Evaluation of kinematic hardening models for multiple stress reversals under continuous cyclic shearing and multi-step bending

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In complex sheet metal forming processes, the material undergoes various strain path changes. For instance, during passing a drawbead, the load changes on the outer layer of the sheet from tension to compression and back to tension. The inner layer receives a contrary stress history. Based on the Bauschinger effect that describes the material's specific decrease of the yield stress after a load reversal, the resultant hardening behavior significantly differs from that of a monotonic loading condition. For a reliable numerical process design, especially in the springback analysis, a consideration of this effect is essential. The load path dependency of the material's hardening behavior is typically mapped with a combination of an isotropic and a kinematic hardening component that permits the modeling of the Bauschinger effect by a translation of the yield surface. The associated model parameters are identified on the basis of cyclic tests, whereas the number of necessary load reversals is still an uncertain factor. In the majority of cases, only one load path reversal is considered, e.g. in uniaxial tension-compression tests.

Within this contribution the evolution of the material behavior under cyclic loading is investigated with consecutive cyclic shearing of DP-K54/78+Z in a modified ASTM shear test. Moreover, complex isotropic-kinematic hardening models, e.g. the Chaboche-Rousselier model, are identified and analyzed for various load cycles. The applicability of the hardening models is evaluated for multiple cyclic loading. For this purpose, experimental multi-step out-of-plane bending operations are realized to consider continuous cyclic loading across the sheet thickness. The accuracy of a numerical multi-step bending model relating to springback is validated with the help of the experimental results.