Effects of Plasticity on Toughness Measurements in Laminated Systems

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Linear-elastic fracture mechanics (LEFM) can be used to determine geometry-independent values of toughness, provided conditions of small-scale yielding are satisfied. These values can be used in the design and failure predictions of layered materials. However, the relatively small characteristic length scale of layered materials, dictated by the thickness of the layers, results in the effects of plasticity often being very significant. Even if testing geometries are devised to determine values of toughness under conditions where LEFM results are applicable, failure in actual service may be accompanied by large-scale yielding. It is therefore necessary to determine suitable approaches for predicting failure in the presence of extensive plasticity.

Crack growth in laminated materials generally occurs under steady-state conditions in which the geometry is essentially unchanged. This provides some special opportunities for analyses and experiments into the phenomena associated with crack growth in the presence of large-scale plasticity. Expressions have been developed to predict the conditions for propagation of a crack in two model systems exhibiting large-scale yielding: thin polymer films on metal substrates and adhesively-bonded metal laminates. The resulting analyses have been used to determine values of toughness, and the extent to which the resulting values of toughness were geometry-independent was investigated.

The laminated specimens were fabricated using commercial structural adhesives to form symmetrical and asymmetrical double-cantilever beams. These were fractured by inserting a wedge along the interface. A range of thicknesses was used for the adherends, such that failure was accompanied by extensive plastic deformation. Post-fracture observations of this deformation coupled with measured constitutive properties of the adherends were then used to compute the interfacial toughness. Despite a wide range in the observed plastic deformation, which depended on the geometry and thickness of the samples, reasonably consistent values of toughness were obtained.