An efficient training technique for teaching deep material networks to reproduce creep loading of short fiber-reinforced thermoplastics

Argha Protim Dey[1], Fabian Welschinger[1], Matti Schneider[2], Sebastian Gajek[2] and Thomas Böhlke[2]

[1] Robert Bosch GmbH, Corporate Sector Research and Advance Engineering,
Robert-Bosch-Campus 1, 71272 Renningen, Germany, arghaprotim.dey@de.bosch.com
[2] Institute of Engineering Mechanics (ITM), Karlsruhe Institute for Technology (KIT), Kaiserstraße 10, 76131 Karlsruhe, Germany, https://www.itm.kit.edu/

Key Words: *Multiscale methods; Computational homogenization; Deep material networks; Creep loading; Short-fiber reinforced thermoplastics.*

The characterization of the long-term deformation or creep of short-fiber reinforced thermoplastics (SFRTs) is not only time consuming but also expensive. The simulative behavior is made further complex due to the presence of multiple scales, both in space (due to the reinforcements) and in time (short- and long-term effects). To circumvent these problems, we use deep material networks (DMNs) [1,2,3] which enables concurrent multiscale simulations on an industrial scale and are several orders of magnitude faster than full-field simulations.

DMNs replace the micromechanical model with a powerful surrogate model. The parameters of the DMNs are traditionally determined using linear elastic precomputations. DMNs can handle inelastic material models after the parameters are determined, and they have been demonstrated to accurately reproduce micromechanical full-field simulations using the original microstructure.

We show that the traditional training technique based on linear elastic precomputations does not ensure that the long-term creep response predicted using DMNs match high-fidelity computations. We introduce a novel training strategy which combines inelastic computations together with linear elastic precomputations. This strategy enables us to consistently generate DMNs which reliably generalize to creep loading.

REFERENCES

[1] Gajek, S., Schneider, M. & Böhlke, T. "On the micromechanics of deep material networks." *Journal of the Mechanics and Physics of Solids* 142, 103984 (2020).
[2] Liu, Z., Wu, C. T. & Koishi, M. "A deep material network for multiscale topology learning and accelerated nonlinear modeling of heterogeneous materials." *Computer Methods in Applied Mechanics and Engineering* 345, 1138–1168 (2019).
[3] Liu, Z. & Wu, C. T. "Exploring the 3D architectures of deep material network in data-driven multiscale mechanics." *Journal of the Mechanics and Physics of Solids* 127, 20–46 (2019).