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AN ASSESSMENT OF TECHNIQUES FOR PREDICTING DELAMINATION: A COMPARISON AMONG STRESS BASED CRITERIA, FRACTURE MECHANICS AND INTERFACE MODELS

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ABSTRACT

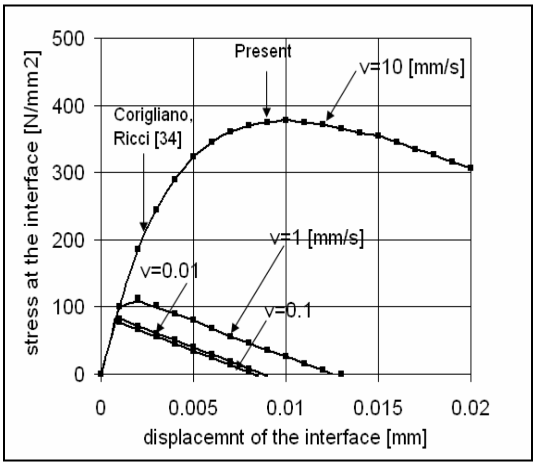
Matrix cracks and delaminations represent a typical damage mechanism in laminated and sandwich composites, which is due to the high stress gradients necessary to keep equilibrium and kinematic compatibility at the interfaces of the dissimilar constituent materials, at free edges and around geometric discontinuities and regions where intense localised loads are applied. When their growth becomes relevant, these defects degrade strength and stiffness and cause a deleterious load redistribution which can consistently reduce the long-term load-carrying capacity. Therefore, the local stress fields causing these defects have to be very accurately predicted and criteria should properly describe the local state of damage and relate it to the overall performance are required. However, not only detrimental effects are related to cracks and delaminations. Indeed, a large amount of the incoming energy in laminated and sandwich composites can be absorbed and dissipated through a complex interaction of local failures in their microstructure giving rise to a controlled, progressive delamination extended to ample regions.

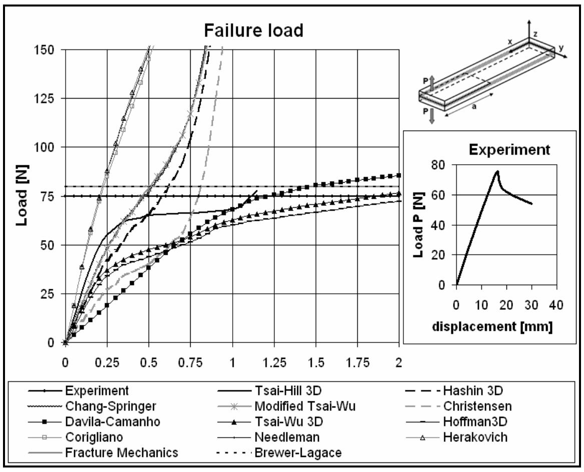
Thus, whichever the nature of delamination might be, an accurate prediction of its effects is basic within the framework of the damage tolerant approach. Therefore, the most sophisticated computational tools and local failure models must be used for the analysis, which has to be performed contemporaneously either at the level of constituents, or at the global scale. No attempt is here made for discussing the computational models (oral presentation only)

The residual strength can be computed either using fracture mechanics, progressive delamination models, or stress based criteria. The designers prefer the stress based methods, although it is a common opinion they are valid only for predicting the initiation of delamination, but not its growth, because conventional plate and shell models can be used and only standard engineering parameters are involved. Fracture mechanics and progressive delamination models require an accurate description of the interfaces and the removal of the constraints, in order to represent the delaminations occurrence. To accomplish with this task, usually many computational layers need to be

stacked in the region where the damage arose. Because of the large number of degrees of freedom involved, the analysis can become prohibitively large, thus both these methods are not attractive, notwithstanding they are potentially more accurate.

Despite the evident practical interest, no study is known to the best of the authors' knowledge where the available failure models, i.e. stress based criteria, fracture mechanics and progressive delamination models, are compared for a reasonably large number of engineering sample cases. To contribute to fill this gap, this comparison will be presented for several sample cases with various loading and boundary conditions, failure modes, lay-ups, relative thickness and constituent materials, for which experimental results are available in literature, considering a variety of failure models. For the maximal accuracy, the analysis is carried out using solid elements (a mixed singular wedge element and a solid elements with the three displacements and three interlaminar stresses as nodal d.o.f.). The accurancy of the failure criteria depends on the mode the delamination crack is opened, the lay-up and the loading and boundary conditions. The criteria specialised for delamination appears much more accurate than the generalising criteria. The fracture mechanics models appears the most accurate in all the cases considered. The interface models are shown to be inaccurate for certain sample cases.





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