

Volume 21  
**Composites**

**1. Introduction to Composites**

**2. Constituent Materials**

Introduction to Constituent Materials  
Introduction to Reinforcing Fibers  
Glass Fibers  
Carbon Fibers  
Aramid Fibers  
Ceramic Fibers  
Discontinuous Reinforcements for Metal-Matrix Composites  
Continuous Fiber Reinforcements for Metal-Matrix Composites  
Fabrics and Preforms  
Braiding  
Epoxy Resins  
Polyester Resins  
Bismaleimide Resins  
Polyimide Resins  
Phenolic Resins  
Cyanate Ester Resins  
Thermoplastic Resins  
Molding Compounds  
Metallic Matrices  
Ceramic Matrices  
Carbon Matrices  
Interfaces and Interphases  
Lightweight Structural Cores  
Bio-Based Resins and Natural Fibers

**3. Engineering Mechanics, Analysis, and Design**

Introduction to Engineering Mechanics, Analysis, and Design  
Micromechanics  
Macromechanics Analysis of Laminate Properties  
Characterizing Strength from a Structural Design Perspective  
Fracture Mechanics of Composite Delamination  
Hygrothermal Behavior  
Fatigue and Life Prediction  
Damping Properties  
Bolted and Bonded Joints

Instability Considerations  
Damage Tolerance  
Out-of-Plane Analysis  
Analysis of Sandwich Structures  
Finite Element Analysis  
Computer Programs  
Testing and Analysis Correlation  
Design Criteria  
Design Allowables  
Computer-Aided Design and Manufacturing  
Design, Tooling, and Manufacturing Interaction  
Cost Analysis  
Rapid Prototyping  
Design Guidelines  
Engineering Mechanics and Analysis of Metal-Matrix Composites  
Fracture Analysis of Fiber-Reinforced Ceramic-Matrix Composites

#### **4. Manufacturing Processes**

Introduction to Manufacturing of Polymer-Matrix Composites  
Process Modeling  
Composite Tooling  
Electroformed Nickel Tooling  
Elastomeric Tooling  
Open Molding: Hand Lay-Up and Spray-Up  
Custom Sailing Yacht Design and Manufacture  
Prepreg and Ply Cutting  
Manual Prepreg Lay-Up  
Fiber Placement  
Automated Tape Laying  
Curing  
Resin Transfer Molding and Structural Reaction Injection Molding  
Vacuum Infusion  
Compression Molding  
Filament Winding  
Pultrusion  
Tube Rolling  
Thermoplastic Composites Manufacturing  
Processing of Metal-Matrix Composites  
Processing of Ceramic-Matrix Composites  
Processing of Carbon-Carbon Composites

## **5. Post-Processing and Assembly**

- Introduction to Post-Processing and Assembly
- Machining, Trimming, and Routing of Polymer-Matrix Composites
- Secondary Adhesive Bonding of Polymer-Matrix Composites
- Processing and Joining of Thermoplastic Composites
- Hole Drilling in Polymer-Matrix Composites
- Mechanical Fastener Selection
- Environmental Protection and Sealing
- Extrusion of Particle-Reinforced Aluminum Composites
- Post-Processing and Assembly of Ceramic-Matrix Composites

## **6. Quality Assurance**

- Introduction to Quality Assurance
- Resin Properties Analysis
- Tooling and Assembly Quality Control
- Reinforcing Material Lay-Up Quality Control
- Cure Monitoring and Control
- Nondestructive Testing
- Quality Assurance of Metal-Matrix Composites

## **7. Testing and Certification**

- Introduction to Testing and Certification
- Overview of Testing and Certification
- Test Program Planning
- Constituent Materials Testing
- Lamina and Laminate Nonmechanical Testing
- Lamina and Laminate Mechanical Testing
- Element and Subcomponent Testing
- Full-Scale Structural Testing

## **8. Properties and Performance**

- Properties and Performance of Polymer-Matrix Composites
- Properties of Metal-Matrix Composites
- Properties and Performance of Ceramic-Matrix and Carbon-Carbon Composites

## **9. Product Reliability, Maintainability, and Repair**

- Introduction to Product Reliability, Maintainability, and Repair
- Designing for Repairability
- Repair Engineering and Design Considerations
- Repair Applications, Quality Control, and Inspection
- Ship Structure Repairs

Rehabilitation of Reinforced Concrete Structures Using Fiber-Reinforced Polymer Composites  
Maintainability Issues  
Bonded Repair of Metal Structures Using Composites  
Worldwide Repair Standardization  
Product Reliability, In-Service Experience, and Lessons Learned

## **10. Failure Analysis**

Introduction to Failure Analysis  
Failure Causes  
Failure Analysis Procedures  
Visual Analysis, Nondestructive Testing, and Destructive Testing  
Microscopy  
Thermal Analysis  
Fractography  
Case Histories  
Fatigue Properties and Quantitative Fractography of Metal-Matrix Composites  
Failure Analysis of Ceramic-Matrix Composites

## **11. Recycling and Disposal**

Introduction to Recycling and Disposal of Composites  
Recycling and Disposal of Polymer-Matrix Composites  
Recycling and Disposal of Metal-Matrix Composites

## **12. Applications and Experience**

Introduction to Applications  
Automotive Applications  
Automotive Applications of Metal-Matrix Composites  
Space Applications  
Aeronautical Applications of Metal-Matrix Composites  
High-Temperature Applications  
Aircraft Applications  
Applications of Carbon-Carbon Composites  
Sports and Recreation Equipment Applications  
Thermal Management and Electronic Packaging Applications  
Marine Applications  
Civil Infrastructure Applications  
Applications of Ceramic-Matrix Composites