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Joining and Repair of Composite Structures

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Foreword

This publication, *Joining and Repair of Composite Structures*, contains selected papers presented at the symposium of the same name held in Kansas City, Missouri, on 17–18 March, 2003. The symposium was sponsored by Committee D-30 on Composite Materials. The symposium chairmen and co-editors were Keith T. Kedward and Hyonny Kim.

Contents

Overview

This book is a peer reviewed summary of the works of a majority of the authors who participated in the Symposium on Joining and Repair of Composite Structures, which took place on March 17 and 18, 2003, in Kansas City, Missouri under sponsorship of the ASTM Committee D30. This symposium addressed a critical and enabling component of composites technology, which was last featured by ASTM International as a Special Technical Publication in 1980 (STP 749). The use of composite structural assemblies in the aerospace, automotive, marine, and recreational industries has seen extensive growth in the intervening period. Inevitably, the joining, assembly, and repair of structures in all these industries continues to severely limit the expanded usage of composites. Certification and associated standards in testing are also key issues for industries that are continuously concerned with the joining, repair, and maintenance of composite structures.

The objective of the symposium was to provide a forum for interaction and synergy between the design, analysis, testing, and fabrication of structural joint and attachment configurations. The challenges faced in repair approaches that are needed to maintain composite and metallic structures add another dimension to the complexities of joining composites. The papers contained in this publication address this objective by covering a spectrum of topics relevant to the joining of composites. Papers focused on design, analysis, and testing are all represented. These are organized in this book by the general topic categories of adhesively bonded attachments, repair, and bolted attachments.

Adhesively Bonded Attachments

The papers in this section cover a wide range of topics encompassing the design, analysis, testing, and fabrication issues associated with adhesive bonding of composites. First, a general analysis of adhesive joints based on the sublaminate analysis methodology (Flanagan and Chatterjee) was shown to be capable of predicting the peel and shear stress distributions in joints of arbitrary lap-like configuration and loading. In another work the nonlinear adhesive constitutive behavior was accounted for in a combined closed-form/numerical calculation of the joint shear stress for joints loaded under in-plane shear (Kim and Lee). Both of these analysis techniques are founded on closed-form model development, but take advantage of current computer technology to obtain solutions. Such analyses remain ultimately useful for the study of the effects of joint parameters on performance of the joint. There are three combined experimental and analytical papers contained in this section. They focus on the development of a test specimen configuration suitable for the strength measurement of lap joints loaded under in plane shear (Tomblin, Seneviratne, Kim, and Lee), and the investigation of a new double-strap joint design configuration (Qian and Sun) that makes use of extra attachments to improve significantly the joint strength. The fifth paper in this subgroup includes the correlation between analysis and testing of thick section thermoplastics composite-to-titanium for a marine application (Leon, Trezza, Hall, and Bittick). The final paper of the section addresses the often controversial issue of "bondable" peel ply application for bonding fiberglass skins to a polyamide honeycomb core (Kieronski, Knock,

Fallon, and Walker). This work indicated that the adhesion appears to be dominated by a mechanical interlocking mechanism in this particular assembly.

Adhesively Bonded Repair

Two papers in this book focus on the topic of repair. The repair of new armor concepts that are to be used on advanced composite military vehicles was investigated, with particular focus on characterizing the dynamic response of the adhesive joints formed in scarf repairs (Gama, Mahdi, Cichanowski, Yarlagadda, and Gillespie). A split Hopkinson pressure bar was used for these experiments. The repair of thick steel structures used in earth excavation equipment was reported on by another group of authors (Roach, Rackow, and Dunn). Bonded composite patches were argued to be more capable than welded repairs for suppressing crack growth in these structures. A primary aspect driving the success of this use of bonded composite repair technology was in determining the best surface preparation technique specifically compatible with both the structure and the application environment.

Bolted Attachments

The four papers contained in this section are on the topic of mechanically-fastened joints. The first in this series gives an overview of the history of bolted and riveted composite joint analyses (Hart-Smith). While these analyses have largely been empirically based, the author projects into the future and describes a physically-based method for joint analysis employing the Strain Invariant Failure Theory (SIFT). Two other works in this section are focused on bolted joint failure prediction. In the first of these, the bolted joint analysis code *IBOLT* is described in detail (Eisenmann and Rousseau). This code is capable of analyzing multiaxially loaded composite joints with various bypass and bearing loading ratios. The second paper demonstrates the use of nonlinear finite element analyses for predicting failure in composite joints based on lamina-level failure criteria (Bau). These predictions were correlated with experimentally-measured ultimate strength databases. Finally, the last paper in this book focuses on the use of standardized ASTM test methods for obtaining filled hole and bolted attachment allowables (Sawicki). Fastener-hole clearance was identified as a key parameter governing composite filled hole strength.

Areas of Future Research

An open forum discussion among the attendees of this symposium was held to discuss the challenges that need to be addressed in the area of joining and repairing composites. The discussion was focused on adhesive joints, particularly on the topic of standardized methods for measuring properties, and for evaluating joints specifically having composite adherends; it was pointed out that most test methods are developed for metal adherends. Determining adhesive properties was of considerable concern among the industrial participants. Existing test methods, e.g., ASTM D 5656 thick adherend, have been cited as being difficult and sometimes nonrepeatable. Ultimately, empirically and theoretically based investigations are needed in order to establish relationships between bulk-measured properties and joint properties where the adhesive exists as a highly confined thin layer. Finally, the scarcity of

information on the dynamic properties of adhesives, as well as the creep behavior of joints were also cited as topics of needed activity.

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