Dynamic delamination phenomena in composite laminated structures

D. Bruno, F. Greco, P. Lonetti, G. Sgambitterra

[1]*Department of Structural Engineering, University of Calabria, Via P.Bucci, Cubo 39-B, 87030, Rende, Cosenza, Italy,*

email: d.bruno@uncal.it, f.greco@unical.it, lonetti@unical.it, g.sgambitterra@unical.it

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Composite materials are frequently affected by interface cracking damage modes, which greatly reduce the structural integrity of laminated structures, leading to premature and catastrophic failure modes. During the last decades many efforts have been made to analyze dynamic fracture behavior, giving rise to several studies devoted to predicting crack growth phenomena [1]. In the framework of composite structures, most research efforts were confined to static or low velocity crack propagation whereas dynamic delamination phenomena are not completely investigated. Indeed, a brief review of the literature denotes that many papers are concerned to analyze the main features of crack growth, neglecting a priori the inertial contributions arising from fast propagating phenomena. However, from an experimental point of view, many observations on laminated composite structures have shown that typically the evolution of such interfacial cracks is highly time dependent [2].

The structural modeling is developed by means of a finite element formulation based on a plane stress behavior, whereas the crack growth is predicted by a Fracture Mechanics approach. In order to simulate the dynamic crack growth, the proposed modeling utilizes a fracture toughness criterion based on the energy release rate (ERR) and the corresponding mode components. The ERR is evaluated by means of the decomposition methodology of the J-integral expression, which is proposed in the framework the dynamic crack propagation [3]. The change of the geometry, produced by a crack advance, is taken into account by means of a moving mesh strategy based on an Arbitrary Lagrangia-Eulerian (ALE) formulation. The analysis is proposed in a non-stationary framework, in which the influence of time dependence and the inertial forces are taken into account.. The structural model is developed by means of a finite element formulation based on 2D continuum model. In order to predict the crack growth phenomena, a combined formulation based on "Moving Mesh Method" (MMM) and Remeshing Technique (RT) compatible with the actual dynamic fracture process is developed. The MMM is utilized to simulate the crack growth along interfacial paths, by means of a Lagrangian approach in which the mesh movements follow those of the physical material. The RT is introduced to avoid distorted elements as well as thus poor approximations in the results. The basic modeling owing to time dependent nature of the problem and inertia effects, transfers the nodal data from the old mesh to the new mesh in each step of the remeshing [4]. Since the dynamic crack growth is intrinsically an unstable phenomenon, crack growth increment cannot be defined by the user, and a dynamic fracture criterion should be employed to find the crack tip velocity and crack extension every time. A parametric study is developed to investigate some features regarding the crack tip behavior, such as crack arrest phenomena, allowable tip speeds and rate dependence of the interfacial crack growth phenomena.

References

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