Preface

Polymers and composites contribute to substantial weight and cost savings in aerospace, marine, ground vehicle, wind power, and infrastructure applications. However, the development of a durable and damage tolerant composite structure is a major challenge, particularly for applications with elevated temperature or harsh operating environments. Meeting this challenge requires advances on several fronts: understanding key requirements of various application domains; innovations in polymer chemistry, material science and nanotechnology for the development of high performance constituent materials; methodologies for tailoring high-performance composite architectures; understanding mechanisms and mechanics of degradation and damage evolution; reliable model-based life predictions; and enabling design practices and validation methods.

Our motivation for this book was to compile a comprehensive knowledgebase and a compendium of analytical and experimental techniques for engineers and materials scientists designing composite structures with long-term durability and damage tolerance requirements. The book presumes that the reader has a basic understanding of composite materials and their performance. The authors of the book, drawn from academia, defense and government research laboratories, and leading practitioners from the industry, provide both scientific and practical perspectives for assessing and predicting long-term durability of the structures. As editors, we have tried to balance the rigorous scientific treatment of the problem with empirical methodologies, modeling/simulation with experimental techniques, and analytical methods with design and validation practices. We collaborated with the contributing authors to provide up to date research and methodologies available at the time of writing. As a field in which scientific theories are just beginning to provide adequate understanding of aging and degradation mechanisms, this book provides the composites community with a firm basis which can pave the way for newer developments that improve the long-term durability and damage tolerance of composite structures. The mechanism based durability and life prediction mechanisms will eventually mature to replace the pervasive empiricism in this field.

The contents of this book span from fundamental physical, chemical and engineering principles required for the evaluation and prediction of the long-term durability of polymeric composites structures to the design and application domain requirements. The sixteen chapters of the book can be classified into five related topics. The first three chapters of the book deal with behavior of constituent materials – resin, additives and modifiers, and the fiber-matrix interfaces. The chapters in this section present elements of chemistry of polymer resins along with the changes that occur when resins are exposed to environmental factors, a survey of the broad range of protection solutions available for composites, and thermodynamic and kinetics-based models used to develop the processing-interphase and interphase-property linkages.

The mechanisms of the response of the structures, damage tolerance, impact damage and physical aging are the subjects of the second section. The damage tolerance of composite structures is intimately linked to the morphology and extent of flaws or damage. Evolution of damage is treated as the formation of a multitude of crack surfaces within a composite that permanently change its response. Impact is a commonly occurring source of threat to composites that can produce a "seed" damage state, which inherently controls the subsequent durability and damage tolerance of the affected structure. Fundamentals of aging, its impact on the mechanical response, and environmental effects on physical aging behavior are discussed. The four chapters of the third section of the book deal with degradation due to environmental factors – moisture and temperature. Determination of diffusivity and moisture uptake in a polymer composite is a key step in the accurate prediction of moisture-induced degradation. The combined influences of damage and stress on moisture diffusion and the prediction of strength degradation in composites due to moisture ingress are illustrated. An understanding of the effects of thermo-oxidation in high-temperature PMCs for structural components subjected to arbitrary service environments is critical to life performance predictions. A comprehensive mechanism-based evaluation of thermo-oxidation is presented as three chapters of this section. These chapters describe the fundamental oxidation chemical reactions in the polymer, the morphological and material behavior changes due to oxidation, oxidation-damage coupling, experimental characterization techniques and a predictive simulation framework. This mechanisms based treatment of the problem provides a scientific basis for simulating long-term thermo-oxidative stability of composite structures as opposed to the empirical weight loss measurements.

The last two sections of the book are devoted to design and validation techniques for achieving long-term durability and application-specific durability requirements. In Sect. 4, the structural design and durability issues of composite joints provide the knowledge base and techniques for designers to address long-term durability concerns at the design stage. Issues to be considered in the design of composites used in primary and secondary composite structures including corrosion prevention measures associated with joining composite and metallic components are described. The unique requirements for developing load spectra for accelerated full-scale durability testing for both composite and combined composite/metallic structures are also discussed. Structural joints are where the durability, or lack of durability, is often most evident in a structure's response to combined environmental effects and mechanical loads. The fifth section addresses application related factors for aerospace structures, engines and civil infrastructure. Since economic considerations often require the use of military and commercial aircraft beyond their original design service lives, it is necessary to understand aircraft in-service induced aging and damage to ensure the airworthiness and structural integrity of these airframes.

The reader of this book may be particularly interested in how the long-term durability needs require considerations at several length and time scales. While the consequences of the durability (or lack of) are felt at the structural scale as illustrated by the complete tear-down analysis of an aircraft structure, the origins of durability are in the design of the polymer molecule at the nano-scale, the microstructure and micro-mechanics of the composite, and complex interactions of the interfaces at the meso-scales. Reliable predictions of performance degradation over long-term use and the modes of eventual failure require rigorous and validated models at several length and time scales along with homogenization theories dealing with scale transition. Validation of such models needs effective and controlled acceleration of degradation processes so long-term effects can be reproduced in laboratory environments within reasonable observation times. We hope that the discussion of the five facets of the problem and their interrelationships, as presented in this book, will inspire researchers – both theoreticians and experimentalists – from the fields of thermo-mechanics, materials, and polymer science to work together and formulate structural durability and life prediction frameworks.

Finally, we thank all the authors for their efforts and valuable writings and all our colleagues who served as reviewers for their comments and opinions.

Hoboken, NJ — Kishore V. Pochiraju
Dayton, OH — Gyaneshwar P. Tandon
Dayton, OH — Gregory A. Schoeppner

http://www.springer.com/978-1-4419-9307-6

Long-Term Durability of Polymeric Matrix Composites
Pochiraju, K.V.; Tandon, G.; Schoeppner, G.A. (Eds.)
2012, X, 677 p., Hardcover
ISBN: 978-1-4419-9307-6