On solving inconsistencies between different types of hardening models

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Over the past decades, many different phenomenological models have been developed; the simple ones only consider isotropic hardening and a von Mises yield surface, whereas the advanced models simultaneously account forthe material's initial anisotropy and different types ofhardening phenomena. The more advanced models are typically calibrated based on a rather extensive set of conventional mechanical tests such as tensile, tension-compression, tension-shear and tension-torsion tests. Furthermore, calibration is most often done in a sequential manner enabling to disentangle different phenomena. For example, first the initial yield surface is calibrated, the next step calibrates for isotropic hardening and so on.

The Levkovitch-Svendsen model is such an advanced model which accounts for isotropic, kinematic and distortional hardening and assumes Hill's 1948 yield criterion to capture the initial anisotropy. Kinematic hardening is described by a Lemaître-Chaboche model, whereas a fourth order tensor, which evolves with equivalent plastic strain and strain path direction, is used to describe distortional hardening. When calibrating this model for a X70 steel grade, an unrealistically high anisotropic shear parameter was required to reproduce the torque–rotation angle curve from a torsion test.

This paper presents the results of a numerical study which was conducted to investigate this observation. Tensile and torsion tests were simulated with different hardening models, thereby always assuming the same Hill 1948 yield surface. First, those tests were simulated using a purely isotropic hardening model and assuming arbitrary strain hardening. The stress-strain and torque-rotation angle curves obtained from those simulations were considered to be the ground-truth in the remainder of the study, i.e. the reference curves.Next, it was tried to reproduce the same tests using a combined isotropic-kinematic hardening model and arbitrarily chosen kinematic hardening parameters. The isotropic hardening part was calibrated based on the reference curve obtained from the tensile test in RD (rolling direction). While the combined isotropic-kinematic hardening model predicted the exact same behaviour as the purely isotropic hardening model for the tensile test in RD, it was not able to reproduce the reference curves from the tensile test in the transverse direction and the torsion test. The same was observed when trying to reproduce the reference curves with a combined isotropic-distortional hardening model.

It was expected that different hardening models would predict the same behaviour for monotonous strain paths, but this is not the case for the models considered in this study. This seems to be an inconsistency complicating the calibration of more advanced constitutive models. In this paper it is shown that this inconsistency can be solved by scaling some parameters in the evolution equations of the kinematic and distortional hardening model with a ratio of two equivalent stresses.

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