8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Simulation of delamination in brittle interfaces using an enriched cohesive zone model

***M. Samimi, B.A.E. van Hal, R.H.J. Peerlings, J.A.W. van Dommelen, M.G.D. Geers**

Materials Technology Institute, Department of Mechanical Engineering, Eindhoven University of Technology; P.O. Box 513, 5600 MB, Eindhoven, The Netherlands.
E-mail: m.samimi@tue.nl, URL: http://www.mate.tue.nl/

Key Words: *Interfacial delamination, Brittle interface, Snap-back behaviour, Cohesive zone models, Hierarchical finite elements enrichment.*

ABSTRACT

To achieve the goal of increasing functionality and decreasing costs in micro-electronic packages, integrated circuit processing and miniaturized conventional fabrication technologies have been combined to result in microsystems. Microsystems consist of multiple thin and stacked layers, manufactured using different materials. Interfacial failure, mainly in the form of debonding or delamination of brittle interfaces, results in malfunction or failure of integrated microsystems. In order to understand the process of delamination, a cohesive zone model (CZM) can be used to simulate delamination as a result of gradual degradation of the adhesion between two materials when they become separated.

Application of cohesive zone models is accompanied by some difficulties especially in the case of relatively brittle interfaces. The solution jump problem, which is defined as discontinuities in the numerical solution of rate-independent models, is known to be one of the main numerical problems in such cases [1]. In other words, the solution of the discretized problem exhibits one or more limit points where the rate of either displacement or force of a control degree of freedom switches sign (see Figure 1). Local path-following techniques can be used to deal with these limit points [2]. The occurrence of solution jumps is an artifact of the mesh size; and hence, can be avoided by sufficiently refining the mesh [3]. However, for realistic interface parameters, i.e. small size of the process zone in brittle interfaces in comparison with other dimensions, the element size has to be extremely small, which results in high computational costs.

Elimination or at least reduction of the oscillations observed in the global load-displacement behavior of systems involving brittle interfaces by local improvement of the description of crack propagation and without further mesh refinement, will enhance the efficiency and robustness of cohesive zone models. Therefore, in this paper, a process driven hierarchical extension is proposed to enrich the separation approximation in the process zone of a cohesive crack.

In the new formulation, the linear separation approximation throughout the cohesive zone element is enriched by adding a piece-wise linear enrichment function multiplied

by a scaling factor such that the crack tip can be located at an arbitrary position within a cohesive zone element. As a result, the crack tip position and scaling factors form additional degrees of freedom. Moreover, continuity of the displacement field requires that bulk elements adjacent to the enriched cohesive zone elements be enriched as well. The principle of virtual work that is valid for nonlinear stress-strain relations is used as the weak form of the equilibrium equations.

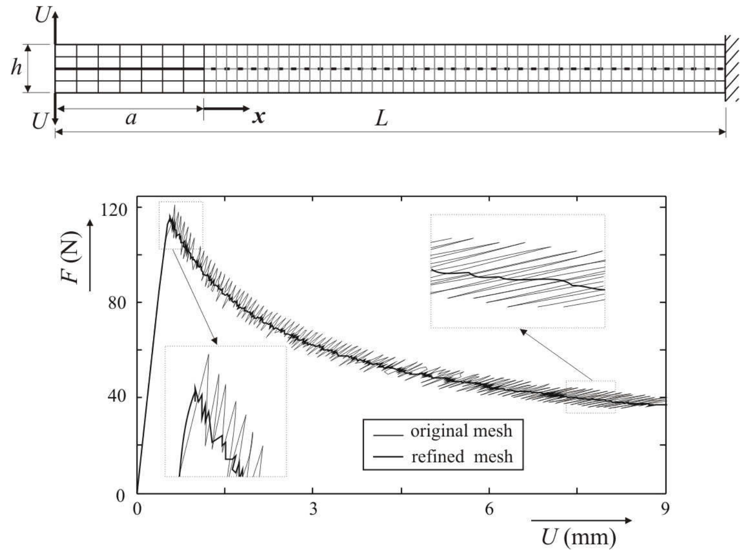

Figure 1: *Double Cantilever Beam (DCB) test [2].*

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