INVESTIGATION OF SCALING LAWS OF THE FIBER/MATRIX INTERFACE CRACK IN POLYMER COMPOSITES THROUGH FINITE ELEMENT-BASED MICROMECHANICAL MODELING

Di Stasio L.[1,2,*], Varna J.[2], Ayadi Z.[1]

[1] *Université de Lorraine, EEIGM, 6 Rue Bastien Lepage, F-54010 Nancy, France*

[2] *Luleå University of Technology, University Campus, SE-97187 Luleå, Sweden*

[*] luca.di.stasio@ltu.se

Research on scaling laws of damage in materials and structures has absorbed the attention of the Fracture Mechanics community since the inception of the field itself. The attractiveness of such relationships resides in their simplicity and predictive power, which would allow a more cost-effective design of structures. Building on early works in dimensional analysis by Buckingham [1], several results have been derived for metals and concrete [2]. Despite the considerable effort spent, Fiber Reinforced Polymer Composites (FRPCs) have proved themselves elusive to such simple analytical description and have even shown to possess counterintuitive thermo-mechanical behaviors, such as the *thin-ply effect* [3] in the context of transverse crack onset. At the microscopic level, the first appearance of transverse cracks is defined by the growth of fiber-matrix interface cracks (or debonds). Characterization of this damage mechanism has been focused on the evaluation of the Energy Release Rate (ERR) under different local and global configurations. Different expressions of a reference ERR have been proposed over the years since the publication of the first analytical solution by Toya [4], but the topic of scaling laws has been left largely unexplored. The aim of this work is to bridge this gap and, if not provide an exhaustive treatment, at least propose a framework to analyze the issue. First, a critical review of the reference ERRs suggested in the literature is proposed. Then, Mode I and Mode II ERRs evaluated for different microstructural arrangements are compared to known analytical results from Linear Elastic Fracture Mechanics (LEFM). From this comparison, the role of size, shape and curvature of the debond is discussed and an interpolation-based analytical formulation is presented. Finally, the expected size of debonds under different microstructural constraints is evaluated by means of this analytical expression and the results compared with the available microscopic observations [5].

[1] E. Buckingham, On physically similar systems; illustrations of the use of empirical equations, Phys. Rev. 4 (1914) 345-376.

[2] Z. P. Bažant, Scaling Laws in Mechanics of Failure, J. Eng. Mech. 119 (1993) 1828-1844.

[3] D.L. Flaggs and M.H. Kural, Experimental Determination of the In Situ Transverse Lamina Strength in Graphite/Epoxy Laminates, J. Compos. Mater., 16 (1982) 103-116.

[4] M. Toya, A crack along the interface of a circular inclusion embedded in an infinite solid, J.Mech. Phys. .Solids, 22 (1974) 325-348.

[5] E. Correa, M. I. Valverde, M .L. Velasco, F. París, Microscopical observations of inter-fibre failure under tension, Compos. Sci. Technol. 155 (2018) 213-220.