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Influence of flow model calibration on fiber orientation and part performance within an integrative simulation workflow for thick-walled CF-SMC parts

Andreas KAPSHAMMER[1], Kepa ZULUETA[2], Severin HUEMER-KALS[3], Zoltan MAJOR[1]

[1] Johannes Kepler University Linz – Institute of Polymer Product Engineering, Altenberger Straße 69, 4040 Linz, Austria

[2] Leartiker S. Coop, Markina-Xemein, Bizkaia, Spain

[3] Graz University of Technology – Insitute of Automotive Engineering, Inffeldgasse 11/II, 8010 Graz, Austria

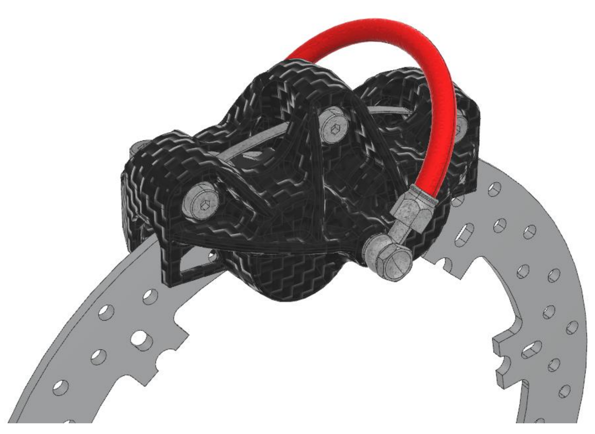
Introduction

Carbon fiber reinforced sheet molding compounds (CF-SMC) are commonly used for thin-walled interior and exterior parts in different engineering disciplines like automotive and aerospace. Its high specific properties combined with good chemical resistance and easy processing make this type of discontinuous composites very attractive for thick-walled, structural applications too. Compression molding enables the rapid and cost-efficient production of complex 3D geometries such as a motorcycle brake calliper. During this processing step the initially 2D random orientated fibers are redistributed as a result of flow induced forces and interactions like fiber-fiber and fiber-matrix interactions. Therefore, an integrative simulation's workflow is necessary to utilize the full engineering potential of CF-SMC components. The rheological flow model in compression molding is crucial to predict the correct fiber orientation for the structural simulation. The current study investigates the influence of differently calibrated rheological flow models on the mechanical performance of a novel CF-SMC motorcycle brake calliper design.

Experimental & Numerical Methods

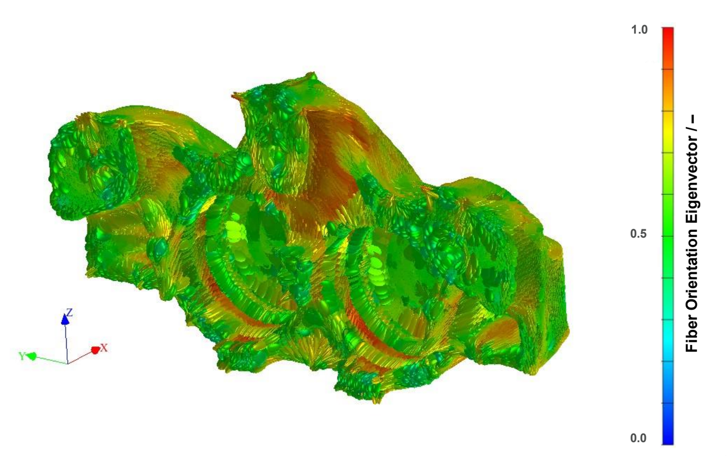
Integrative Simulation Workflow

CAD - Design → Process Simulation → Fiber Orientation Mapping → Material Model Calibration → Structural FE Simulation

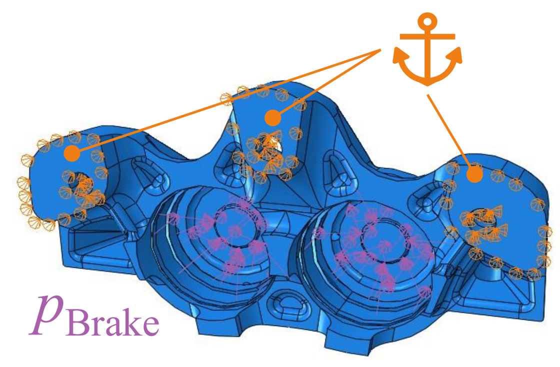


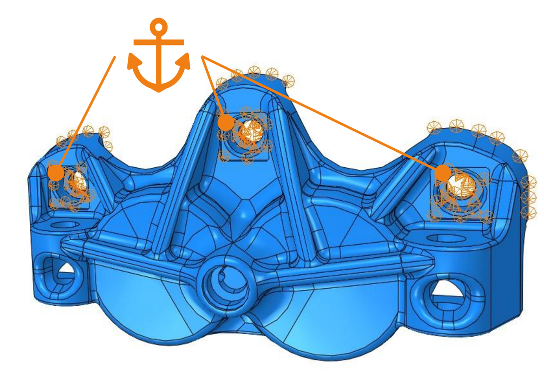
Calibrated Thermo-Rheological Models:

- Power Law – 0.1 mm/s (Squeeze Flow)
- Power Law – 1 mm/s (Squeeze Flow)
- Power Law – 10 mm/s (Squeeze Flow)
- Power Law – overall (Squeeze Flow)
- Cross Model – (Oscillatoric Rheometer)



Tensile Modulus / MPa	E_{11}	E_{22}	E_{33}
	25 414	19 993	3 048
Poisson Ratio / –	ν_{12}	ν_{13}	ν_{23}
	0.37	0.28	0.31
Shear Modulus / MPa	G_{12}	G_{13}	G_{23}
	8 455	954	937

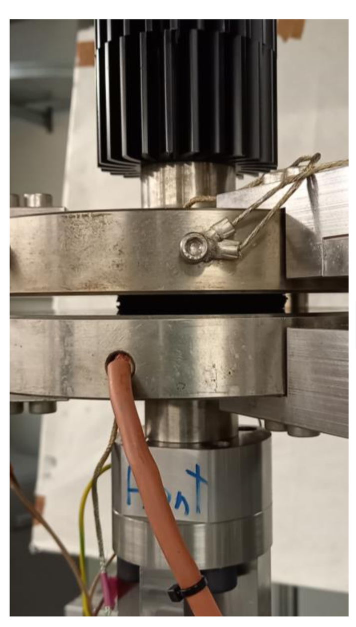


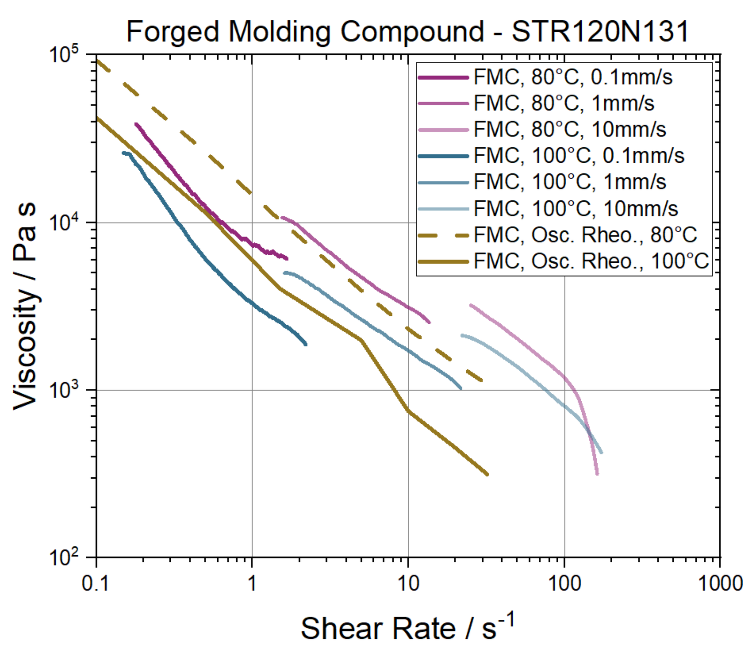


$$p_{Brake} = 5\ bar$$

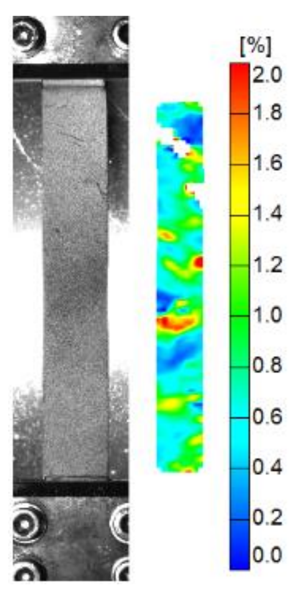
Experimental Methods

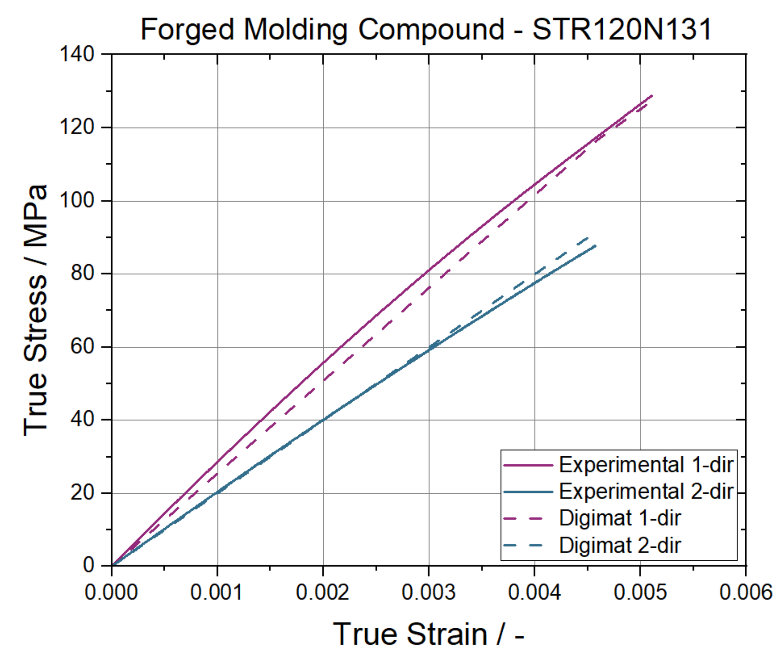
Squeeze Flow Rheometer





Tensile Tests





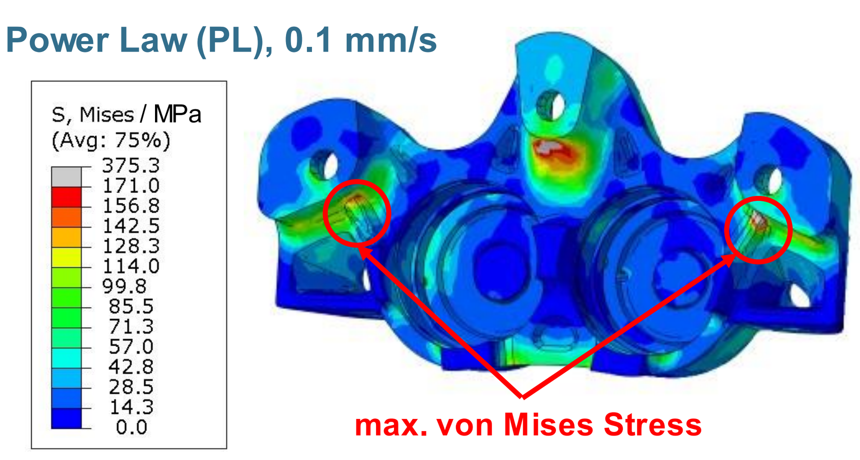
Results

The maximum calliper opening at a brake pressure of 5 MPa, and the maximum occurring von Mises stress in the highly loaded rip regions are chosen for comparison. As reference, a 2D random fiber orientation is used.

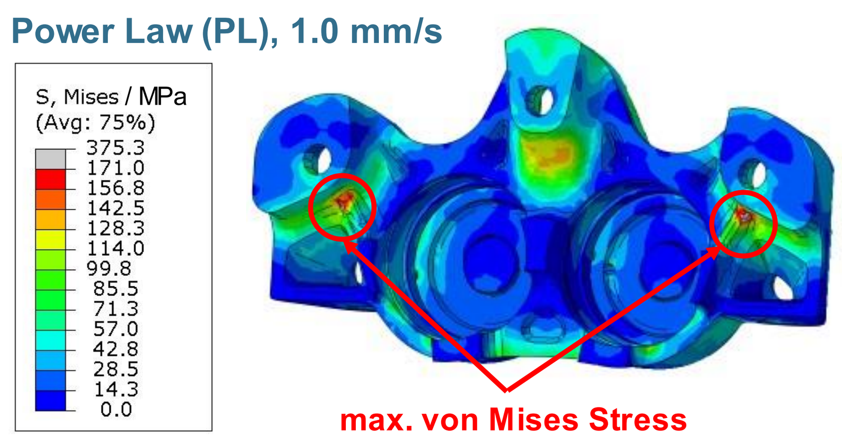
Findings:

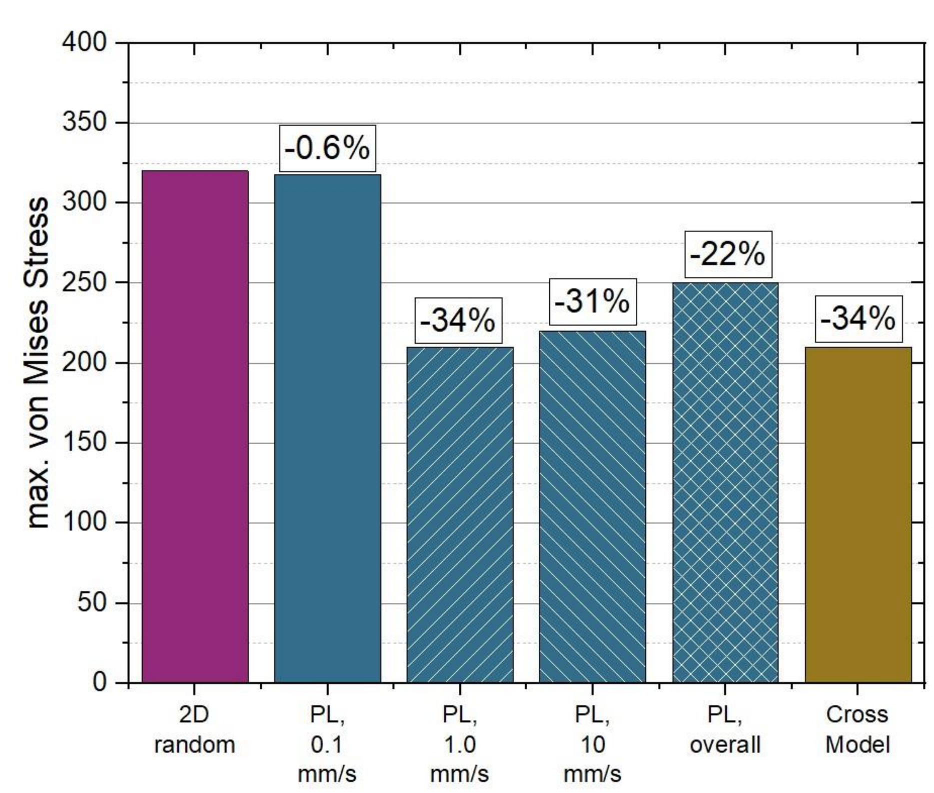
- significant influence of the used rheological flow model
- Power law – 1 mm/s and Cross model show the highest stress reduction of -34%.
- calliper opening displacement: -63% up to -66%.

Power Law (PL), 0.1 mm/s



Power Law (PL), 1.0 mm/s





Conclusion

In this work the influence of two rheological flow models on the resulting structural performance of a novel CF-SMC brake calliper design was investigated. Based on the applied integrative simulation framework, the importance of well-calibrated flow models for compression molding simulations is shown. Models derived from different test velocities (0.1 mm/s up to 10 mm/s) and test methods (squeeze flow and oscillatory rheometry) lead to a high variation of the resulting stress distribution in the structural simulation, which is relevant for component failure and damage behavior. However, the reduction in the calliper opening displacement is less sensitive to the mapped fiber orientations.

Institute of Polymer Product Engineering

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JOHANNES KEPLER UNIVERSITÄT LINZ