The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Asymptotic fiber orientation states of the quadratically closed Folgar-Tucker equation and a subsequent closure improvement

Tobias Karl[1,2,*], Davide Gatti[2], Bettina Frohnapfel[2], and Thomas Böhlke[1]

[1] Institute of Engineering Mechanics, Chair for Continuum Mechanics
[2] Institute of Fluid Mechanics
Karlsruhe Institute of Technology (KIT), Kaiserstraße 10, 76131 Karlsruhe, Germany
[*] corresponding author, tobias.karl@kit.edu

Keywords: *Fiber suspensions, Composite materials, Asymptotic analysis, Anisotropy, Fiber orientation evolution*

Fiber-reinforced composites are used in lightweight design due to their advantageous stiffness to mass density ratio. The fiber orientation state determines the anisotropy and is conveniently described by the second-order fiber orientation tensor, whose evolution can be simulated with the Folgar-Tucker equation [1]. The Folgar-Tucker equation requires closure [1], which in the simplest case can be done quadratically [2].
In a first step, the present work discusses exact solutions for the asymptotic fiber orientation states of the Folgar-Tucker equation based on the quadratic closure in homogeneous flows. These novel analytical expressions take into account the fiber-fiber interaction. Furthermore, since the common quadratic closure shows disadvantages with respect to the predicted material symmetry in the framework of orientation-dependent linear elastic homogenization, a novel fully symmetric quadratic closure is suggested. Two versions of this new closure are derived regarding the prediction of anisotropic properties and the computation of fiber orientation evolution.
The results show, that the new closure significantly improves the orientation evolution and the prediction of elastic anisotropy compared to the common quadratic closure. The results differ only slightly from those of the more elaborate and frequently used IBOF-closure [3] and show an overall good agreement with measured orientation data. In conclusion, the suggested closure turns out to be an efficient, simple structured and accurate method for simulating fiber-reinforced composites.

REFERENCES

[1] S.G. Advani and C.L. Tucker, The Use of Tensors to Describe and Predict Fiber Orientation in Short Fiber Composites, *J. Rheol.*, Vol. **31**, pp. 751–784, 1987

[2] M. Doi, Molecular dynamics and rheological properties of concentrated solutions of rodlike polymers in isotropic and liquid crystalline phases, *J. Polym. Sci.* Vol. **19**, pp. 229-243, 1981

[3] D.H. Chung and T.H. Kwon, Invariant-based optimal fitting closure approximation for the numerical prediction of flow-induced fiber orientation , *J. Rheol.* Vol. **46**, pp. 169–194, 2002