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STATIC AND DYNAMIC INTERACTION EFFECTS OF MULTIPLE DAMAGE MECHANISMS IN MULTILAYERED STRUCTURES

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ABSTRACT

Multilayered structures subject to severe dynamic loading conditions, such as laminated and structural composites and sandwich systems subject to high velocity impact and blast, typically develop multiple damage mechanisms that grow, interact and contribute to the energy absorption capability of the systems. In laminated systems, for instance, the dominant failure mechanism is multiple delamination of the layers. In composite sandwich systems, multiple delamination of the face sheets couples with damage mechanisms in the core and interfacial fracture at the face/core interface.

The aim of this work is to investigate the interactions of multiple damage mechanisms in multilayered systems subject to dynamic loading conditions and the effects of such interactions on the mechanical response and different key properties. Reference is made to model systems that represent plates deforming in cylindrical bending and approximate models are used in order to obtain analytical or semi-analytical solutions for special configurations and static loading and simplified computations for dynamic cases. The approximate methods allow the boundaries of different behavior domains to be mapped exhaustively and accurately; this is not easily done with purely numerical solutions.

A model has been formulated in [1,2] to study multiple dynamic delamination fracture in multilayered plates. The model represents the plate as a set of Timoshenko layers joined by cohesive interfaces that define all potential fracture planes. The cohesive traction laws of the interfaces are defined with different possible features to represent different physical mechanisms (intact regions, cohesive and bridged delaminations, regions of contact and friction). The solution is semi-analytical for special crack configurations and static loading (see also [3]). The dynamic solution is found by discretizing the problem and applying a finite difference numerical scheme [4] coupled with an iterative numerical procedure to define the regions of contact and cohesion, which are unknown a priori.

Using the models formulated in [1,2,3], a number of interesting interaction effects have been highlighted and maps that describe different behaviour domains have been

obtained (Fig. 1). In this paper the models will be used to study the problem of energy absorption through multiple delamination fracture in laminated systems. The results show that if the system can be designed so that delaminations will form along predefined planes, the energy absorption capability of the system can be optimized. Following the approach of [1-3], models are currently being formulated to study the interaction of multiple damage mechanisms in composite sandwich systems. Preliminary results will be presented at the conference.

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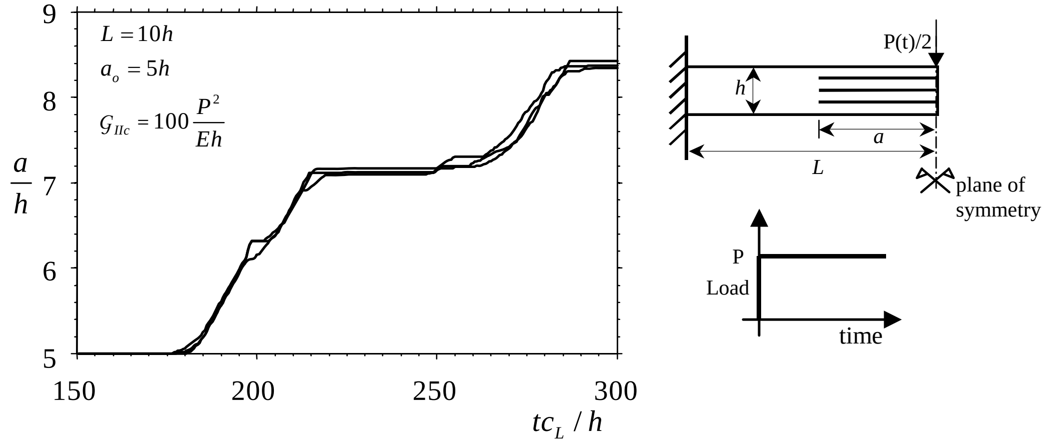

Figure 1. Crack propagation history in a clamped-clamped, homogeneous and brittle beam with three equally spaced, equal length, central delaminations subject to a step force at the midspan (frictionless contact). The problem is essentially mode II. The cracks maintain equal lengths at all times and the equality of length is stable with respect to length perturbations. This behaviour is unaffected by the duration and shape of the load and the geometrical parameters. Depending on the spacing of the delaminations, homogeneous systems with unequally spaced cracks may instead show the dominant growth of only one crack, typically at higher speed. This behaviour has been mapped in [1] (c_L is the longitudinal wave speed, E the longitudinal Young's modulus, $\mathcal{G}_{IIcr}$ the fracture energy)