THEORY OF COMPOSITES DESIGN

PREFACE

The cover is *America*^{3}, winner of the America's Cup final in San Diego on May 16, 1992 over *Il Moro* from Italy. A Stanford team was organized to support *A*^{3} in composites design and manufacturing. Sung Ha and I worked together on this project in 1990. He just completed his Ph.D and I just arrived on campus after retirement from 22 years with the US Air Force at Wright-Patterson AFB.

The first edition of this book was written in 1992 (ISBN 0-9618090-3-5), made into an electronic edition in 2003, and updated in 2008. This book is part of our online, 12-week Composites Design Tutorials, which first offering in September 4, 2007; the second in April 8, 2008; and the third in September 2, 2008.

After Section 1 introduction, the next five sections cover the stiffness of unidirectional and laminated composites. Section 7 covers micromechanics, and Sections 8 and 9, the quadratic failure criterion. Micro cracking in the matrix is modeled by a degradation factor so both first- and last-ply-failures can be calculated. Section 10 describes an Excel-based calculator: Mic-Mac/Lite that is a powerful tool to practice on laminated plate theory with FPF and LPF.

My approaches in composites design include the use sublaminates to build strong and tough laminates (Sect 5.5, 6.2): the thinner and the more repeated the sublaminate, the more homogenized the laminate. When a laminate is highly repeated, continuous stacking can be very cost effective. There is no need to be concerned with mid-plane symmetry (Sect 6.8). Strength ratio or failure index (Sect 8.9) are useful for linear scaling of laminate thickness. Their values give more information about failure or no failure. Invariants of elastic constants (Sect 3.4) are fundamental relations that guide laminate design. Use of 3 instead of 4 ply angles (Fig 4.11) can reduce cost of lamination and increase strength and toughness because 3 angles can be homogenized simpler than 4 angles. All these features can make composites more reliable and competitive.

We see unlimited opportunities for composites in not only fuel-efficient airplanes and engines, but also wind turbines and cars. For CFRP we should be able to achieve 50 percent weight savings over aluminum. We are optimistic that with training and innovation composites will serve society well.

Special thanks to Dr. Pranav D. Shah for his effort in making the latest updating of this book possible.

Stephen W. Tsai
Stanford University
Summer 2008