Delamination of an adhesive sandwich layer by hydrolysis: initiation and growth

Alessandro Leronni¹, Sina Askarinejad¹, Norman A. Fleck¹

¹ Department of Engineering, University of Cambridge, Cambridge, UK
E-mail: al2040@cam.ac.uk, sa898@cam.ac.uk, naf1@cam.ac.uk

Keywords: diffusion, fracture, corrosion

In shipbuilding, hybrid adhesive joints offer many advantages compared to standard steel solutions with bolted or welded connections. However, their safe implementation is still hampered by a poor knowledge of their long-term behaviour in harsh environmental conditions. An extensive experimental campaign on the aqueous corrosion-driven delamination of an interface between a low carbon steel and a methyl methacrylate adhesive has been carried out by our group to identify the precise delamination mechanism taking place. It has been found that, in closed joint configurations, delamination does not require oxygen supply and hence hydrolysis of the adhesive/steel interface is the dominant mechanism. Here, a mathematical model for the initiation and growth of delamination in a steel/adhesive/steel sandwich structure due to hydrolysis is presented. The competition between the diffusion of water through the adhesive and along the delamination from the side-face of the joint is considered. Hydrolysis at the intact adhesive/steel interface is described as a first-order chemical reaction. A material length scale is defined as the ratio between the diffusivity of water in the adhesive and the rate constant of hydrolysis. It is envisaged that the delamination front advances when the total amount of water per unit area consumed over time in hydrolysis at the current delamination tip reaches a critical value [1]. Non-dimensional maps are given for the initiation time [2] and growth rate of delamination as a function of the ratios of delamination length and material length scale to adhesive height, and of the relative diffusivity of water within delamination and adhesive. The full numerical solution is discussed by identifying different possible regimes of behaviour. When the material length scale is much smaller than both delamination length and adhesive height, and when the amount of water provided by the delamination path is much less than that provided by the adhesive layer, a regime presenting a close analogy with a Mode III elastic crack exists.

Fig. 1: Problem statement.

References
