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Predicting Damage and Failure along the Process Chain of Forming to Crashworthiness Simulation: The effect of full 3D Stress States

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Typically, the simulation of sheet metal forming processes as well as crashworthiness studies are based on classical Reissner-Mindlin shell elements. In forming simulations these interact with rigidly discretized tools while in crashworthiness interaction takes place with other deformable parts. With the need for reliable prediction of failure mechanisms in crashworthiness – especially for advanced high strength steel grades - the history of deformation and pre-damaging of the material during the production process needs to be taken into account in subsequent loading scenarios. A typical approach is therefore to map data like thinning, plastic strain and scalar damage from fine forming meshes to rather coarse crash meshes. It is obvious that stringent calibration procedures in both disciplines as well as in the intermediate mapping procedure need to be employed in order to accomplish the goal of predictive failure modes in crashworthiness simulations.

However, the aforementioned process chain shows significant drawbacks in load cases where the strain and damage growth cannot be captured correctly by the applied discretization. This is the case e.g. in typical stretch-bending processes (see [1]). Here the classical shell element is not able to capture the high lateral stress components emerging from certain contact situations due to the underlying shell assumption. It can be shown that in such cases the predictability of the complete process chain is affected. Possible solutions like enhanced 2D shell models, where the condition of zero lateral stresses is modified, as well as 3D shell formulations are discussed. However, the aforementioned calibration procedure must be reworked and the applied plasticity and damage models need to be implemented also for 3D stress states. Clearly this adds also another dimension to the set of calibration tests needed.

In the present paper the finite element code LS-DYNA is employed. Plasticity models of Barlat-type are used in forming while classical J2-plasticity is applied in crashworthiness. Both models are coupled with the enhanced GISSMO-damage model. The paper discusses possible improvements in constitutive modelling and discretization that can lead to a more robust forecast of failure in the design process.

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