Ductile failure in large-scale analyses of aluminium structures

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Modelling of ductile failure in aluminium alloys is of high importance during the design of lightweight structures subjected to impact loading. Such designs are today based on numerical analyses and their credibility is crucial to reduce the development time and costs of such products. Under impact conditions, lightweight structures are most likely exposed to severe loadings and failure is a phenomenon which cannot be ignored. To accurately capture ductile failure, an analyst should employ advanced constitutive models to describe properly the local behaviour of the materials as well as proper discretization to predict the correct deformation mode of the structure. This approach would lead to the use of advanced anisotropic yield surfaces to capture accurately the anisotropic yielding and plastic flow of aluminium alloys as well as fine solid element meshes to predict correctly the strain localization process [1]. Unfortunately, these approaches require large investments from the user both in terms of calibration of the constitutive models and CPU time when running the numerical analyses. These large costs prevent the use of these techniques into large-scale analyses and simplified approaches are still required within an engineering environment.

The aim of this work is then to propose a constitutive and failure criterion suitable within an engineering context both in terms of calibration cost and applicability for shell element analyses. The yielding and plastic flow of the investigated aluminium alloy is then reduced to an isotropic non-quadratic model using ***MAT_36** and ductile failure is predicted using the Cockcroft-Latham failure criterion added to the model through the ***MAT_ADD_EROSION** keyword. A simple calibration procedure based on a single tension test is applied to calibrate the constitutive model and the failure criterion. Based on the tensile test results, a simple but cost-effective regularization scheme is proposed to handle the mesh sensitivity of the failure model for shell elements of various sizes.

The calibration and validation of the proposed approach is presented based on quasi-static and low-speed impact tests carried out on large aluminium stiffened panels recently published by Morin et al. [2]. A satisfactory agreement is found between the proposed modelling approach and the experiments.

Literature

[1] D. Morin, O.S Hopperstad, O-G Lademo, M. Langseth, Multiscale Modelling of Aluminium Components for Crash Loadings, 10th European LSDYNA conference, Manchester, UK, 2013

[2] D. Morin, B. L. Kaarstad, B. Skajaa, O. S. Hopperstad, M. Langseth, Testing and modelling of stiffened aluminium panels subjected to quasi-static and low-velocity impact loading, accepted for publication in International Journal of Impact Engineering.