On the modelling of slant fracture in metal sheet structures

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The numerical simulation of crack propagation is very important for residual strength prediction of large thin-walled panels, since a cracked sheet can sustain significantly increasing loads even after crack initiation. The present investigation addresses one particular issue of this degradation, that is the so-called slant fracture, i.e. the change of the fracture plane from perpendicular to the loading direction to a plane characterised by a normal 45° inclined to it, see Fig. 1, which leads to a mixed mode I/mode III problem and in the transition regime even to a more complex mode I/mode II/mode III situation. In addition to the failure modes involved, a second challenge is the stress state varying with the thickness of the sheet, even if the failure mechanism is the same. The numerical tool used in this study is the cohesive model. This has been proven to be efficient for large amounts of crack extension in sheet metal structures, which are usually simulated with the assumption of plane stress conditions and as such modelled by shell elements in a finite element framework. However, if thickness effects are to be studied, 3D modelling must be employed. In this case, the slant fracture is usually still ignored, and the crack propagation is modelled by a flat fracture plane. This procedure may be useful, if large amount of crack propagation is to be simulated and hence the transition regime is of vanishing importance. However, the transferability of cohesive parameters from one thickness to another, which is thought to be the advantage of 3D modelling is completely lost. The modelling of the transition regime by so-called effective cohesive parameters, which is also referred in literature, does not overcome the incorrect thickness effect. In the present study it will be shown that for varying thicknesses the correct crack extension and thus residual strength of a precracked thin-walled panel can be predicted with a full 3D model of the slanted fracture plane only. Of course, for such simulation the cohesive parameters needed are not only those for normal separation, but an additional set for tangential separation must be defined as well, but the parameters are constant and do not depend on sheet thickness or local stress state.

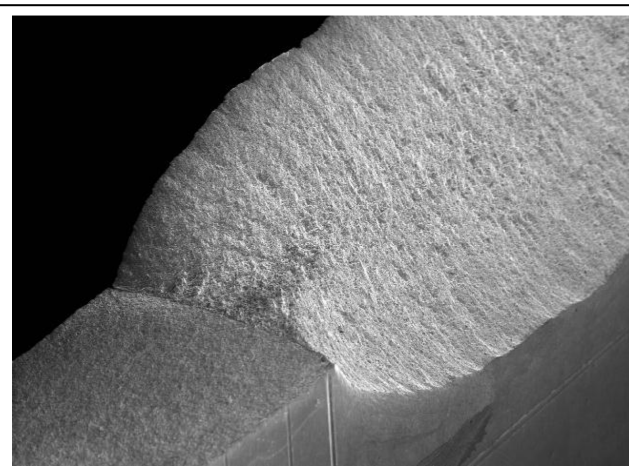

Figure 1: Fracture surface of a 3 mm thick aluminium sheet. the surface turns immediately to 45° w.r.t. the loading direction.