IDENTIFICATION OF THE YIELD SURFACE FOR SHEET STEEL USING AN OPTICAL MEASUREMENT SYSTEM

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1. Introduction

The usage of full-field deformation data from experiments for the identification of material parameters is a topic of current research. The continuous improvement of optical measurement systems leads to promising results in parameter identification and optimization [1]. With the high amount of data points the displacement and deformation field is not only a mean value but can be resolved locally which leads to a higher accuracy of the identified parameters.

The goal of this research is to get reliable results from the full-field measurement data through a Finite Element Model Updating Method with a lower amount of experiments compared to taking the yield values and Lankford coefficients for the characterization of the yield surface of sheet steel.

2. Experimental Characterization

In this work a deep-drawing sheet steel (DC04) is characterized, which was fabricated in a cold-rolling process. Due to this method of production sheet steel shows orthotropic material behaviour. To verify this fact uni- and biaxial tension and compression experiments were performed (fig. 1).

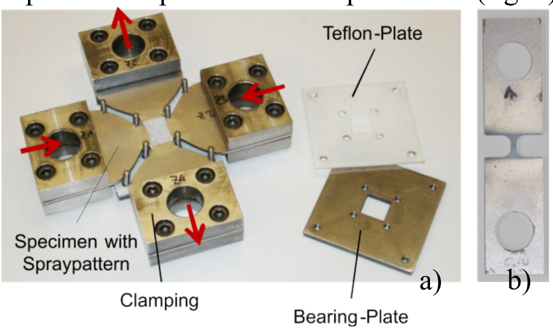

Fig. 1: a) biaxial tension and compression specimen, b) uniaxial compression specimen

The uniaxial specimens were tested with electro-mechanical machines and the biaxial ones with a hydraulic machine. In all these experiments the deformation was recorded with an optical full-field measurement system.

Assuming a homogeneous stress and deformation distribution in the measuring area of the specimen, the mean yield stress can be plotted in a stress-stress diagram (fig. 2).

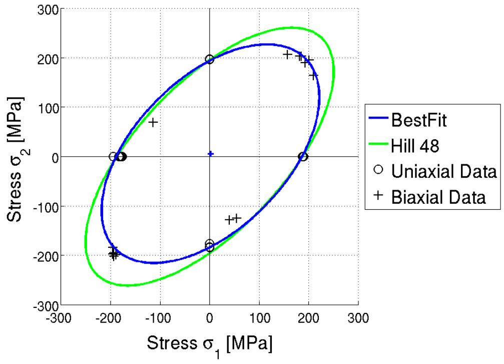

Fig. 2: Experimental Yield Surface

Hill's 48 yield surface in fig. 2 is calculated by utilizing yield values and Lankford coefficients. These parameters were identified through uniaxial tensile tests with specimen in three different angles to the rolling direction of the sheet (0°, 45° and 90°) [2]. The "Best-Fit" yield surface is obtained through a Least-Square Fit, based on the Galerkin-Method, see [3]. Input parameters are the experimentally determined yield values of all uni- and biaxial tests.

Comparing both yield surfaces a discrepancy especially in the biaxial region can be found. To be able to get better fitting material parameters a numerical parameter optimization is utilized.

3. Parameter Optimization

The identification is set up for two different experiments: the uni- and the biaxial tension test. The optimization is done by running Finite Element (FE) Simulations and iteratively changing the material parameters until the difference of the numerical results to the experimental ones is minimal.

Models of the uni- and biaxial specimen are built up and discretized with four-node, bilinear, isoparametric, plane stress quadrilateral elements. Symmetric boundary conditions are used to reduce the total amount of degrees of freedom. The load on the uniaxial specimen is applied through a displacement boundary condition and the biaxial model is loaded with forces. As material model an anisotropic elasto-plastic behaviour with Hill's 48 yield surface and Hockett-Sherby hardening is chosen.

The data from the optical measurement system has to be preprocessed for the parameter optimization. The software lays a grid on the tested specimen and calculates the displacement and deformation for all intersection points with Digital Image Correlation (DIC). To get the data values at the nodes of the FE mesh an interpolation routine is used. The loads for the simulation are taken from the experiments.

To verify the convergence of the optimization two algorithms (gradient-free Nelder-Mead Simplex and Levenberg-Marquardt with gradient through Finite Differences) and different initial points were utilized. The objective function is a weighed least-square sum of the differences, of the displacement values at specified optimization points and of the reaction forces, between simulation and experiments (fig. 3).

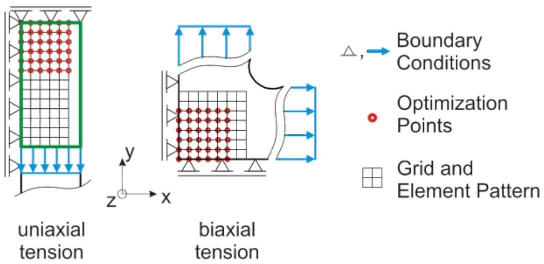

Fig. 3: Uni- and biaxial models with boundary conditions for the optimization

Like in the uniaxial tensile experiments for each angle to the rolling direction (0°, 45° and 90°) three test specimens are taken for the simulation. The biaxial run takes the measured data from three experiments.

4. Identification Results

Figure 4 shows the results of the optimization process. As expected both identified yield surfaces fit the experimentally measured data better than the Hill 48 yield surface, which was generated from the uniaxial tensile yield values and the Lankford coefficients.

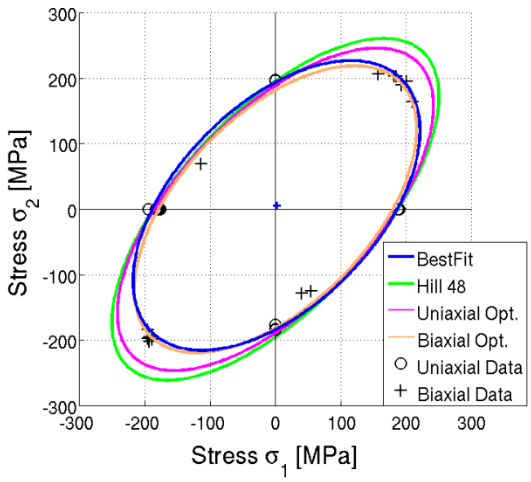

Fig. 4: Optimized Yield Surfaces

The uniaxial result shows a better correlation to the experimental data at the uniaxial data points for 0° and 90°, but the biaxial state cannot be represented well enough by the 45° specimens. The optimized biaxial yield surface shows a good fit in the biaxial area but does not perfectly fit at the uniaxial points. Both identified yield surfaces can be improved by implementing an anisotropic hardening function.

The convergence of the process is proven as the two utilized optimization algorithms and the different initial starting points lead to the same result. Even though the gradient for the Levenberg-Marquardt algorithm is determined through Finite Differences its performance is much better.

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References

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