COMPOSITES BONDING

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The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution to time and effort on behalf of ASTM.

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Foreword

This publication, *Composites Bonding* contains papers presented at the symposium of the same name held in DWF Airport, TX on 14–15 October, 1993. The symposium was sponsored by ASTM Committee D-14 on Adhesives and its Subcommittee D14.40 on Adhesives for Plastics. Dennis Damico of Lord Corporation in Erie, PA, Thomas L. Wilkinson, Jr., of Reynolds Metals Company in Richmond, Va and Sandra L. F. Niks of General Motors in Rochester Hills, MI presided as symposium chairmen and also are the editors of the resulting publication.

Contents

Overview

Introduction

The symposium focused on theoretical as well as practical aspects of bonding composites to themselves and to other polymeric and inorganic surfaces. Areas of interest included the surface science of composites, surface preparation, bonding and adhesives, adhesive testing and durability, and adhesive application and use in the manufacturing environment. The composites of interest included aerospace composites, automative composites, composites used in the recreational marine industry, and others.

The symposium was organized to include current information on composite surface preparations (chemical, physical, and mechanical), the effective surface preparation on adhesives and adhesive durability, surface characterization (chemical and physical), joint design, bond performance under environmental and physical stress (both static and mechanical–dynamic), analysis of bond failures (both chemical and using other means), adhesive testing (cleavage, peel, and shear), adhesive application, designing with adhesives, predicting adhesive performance, and cross bonding of composites to other materials.

This volume contains sections on the design of adhesive joints, fractographic analysis of surface preparation of composite materials, the effect of temperature and humidity on the fatigue behavior of bonded joints, the durability of adhesive bonded epoxy carbon fiber composites, the prediction of performance of adhesive bonded joints in acoustical evaluations, the repair of thermoplastic resin composites and the durability of adhesive bonded epoxy carbon fiber composites, the durability of adhesive bonded carbon fiber composites, and the relationship of physical properties of curing adhesives to joint strength development.

This volume is designed to convey recent developments in the study of composites of a number of different kinds ranging from automotive to aerospace and includes work that has been conducted from around the world and not yet published in this type of format.

This book will be useful to anyone interested in furthering their understanding of adhesive joints, the dynamic mechanical properties of interfaces, the study of failure mechanisms, the study of types of adhesives, the ability to bond composites, the durability of joints, and the relationship of different types of composites commonly used in industry. It will be useful to people attempting to better understand the durability of adhesives and bonded joints as well as individuals interested in predicting long-term survival of joints, as well as bond development. It also offers information on adhesive performance and failures on a macromolecular scale as well as on atomic scales.

The ongoing need to better understand and predict failure in bonded composites is further characterized in this volume. Previously, no cross-sectional examples of bonding applications and testing that represents such a diverse combination of approaches to bond development testing and durability has been available.

The contributions to this volume have shed significant new insight into analyzing failed surfaces, relating actual part bonding to real world examples, and further relating applied research studies to theoretical engineering properties. The studies presented here suggests additional work is still needed in cross bonding composites to other materials as well as further characterizing surfaces and interfaces of bonded composites. It also suggests the need to further contribute to understanding of the bonds of various types of composites that exist in the world today ranging from lower strength SMC to higher strength aerospace composite materials.

Summary

Surface Pretreatment and Adhesive Bonding of Carbon Fiber-Reinforced Composites

The results of lap shear and wedge testing in various environments are correlated to the surface composition of the composite, as measured by X-ray Photoelectron Spectroscopy (XPS), Ion Scattering Spectroscopy (ISS), contact angle analysis, Scanning Electron Microscopy (SEM) and profilometry. Surface pretreatments which are studied include grit-blasting, peel ply and plasma treatment. The combined results are used to address the role of the interphase in determining the initial strength as well as the durability of composite-to-composite bonds.

Evaluation of Adhesives and Primer Systems for Bonding Carbon/Epoxy Composites to a Variety of Metallic Substrates

The study focused on identifying adhesives and processes for lightweight bridging and helicopters. Based on the requirements of the above systems, the study examined a variety of epoxy paste-room temperature curable adhesives as well as epoxy paste adhesives which require elevated cures and have properties similar to film adhesives. Results of lap shear, floating roller peel, double cantilever beam, and wedge testing are discussed for carbon/epoxy joints prepared with an abrasion treatment.

Aerospace Structural Adhesive for Bonding Graphite Epoxy Laminates and Graphite Epoxy Honeycomb Structures

A new structural composite bonding adhesive is presented. Data is presented over graphite epoxy prepreg demonstrating the adhesive utility in both co-curing and secondary bonding applications. The data presented includes composite double overlap shear, sandwich beam shear, and sandwich flatwise tensile both initially and after hot wet exposure. Effects of prebond aging of the adhesive are discussed.

Repair of Thermoplastic Resin Composites by Fusion Bonding

This paper discusses methods for repair of thermoplastic resin composites. The emphasis is on field repair. Several conceptual repair cases are presented. Patching type repair on PEEK composite APC-3 have been carried out by using resistance welding and induction heating methods. Healing-type repair gas been made by induction heating. The quality of repaired panels was inspected by using ultrasonic C-scan and by using SPATE techniques.

Predicting the Strength of Bonded Carbon Fiber/Epoxy Composite Joints

In this paper, a failure criterion is presented to predict the failure of bonded double-lap joints. This analysis discusses the use of two commercially available cold-cure adhesives for bonding unidirectional carbon/epoxy composite substrates.

The main focus of this paper concentrates on the analytical aspect of the phenomenon. It attempts to corroborate and explain what is clearly self-sustaining from both finite element analysis and experimental tests. It is from these observations, that a two-parameter failure criterion is proposed.

Predicting Performance of Adhesively Bonded Joints Based on Acousto-ultrasonic Evaluation

The work described here deals with predicting performance of adhesively bonded joints of composite material laminates with non-uniform bond condition, based on a nondestructive evaluation of the joint using the acousto-ultrasonic method. The actual condition of the bonded joints has been determined using scanning acoustic microscopy; the specimen design used for this study was selected to make this possible. Results of the nondestructive evaluation and mechanical testing are presented, and the procedure for predicting performance based on the acousto-ultrasonic evaluation is described.

Prediction of Adhesion of Textile/Elastomer Composites at Various Rates and Temperatures Via Time-Temperature Superposition

This study investigates the application of time-temperature superposition of peel rate and test temperature on the peel adhesion of various adhesive/textile systems. The prediction of adhesion levels at high rates is difficult to obtain in the laboratory, however at lower rates ranking is possible through Dynamic Contact Angle Analysis. Time-temperature superposition allows estimation of the adhesion levels at various rate and temperature conditions that are beyond the absolute capabilities of common test equipment.

The Durability of Adhesive Bonded Epoxy Carbon Fiber Composite

This paper compares data from laboratory exposure tests on lap and wedge joints made from epoxy matrix carbon fiber composite with a range of epoxy adhesives. With the increasing use of adhesive bonded fiber reinforced composites in airframes, it is advantageous to have an accelerated aging test.

The Effect of Temperature and Humidity on the Fatigue Performance of Composite Bonded Joints

This paper presents results from an investigation into the effects of environment on the fatigue behavior of joints using supported and unsupported adhesive.

The results obtained showed that the fatigue behavior of adhesive joints was considerably affected by temperature, humidity, and support medium. Cohesive failure of adhesive interfacial failure, and interlaminar failure of adherends were all observed such that predictions of structural integrity would be difficult to make. In addition, failure modes observed could be aggravated by, or themselves exaggerate, gross defects or inconsistencies already present in a structure, e.g. impact damage. Optimum static performance may not give acceptable fatigue behavior.

Fractographic Analysis of Graphite/Epoxy Surface Preparations for Adhesive Bonding

This paper discusses surface preparation of graphite/epoxy, composite materials prior to adhesive bonding in order to prevent premature failure at the adhesive/composite bondline. Previous work has shown that abrading the composite surface produces increased lap shear strengths over peel ply prepared surfaces. Each of these surface preparations produces different failure modes and fracture characterisitics. A study was conducted in order to better understand the reason for varying strengths and to gain a better understanding of the fracture characterisitics.

Joint Design: Finite Element Aided Design of Adhesive Joints

This paper describes the program Joint Design that has been built to counter the drawbacks in classical finite element programs. Developed for the design of adhesives joints, it was planned and adapted for them, with the following major features: 1) the use of mixed (stress-displacement) interface finite elements (the mixed interface finite elements permit to introduce the component of stress vector as a degree of freedom), 2) significant decrease of the computational time, obtained by adequate simplifications and by improvements in the numerical data storage and processing with a storage of dimensionless predefined regular meshes, and global stiffness matrices, 3) re-analysis under slightly modified conditions (loads, boundary conditions, materials properties), 4) interactive user friendly package, possibly the use by designers with little or no knowledge of the internal structure and methods of the program and 5) portability on the most current and low cost microcomputers (IBM PC/AT with arithmetical co-processor).

The Failure Properties of Bonded SMC Assemblies

This paper describes the investigation of failure modes of several types of SMC bonded with epoxy adhesives. A variety of surface analysis techniques, including X-ray Photoelectron Spectrometry (XPS), Infrared Spectroscopy and Scanning Electron Microscopy (SEM) were used to characterize the surfaces of the SMC before bonding and after failure. XPS was able to distinguish failure modes in cases that were visually non-obvious. The failure modes and strengths wre consistent with a stress model based on the bulk properties of the SMC and the adhesive.

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