Mechanics of architected interfaces for the design of tough composite-metal joints

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Abstract

Thermoplastic (TP) composite materials are increasingly replacing thermoset composites in complex applications, such as in aeronautics, due to their excellent properties. Manufacturing complex structures often involves joining TP composites with other materials, such as metals. Due to the melting behavior of TPs, adhesive bonding can be replaced by co-consolidation or welding (1). However, interfacial failure can occur, necessitating the development of toughening strategies. One common approach is to modify the surface roughness through grit or sandblasting to promote mechanical interlocking (1). Other strategies have also been explored, such as creating grooves, dimples, grids (2), or even complex interlocking microstructures on one or both substrate surfaces (3). Among these, introducing grooves oriented perpendicular to the crack propagation direction has shown the most promising results. However, no consensus has been reached regarding the optimal design. This work aims to find such a consensus and provide design guidelines.

To achieve this, finite element modeling with cohesive elements is employed. A double cantilever beam geometry is modeled, with the two arms made of dissimilar materials and grooves inserted at the interface. It is assumed that without grooves, interfacial failure takes place while in the presence of a groove, the crack can either propagate through the second material or follow the groove pattern. The influence of groove spacing, width, and depth on joint toughness and failure mechanisms is investigated, taking into account the elastic mismatch of both materials as well as the cohesive properties of the materials and the interface.

(1) Marinosci et al., Int. J. Adhes. Adhes., 109, 2021.

(2) Naat et al., J. Adhesion, 99, 2023.
(3) Naat et al., Int. J. Adhes. Adhes., 126, 2023.

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