Predictive fracture modelling in crashworthiness: A discussion of the limits of shell discretized structures

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Abstract

For many years shell formulations were used extensively in crashworthiness applications in order to predict deformations and even rupture of thin shell-like structures. From a general shell theory point of view there are probably no arguments to change this in the near future, unless none of the basic shell assumptions like using them for thin structures, having plane sections and only minor stresses in thickness direction, will be violated.

However, especially if damage, localization and eventually rupture is regarded, the aforementioned assumptions limit the applicability and eventually the means to calibrate such models. For instance, if the rupture strain in biaxial loading is to be calibrated from experiments one can have straight biaxial tests or penetration tests (i.e. the Nakazima tests). For both setups classical shell elements deliver the same value for triaxiality of 2/3. While this is the correct solution for a biaxial test, the Nakazima test suffers from the fact that lateral stresses applied to the sheet are not being covered at all in classical shell formulations. Hence the stress triaxiality and the loading angle are not predicted accurate enough (see Fig. 1). Another well-known issue is the inability of 5-parameter shells to correctly predict a correct stress state in localization zones due to the violation of the plane section assumption.

The present paper will describe such limitations in detail, focus on different calibration techniques and resulting drawbacks in the final crashworthiness application. Furthermore, available remedies will be presented and discussed.

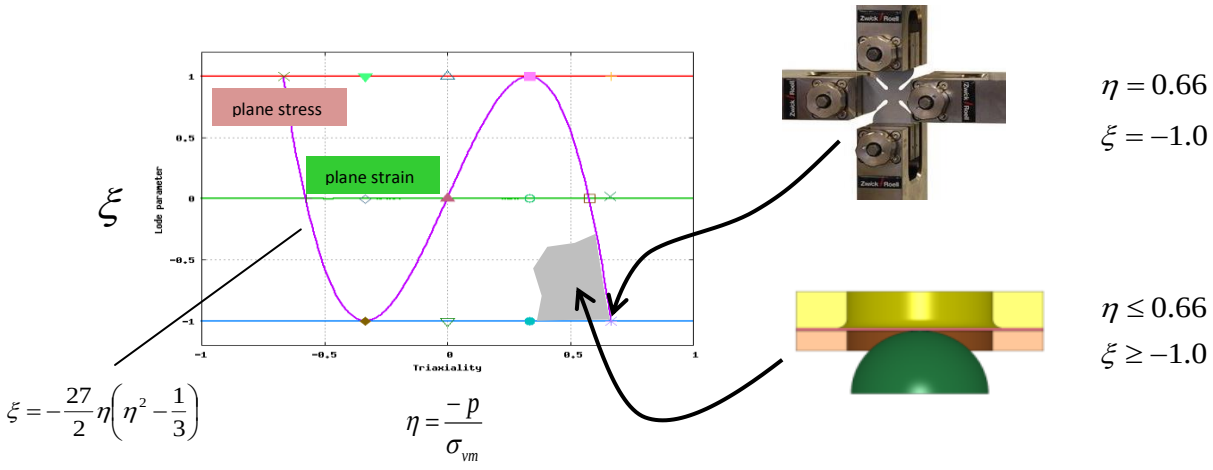

Figure 1: States of stress in biaxial and Nakazima test setup