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DEBONDING MODELLING OF INDENTATION LOADED FIBRE METAL LAMINATES

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Summary: Fibre metal laminates (FMLs) are a hybrid laminate concept formed by thin metal sheets and fibre reinforced plastic layers. FMLs were originally developed for aeronautical engineering applications to possess high fatigue tolerance. The concept was later on found to hold high resistance against impact loading. The high impact resistance of FMLs has been explained by the strain rate hardening of the constituent materials, as well as by various failure modes provided by the laminated structure. The strong failure modes, i.e. fibre failure, metal plastic deformation and metal cracking, have gained the majority of the research interest due to their dominant effect on the laminate energy absorption. The weak failure modes, i.e. metal-composite debonding, composite delamination and matrix cracking, may however adapt the failure process and lead to premature laminate failure due to intensified attendance of some strong failure mode.

Shear forces caused by impact and indentation loadings result in out-of-plane shear stresses in panels. In layered structures, such as composites or FMLs, this promotes the delamination initiation and progress at the layer interfaces by fracture mode II. However, our previous study on the impact response of stainless steel FMLs verified the involvement of peeling forces (fracture mode I) in the debonding process [1]. The peeling force participation was explained to occur during the unloading part of the impact event as a result of dissimilar load responses of steel and composite (elastic-plastic vs. linear elastic). Therefore, the present study focuses on evaluating the importance of fracture mode I to debonding process by FE modelling.

The basic form of impact event, i.e. quasi-static indentation loading, was used as a basis for the modelling. The modelled laminate consisted of two 304L stainless steel sheets (t = 0.6 mm) on the surfaces and four layers of M21/T700GC carbon fibre epoxy UD layers [0/90/90/0] bonded in the middle by two FM300NK epoxy adhesive films. The model was built with the Abaqus software in 3D deformable frame using 8-node linear solid brick elements (C3D8R). The CFRP layers and adhesive films were modelled as a linear-elastic material, whereas the applicability of Isotropic and Johnson-Cook hardening models were investigated to complete the elastic-plastic model of the stainless steel. The indentation was modelled by a forced displacement of a hemispherical contact head (r = 15.9 mm) and the laminate was supported by preventing the displacements at the support boundary (r = 80 mm). The maximum contact force of 4.9 kN was reached during the loading step which represents the maximum force of 10 J impact event. Cohesion elements and virtual crack closure technique (VCCT) were applied for debonding energy release rate investigation. The preliminary results by VCCT suggest full mode II dominant debonding during the loading step of the indentation, whereas, the unloading step is controlled by mode I.