A generalised hybrid damage mechanics model for steel sheets and heavy plates

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To Ailin Liu & Kang Zhong

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Abstract

The damage onset and evolution are of significant importance in the forming processes of high strength steels. These two features and their influence on fracture have challenged the predictive capability of the conventional damage mechanics models. The present thesis contributes to the accurate fracture prediction of both high strength steel sheets and heavy plates by proposing a new generalised hybrid damage mechanics model. A dual-phase steel sheet (DP600) and a high strength low alloy steel plate (S355J2+N), which show very different relation patterns between damage and fracture, are investigated. For both steels, an easy and systematic material parameter calibration procedure with different experiments is designed. Good prediction applying the model to Nakajima tests for the steel sheet and to bending tests for the heavy plate is achieved. This validates the generalised transferability and flexibility of the proposed model for high strength steels with complex damage-fracture relation under various stress states. As the model is formulated in a phenomenological sense, it also suffers from two drawbacks: having a large number of material parameters and a weak link to the material microstructure. Therefore, two approaches are provided to overcome these shortcomings: justified simplification of the model formulation for specific applications and linking the microstructure to the phenomenological material parameters by multiscale modelling.

Kurzzusammenfassung

Die Schädigungsinitiierung und -entwicklung spielen eine signifikante Rolle in den duktilen Versagensmechanismen, die in den Umformprozessen moderner hochfester Stähle dominieren. Dies stellt eine Herausforderung für die konventionellen Schädigungsmodelle dar. In der aktuellen Arbeit wird ein neues hybrides Schädigungsmodell vorgestellt, mit dem eine genaue Beschreibung des Versagens von Stahlblechen verschiedener Dicken erzielt werden kann. Untersucht werden ein Feinblech aus Dualphasen-Stahl (DP600) und ein Grobblech aus einem mikrolegierten Stahl (S355J2+N), die sehr unterschiedliche Schädigungsabhängigkeiten des Versagens aufweisen. Für beide Stähle wird ein einfaches und zuverlässiges Verfahren zur Kalibrierung der Materialparameter anhand von verschiedenen Experimenten entwickelt. Bei Modellanwendungen zur Simulation von Nakajima- und Biegeversuchen konnten gute Übereinstimmungen erreicht werden. Dies bestätigt die allgemeine Übertragbarkeit und die Flexibilität des vorgestellten Modells bei Stahl-Anwendungen, gekennzeichnet durch den komplexen Zusammenhang zwischen Schädigung und Versagen bei unterschiedlichen Spannungszuständen. Da es sich um ein phänomenologisches Model handelt, leidet es unter zwei Nachteilen: Eine hohe Anzahl von Materialparametern und eine schwache Verbindung zum Gefüge. Zur Überwindung dieser Defizite werden zwei Ansätze präsentiert: zum einen wird die Modellformulierung bei bestimmten Anwendungen vereinfacht und zum anderen wird mithilfe der Multiskalenmodellierung eine Verbindung zwischen dem Gefüge und den phänomenologischen Materialparametern hergestellt.

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