Implicit Material Modelling Using Artificial Intelligence techniques

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Abstract. In the past few years, there has been tremendous advances in the accuracy and predictive capabilities of tools for the simulation of materials. Predictive modeling has now become a powerful tool that can also deliver real value through application and innovation to the global industry. Simulation of forming operations, particularly using the finite element method, is clearly dependent on the accuracy of the constitutive models. In the last years, several methodologies were developed to improve the accuracy of constitutive models through parameter identification and calibration methodologies. However, independently of the efficacy of the calibration methods, the accuracy of a constitutive model is always constrained to its predefined mathematical formulation. Additionally, using known elastoplastic formulations, it is impossible to reproduce the material phenomena if these phenomena are not formulated mathematically.

In the past several years, artificial intelligence (AI) techniques have become more robust and complex. This field has set the ambitious goal of making machines either seemingly or genuinely intelligent. The sub-field of artificial intelligence known as machine learning attempts to make computers learn from observations. While statistical time series models are special- ized for their task, machine-learning algorithms are general tools that can be fitted to a vast number of problems, including predicting the stress-strain relationship of the material.

This work propose to model the behavior of a metal material using machine-learning (ML) techniques and use this ML in forming simulations. Initially, the ML model is designed and trained using a known plane stress elastoviscoplasticity model to evaluate its competence to replace the classical models. Different ML topologies and optimization techniques are used to train the model. Then, the AI model is introduced into a FE code, as a user subroutine, and its attainment in forming simulations is evaluated. The replacement of classical formulations by AI techniques for the material behavior definition is analysed and discussed.

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