Proceedings of the 1st international Symposium on AI and Fluid Mechanics
Abstract No S4 A11

Exploring the Use of Feed-Forward Multilayer Perceptron Networks for Modeling the Non-Linear Behaviour of Viscoelastic Fluids

[1]J.L Cummings*; [2,3]C. Fernandes 2; [4]F. Dong 3; [3,5]M.A Alves; [1]M.S.N Oliveira

[1]James Weir Fluids Laboratory, Department of Mechanical & Aerospace Engineering, University of Strathclyde, Glasgow, UK

joshua.cummings@strath.ac.uk

[2]Transport Phenomena Research Centre (CEFT), Department of Mechanical Engineering, Faculty of Engineering, University of Porto (FEUP), Portugal

[3]ALiCE, Associate Laboratory in Chemical Engineering, Faculty of Engineering, University of Porto (FEUP), Portugal

[4] Department of Computer and Information Sciences, University of Strathclyde, Glasgow, UK

[5]CEFT, Department of Chemical Engineering, Faculty of Engineering, University of Porto (FEUP), Portugal

Abstract

This work assesses the performance of a fully connected feed-forward multilayer perceptron network in the Rheological Universal Differential Equation (RUDE) framework for constitutive model learning proposed by Lennon et al. [1]. Synthetic data sets are generated by simulating large amplitude oscillatory shear (LAOS) experiments specifically designed to capture complex viscoelastic behaviour. The performance of the network is first validated using the Giesekus model, where a direct mapping exists between the neural network output and the parsimonious ground truth, allowing direct querying of the network for performance assessment. Training is then undertaken for models for which no clear mappings exist, such as the FENE-P, sPTT and related non-linear constitutive models. The capabilities of the neural network under partial and complete information scenarios are reported. The performance is then examined using a CFD-based approach. To achieve this, the neural network architecture is integrated natively into the OpenFOAM and RheoTool [2] environment, where the constitutive model is computed via a forward pass query to the fully trained neural network specifically to accommodate non-linearities which may manifest for more complex models. Each of the trained networks is then used in Rheotool and its rheometric and computational performance assessed in different benchmark flows. Finally, the influence of network architecture is investigated by varying hidden layer width for a fixed number of layers, followed by adjusting the network depth with a fixed number of neurons per layer. The capabilities and performance of these modified networks are evaluated for all of the considered constitutive models.

[1] Lennon K. et al., 2023. *Proceedings of the National Academy of Sciences*, 120(27) e2304669120.

[2] Pimenta, F. and Alves, M.A., 2017. *Journal of Non-Newtonian Fluid Mechanics*, 239, 85.

Keywords: Rheology, Viscoelastic, Constitutive Model, OpenFOAM