DAMAGE AND FAILURE ANALYSIS OF COMPOSITE STRUCTURES WITH MANUFACTURING DEFECTS

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Composite materials are currently being used in a wide range of applications, including space structures, air vehicles, boats and ships, and rapidly expanding areas of energy production, particularly wind turbines. As broad are the applications, so are the manufacturing methods, and not all of these can be controlled to assure the quality needed for performance requirements. In fact the conventional approach to accept/reject a composite part based on detection of manufacturing defects, e.g. voids of a certain volume fraction or delaminations of a certain size, by ultrasonic or other inspection techniques, is not viable except in the high end of aerospace applications. Many applications today, particularly the wind turbine rotor blades, would be prohibitive in cost if designed on the basis of negligible defects. In these structures significant amount of manufacturing defects are inevitable, and a sound engineering approach would be to account for their effects rather than apply arbitrarily large factors of safety and conduct expensive full-scale tests as proof of safety.

The traditional “effects of defects” approach, practiced a few decades ago, relied on testing with simulated defects, e.g. artificially induced delamination, and analyses where defects were embedded in a homogenized composite. Today, our experimental techniques have advanced to the extent that images of defects such as voids can be generated in three-dimensional geometry, and computational methods can analyze local stress fields around defects with high accuracy. These advances call for a “defect engineering” approach that can produce a cost/performance trade-off based design strategy. This presentation will describe such a strategy and will illustrate the concepts with case studies performed recently to investigate the effects of defects in ways that are compatible with physical observations.