Quantification of the effect of uncertainty of material parameters on damage initiation in finite strain elastoplasticity

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In metal forming processes, initial material properties, among other factors, influence the component's life time and performance properties together with deformation induced material degradation. In process simulations, initial material properties, such as material parameters, are typically assumed to be constant for a given material, i.e. constant across different material batches. In practise, however, initial material properties exhibit uncertainty due to intrinsic variabilities resulting from, e.g., casting and preceding production processes. To enhance metal forming process simulations with regard to variability in resulting material parameters, quantifying such uncertainty is most important for reliable simulation-based prediction of process-induced material properties.

To this end, a numerically efficient variance-based global sensitivity analysis framework is developed [1] to quantify the effect of uncertainty of material parameters on damage initiation indicators, such as stress triaxiality and Lode angle. The established framework incorporates a Gaussian regression surrogate model along with a Bayesian active learning strategy to improve the computational efficiency. A key challenge in its application to the boundary value problem of a tensile test specimen are localisation effects of plastic contributions and resulting mesh-dependency observed beyond the onset of necking, preventing further uncertainty quantification. To overcome such localisation, a micromorphic- and gradient-type regularisation for plasticity is implemented, which enables uncertainty quantification at high loadings. Its application reveals that extremal values of damage initiation indicators show particularly high sensitivity for parameters related to nonlinear hardening and underlines the potential of damage control through optimisation of the material's nonlinear hardening behaviour.

References

[1] M. Böddecker, M.G.R. Faes, A. Menzel, and M.A. Valdebenito. Effect of uncertainty of material parameters on stress triaxiality and Lode angle in finite elasto-plasticity — A variance-based global sensitivity analysis, Adv. Ind. Manuf. Eng., 7:100128, 2023. https://doi.org/10.1016/j.aime.2023.100128