DEVELOPMENT OF A SOLID MECHANICS BASED MATERIAL MODEL DESCRIBING THE BEHAVIOR OF SMC MATERIALS

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Overview

In the past, a limited number of software tools were developed to simulate the compression molding of sheet molding compounds (SMC). First attempts were based on 2D or 2.5D modelling approaches without considering the flow in the thickness direction. Based upon the simulation of injection molding there are a few specialized software for compression molding in a 3D format [1] [2].The material models used in these software tools are based purely on fluid shear (viscosity) and are not capable of describing the complex behavior of a SMC material consisting of high fiber volume content and long fiber reinforcement.

In many current solutions the model for the fiber orientation is based on the Folgar-Tucker-Equation. Another possibility to describe the fiber orientation in a SMC material is the explicit modeling of the fibers as beam elements [3]. Here the fibers can be represented with a customized length and effects like fiber breakage and interaction can be taken into account. But this mesoscopic modelling approach demands high computing resources and calculation time.

The specialized software tools are restricted with respect to the available models and methods inside the software. A general FEM-Software such as ABAQUS® or LS-DYNA® gives a great advantage in the development process of customized material models for SMC materials [4][5]. With the multi-physics solver and the tools for user-defined material models all the necessary factors and effects can be taken into account.

In this work, a solid mechanics based material model describing the compression molding behavior and resulting fiber orientation in SMC materials is developed as a work in progress. Starting from the Folgar-Tucker description of the fiber orientation a user-defined material model is constructed within the commercial finite element code LS-DYNA®. In addition, mechanical and thermal effects that can be observed in SMC materials and which have a direct impact on the fiber movement are included into the model (Figure 1). Effects that are planned to be included but have not been realized at the moment are marked in a grey tone. Finally, modified formulations for the fiber orientation calculation to consider the long fiber reinforcement and high fiber content are considered.

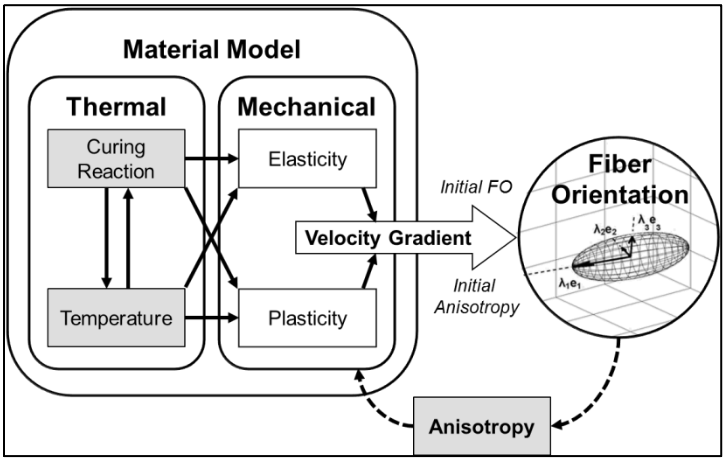

Figure 1: *Influence factor on the material model for Sheet molding compounds (SMC)*

Current results and discussion

In this work, the first idea for the calculation of the fiber orientation is based on a simple Folgar-Tucker equation that is normally used to describe injection molding processes of short fiber reinforced thermoplastic materials. Figure 2 shows the realization of this model in a user-defined material in LS-DYNA®. In a visualization created in Matlab® the eigenvalue and eigenvector of the tensor shows the main orientation of the fiber distribution inside one element of the FE mesh.

Most of the mechanical and thermal effects influence directly the velocity gradient that plays an important role in the Folgar-Tucker equation.

In most actual software solutions the problem is typically thought of as a fluid mechanics problem but the high fiber volume content defines it more as a solid mechanics problem. Therefore in this case, the flow of the material should be based on an elastic-plastic deformation instead of a purely viscosity based formulation.

All SMC materials show an anisotropic behavior that is based on the local fiber orientation. The elastic-plastic formulation should be orthotropic with directional scale parameters described by the fiber orientation tensor of the previous timestep.

If all influencing factors are taken into account there will be a final comparison of the resulting simulated and experimental fiber orientation. It is expected that the Folgar-Tucker model is not adequate enough to show accuracy in the orientation so a step backward will be taken to make developments in the mathematical model to change the formulation from a short fiber to a very long fiber based description.

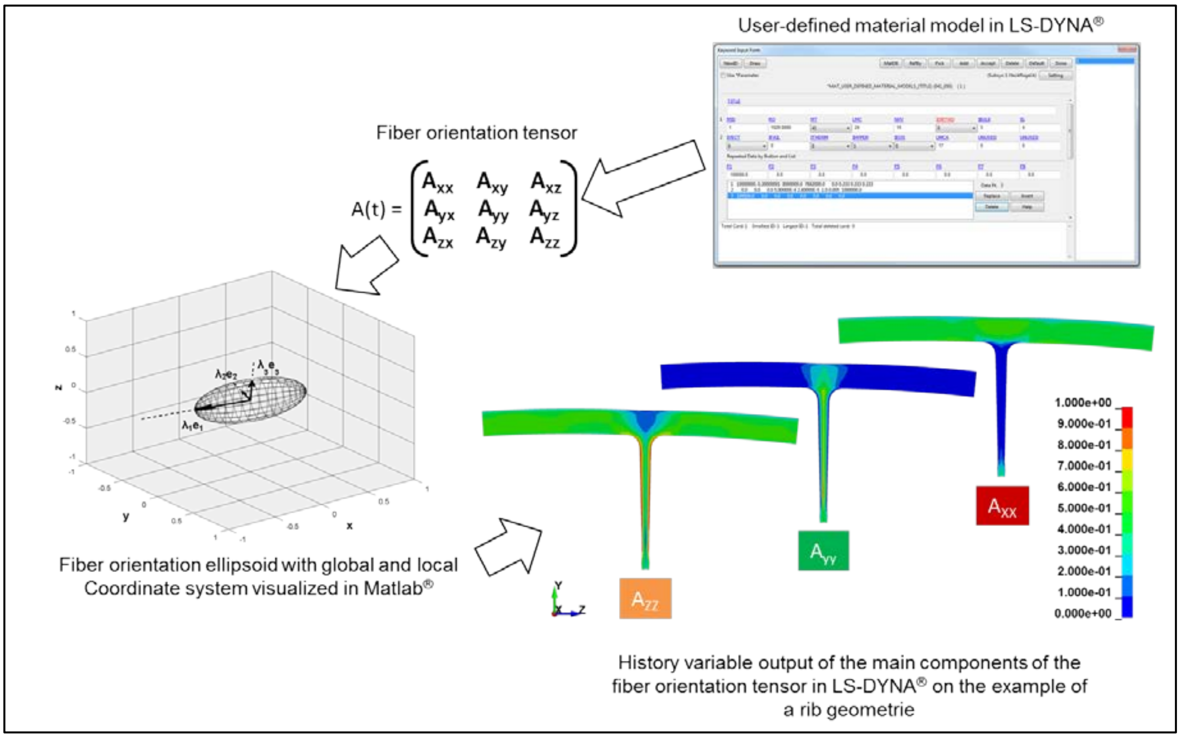

Figure 2: *Description of the fiber orientation distribution in general as the fiber orientation tensor and in an example of the compression molding of a simple rib geometry*

References

[1] Hsu, Chih-Chung, Hsien-Sen Chiu, Chao-Tsai Huang, Rong-yeu Chang [2014]: Through fiber orientation investigation to visualize compression molding. PPS, (29): 619-622.

[2] Li, Yang, Zhangxing Chen, Hongyi Xu, Jefferey Dahl, Danielle Zeng, Mansour Mirdamadi, Xuming Su [2017]: Modeling and Simulation of Compression Molding Process for Sheet Molding Compound (SMC) of Chopped Carbon Fiber Composites. SAE International Journal of Materials and Manufacturing, 10(2).

[3] Hayashi, Shinya; Chen, Hao; Hu, Wei [2017]: Compression Molding Analysis of Long Fiber Reinforced Plastics using Coupled Method of Beam and 3D Adaptive EFG in LS-DYNA®. 11th European LS-DYNA Conference 2017, Salzburg, Austria.

[4] Schommer, D., M. Duhovic, F. Gortner, M. Maier [2014]: Advanced Simulation of Polymer Composite SMC Compression Molding using Fluid-Structure Interaction in LS-Dyna®. 13th International LS-DYNA Users Conference,

[5] Müller. Timo; Henning, Frank [2015]: Simulation of combined forming and injection molding processes. 2015 SIMULIA Community Conference.