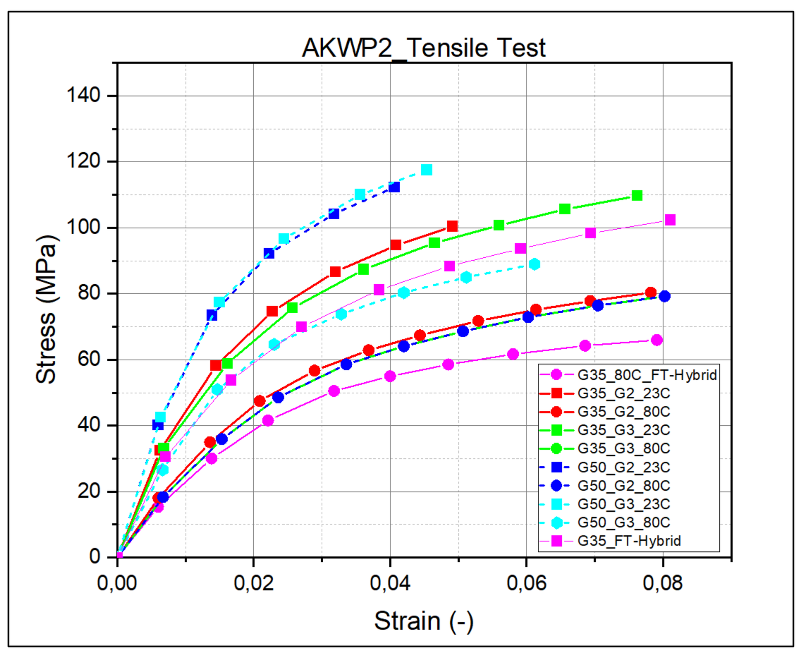


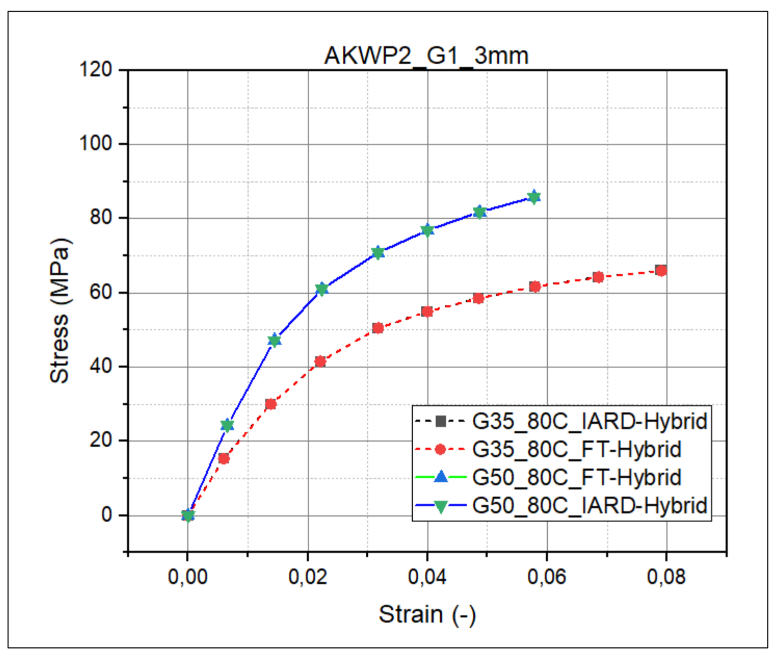
Materials :
PA GF35% and GF50%
Environmental Conditions :
23°C and 80°C at 50% RH

Tensile (left) and 3P Bending Setup (right)

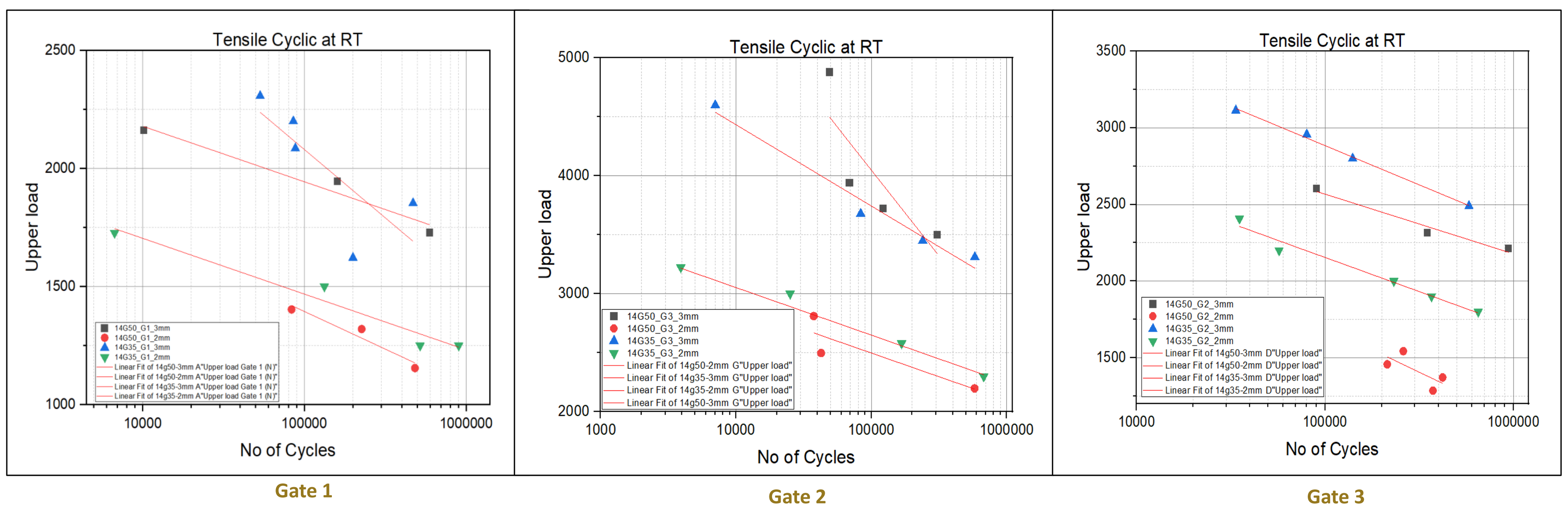
Servo-hydraulic MTS testing system, incorporating a 10kN load cell

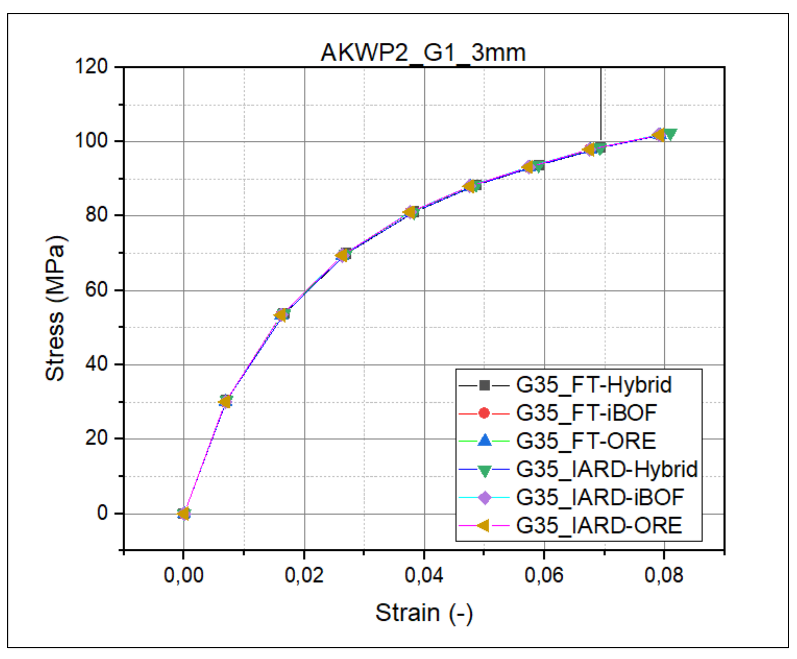
Results

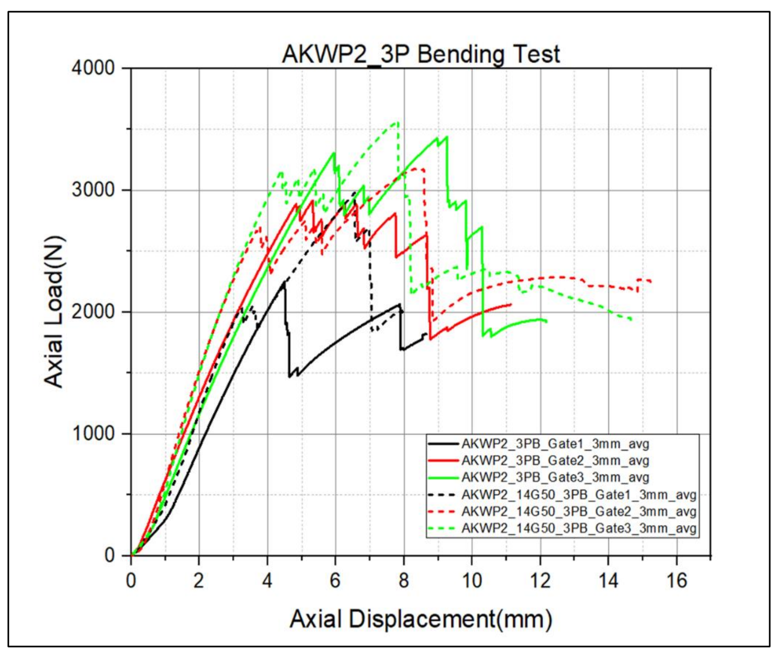




Tensile Cyclic (10Hz) at 23°C - 14G50 & 14G35







- Simulation and experimental results highlight strong weld lines at Gate 1 due to significant shear forces and thermal gradients at flow front meeting points.
- Experimental results confirm the predicted effect of fiber orientations, with increased fiber concentration resulting in higher strength and modulus values.
- The trend continues in tests at elevated temperature (80°C and 50% RH), with load values around 40% less than those at room temperature.
- Much less influence of the different fibre orientation model is observed with current Ci and Cm parameters in comparison to gate design influence.

Conclusion

The results highlight the significance of local stress, local fiber orientation, and gate design in achieving uniform filling, minimizing defects, and improving mechanical performance. The fibre orientation model coefficients will be further studied and optimized with iterative simulations. This integrative approach combining experimental testing and simulation helped us gain a deeper understanding of the performance and characteristics of the components under different test conditions.

Institute of Polymer Product Engineering

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This collaborative research was conducted between the Institute of Polymer Product Engineering at Johannes Kepler University Linz and Asahi Kasei Europe.
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