VII ECCOMAS Young Investigators Conference
YIC2023
19-21 June 2023, Porto, Portugal

Constitutive model selection for sheet metal forming based on the analysis of identifiability of the material parameters

Mariana Conde[+,*], Sam Coppieters[†] and António Andrade-Campos[+]

[+] Department of Mechanical Engineering, TEMA - Centre for Mechanical Technology and Automation,
LASI Associate Laboratory, University of Aveiro
Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

[†] Department of Materials Engineering, KU Leuven - Ghent Campus
Gebroeders De Smetstraat 1, Ghent, 9000, Belgium

[*]e-mail: marianaconde@ua.pt

Abstract: The efficient development and production of high-quality metal parts usually require realistic numerical simulations before the manufacturing procedure. The selection of the constitutive model has a considerable influence on the predicted material's behaviour and, consequently, on the simulation of the production process. A large number of constitutive models have been proposed to describe different mechanical phenomena. However, its selection is a laboured task that requires expertise. An inadequate choice of models can lead to errors in the numerical predictions and, thus, large costs and delays in the manufacturing procedure. An automatic constitutive model selection tool, as a recommendation engine, is the answer to solve this issue. This work aims to compare the quality of the models for a simulation of a DP600 steel. The approach is based on the identifiability analysis that considers the strain gradient variation due to the perturbation of the constitutive parameters. With this approach, it is possible to investigate if a constitutive model is adequate for calibration and reproduction of the material behaviour at hand.

Keywords: Constitutive model selection, Sheet metal forming, Finite Element Analysis, Identifiability

1 Introduction and literature review

The automotive and aircraft industries usually require high quality in their products and short time-to-market. Their efficiency relies, among others, on the correctness of the Finite Element Analysis (FEA) of the forming processes. However, in some cases, the lack of knowledge and time to correctly describe the material's behaviour is observed. This can lead to errors in the numerical simulations and, consequently, large costs and delays. To have material behaviour predictions, it is necessary to select an adequate constitutive model and correctly identify the corresponding material parameters. In the last decades, a large number of models were developed, implemented in numerical simulations and validated experimentally [1, 2]. The choice of the constitutive models that describe the material behaviour is an issue that a Finite Element Analysis (FEA) software user faces. Its selection for a specific material and process requires high expertise, an exhaustive investigation and mechanical experimentation. Many authors have been comparing simulations with different models with experimental data and finding which is more adequate for a specific material and process mainly based on trial-and-error approaches [1, 3, 4, 5]. Yet, this comparison can be very time-consuming, requiring several mechanical experiments, the calibration of the different models, the simulation of a process and its validation. Thus, a flexible and automatic tool or strategy for model selection is lacking in the industry and scientific community.

2 Proposed solution and methodology

The work aims at proposing a methodology to help in the model selection decision-making considering different materials. The approach is based on the identifiability analysis [6]. It involves the simulation of adequate mechanical tests for material calibration with perturbations on the material parameters. If the variation in the strain gradients is low when the parameters are perturbed, it means that the calibration of the considered model should be problematic. Therefore, the use of the model is not recommended for the material at hand.

3 Disclamer

The results reflect only the authors' view, and the European Commission is not responsible for any use that may be made of the information it contains.

4 Acknowledgements

This project has received funding from the Research Fund for Coal and Steel under grant agreement No 888153. The authors also acknowledge the financial support under the scope of projects UIDB/00481/2020 and UIDP/00481/2020—FCT—Fundação para a Ciencia e a Tecnologia and CENTRO-01-0145-FEDER022083—Centro Portugal Regional Operational Programme (Centro2020), under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund. Mariana Conde is grateful to the Portuguese Foundation for Science and Technology (FCT) for the PhD grant 2021.06115.BD.

References

[1] R. J. Nedoushan, *et al.* Simulation of hot forming processes: Using cost effective microstructural constitutive models. Int J of Mech Sc 2014;85:196–204.

[2] Banabic. Advances in anisotropy of plastic behaviour and formability of sheet metals. Int J of Ma 2020;13:749–787

[3] S. Ben-Elechi, *et al.* Sensitivity of friction coefficients, material constitutive laws and yield functions on the accuracy of springback prediction for an automotive part. Int J of Mat For 2021;14:323-340.

[4] S. Kilic, *et al.* Investigation of the Performance of Flow Models for TWIP Steel, J of Mat Eng and Perf 2018;27:4364–4371.

[5] J. Lin, *et al.* Effect of constitutive model on springback prediction of MP980 and AA6022-T4. Int J of Mat For 2020;13:1–13.

[6] Y. Zhang, *et al.* Enhancing the information-richness of specimens for identification of plastic anisotropy through full-field strain fields. Int J of Mech Sc 2021;214:106891.