Characterizing Adhesion and Failure in Overmolded T-Joint Composites with Novel Isostatic Fixtures

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Abstract

Overmolding, a widely used technique across industries, involves molding a material, usually a thermoplastic, over an existing base. A key design challenge in overmolding is the risk of failure at the interface between the base laminate and the overmolded part. Research has focused on understanding the adhesion between composite laminates and overmolding materials, addressing various material pairings, such as thermoplastic overmolding on thermoplastic and metal substrates (1)(2)(3)(4).
As discussed in the literature, there is currently no normalized test to directly measure the maximum stress at the laminate/overmold interface. Tensile testing of overmolded T-joints is widely used to assess their mechanical behavior (1)(2)(4). Yet, during these tests, the base laminate can experience unintended bending, which often results from inaccuracies in the boundary conditions (5). Additionally, misalignments in load application can lead to considerably lower failure loads. Previous studies, which involved numerical simulations by means of a cohesive zone model (6), show that bending of the base laminate, as well as load misalignment, can lead to a non-uniform stress distribution along the interface, where failure is controlled by the maximum stress for crack initiation and by the energy required for crack propagation. A fine control of the loading conditions during a T-joint tensile test would enable us to impose different types of stress distributions along the interface, from (nearly) uniform distributions adapted for direct identification of the maximum stress to high stress gradients which could be encountered in real-life loading conditions.

This work aims to bridge this gap by designing novel isostatic test fixtures. The fixture with double ball joints allows to control the loading axis while not adding extra moment inadvertently. The distance between the two bending supports can be adjusted between 6 and 17 mm to modulate the bending of the base laminate. To eliminate bending and reach a more uniform stress distribution at the interface, a thick metal support can be glued on the back face of the base laminate. Finally, the loading axis and the T-joint axis can be misaligned by 5 mm maximum, adding a controlled moment on the T-joint. The different testing configurations enable us to identify and validate the numerical model.

To understand the influence of the geometry of the overmolded part, the tests were carried out on two different T-joint shapes: a straight T-joint and a T-joint with an additional chamfer. Both joint shapes were tested with different boundary conditions, described above.

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During tests involving the glued metal support, a uniform stress distribution was able to be achieved, yet not maintained until ultimate failure. Indeed, the load transfer goes primarily through the interface, leading to various cracks forming within the base laminate, thus changing the boundary conditions seen by the laminate/overmold interface. The direct identification of the maximum stress is thus not feasible; however it can still be determined through inverse identification by correlating experimental and simulation results. During tests involving bending of the base laminate or load misalignment, the tendencies of the maximum load as a function of the boundary conditions predicted numerically were confirmed experimentally. Different cracking locations were observed and links with the simulations were able to be established. Therefore, the numerical approach was validated by the tests. The remained scatter in the results highlighted the need of stabilization of the manufacturing process.

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