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MODELLING TECHNIQUES FOR DELAMINATION AND FRACTURE OF COMPOSITES

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ABSTRACT

In this study, modelling techniques based on new extended finite element methodologies for the study of fracture, in general, and delamination in composites, in particular are presented. Recent approaches have successfully modelled fracture without the need of continuing refinement of the finite element mesh. This is an outstanding advantage in terms of reliability and computational cost. Details of the initiation criteria and evolution of a crack are provided. It is argued that the strategies presented herein would appeal to the engineering practice as reliable techniques for structural integrity assessment of novel designs. The results are validated against data from the literature showing the robustness and accurateness of the techniques presented.

Keywords: fracture, delamination, finite elements, crack, damage, structural integrity, structure, engineering materials.

INTRODUCTION

The standard Finite Element Method (FEM) is beaten in terms of computational cost on the assessment of fracture problems if it is compared to novel numerical methods. This is due to the huge cost derived from re-meshing to track the crack paths with FEM. Thus, relatively novel methodologies based on the extended Finite Element Method (XFEM) or the most novel Extended Isogeometric Analysis (XIGA) have reduced significantly re-meshing and, in many cases, there is no need of remeshing. Extended finite element strategies embed within Heaviside functions for modelling explicitly the discontinuity associated to material cracks. Therefore, cracks are modelled as an effective jump in the displacement field. This feature is shared by both XFEM and XIGA. Moreover, functions for the representation of the singular stress field ahead of the crack tip are easily integrated. For instance, trigonometric polar functions are used for the approximation of the stress singularity at the crack tip, see Curiel-Sosa and Karapurath (2012). These types of functions are called, in general, enrichment functions.

Singularity at the crack tip is appropriate for linear elastic materials. However, for the case of nonlinear materials the singularity vanishes and, hence, there is no need of using such trigonometric polar functions for enhancement of the computations. In addition, for the case of delamination in composites, the bimaterial interface affected has a special stress field ahead of the crack tip. In such case, special enrichment is necessary for enhancing accurateness. The issue of mesh-dependency in the computation of damage is discussed as this is a major burden to show reliability on the simulation of complete failure in a composite structure. The removal

of re-meshing guarantees a significant reduction of computational time as well as a more reliable tracking of the crack paths. This is indeed an advancement that engineering practice will arguably absorb straightforwardly.

RESULTS AND CONCLUSIONS

Evidence of the robustness and accurateness of the strategies is shown through several benchmark problems and results of interest. This included the following:

- Dynamic Freund problem: computation of stress intensity factors associated to a stress wave travelling through a cracked plate. The results are compared with the analytical solution showing close match but affected by small oscillations linked to the explicit solver used.
- Cross-ply laminate subjected to progressive transversal crack: the energy release rate (ERR) is computed and compared to values obtained with classical finite elements, analytical and with the Boundary Element Method (Tafazzolimoghaddam & Curiel-Sosa, 2015). The J-integral is considered for the computation of ERR.
- Cross-ply laminate with transversal cracks and delamination (Navarro-Zafra, Curiel-Sosa & Serna Moreno, 2016). Delamination was triggered when the transversal cracks were getting closer -and in almost perpendicular direction- to the interface
- Onset and progression of cracking on parts obtained by selective laser sintering process: it was found that crack occurred invariably between the two closest un-melted particles (Ibbett et al, 2015). A range of tests are presented to show evidence of this as well as the effect of un-melted particles over the crack direction.
- Isogeometric analyses and simulation of cracks associated to creep.

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