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SIMULATION OF THE RESPONSE OF COMPOSITE STRUCTURES TO INTENSE DYNAMIC LOADING

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ABSTRACT

Fiber-reinforced composite materials are widely being used in advanced structures such as aircrafts where damage is a primary design concern. From the failure mechanics standpoint, these materials fall under the category of quasi-brittle materials that exhibit a strain-softening behavior marked by a progressive growth of damage. Predicting the initiation and evolution of damage in such structures is crucial and poses considerable challenges to the structural analyst. In general, computational modeling of composite structures faces a number of obstacles owing to their highly anisotropic material behavior and multitude of damage mechanisms. The complexity of the problem escalates when the applied loads are of a dynamic nature such as those that occur during impact.

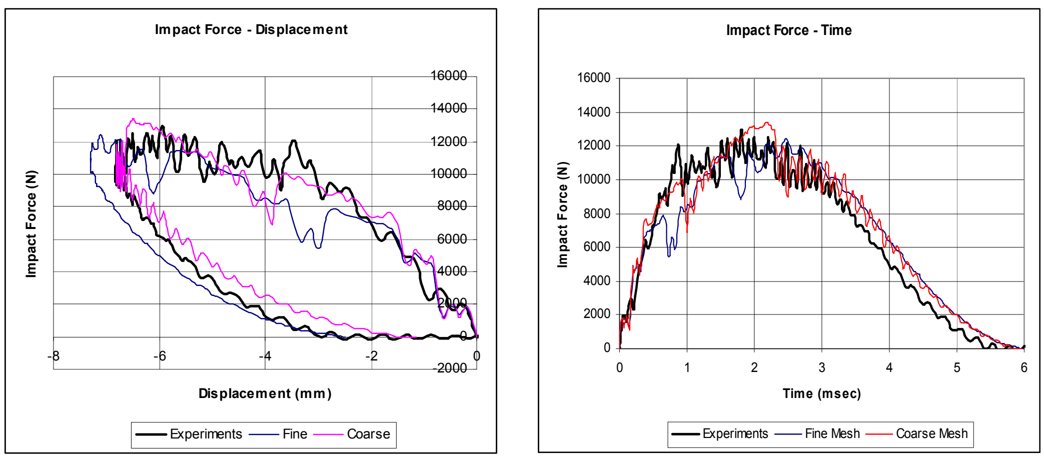
In this study, a comprehensive yet efficient structural model is proposed which is capable of simulating the two major modes of failure in composite panels: the inter-laminar damage (delamination) is modeled using the cohesive crack concept [1] while the intra-laminar damage modes (matrix cracking and fiber breakage) are simulated using the generalized smeared crack/crack band approach [1]. The mesh size and orientation sensitivity issues that plague all strain-softening based models are addressed using a non-local regularization scheme [2], [3]. The numerical testbed used in this study is the nonlinear explicit finite element code, LS-DYNA. The predictive capability and efficacy of the proposed model in capturing the nonlinear dynamic response of composite structures will be demonstrated by considering a case study involving a carbon-fiber reinforced epoxy plate subjected to a non-penetrating transverse impact loading event [4], [5].

The proposed numerical model consists of layers of shell elements that represent the sub-laminates tied together using the tie-break contact option in LS-DYNA. The latter provides a means of modelling delamination. In this contact type, the layers are initially tied together. A stress-based criterion can be defined for the initiation of delamination and a linear softening traction-opening curve can be defined to govern the post-failure behaviour of the contact (or propagation of delamination). The intra-laminar damage is simulated using a built-in material model in LS-DYNA, MAT_PLASTICITY_WITH_DAMAGE, which can be used to model the

softening behaviour of the material with the option of a non-local averaging scheme.

The simulation results are compared with the experimental data in a variety of ways: time histories of deformation, contact force and dissipated energy, hysteresis loops contained within force-deformation diagrams, etc. The delaminated and damaged areas from the experiments are also compared with the predictions of numerical simulation.

Figure 1 shows examples of the predicted impact force–displacement and force-time history compared with the experimental measurements. As shown, there is a very good agreement between the predictions of the numerical simulations and experiments in both cases involving fine and coarse meshes.



(a) (b)

Figure 1 - Comparison between the numerically predicted and experimentally measured a) load-displacement curves, and b) load-time histories

REFERENCES

[1] Bazant Z.P. and J.Planas. 1998. *Fracture and Size Effect*, CRC Press LLC.

[2] Bazant Z.P., Jirasek M. "Nonlocal integral formulations of plasticity and damage: survey of progress", *Journal of Engineering Mechanics*, Vol. 128, No. 11, pp 1119-1149, (2002).

[3] Jirasek M. "Nonlocal models for damage and fracture: comparison of approaches", *International Journal of Solids and Structures*, Vol. 35, No. 31-32, pp 4133-4145, (1998).

[4] Dolfosse, D., Poursartip, A. et al., "Non-penetrating impact behaviour of CFRP at low and intermediate velocities", in *Composite Materials: Fatigue and Fracture, ASTM STP 1230, ed. RH Martin*, ASTM, Philadelphia, PA, USA, pp. 333-350, (1995)

[5] K.V. Williams, R. Vaziri and A. Poursartip, "A physically based continuum damage mechanics model for thin laminated composite structures", *International Journal of Solids and Structures*, 40, pp. 2267–2300, (2003)