Comparison of Fatigue Delamination Propagation in DCB Specimens

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Double cantilever beam (DCB) specimens composed of carbon fiber reinforced polymer laminate composites were tested. Two material systems were investigated. In the first, the specimens were fabricated from 15 plies of a plain woven prepreg (G0814/913) arranged in a multi-directional (MD) layup [1]. The plies alternated with yarn in the $0^0/90^0$- directions and $+45^0/-45^0$- directions with the delamination between these two ply types. For the second material type, the specimens were fabricated from 19 plies with the delamination between a unidirectional fabric and a woven ply with yarn in the $+45^0/-45^0$- directions [2]. The remainder of the plies were woven, with yarn alternating between the $0^0/90^0$ and $+45^0/-45^0$- directions. This laminate was produced by means of a wet-layup.

Fatigue delamination propagation tests were carried out with different displacement cyclic ratios R_d where

$$R_d = \frac{d_{min}}{d_{max}} \tag{1}$$

with d_{min} and d_{max} the minimum and maximum displacements in a fatigue cycle. For the prepreg laminate, $R_d = 0.1$, 0.33, 0.5 and 0.75; for the wet-layup, $R_d = 0.1$ and 0.48. The tests were carried out with frequencies between 4 and 6 Hz, many of them running continuously up to 3,000,000 cycles.

The delamination propagation rate da/dN was calculated from the experimental data and plotted using a modified Paris law with different functions of the mode I energy release rate $\mathcal{G}_I$, as well as its normalized value $\hat{\mathcal{G}}_I$; the energy release rate was normalized with respect to its fracture toughness. As expected, the da/dN curves depend on R_d. Using a different parameter, it is possible to obtain a master-curve for all R_d-ratios. Define

$$\Delta\bar{\mathcal{K}}_I \equiv \frac{\sqrt{\hat{\mathcal{G}}_{Imax}} - \sqrt{\hat{\mathcal{G}}_{Ith}}}{\sqrt{1-\sqrt{\hat{\mathcal{G}}_{Imax}}}} \tag{2}$$

where $\hat{\mathcal{G}}_{Imax}$ is the maximum value of the normalized energy release rate in a cycle and $\hat{\mathcal{G}}_{Ith}$ is the normalized value of the threshold energy release rate. Using the parameter in eq. (2) in a Paris type law, it may be observed in Fig. 1 that for each material system a unified master-curve is found. There is no dependence on R_d . The data is shown as dots. The slope of 5.2 for the prepreg is higher than that of 4.0 for the wet-layup. But the rate of propagation is higher for the wet-layup.

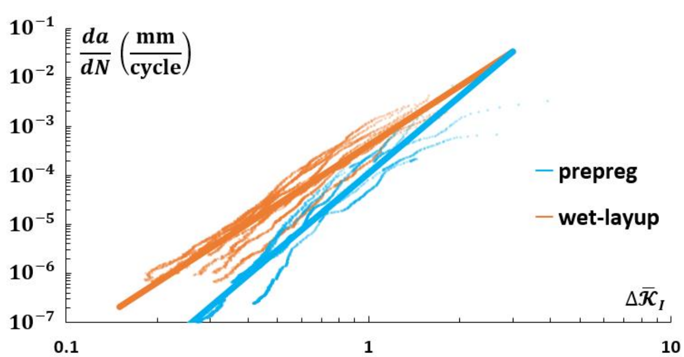

Figure 1. Delamination propagation rate as a function of $\Delta\bar{\mathcal{K}}_I$ [3].

1. I. Simon, L. Banks-Sills and V. Fourman, "Mode I Delamination Propagation and R-Ratio Effects in Woven Composite DCB Specimens for a Multi-Directional Layup", *International Journal of Fatigue*, 96 (2017) 237-251.
2. T. Chocron and L. Banks-Sills, "Nearly Mode I Fracture Toughness and Fatigue Delamination Propagation in a Multi-Directional Laminate Fabricated by a Wet-Layup", Fizicheskaya Mezomekhanika, (in Russain), 21 (2018) 103-134; Physical Mesomechanics, (in English), 22, (2019) 107-140.
3. L. Banks-Sills, I. Simon and T. Chocron, "Multi-Directional Composite Laminates: Fatigue Delamination Propagation in Mode I – A Comparison", *International Journal* of Fracture, 219 (2019) 175–185.