# Composites Contents

*Listing of current literature of interest to the composite community as a service to our readers.*

**Introduction**

In this section, the relevant portions of the tables of contents of current journals which publish composites articles will be reproduced. The entire tables of contents will be reproduced for dedicated composites journals, but in order to conserve space and reduce printing costs, only the composites-related articles of non-dedicated journals will be reproduced. At this time, permission to reproduce the tables of contents has been granted by the following journals:

- AIAA Journal
- Composite Science and Technology
- Composite Structures
- Composites
- Computers and Structures
- Engineering Fracture Mechanics
- Experimental Mechanics
- Experimental Techniques
- International Journal of Analytical and Experimental Model Analysis
- International Journal of Fracture
- International Journal of Solids and Structures
- Journal of Adhesion
- Journal of Applied Mechanics
- Journal of Composite Materials
- Journal of Engineering Materials and Technology
- Journal of Materials Science
- Journal of Reinforced Plastics and Composites
- Journal of Sound and Vibration
- Journal of Testing and Evaluation
- Mechanics of Composite Materials
- Polymer Composites
- SAMPE Journal
- SAMPE Quarterly
- The Shock and Vibration Digest

The Editor welcomes suggestions for improvements to "Composites Contents," although library acquisition and accessibility may prevent some additions to the list of journals surveyed.

Dr. Ronald F. Gibson, *Contents Editor*
Advanced Composites Research Laboratory
Department of Mechanical Engineering
Wayne State University
Detroit, MI 48202

**AIAA Journal**

*Vol. 29, No. 5, May 1991*



*Vol. 29, No. 6, June 1991*



*Vol. 29, No. 8, Aug. 1991*



*Vol 29, No. 9, Sept. 1991*

**Computers and Structures**

*Vol. 39, No. 3/4, 1991*



*Vol. 39, No. 5, 1991*



*Vol. 39, No. 6, 1991*



*Vol. 40, No. 1, 1991*



*Vol. 40, No. 2, 1991*



*Vol. 40, No. 3, 1991*



*Vol. 40, No. 4, 1991*



*Vol. 40, No. 5, 1991*



*Vol. 40, No. 6, 1991*

*Vol. 41, No. 1, 1991*

Post-buckling Behaviour of Orthotropic Rectangular Plates—Hu Wang, Maocai Ou, and Tsunkuei Wang, pp. 1–6

Deformation of Varying Thickness Composite Cylindrical Shell Subjected to Fluid Loading with Various End Conditions—B. S. K. Sundarasivarao and N. Ganesan, pp. 67–74

Curved Composite Beams-Optimum Lay-Up for Buckling by Ranking—B. Tripathy and K. P . Rao, pp. 75–82

Stress Analysis Around Holes in Orthotropic Plates by the Subregion Mixed Finite Element Method—Zhao Jinping and Shan Huizu, pp. 105–108

*Vol. 41, No. 2, 1991*

Vibration Analysis of FRP Faced Sandwich Plates Using Hybrid-Stress Finite Element Method—K. M. Rao and H.-R. Meyer-Piening, pp. 177–188

A Two-Dimensional Automatic Mesh Generator for Finite Element Analysis for Random Composites—S. Ghosh and S. N. Mukhopadhyay, pp. 245–256

Large Deflections of Laminated Cylindrical and Doubly-Curved Panels Under Thermal Loading—N. N. Huang and T. R. Tauchert, pp. 303–312

Partial Hybrid Stress Method Applied to the Higher-Order Laminated Plates Theory—Yi-Ping Tseng and Tzu-Chiang Wu, pp. 313–324

Elasto-Plastic Analysis of an Aluminum Alloy Matrix Reinforced with Silicon Carbide Fibers Packed in a Hexagonal Array—P. K. Gotsis, A. H. Shabaik, and G. H. Sines, pp. 345–354

Embedded and Surface Flaws in Unidirectional Composites—L. Chai and L. R. Dharani, pp. 397–402

*Vol. 41, No. 3, 1991*

Sensitivity Analysis and Optimal Design of Thin Laminated Composite Structures—H. C. Mateus, C. M. Mota Soares, and C. A. Mota Sores, pp. 501–508

Minimum-Cost Reinforced Concrete Beams and Columns—S. Kanagasundaram and B. L. Karihaloo, pp. 509–518

**Engineering Fracture Mechanics**

*Vol. 39, No. 1, 1991*

Effect of Thermal Expansion Anisotropy on Microcracking in Ceramic Composites—F. Delale and H. Boduroglu, pp. 45–60

The General Conclusions of Stress Intensity Factors for the Cracks at the Interface Between 2 Different Orthotropic Media—P. H. Wen, pp. 93–104

Failure Analysis of a Shear Loaded Graphite Epoxy Beam Containing an Irregular Cutout—K. Hollmann, p. 159

*Vol. 39, No. 2, 1991*

The General Solution to an Infinite Orthotropic Plate with a Cruciform Crack Under Arbitrary Anti-Plane Shear Stresses—X. S. Zhang, pp. 229–234

Damage Field and Its Evolution in a Glass-Fiber Cloth Epoxy Composite Plate with Central Hole—L. H. Peng, W. Shen, C. L. Chow, and A. Asundi, pp. 259–268

*Vol. 39, No. 3, 1991*

Crack Tip Yield Zone Estimates in Mode II Interlaminar Fracture of Interleaved Composites—A. Aksoy and L. A. Carlsson, pp. 525–534

On the Stress Distribution in a Periodic Reinforced Elastic Composite with Partially Unbonded Fiber—A. Kaczynski and S. J. Matysiak, pp. 561–568

*Vol. 39, No. 4, 1991*

An Engineering Method of Determining the Delamination Fracture Toughness of Composite Laminates—Q. Y. Xiang, S. Y. Du, and W. Duo, pp. 623–628

Elastodynamic Response of an Interface Crack in a Layered Composite Under Anti-Plane Shear Impact Load—H. L. De and H. T. Wei, pp. 687–694

Boundary Element Formulation with Special Kernels for an Anisotropic Plate Containing an Elliptical Hole or a Crack—M. Kamel and B. M. Liaw, pp. 695–712

*Vol. 39, No. 5, 1991*

Dynamic Fracture of a Tapered Idealized Fiber-Reinforced Cantilever—L. F. Mannion, pp. 785–790

Kinked Cracks in an Anisotropic Material—C. R. Chiang, p. 927

*Vol. 39, No. 6, 1991*

A Special Finite Element for the Analysis of the Singularity in a Bimaterial Containing a Crack Perpendicular to the Interface—R. Elabdi, pp. 1061–1066

*Vol. 40, No. 1, 1991*

J-integral Criterion of Delamination Onset in Toughened Matrix Composite Laminates—Xiang Qiao Yan, Shanyi Du, and Duo Wang, pp. 67–74

Coplanar Cracks at the Interface of Bonded Dissimilar Orthotropic Elastic Half-Planes—H. S. Saxena, R. S. Dhaliwal, and J. G. Rokne, pp. 177–186

*Vol, 40, No. 2, 1991*

The Accurate Solutions of Stress Intensity Factor for a Crack at the Interface Between Two Different Media—Wen Pi-Hua, pp. 255–264

Cyclic Stress Response and Cyclic Fracture Behavior of Silicon Carbide Particulate Reinforced Aluminum Metal-Matrix Composite—T. S. Srivatsan, R. Auradkar, and A. Prakash, pp. 277–296

Reliable Design Failure Criteria for Composite Chambers—W. C. Hwang and Y. C. Lin, pp. 465–474

*Vol. 40, No. 3, 1991*

Boundary Element Analysis of Cracks Normal to Bimaterial Interfaces—Y. W. Kwon and R. Dutton, pp. 487–492

A Damage Evolution Equation of Particle-Filled Composite Materials—Jianping Zhou and Yinchu Lu, pp. 499–506

*Vol. 28, No. 3, 1991*

Analysis of a Broken Fiber in a Weakly Bonded Composite—H. R. Schwietert and P. S. Steif, pp. 283–298
The Tensile Strength of a Fiber-Reinforced Ceramic—H. R. Schweitert and P. S. Steif, pp. 299–316
Dynamic Instability of Shear-Deformable Viscoelastic Laminated Plates by Lyapunov Exponents—G. Cederbaum, J. Aboudi, and I. Elishakoff, pp. 317–328
Vibration and Buckling Characteristics of Composite Cylindrical Panels Incorporating the Effects of a Higher Order Shear Theory—A. N. Palazotto and P. E. Linnemann, pp. 341–362
Modeling of Delamination in Composite Laminates Using a Layer-Wise Plate Theory—E. J. Barbero and J. N. Reddy, pp. 373–388

*Vol. 28, No. 4, 1991*

A Material Multiple Theory of Elastic Dielectric Composites—S. A. Zhou, pp. 423–448

*Vol. 28, No. 5, 1991*

Stress Variation Due to an Impact Line Load on a 4-Ply Fibre Composite Plate—W. A. Green and E. R. Green, pp. 567–594
Application of the M-Integral to Cracked Anisotropic Composite Wedges—K. C. Wu, pp. 595–606

*Vol. 28, No. 6, 1991*

Toughening and Strengthening of Ceramics Reinforced by Dilatant Transformations and Ductile Particles—D. M. Stump, pp. 669–690
Elastodynamic Responses Due to Anti-Plane Point Impact Loadings on the Faces of an Interface Crack Along Dissimilar Anisotropic Materials—M. K. Kuo and S. H. Cheng, pp. 751–768

*Vol. 28, No. 7, 1991*

Thermal Bending of Shear-Deformable Orthotropic Cylindrical Shells Reinforced by Cylindrically-Orthotropic Rings—V. Birman, pp. 819–830
Free Vibrations of Spinning Composite Cylindrical Shells—O. Rand and Y. Stavsky, pp. 831–844
A Variational Principle for Gradient Plasticity—H. B. Muhlhaus and E. C. Aifantis, pp. 845–858
Saintvenant Solutions for Prismatic Anisotropic Beams—J. B. Kosmatka and S. B. Dong, p. 917

*Vol. 28, No. 8, 1991*

Free Vibration of Laminated Composite Rectangular Plates—M. S. Qatu, pp. 941–954
Effect of Inclusion Shape on Stiffness of Isotropic and Transversely Isotropic Two-Phase Composites—B. J. Lee and M. E. Mear, pp. 975–1002
A Model for Load-Transfer from an Embedded Fiber to an Elastic Matrix—W. S. Slaughter and J. L. Sanders, pp. 1041–1052
The Stresses in a Thermally Loaded Bimaterial Interface—M. Y. Tsai and J. Morton, p. 1053

*Vol. 28, No. 9, 1991*

Nonlinear Dynamic Analysis of Anisotropic Cylindrical-Shells Containing a Flowing Fluid—A. A. Lakis and A. Laveau, pp. 1079–1094
Plastic Buckling of Metal Matrix Laminated Plates—M. Paley and J. Aboudi, pp. 1139–1154
Buckling and Postbuckling of Symmetrically Laminated Moderately-Thick Spherical Caps—C. S. Xu, pp. 1171–1184

*Vol. 29, No. 1, 1992*

Application of Higher Order Theories to the Bending Analysis of Layered Composite Plates—K. Rohwer, pp. 105–120

*Vol. 29, No. 2, 1992*

Effect of Stress Waves on Laminated Composite Plates—James Davidson Walker and Efthymios Stefanos Folias, pp. 145–170
Boundary Layer Effects of Interlaminar Stresses Adjacent to a Hole in a Laminated Composite Plate—E. S. Folias, pp. 171–186
A Recursive Concentric Cylinder Model for Composites Containing Coated Fibers—Muzaffer Sutcu, pp. 197–214
Stress Intensity Factor for Ceramics Toughened by Micro-cracking Caused by Dilatant Second Phase Particles—Kai Duan, Brian Cotterell, and Yiu-Wing Mai, pp. 231–242

*Vol. 29, No. 3, 1992*

Crack Extension and Kinking in Laminates and Bicrystals—Tzu-Chiang Wang, C. Fong Shih, and Zhigang Suo, pp. 327–344

**Journal of Adhesion**

*Vol. 34, Nos. 1–4, 1991*

Viscoelastic and Nonlinear Adherend Effects in Bonded Composite Joints—L. A. Mignery and R. A. Schapery, pp. 17–40
A Direct Comparison of the Fragmentation Test and the Microbond Pull-Out Test for Determining the Interfacial Shear Strength—V. Rao, P. Herrerafranco, A. D. Ozzello, and L. T. Drzal, pp. 65–78
Effect of Plasma Treatment on the Adhesion of Carbon Fibers to Thermoplastic Polymers—W. D. Bascom and W. J. Chen, pp. 99–120
The Interlaminar Bond Strength of Flexible Polymer-Metal Laminates—K. R. Cropper and R. J. Young, pp. 153–174

**Journal of Applied Mechanics**

*Vol. 58, No. 2, June 1991*

Stress Analysis of Multilayered Anisotropic Elastic Media—Hyung Jip Choi and S. Thangjitham, pp. 382–387
Elastic Moduli of Thickly Coated Particle and Fiber Reinforced Composites—Y. P. Qiu and G. J. Weng, pp. 388–398
Antiplane Shear Interface Cracks in Anisotropic Bimaterials—Kuang-Chong Wu and Yu Tsung Chiu, pp. 399–403
Dynamic Stress on a Partially Bonded Fiber—Andrew Norris and Yang Yang, pp. 404–409

Elastic-Plastic Dynamic-Response and Buckling of Laminated Thin Shells—D. G. Liaw and H. T. Y. Yang, pp. 1039–1063

A Universal Model for the Overall Thermal-Conductivity of Porous-Media—D. Y. Tzou, pp. 1064–1084

*Vol. 25, No. 9, 1991*

Longitudinal Splitting in Epoxy and K-Polymer Composites—Shear Lag Analysis Including the Effect of Fiber Bridging—J. A. Nairn, S. L. Liu, H. H. Chen, and A. R. Wedgewood, pp. 1086–1107

Flexural Testing of General Multilayered Composites—J. T. Mottram, pp. 1108–1126

A Model of the Resin Impregnation in Thermoplastic Composites—J. W. Seo and W. L. Lee, pp. 1127–1142

Effects of Nonuniform Crystallinity on Stress Distributions in Cross-Ply Graphite Peek (APC-2) Laminates—K. Lee and Y. Weitsman, pp. 1143–1157

Evaluation of Interfacial Frictional-Properties for Fiber-Reinforced Ceramic Composites—J. R. Yeh, pp. 1158–1170

Repeated Impact Failure of Continuous Fiber Reinforced Thermoplastic and Thermoset Composites—B. P. Jang, C. T. Huang, C. Y. Hsieh, W. Kowbel, and B. Z. Jang, pp. 1171–1203

A Constitutive Relation for the Viscous-Flow of an Oriented Fiber Assembly—R. B. Pipes, J. W. S. Hearle, A. J. Beaussart, A. M. Sastry, and R. K. Okine, pp. 1204–1217

Damage Tolerance of Woven Graphite Epoxy Buffer Strip Panels—J. M. Kennedy, pp. 1218–1241

**Journal of Engineering Materials and Technology**

*Vol. 113, No. 4, Oct. 1991*

Computer-Aided Modeling of Polymer Processing: A Review—Amphere A. Tseng and Julius C. Cheng, pp. 363–371

Elastic Buckling of Infinitely Long Specially Orthotropic Plates on Tensionless Foundations—K. W. Shahwan and A. M. Waas, pp. 396–403

Elastic Wave Propagation in Laminated Composite Plates—W. M. Karunasena, R. L. Bratton, S. K. Datta, and A. H. Shah, pp. 411–418

Machining of Graphite/Epoxy Composite Materials with Polycrystalline Diamond (PCD) Tools—M. Ramulu, M. Faridnia, J. L. Garbini, and J. E. Jorgensen, pp. 430–436

EDM Surface Characterization of a Ceramic Composite $TiB_2$/SiC—M. Rumulu and J. L. Garbini, pp. 437–442

Nonlinear Response of Resin Matrix Laminates Using Endochronic Theory—S. R. Mathison, M. J. Pindera, and C. T. Herakovich, pp. 449–455

Evaluation of the Vanishing Fiber Diameter Model for Composite Plasticity—F. J.-K. Hsu and E. P. Fahrenthold, pp. 465–474

**Journal of Materials Science**

*Vol. 26, No. 1, June 1991*

Corrosion of Sic Fibres with HN03—J. Rubio, F. Rubio, and J. L. Oteo, pp. 2841–2845

Stress Birefringence in Compressible Polymer Fibres with Irregular Transverse Sections—M. M. Eltonsy, pp. 2857–2860

Precipitation Hardening of Cast SiCp Reinforced Mg-6Zn—P. K. Chaudhury and H. J. Rack, pp. 2893–2899

Effect of a High-Temperature Cycle on the Mechanical Properties of Silicon Carbide Titanium Metal Matrix Composites—R. A. Naik, W. D. Pollock, and W. S. Johnson, pp. 2913–2920

Pressureless Sintering of AIN SiC Composites—W. C. J. Wei and R. R. Lee, pp. 2930–2936

Thermal Shock Resistance of Laminated Ceramic Matrix Composites—Y. R. Wang and T. W. Chou, pp. 2961–2966

Thermal Expansion Stress in a Metallic Matrix Composite—Insitu TEM Observations—J. P. Cottu and J. J. Couderc, pp. 2985–2990

Weibull Strength Statistics for Graphite Fibres Measured from the Break Progression in a Model Graphite Glass Epoxy Microcomposite—R. Gulino and S. L. Phoenix, pp. 3107–3118

*Vol. 26, No. 12, June 1991*

The Wetting, Reaction and Bonding of Silicon Nitride by Cu-Ti Alloys—D. H. Kim, S. H. Hwang, and S. S. Chun, pp. 3223–3234

Conducting Polymers with Controlled Fibrillar Morphology—R. P. Burford and T. Tongtam, pp. 3264–3270

*Vol. 26, No. 13, July 1991*

Analysis of 3-Dimensional Textile Preforms for Multidirectional Reinforcement of Composites—G. W. Du, T. W. Chou, and P. Popper, pp. 3438–3448

Synthesis of Intermetallics for High Temperature Structural Applications—(Mn5Si3)16H Crystal Structure—P. B. Celis and K. Ishizaki, pp. 3497–3502

Nanocomposites in Mullite-Zr02 and Mullite-Ti02 Systems Synthesized Through Alkoxide Hydrolysis Gel Routes—Microstructure and Fractography—P. Colomban and L. Mazerolles, pp. 3503–3510

SiC Matrix Composites Containing Transition Metal Boride Particulates Internally Synthesized by Carbothermal Reaction—T. Tani and S. Wada, pp. 3526–3532

Microstructure and Micromechanics of the Interface in Carbon Fibre Reinforced Pyrex Glass—S. M. Bleay and V. D. Scott, pp. 3544–3552

Development of Solidification Microstructures in a Fibre Reinforced Alloy—Q. F. Li, D. G. McCartney, and A. M. Walker, pp. 3565–3574

Case Study of Dry Mixing of 8-Alumina (Saffil) and Silicon Carbide (Nicalon) Fibres with a Rapidly Solidified Al-20Si-X Powder—J. H. Terhaar and J. Duszczyk, pp. 3628–3638

Ceramic Fibres from Polymer Precursor Containing Si-O-Ti Bonds. 2. Synthesis of Various Types of Ceramic Fibres—Y. Hasegawa, C. X. Feng, Y. C. Song, and Z. L. Tan, pp. 3657–3664

*Vol. 26, No. 14, July 1991*

Effect of Temperature and Strain Rate on Tensile Mechanical Properties of ARALL-1 Laminates—H. F. Wu, pp. 3721–3729

Microstructure and Mechanical Properties of Hot-Pressed SiC-TiC Composites—H. Endo, M. Ueki, and H. Kubo, pp. 3769–3774

An Approach to the Mechanical Behavior of SiC/SiC and C/SiC Ceramic Matrix Composites. 2. Theoretical Approach—E. Inghels and J. Lamon, pp. 5411–5419

Monte-Carlo Simulation of Multiple Fracture in the Transverse Ply of Cross-Ply Graphite Epoxy Laminates—S. Ochiai, P. W. M. Peters, K. Schulte, and K. Osamura, pp. 5433–5444

Creep Failure Mechanisms in a Particulate-Filled Epoxy Resin—J. W. Smith, W. J. Cantwell, A. Demarmels, and H. H. Kausch, pp. 5534–5542

Ceramic Composites—TiB2-TiC-SiC. 1. Properties and Microstructures in the Ternary System—F. Demestral and F. Thevnolt, pp. 5547–5560

Characterization and Testing of Fibre-Modified Bitumen Composites—P. V. Peltonen, pp. 5618–5622

On the Growth Mechanism of Silicon Carbide Whiskers—G. McMahon, G. J. C. Carpenter, and T. F. Malls, pp. 5655–5663

Phosphate Glass-Ceramic Titanium Composite Materials—R. Rogier and F. Pernot, pp. 5664–5670

**Journal of Reinforced Plastics and Composites**

*Vol. 10, No. 4, July 1991*

3-Dimensional Finite Element Formulations for Laminated Plates—S. P. Wanthal and H. T. Y. Yang, pp. 330–355

Impact Behavior of Hybrid-Fiber and Hybrid-Matrix Composites—C. J. Wang, B. Z. Jang, J. Panus, and B. T. Valarie, pp. 356–378

A Probability Neural Network (PNN) Estimator for Improved Reliability of Noisy Sensor Data—C. T. Chen and S. R. Leclair, pp. 379–390

The Effect of Accelerator on the Crosslink Density and Mechanical Behavior of an SBR-Filled Elastomer—G. Spathis, E. Kontou, and A. Saklabani, pp. 391–399

Stress Wave Propagation in Hybrid Composite Materials—Y. L. Li, C. Ruiz, and J. Harding, pp. 400–422

A Simple, Elasto-Plastic Contact Law for Composites—D. S. Cairns, pp. 423–433

On the Design of the Cracked Sandwich Beam (CSB) Specimen—L. A. Carlsson, p. 434

*Vol. 10, No. 5, 1991*

Hydrothermal Effects on Chopped Fiber Woven Fabric Reinforced Epoxy Composites. A. Moisture Absorption Characteristics—K. S. Singh, P. N. Singh, R. M. V. G. K. Rao, pp. 446–456

Hygrothermal Effects on Chopped Fiber Woven Fabric Reinforced Epoxy Composite. B. Degradation Studies—K. S. Singh, P. N. Singh, R. M. V. G. K. Rao, pp. 457–462

Melt State Dynamic Mechanical-Properties of Polyethylene/EPDM/Silicon Dioxide Composites—C. Scott, H. Ishida, and F. H. J. Maurer, pp. 463–476

Optimum Design of Composite Laminates for Strength by Ranking—K. P. Rao, J. C. Isaac, S. Viswanath, and S. S. Murthy, pp. 477–494

Micro-Failure Prediction of the Strength of Composite-Materials Under Combined Loading—J. Aboudi, pp. 495–503

Micromechanics Analysis of Space Simulated Thermal-Stresses in Composites. 1. Theory and Unidirectional Laminates—D. E. Bowles and O. H. Griffin, pp. 504–521

Micromechanics Analysis of Space Simulated Thermal-Stresses in Composites. 2. Multidirectional Laminates and Failure Predictions—D. E. Bowles and O. H. Griffin, pp. 522–539

**Journal of Sound and Vibration**

*Vol. 147, No. 1, May 1991*

Formulation of an Elastodynamic Theory of Laminated Shear-Deformable Flat Panels—L. Librescu, pp. 1–12

Vibration Analysis of Thick, Polar Orthotropic, Variable Thickness Annular Disks—V. Soamidas and N. Ganesan, pp. 39–56

*Vol. 147, No. 3, June 1991*

Buckling and Vibrations of Polar Orthotropic Circular Plates of Linearly Varying Thickness Resting on an Elastic Foundation—U. S. Gupta, R. Lal, and S. K. Jain, pp. 423–434

Analysis of Transverse Vibrations of Composite Membranes Using the Integral Equation Method and Rayleigh Optimization Suggestion—R. H. Gutierrez and P. A. A. Laura, pp. 515–518

*Vol. 148, No. 1, July 1991*

Clamped Orthotropic Plates—J. R. Kuttler, pp. 160–161

*Vol. 148, No. 2, July 1991*

Modified Panovko Method for Vibration Analysis of a Structural Element with Different Tension and Compression Behavior—I. Elishakoff, V. Birman, and C. W. Bert, pp. 215–222

On Asymmetric Vibrations of Layered Orthotropic Shells of Revolution—A. V. Singh, L. Zhu, and S. Mirza, pp. 265–278

*Vol. 148, No. 3, Aug. 1991*

Vibration Analysis of Laminated Conical Shells with Variable Thickness—J. L. King, pp. 477–492

An Improved Theory for the Free Transverse Vibrations of Anisotropic Beams—J. L. King, pp. 493–506

Axisymmetric Free Vibrations of Finite Anisotropic Cylinders—P. R. Heyliger, pp. 521–532

*Vol. 149, No. 1, Aug. 1991*

Wave Propagation in Semi-Infinite Plane Anisotropic Thin Circular Shells—S. K. Bhattacharyya and C. P. Vendhan, pp. 71–82

*Vol. 150, No. 1, Oct. 1991*

Wave Propagation in Angle-Ply Laminates—J. Aboudi and I. Hevroni, pp. 15–24

*Vol. 150, No. 2, Oct. 1991*

On Sound Transmission into an Orthotropic Infinite Shell: Comparison with Koval's Results and Understanding of Phenom-

**Mechanics of Composite Materials**

*Vol. 26, No. 5, Sept.-Oct. 1990*



*Vol. 26, No. 6, Nov.-Dec. 1990*

*Vol. 27, No. 1, Jan.-Feb. 1991*



**Polymer Composites**

*Vol. 12, No. 2, April 1991*



*Vol. 12, No. 3, June 1991*

*Vol. 12, No. 4, Aug. 1991*



*Vol. 12, No. 5, Oct. 1991*



**Sampe Journal**

*Vol. 27, No. 4, July/Aug. 1991*



*Vol. 27, No. 5, Sept./Oct. 1991*



*Vol. 27, No. 6, Nov./Dec. 1991*



**Sampe Quarterly**

*Vol. 22, No. 4, 1991*

*Vol. 23, No. 1, 1991*



**The Shock and Vibration Digest**

*Vol. 23, No. 6, June 1991*



*Vol. 23, No. 7, July 1991*

# World of Composites

*EDITOR'S NOTE:*
*This issue of the World of Composites will begin with a review of recent activities in ASTM's Committee D-30 on High Modulus Fibers and their Composites. Composites activities in the American Society of Mechanical Engineers will then be highlighted. This will be followed by reviews of the research work at the University of Delaware's Center for Composite Materials and at Virginia Polytechnic Institute's Center for Composite Materials and Structures. Finally, three recent composites publications will be outlined.*

## ASTM COMPOSITES ACTIVITIES

*D-30 Supporting Initiative for Industry-Wide Standards*

### D-30 Supports Industry-Wide Standardization Initiative

ASTM Committee D-30 is actively pursuing advanced composites standardization on both the national and international level. The lack of standardization in materials testing and specification practices has been identified by the advanced composites industry as a key roadblock to future growth. The problem is industry wide in scope and will require the cooperation of government agencies, materials suppliers, end users, and standards organizations for an effective solution. D-30 is part of an ad hoc committee that has been formed, in conjunction with representatives from SACMA, AIA, DoD, MIL HDBK-17, SAE, CMC, the FAA, and ANSI, to develop an Industry-Wide Standardization Initiative for Advanced Composite Materials.

Key elements of the proposed initiative are: (1) coordination of materials testing, process specification and materials specification activities within the United States; (2) provision of sustained technical support for evaluation and development of standard methods for materials specification and characterization; and (3) harmonization of standards in the international community. With extensive experience in the development of test methods for advanced composites, D-30 is seeking to play a key role in the standardization initiative. Proposals call for using ASTM expertise to write the standard composite test methods that evolve out of the initiative. Similarly, materials specifications would be developed using the systems already in place at SAE.

D-30 will participate in a Workshop on Standardization for Advanced Composite Materials, scheduled for 1–3 Sept. 1992 in Washington, D.C., to further the initiative. During the workshop, experts will deliver a series of well-researched position papers describing the state of U.S. standardization, the status of international standardization activities, the state of technical development in testing for mechanical properties and processing variables, and the cost penalties arising from inadequate standardization. This information will be used to define the standardization requirements and to perform a cost-benefit analysis. The end product of the workshop will be a definitive plan outlining an organizational structure, a tactical plan for implementation of the standardization initiative, including key milestones, and the cost-benefit analysis to support a proposal to obtain corporate buy-in and funding for the initiative.

On the international front, Rod Martin, Chairman of the International Harmonization Task Force in D-30, has submitted a proposal to ASTM's Institute for Standards Research (ISR) seeking support to work with VAMAS on the harmonization of ASTM test methods with those in Japan and Europe. The proposal seeks to "harmonize" six of the most commonly used test methods and determine precision and bias for the unified methods through international round robin testing.

## AMERICAN SOCIETY OF MECHANICAL ENGINEERS

*Future Symposia and Research Thrusts Noted*

### Future Symposia

The Composites Committee of ASME's Applied Mechanics Division has announced its symposia plans for 1992 and 1993. The meeting sites and symposia follow.

*1992 Winter Annual Meeting—Anaheim, CA, 8–13 Nov. 1992*

*Damage Mechanics in Composites* organized by D. Allen (Texas A&M) and D. C. Lagoudas (RPI). Cosponsored with the Aerospace Division.

*Macroscopic Behavior of Heterogeneous Materials from the Microstructure*, organized by S. Torquato (N.C. State) and D. Krajcinovic (Arizona State).

*Vibroacoustic Characterization of Materials and Structures*, organized by P. K. Raju (Auburn). Cosponsor only.

### *1993 First Joint SES, ASME-AMD, ASCE-EMD Meeting—University of Virginia, Charlottesville, VA, 6–9 June 1993*

*Numerical Issues in the Modeling of Composite Processing*, organized by J. N. Reddy (Virginia Tech) and N. Chandra (Florida State).

### *1993 Winter Annual Meeting—New Orleans, 28 Nov.–3 Dec. 1993*

*Smart Composite Materials*, organized by T. W. Chou (Delaware).

## Research Thrusts

The Committee also identified two topics for future research thrusts in composites.

*Inelastic Thermomechanical Micromechanics with Damage*—The ever increasing demand for lightweight, dimensionally stable, and active structures and materials that are suitable for applications over a wide range of temperatures and environments points to the need for enhanced understanding and micromechanical modeling capability for fibrous composite materials. Of particular interest are the roles of the fiber/matrix interface, imperfect bonding, thermal gradients, and inelastic, time- and temperature-dependent response for extended lifetimes. The micromechanics of failure for multiaxial stress states is another important topic that must be developed. A complete understanding of the micromechanics of failure is particularly important for thick composites.

*Smart Materials, Structures, and Processes*—The growing interest in smart materials and structures naturally brings to mind the myriad of potential applications and problems associated with the use of fibrous composites for such applications. Research areas include intelligent processing, hybrid structures, damage assessment, micromechanics of embedded sensors, design optimization, passive and active damping. There is also a need to develop a scientific foundation for manufacturing processes and fabrication of composite materials and structures. Basic micromechanics will also be needed to create a foundation for analysis and design of active/smart materials that exhibit interactions between physical effects (such as phase transformations) and thermomechanical response. The availability of such models will enhance the development of new materials with optimum properties.

The executive committee will consolidate the research thrust recommendations of all the technical committees and then make the consolidated statement available to those agencies requesting such information.

---

# CENTER FOR COMPOSITE MATERIALS UNIVERSITY OF DELAWARE

*Research Highlighted, Two Grants Noted, Tech Park Opens*

## Robotics Applied to Nondestructive Evaluation and Filament Winding

Karl Steiner, Assistant Director of the Center for Composite Materials (CCM), has applied robotics to help set up the Center's nondestructive evaluation (NDE) lab and to research online consolidation of composites. To accomplish this, Steiner, who joined the Center eight years ago, has drawn on his electrical engineering/computer science background.

### *Nondestructive Evaluation*

Steiner's initial objective upon joining the Center was to help develop a robotic ultrasonic NDE system to enable investigation of complex geometries. The resulting lab is used extensively by faculty, staff, students, and industrial sponsors. It features a six-axis robot which is suspended upside-down from a gantry above an immersion tank. The scanning procedure is controlled by a microprocessor, which communicates with the robot while triggering the pulser of an ultrasonic analyzer at preselected time intervals. Ultrasonic waves transmitted from the transducer travel through the water into the composite part under inspection. The reflected echo is digitized and subsequently displayed on the screen of a computer workstation.

In recent years, the primary focus of the work in the NDE lab has been on image enhancement, with two methods evolving from the program: ultrasonic C-scanning and digitized full-waveform scanning. For C-scanning, in-house-developed software for image enhancement is used to view and manipulate the C-scan results on the screen. The facilities allow the inspection of parts with both types of digital C-scans—pulse-echo and through-transmission.

The second NDE technique, digitized full-volume waveform scanning, has been developed and implemented at the Center over the past five years. With this method, no gates have to be chosen before the scan procedure, which opens the field to statistical waveform analysis and complete postprocess image interpretation. While the use of this approach requires a dramatic increase in computer storage capacity over traditional C-scan technology, it provides complete information about scanned information and enables reevaluation at any time. Although this type of scanning is not feasible for inspection of large structures, it is very valuable for in-depth analysis of localized areas with potential defects.

Current efforts are devoted to developing the next generation of the enhancement programs to make them more user-friendly and enable the use of new computer graphics technology. Recently developed software include INDEX which enables the user to enhance interactively digitized images and thus highlight particular features that would otherwise be hidden to the human eye. In addition, the scanning procedure has been improved through the development of software that controls the entire process interactively through the computer graphics terminal. Before this effort, four individual computers were required to perform the scan.

The NDE work done goes beyond simple testing. Efforts have focused on understanding the relationship between the ultrasonic waveform and the variety of defects and abnormalities that can influence a composite structure. Researchers are trying not only to find defects and flaws but also to categorize them, to know their depth within the composite, and to understand how they will influence the performance of the material.

In one current investigation, a variety of defects were artificially implanted in samples manufactured from carbon-fiber prepregs. Cracks and delaminations were generated by impact and bending tests, and the specimens were scanned to find correlations between the defects and their displayed images. Finally, the specimens were cut and analyzed under the microscope. Such NDE studies provide information about thickness variations, fiber orientation, fiber/matrix distribution, porosity content, contaminations, delaminations, and impact damage.

### *Robotic Thermoplastic Filament Winding*

Filament winding is one of the techniques under study in the Center's online consolidation manufacturing science thrust area. The goal was to establish a new approach to filament winding by using an off-the-shelf six-axis robot system and attaching a seventh axis for mandrel rotation. Initial efforts focused on wet winding of thermoset composites; then, in 1990, work shifted to developing a lightweight prototype filament-winding head for thermoplastics.

Several inherent limitations in thermoset winding—one related to the positioning of the fibers, the other to the mandrel geometry—provided the motivation to develop a technique for thermoplastics. First, thermoset winding requires the fibers to follow the geodesic path, the shortest distance between two points on the mandrel surface. This limits the positioning of fibers on geometries with changing diameter and restricts the mandrel design to convex curvatures. In addition, traditional filament-winding machines are unable to wind mandrels with multiple axes of rotation, such as T-sections.

Robotic thermoplastic filament winding offers solutions to both of these limitations. Thermoplastics can be consolidated online during winding, allowing the designer to deviate drastically from the geodesic path. Concave mandrel sections can be mastered by "welding" the new material to the mandrel and the already-consolidated substrate. Integration of a multi-axis robot manipulator allows for great flexibility to place the payout eye of the fiber delivery system and can be used in connection with a mandrel actuator to place fibers along arbitrary shapes with multiple axes of rotation.

The initial effort in this area features construction of a placement head based on a hot gas torch system. It was used to make demonstration components of conical and cylindrical geometry from glass/polypropylene prepreg. The equipment was then applied to an experimental study of robotic thermoplastic filament winding of complex geometries. With the goal of process optimization, critical parameters as consolidation pressure, temperature, and winding speed were examined. Initially, rings were wound while these parameters were varied. Microscopic analysis and mechanical tests were then performed to evaluate the specimens and determine the optimized parameters.

The researchers then investigated three different mandrel geometries. This research showed the ability of thermoplastic filament winding to overcome the limitations of the traditional thermoset process. The advantages are particularly apparent during the production of nongeodesic parts and concave mandrel sections. This work was also significant in supplying information that can be used to design and build the next generation of a thermoplastic placement head. The second-generation thermoplastic filament-winding head being developed will operate at higher speeds. It will also be able to process higher temperature composites like graphite/PEEK, in contrast to its predecessor, which could be used only for low-melting-point thermoplastics. Finally, the new winding head will also implement a cutting-and-restarting mechanism for thermoplastic tape "on the fly."

As with the NDE effort, advances in filament winding hardware are complimented by software development. The interaction between the robot and the servomotor have been improved by building a custom interface. In another study, a code that allows shapes to be generated and then simulated, analyzed, and optimized on a computer graphics workstation has been developed. The output of this code is being used with a solid model that can subsequently be used as a robotic simulator which analyzes the paths generated and determines how the robot has to move to place the fibers in the desired configuration. The simulator is used to test proposed windings off-line. Once it has been demonstrated that a given shape can be wound, the program is down loaded to the workcell.

Steiner is now looking ahead to two major new funding sources that will support the next stage of his work in NDE and online consolidation. Through a five-year grant from the Army Research Office/University Research Initiative Program, he will be a co-investigator on three projects that are part of a multidisciplinary program in manufacturing science of polymeric composites:

- In-Process Inspection and Process Control of Thermoplastic Composite Pultrusion with Ultrasonic NDE Methods,
- Novel Online Inspection Techniques: Sensor Development for Evaluation, Testing, and Online Control, and
- Online Sensing and Process Control of an Automated Fusion Bonding Process for Joining Thermoplastic Composites.

In addition, funds from DARPA will enable him to develop further the second-generation placement head for high-speed winding of high-temperature thermoplastics.

## Joining Research—An Update

The Center's work in the joining of thermoplastic composites was first outlined in the Fall Issue of the *Journal*. That article noted that investigators were pursuing three fusion-bonding approaches: resistance, induction, and ultrasonic welding. Updates in two of these techniques are presented here.

### *Induction Welding*

Unlike resistant welding, which is now a relatively mature technology, the heat generation mechanisms of induction welding have been poorly understood.

In contrast to previous investigations using susceptor materials at the bond interface, a recent study at the Center focused on fundamental material science issues that explain heat generation in cross-ply graphite/PEEK composites subjected to an external, transversely applied alternating magnetic field. This work has shown that the dominant mechanism of heat generation is due to dielectric heating of the matrix.

Researchers have developed several models as a result of the work. The first predicts the planar electrical potential distribution in cross-ply carbon-fiber composites subjected to alternating magnetic fields. This model predicts the strength and distribution of these heat sources in the plane of cross-ply laminate configurations. The second model predicts the through-the-thickness distribution of heat generation in cross-ply carbon-fiber composites as a function of the potential distribution. The third model predits the two-dimensional (2-D) transient thermal history in the plane for various process parameters and laminate stacking sequences which substantiate the proposed theory of induction heating. Data from AS4 graphite-reinforced PEEK laminate surface temperature measurements were in good agreement with the theory. Experimental validation of transient surface temperature profiles were also conducted.

The findings of experimental work include the following:

- Heating of continuous carbon-fiber-reinforced polymers by the application of an alternating magnetic field is due to dielectric losses in the polymer.
- The loss tangent is substantially dependent on the moisture content in PEEK during magnetically induced dielectric heating of PEEK/carbon-fiber composites.
- The strength and distribution of the electrical field—and thus the heating in the plane of the laminate—is dependent upon the shape and size of the inductive flux field (coil) relative to the shape and size of the specimen. Increasing the size of the coil—while not removing the peaks in heating—diminishes the gradients of heating in the plane.
- The distribution of heating in the plane of the laminate is predictable and consists of peaks located at the intersections of the exterior orthogonal tangents of the coil. This result indicates that heating is not due to joule losses in the fibers.
- To maximize the heating at any point in the plane of the cross-ply or angle-ply laminate, the fiber volume fraction should be maximized, the fiber diameter should be minimized, the interply resin thickness should be minimized, and the ply thickness above and below the interface should be maximized.

This work will provide the foundation for the next stage of induction welding research. Future efforts will focus on applying new-found understanding of the thermo-electromagnetic response of composites to inductive fields in an investigation of bonding phenomena and further concept development in bonding/repair operations.

### *Resistance Welding*

In the resistance welding area, Center researchers are moving into welding dissimilar materials. With support from two industrial sponsors, Lockheed and Sikorsky Helicopters, the joining team is developing two alternate techniques for this technology.

The objective of the Lockheed project is to demonstrate large-scale resistance welding of heat-stiffened panels. The work involves co-cure of an amorphous thermoplastic polymer with a graphite thermoset material, as well as more traditional amorphous bonding of thermoplastic components. In conjunction with Sikorsky, CCM researchers are investigating the use of a novel hybrid thermoplastic prepreg material for joining thermoset materials using the Center's thermoplastic resistance-welding technology.

The core technology developed under the aegis of these two projects will be integrated into the Center's growing resistance-welding research program. The overall goal of the program is to optimize the resistance-welding process parameters and incorporate them into a computer-controlled system, with built-in sensors for online monitoring and control, enabling large-scale composite components to be joined with high quality and performance.

## Center Receives Two New Grants

### *Army Funding Renewed*

The United States Army Research Office (ARO) has awarded the University of Delaware Center for Composite Materials (CCM) more than $3.8 million over five years for a multidisciplinary program in the manufacturing science of polymeric composites. The funds, awarded through the ARO's University Research Initiative (URI) program, are a continuation of a five-year grant awarded in 1986 that established CCM as an ARO/URI Center of Excellence for Manufacturing Science, Reliability, and Maintainability Technology. CCM competed with more than 20 other academic institutions to win the renewal grant.

Roy L. McCullough, CCM Director, and Tsu-Wei Chou, Jerzy L. Nowinski Professor of Mechanical Engineering, are coprincipal investigators on the new research program. Their proposal to the Army consisted of a highly interdisciplinary program involving 13 faculty and professional research staff members from several departments at the University bringing together diverse expertise to meet the Army's needs in a variety of areas. A majority of the individual projects making up the program will have at least two coinvestigators to ensure a broad perspective on the work.

The 34 000-ft$^2$ Composites Manufacturing Science Laboratory (CMSL) will play an important role in the planned Army manufacturing science program. A major component of the original URI program was a $1-million equipment grant; the equipment purchased with those funds is now in place in the CMSL, with plans for its use in experimentation to verify the many process models already developed by Center researchers.

The ten projects making up the program are collectively aimed at improving reliability and extending the useful life of structural components by optimizing and controlling potentially low-cost manufacturing processes. University investigators anticipate a great deal of synergy between the Army program and the work performed with the support of its industrial consortium. The common denominator is interest in improving the overall properties of composite materials and in developing increasingly automated systems in which online control and monitoring are possible.

### *Research Group Wins Prestigious International Grant*

The University of Delaware's Center for Composite Materials, United Technologies Research Center, the University of Tokyo, Nippon Carbon, and the Institute of Industrial Science in Japan have joined forces to win a grant from the International Joint

Research Division of the New Energy and Industrial Technology Development Organization (NEDO) in Japan. The group will investigate "The Effect of the Interface on Microfracture Mechanisms for Fiber-Toughened Ceramic-Matrix Composites."

The objectives of the three-year program are twofold: (1) analytical modeling of the thermomechanical behavior of single and multiple fiber-reinforced glass-ceramic composites and (2) study of the fracture mechanisms of these materials at ambient and elevated temperatures.

NEDO, a semigovernmental agency supervised by Japan's Ministry of International Trade and Industry (MITI), established its International Joint Research Program in 1988. The program aims to promote creative basic research through international cooperation and, in the process, help improve the international standard of science and technology while contributing to the advancement of international exchange.

## Delaware Technology Park

*Groundbreaking Held*

In a ceremony attended by representatives from the University of Delaware, the State of Delaware, and local chemical companies, ground was broken for the first building in the Delaware Technology Park (DTP) on Monday, 6 Jan. 1992. Dick J. Wilkins serves as both President of the Park and Executive Director of the affiliated Institute for Applied Composites Technology (IACT). The IACT is a nonprofit organization comprised of representatives from the State, University of Delaware, and industry. It will serve as the umbrella organization under which the business and academic communities will work to link research with manufacturing in the development of new technologies. The IACT will be headquartered in the Phase I building of the DTP which will be located on 40 acres of land leased from the University of Delaware. When complete, likely by the year 2000, the DTP will consist of a series of buildings totaling over 300 000 $ft^2$. In addition to housing IACT, the DTP will provide a variety of services to industry.

The first Park building is scheduled for occupancy by early 1993. Du Pont's Advanced Composites Technology Development Center will be the first tenant. The company's DTP location will consolidate several existing sites and provide additional room for growth.

# CENTER FOR COMPOSITE MATERIALS AND STRUCTURES VIRGINIA POLYTECHNIC INSTITUTE

*Materials Response Group Profiled, Recent Research Reviewed*

## The Materials Response Group

The Center for Composite Materials and Structures' Materials Response Group (MRG) was created through the acquisition of a grant awarded by the U.S. Army to several faculty members in 1969 in the area of engineering science and mechanics of composites.

The Materials Response Group is concerned with the development of understandings, philosophy, and models of the strength, stiffness, and life of engineering materials and material systems. The MRG develops and uses experimental and analytical techniques to study the mechanical behavior of those materials.

Research thrusts include damage analysis, fatigue, fracture, durability, adhesion, visual analysis, performance simulation, material systems, and nondestructive evaluation.

The performance of high-temperature composites is one of the areas in which the group has specialized. The MRG has developed an initiative in ceramic composites. High-temperature, ceramic composites are primary materials in the design and development of advanced power systems such as engines for the High Speed Civil Transport airplane and fossil fuel energy plants. Ceramic composites offer the durability and reliability needed to operate efficient and economic energy systems in high-temperature and (often) corrosive environments.

The use of ceramic composites in high-temperature structures requires the technical community to make the transition from properties of materials to performance of components. Long-term performance of ceramic composites is of particular interest because of the structural integrity requirements of energy systems.

The transition from properties of materials to performance of components requires comprehensive characterization and an understanding of the mechanics of long-term behavior of ceramic composite systems. For example, properties such as high-temperature strength, modulus of rupture, and fracture toughness do not provide sufficient information to design a heat exchanger tube or a compressor component which may experience multiaxial stresses at temperatures as high as 3000°F (1648.8°C) for 18 000 h.

Members of the MRG are working with several industries and government agencies to provide the experimental data and analytical basis for the design, development, and certification of high-temperature ceramic composite components. This comprehensive program includes the Department of Energy/Oak Ridge National Laboratories, the Air Force Office of Scientific Research, General Electric Aircraft Engines, Southern Research Institute, Rolls-Royce, Allied Signal, and Babcock and Wilcox.

Two major capabilities of the MRG's ceramic composites program are a high-temperature, mechanical testing laboratory and a long-term performance simulation model. The centerpiece of the testing laboratory is a specially designed, high-stiffness Instron servohydraulic testing machine with combined axial-torsional loading capability. The facility includes a furnace for high temperature testing to 1500°C, a high-temperature extensometer, hydraulic grips for testing tubular ceramic composite components, and computer control and data acquisition. The performance simulation model, based on the critical element concept for predicting remaining strength and life, is a mechanistic predictive methodology for long-term behavior of composite material systems. The model includes the evolution of properties and performance associated with variations in material state and stress state caused by high-temperature loading conditions.

The unique experimental and analytical capabilities are being used by the MRG and the research sponsors to develop experimental data and performance predictions for high-temperature ceramic components. High-temperature test data and performance predictions are used to advance the understanding of the factors that control long-term performance of ceramic composites, to measure the properties and performance information required to design ceramic composite components, and to provide critical and comprehensive evaluation of performance to material developers and component designers.

Faculty and associate members of the Materials Response Group include:

**David A. Dillard**, Associate Professor
*Research interest:* Time-dependent behavior of polymers, adhesives, wood, and composite materials—particularly, the role which environment plays on structural durability, and in developing appropriate test methods for adhesive systems.

**Edmund G. Henneke, II**, Professor and Department Head
*Research interest:* Nondestructive evaluation of composite materials and associated mechanical characterization of these materials and study of wave propagation in anisotropic materials.

**Ronald D. Kriz**, Associate Professor
*Research interest:* Modeling damage development in fiber-reinforced composite laminates, nondestructive ultrasonic and optical methods for detection of surface damage, and monitoring degradation of properties in laminated composites.

**Don H. Morris**, Professor and Assistant Department Head
*Research interest:* Fracture of thick composite laminates subjected to axial and bending loads, an experimental study of damage initiation and growth in three-dimensional composites.

**Kenneth L. Reifsnider**, Alexander Giacco Chaired Professorship
*Research interest:* Mechanics of damage evolution and strength and life modeling.

**Robert A. Simonds**, Laboratory Engineer
*Research interest:* Instrumentation, automated data acquisition and control, mechanical testing of composite materials.

**Wayne W. Stinchcomb**, Professor
*Research interest:* Test method development, material response measurements and evaluation, and damage analysis.

## Recent Research Highlights

Investigators at the Center For Composite Materials and Structures (CCMS) are conducting research on a wide variety of topics. Recent research topics include the following.

### *Analysis, Shape Sensitivities and Approximations of Modal Response of Generally Laminated Tapered Skew Plates*

A method is developed for the static, free vibration, and shape sensitivity analyses of generally laminated tapered skew plates having arbitrary edge conditions such as clamped, simply supported, or free. The procedure consists of the application of the Rayleigh-Ritz method with Chebyshev polynomials in the displacement function. An approximate approach that uses artificial, stiff springs is used to satisfy the geometric boundary conditions. This method enables one to analyze plates of various geometric shapes defined by natural coordinates. Before using it for a plate, the method is first applied to the one-dimensional problem of free torsional vibrations of doubly symmetric thin-walled beams of open section, subjected to an axial compressive static load and resting on a continuous elastic foundation. Accurate numerical results for natural frequencies for various values of warping and elastic foundation parameters are presented. The method is then extended to laminated plates and accurate frequencies, and mode shapes are obtained for various plate geometries and lamination sequences. The sensitivity of the natural frequencies and the mode shapes with respect to various shape parameters is also determined. These derivatives are then used to approximate the natural frequencies and mode shapes, and the approximations are found to be in good agreement with those obtained from reanalysis over the range of the particular shape parameter.

The results of the study indicate that Chebyshev polynomials can be efficiently used in the Rayleigh-Ritz method to determine accurately the modal response of generally laminated trapezoidal plates. The investigators also noted that the shape sensitivities of the modal response have been accurately used to approximate the natural frequencies and mode shapes.

### *On Iso- and Nonisothermal Crack Problems of a Layered Anisotropic Elastic Medium*

The iso- and nonisothermal crack problems of layered fiber-reinforced composite materials are investigated within the framework of linear anisotropic thermoelasticity and under the state of generalized plane deformation. By using the Fourier integral transform technique and the flexibility/stiffness matrix formulation, the current mixed boundary value problems are reduced to solving a set of simultaneous singular integral equations with the Cauchy-type kernels. The crack-tip stress intensity factors are then defined in terms of the solutions of the integral equations. Numerical results are presented addressing the unique features of a class of crack problems which involve highly anisotropic fibrous composite materials under in-plane normal (Mode I), in-plane shear (Mode II), and anti-plane shear (Mode III) crack surface loadings. Specifically, the cases of a parallel crack imbedded (1) within a homogeneous and anisotropic slab, (2) between two bonded dissimilar anisotropic half-spaces, and (3) within the matrix-rich interlaminar region of a generally laminated anisotropic slab are considered. The effects of relative crack size, crack location, and fiber volume fraction on the stress intensity factors are examined as a function of layer fiber angle. For the case of layered composites, the interlaminar region is modeled as a separate interlayer. As the interlayer thickness approaches zero, the interlaminar crack model illustrates no smooth transition to the ideal interface crack model which exhibits oscillatory singularities. The mixed-mode crack tip response is obtained in terms of the simultaneous presence of the three fracture modes. It is demonstrated that the values of stress intensity factors are strongly influenced by the laminate stacking sequence and layer orientation angle. In addition, the imposition of the partially insulated crack surface condition is shown to alleviate the severity of thermally induced stress fields around the crack tip.

### *An Evaluation of the Iosipescu Specimen for Composite Materials Shear Property Measurement*

A detailed evaluation of the suitability of the Iosipescu specimen tested in the modified Wyoming fixture is presented. An experimental investigation using conventional strain gage instrumentation and moire interferometry is performed. A finite element analysis of the Iosipescu shear test for unidirectional and cross-ply composites is used to assess the uniformity of the shear stress field in the vicinity of the notch and demonstrate the effect of the nonuniform stress field upon the strain gage measurements used for the determination of composite shear moduli.

From the test results for graphite-epoxy laminates, it is shown that the proximity of the load introduction point to the test section greatly influences the individual gage readings for certain fiber orientations, but the effect upon shear modulus measurement is relatively unimportant. A numerical study of the load contact effect shows the sensitivity of some fiber configurations to the specimen/fixture contact mechanism and may account for the variations in the measured shear moduli. A comparison of the strain gage readings from one surface of a specimen with corresponding data from moire interferometry on the opposite face documented an extreme sensitivity of some fiber orientations to eccentric loading which induced twisting and yielded spurious shear stress-strain curves.

In the numerical analysis, it is shown that the Iosipescu specimens for different fiber orientations have to be modeled differently to approximate closely the true loading conditions. Correction factors are needed to allow for the nonuniformity of the strain field and the use of the average shear stress in the shear modulus evaluation. The correction factors, which are determined for the region occupied by the strain gage rosette, are found to be dependent upon the material orthotropic ratio and the finite element models.

Based upon the experimental and numerical results, recommendations for improving the reliability and accuracy of the shear modulus values are made, and the implications for shear strength measurement discussed.

Further application of the Iosipescu shear test to woven fabric composites is presented. The limitations of the traditional strain gage instrumentation on the strain weave and high two plain weave fabrics is discussed. Test result of an epoxy-based aluminum particulate composite is also presented.

A modification of the Iosipescu specimen is proposed and investigated experimentally and numerically. It is shown that the proposed new specimen design provides a more uniform shear stress field in the test section and greatly reduces the normal and shear stress concentrations in the vicinity of the notches. While the fabrication and the material cost of the proposed specimen is tremendously reduced, it is shown the accuracy of the shear modulus measurement is not sacrificed.

The investigators concluded that the lack of pure shear in the specimen test section is an inherent property for the 0° Iosipescu specimen. The strains recorded by the two strain gages at the ±45° directions to the longitudinal axis are not equal in magnitude and opposite in sign. Because of the relatively uniform normal strain fields in the specimen test section, the lack of pure shear in the 0° specimen does not affect the accurate measurement of shear strain.

The data also indicate shear strain distribution in the test section is not similar for all material systems. Correction factors should be applied to account for the nonuniform shear strain field in the calculation of shear modulus. Numerically determined correction factors depend on the finite element models.

The variation in the measured shear modulus for the 0° specimens is attributed to the sensitivity of the shear strain distribution to the local loading details. The variation in the 90° specimens is due to the specimen twisting. The effect of twisting on the initial shear modulus measurement can be eliminated by taking an average of front and back shear strains.

## EUROPEAN COMPOSITE AWARD

### *New Award to be Presented in July*

To encourage the use of reinforced materials (composites), a major new international competition, the first "European Composite Award," will be inaugurated on the occasion of the international exhibition and conference "Verbundwerk 92" (1–3 July, Wiesbaden). The Award will subsequently be made every year, announce the German sponsors, exhibition organizers Demat Exposition Managing, Frankfurt, and publishers Kunststoff Information, Bad Homburg. The object of the new "European Composite Award" is to recognize both exceptional technical and scientific work and especially successful product launches in the area of reinforced materials and publicize them widely. The Award will especially promote the use of composites in many sectors still lacking notable market success.

The "European Composite Award" will be made in two categories: Research and Development—recognizing developing in the scientific and technical field which opens up to immediate or future possibilities for application and Markets for Composites—recognizing particularly successful products and applications introduced into the market during the previous two years.

Eligible for the Award are private individuals, institutes, technical colleges, research establishments, and companies which, by competing for the Award, can underline their technoeconomic and commercial involvement in the reinforced materials sector.

An international jury chaired by Prof. Dr.-Ing. H. G. Niederstadt (DLR Braunschweig) will decide the awards in both categories. The official presentation of the Awards will be held under the auspices of the "Verbundwerk 92," exhibition and conference, from 1 to 3 July 1992 in Wiesbaden.

# RECENT COMPOSITES PUBLICATIONS

*Two Texts Outlined, New Journal Launched*

## Composite Materials: Testing and Design (10th Volume)

**REFERENCE:** Grimes, G. C., Ed., *Composite Materials: Testing and Design (10th Volume), ASTM STP 1120*, American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103, 1992, ISBN: 0-8031-1426-5, 495 pp., hardcover, $105.

Over the last 21 years, the 10 ASTM Composite Materials conferences and the resulting ASTM STP publications have become industry standard reference documents. Experts in the field of composite materials and structures from government, industry, and academia discuss current research and development on composites and the state-of-the-art engineering applications to structures in the latest volume in the series.

Important composite materials technical issues are discussed in eight sections:

- Compression Test Methodology Analysis and Development,
- General Test Methodology Analysis and Development,
- Material Mechanical Properties and Failure Criteria,
- Advanced Materials Analysis and Test,
- Analysis, Test, and Certification of Structure,
- Quality Assurance and Process Control,
- Interlaminar Fracture Analysis and Test, and
- Damage, Flaws, and Repair.

For those involved in composite research or design of advanced composite structures.

There are 28 peer-reviewed papers including:

The Influence of Fiber Waviness on the Compressive Behavior of Unidirectional Continuous Fiber Composites

Thermomechanical Testing of High-Temperature Composites: Thermomechanical Fatigue (TMF) Behavior of SiC(SCS-6)/Ti-15-3

Effects of Processing Variables on the Quality of Co-Cured Sandwich Panels

Free-Edge Stress Analysis of Glass-Epoxy Laminates with Matrix Cracks

Damage Tolerance of Three-Dimensional Commingled Peek/Carbon Composites

A Scientific Approach to Composite Laminated Strength Predictions

A Macro-Micromechanics Analysis of A Notched Metal Matrix Composite

Analysis and Testing of a composite Sandwich Shell Horizontal Tail

## Fatigue of Composite Materials

**REFERENCE:** Reifsnider, K. L., Ed., *Fatigue of Composite Materials*, Composite Materials Series Vol. 4, Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands, 1991, ISBN: 0-444-70507-4, 520 pp., $179.50.

This book provides the first comprehensive review of its kind on the long-term behavior of composite materials and structures subjected to time variable mechanical, thermal, and chemical influences, a subject of critical importance to the design, development, and certification of high performance engineering structures. Specific topics examined include damage, damage characterization, and damage mechanics; fatigue testing and evaluation; fatigue behavior of short and long fiber-reinforced polymer and metal matrix materials; viscoelastic and moisture effects; delamination; statistical considerations; the modeling of cumulative damage development; and life prediction. The volume provides an extensive presentation of data, discussions, and comparisons on the behavior of the major types of material systems in current use, as well as extensive analysis and modeling (including the first presentation of work not found elsewhere). The book will be of special interest to engineers concerned with reliability, maintainability, safety, certification, and damage tolerance; to materials developers concerned with making materials for long-term service, especially under severe loads and environments; and to lecturers, students, and researchers involved in material system design, performance, solid mechanics, fatigue, durability, and composite materials. The scope of the work extends from entry level material to the frontiers of the subject.

## International Journal of Damage Mechanics

*Editor-in-Chief: C. L. Chow, Ph.D., D.Sc., Director of Mechanical Engineering, Southern Illinois University, Edwardville*

In the pats two decades there has been considerable progress and significant advances made in the development of fundamental concepts of damage mechanics and their application to solve practical engineering problems. For instance, new concepts have been effectively applied to characterize creep damage, low and high cycle fatigue damage, creep-fatigue interaction, brittle/elastics damage, ductile/plastic damage, strain softening, strain-rate-sensitivity damage, impact damage, and other physical phenomena. The materials include polymers, composites, ceramics, and metals.

This area has attracted the interest of a broad spectrum of international research scientists in micromechanics, continuum mechanics, mathematics, materials science, physics, chemistry, and numerical analysis.

However, sustained rapid growth in the development of damage mechanics requires the prompt dissemination of original research results, not only for the benefit of the researchers themselves, but also for practicing engineers who are under continued pressure to incorporate the latest research results in their design procedures and processing techniques with newly developed materials.

The new *International Journal of Damage Mechanics* has been inaugurated to provide an effective mechanism which will accelerate the dissemination of information on damage mechanics not only within the research community but also between the research laboratory and industrial design department, and it should promote and contribute to future development of the concept of damage mechanics.

*Publication Details*

**Frequency**: Quarterly; January, April, July, October
**Volumes**: Annual; Vol. 1 consists of 1992 issues
**ISSN**: 1056-7895
**Size**: 6 by 9 in., approximately 140 pp. per issue
**Index**: Author and subject Index for each volume in October issues
**Advertising**: None except for announcements of professional publications and conferences
**Subscription prices**: One year $215.00, two years $420.00, three years $625.00. Postage outside U.S.: please add $36.00/year for surface mail; $54.00/year for airmail.

# Calendar on Composites

*The following meetings may be of interest to researchers in the field of composite materials.*

**29 June–3 July 1992**
*6th International Conference on Solid Films and Surfaces*
Noisy-Le-Grand, France
Contact: Dr. J. Lecante, CEA and LURE, Batiment 209 D, Universite Paris-Sud-91405 Orsay Cedex, France; Telephone: 33-164-46-80-03, FAX: 33-164-46-41-02

**30 June–2 July 1992**
*24th National Symposium on Fracture Mechanics*
Gatlinburg, Tennessee
Contact: Chairman Professor John D. Landes, University of Tennessee, Department of Engineering Science and Mechanics, 310 Perkins Hall, Knoxville, TN 37996-2030; Telephone: 615-974-7670, FAX: 615-974-2669

**1–3 July 1992**
*LOCALIZED DAMAGE '92, Second International Conference on Computer Aided Assessment and Control*
Southampton, United Kingdom
Contact: Sue Owen, Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, SO4 2AA, United Kingdom; Telephone: 0703-293223, International Telephone: 44-703-293223, FAX: 0703-292853, International FAX: 44-703-292853

**1–3 July 1992**
*4th Industry Fair of Europe for Reinforced Materials and Composite Technologies*
Contact: Diana Schnabel, DEMAT Exposition Managing, P.O. Box 110 611, 6000 Frankfurt 11, Germany; Telephone: xx69/23 43 31, FAX: xx69/25 30 71

**1–3 July 1992**
*4th International Conference "Competitive Composites by New Manufacturing Technologies"*
Contact: Diana Schnabel, DEMAT Exposition Managing, P.O. Box 110 611, 6000 Frankfurt 11, Germany; Telephone: xx69/43 31, FAX: xx69/25 30 71

**3–7 August 1992**
*The Second International Symposium on Composite Materials and Structures*
Beijing, China
Contact: Prof. Tian-Xiang Mao, Institute of Mechanics, Academia Sinica, No. 15, Zhong Guancun Rd., Beijing, 100080, China

**22–28 August 1992**
*18th International Congress of Theoretical and Applied Mechanics*
Haifa, Israel
Contact: Professor A. Solan, Secretary ICTAM 1992, Faculty of Mechanical Engineering, Technion-Israel Institute of Technology, Haifa 32000, Israel; Telephone: 04-292111, FAX: 04-324533 or 04-221581

**8–10 September 1992**
*Composites ECCM Testing & Standardisation*
Amsterdam, The Netherlands
Contact: Mrs. Dominique Doumeingts, EACM, 2 Place de la Bourse, 33076 Bordeaux Cedex. France; Telephone: 33-56-52-98-94/56-52-65-47, FAX: 33-56-44-32-69, Telex: 572-651-F-CEBSO

√ **22–23 October 1992**
*Experimental Techniques and Design in Composite Materials Seminar*
Cagliari, Sardinia, Italy
Contact: Prof. Francesco Ginesu, University of Cagliari, Department of Mechanical Engineering, Piazza d'Armi, 09123 Cagliari, Italy; Telephone: +39-70-2000352, FAX: +39-70-2000362

**3–6 November 1992**
*BEM 14, 14th Boundary Element International Conference*
Seville, Spain
Contact: Sue Owen, Conference Secretariat, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton, SO4 2AA, United Kingdom; Telephone: 0703-293223, International Telephone: 44-703-293223, FAX: 0703-292853, International FAX: 44-703-292853

**8–13 November 1992**
*A Symposium on Damage Mechanics in Composites, ASME Winter Annual Meeting*
Anaheim, California
Contact: Dr. David H. Allen, Center for Mechanics of Composites, Texas A&M University, College Station, TX; Telephone: 409-845-1669, FAX: 409-845-6051

**8–13 November 1992**
*Proposal for A Symposium on the Macroscopic Behavior of Heterogeneous Materials From the Microstructure, ASME Winter Annual Meeting*
Anaheim, California
Contact: Prof. Sal Torquato, Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC 27695-7910; Telephone: 919-515-3241, FAX: 919-515-7968

**11–13 November 1992**
*International Conference on Computational Methods in Engineering: ICCME '92*
Marina Mandarin Hotel, Singapore
Contact: ICCME '92 Secretariat, c/o Mansfield International Conference & Exhibition Organisers Pte Ltd., 71 Robinson Rd., 4th Storey Crosby House, Singapore 0106; Telephone: 65-228-0913, FAX: 65-226-3733

**16–17 November 1992**
*Symposium on Compression Response of Composite Structures: ASTM*
Miami, Florida
Contact: Dorothy Savini, Symposia Operations, ASTM, 1916 Race St., Philadelphia, PA 19103-1187; Telephone: 215-299-5413

**15–19 February 1993**
*International Conference on Advanced Composites*
Wollongong, Australia
Contact: T. Chandra, Conference Chairman, Department of Materials Engineering, University of Wollongong, Wollongong NSW 2500 Australia; Telephone: 61-42-213008, FAX: 61-42-213112, E-MAIL: T.CHANDRA@UOW.EDU.AU

**21–26 February 1993**
*International Symposium on The Interphase (Adhesion Society, Inc.)*
Williamsburg, Virginia
Contact: Dr. Louis H. Sharp, 28 Red Maple Rd., Hilton Head Island, SC 29928; Telephone: 803-671-4810, FAX: 803-671-4810

**23–25 February 1993**
*Asia Pacific Conference on Materials Processing*
Nanyang Technological University, Singapore
Contact: Prof. F. W. Travis, Organising Secretary, Asia Pacific Conference on Materials Processing, School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Ave., Singapore 2263; Telephone: 2641744, ext. 5500 or direct line 6605500, FAX: 2641859, Telex: RS 38851 NTI. BITNET: MFWTRAVIS@NTIVAX

**13–17 April 1993**
*9th International Conference on Wear of Materials*
San Francisco, California
Contact: Dr. R. G. Bayer, IBM Corp., Technology Laboratory, P.O. Box 8003, Endicott, NY 13760; FAX: 607-757-1126

**4–6 May 1993**
*Fifth Symposium on Composite Materials: Fatigue and Fracture (ASTM)*
Atlanta, Georgia
Contact: Dr. Roderick H. Martin, Symposium Chairman, Analytical Services and Materials, Inc., MS 188E, NASA Langley Research Center, Hampton, VA 23665-5225; Telephone: 804-864-3482, FAX: 804-864-7729

**6–9 June 1993**
*First Joint SES, ASME-AMD, ASCE-EMD Meeting*
Charlottesville, Virginia
Contact: Carl T. Herakovich, Applied Mechanics Program & Civil Engineering Department, University of Virginia, Charlottesville, VA 22903-2442; Telephone: 804-924-3605, FAX: 804-982-2951, E-MAIL: HERAK@VIRGINIA.EDU

**13–18 June 1993**
*21st Biennial Conference on Carbon*
Buffalo, New York
Contact: Prof. D. Chung, Composite Materials Research Laboratory, Furnas Hall, State University of New York at Buffalo, Buffalo, NY 14260; Telephone: 716-636-2520, FAX: 716-636-3875

**12–16 July 1993**
*The Ninth International Conference on Composite Materials (ICCM/IX)*
Madrid, Spain
Contact: Prof. Antonio Miravete, Department of Mechanical Engineering, University of Zaragoza, Maria de Luna, 3, 50015 Zaragoza, Spain; Telephone: 34-76-517401, FAX: 34-76-512932

**2–4 November 1993**
*3rd Pacific Rim Forum on Composite Materials*
Honolulu, Hawaii
Contact: Stephen W. Tsai, Department of Aeronautics and Astronautics, Stanford University, Stanford, CA 94305-4035; Telephone: 415-725-3305, FAX: 415-725-3377

**28 November–3 December 1993**
*ASME Winter Annual Meeting*
New Orleans, Louisiana
Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

**13–18 November 1994**
*ASME Winter Annual Meeting*
Chicago, Illinois
Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

**12–17 November 1995**
*ASME Winter Annual Meeting*
San Francisco, California
Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

**17–22 November 1996**
*ASME Winter Annual Meeting*
Atlanta, Georgia
Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

**Send items for this calendar to:**
*Prof. M. W. Hyer, Department of Engineering Science and Mechanics*
*Virginia Polytechnic Institute and State University*
*Blacksburg, VA 24061-0219*
*Telephone: 703-231-5372*
*FAX: 703-231-4574*
*E-MAIL: HYERM@VTVM1.CC.VT.EDU*

# NOTES

1916 Race Street
Philadelphia, PA 19103
Phone: (215) 299-5454
FAX: (215) 977-9679

European Office
27–29 Knowl Piece, Wilbury Way
Hitchin, Herts SG4 OSX, England
Phone: 0462–437933
FAX: 0462–433678

# 1992 MEMBERSHIP APPLICATION

THIS APPLICATION IS FOR SOCIETY MEMBERSHIP ONLY.

EACH TECHNICAL COMMITTEE REQUIRES A SEPARATE APPLICATION.

PLEASE SEND APPLICATIONS FOR THE FOLLOWING

COMMITTEE (S) ________________________

APPLICATION IS MADE FOR MEMBERSHIP IN ASTM:

**SEE BENEFITS AND FEES ON REVERSE SIDE**

☐ MEMBER — AN INDIVIDUAL, GOVERNMENT REPRESENTATIVE, OR AN INSTITUTION (EDUCATIONAL, PUBLIC LIBRARY, OR A SCIENTIFIC ENGINEERING, OR TECHNICAL NON-PROFIT SOCIETY) SUBSCRIBING TO THE PURPOSES OF THE SOCIETY PROVIDED IN THE CHARTER AND BYLAWS.

☐ ORGANIZATIONAL — AN INDIVIDUAL, BUSINESS, GOVERNMENTAL, RESEARCH, OR PROFESSIONAL ORGANIZATION, OR TRADE ASSOCIATION, OR SEPARATE FACILITY THEREOF SUBSCRIBING TO THE PURPOSES OF THE SOCIETY PROVIDED IN THE CHARTER AND BYLAWS.

PLEASE PRINT ALL INFORMATION CLEARLY. DO NOT EXCEED THE CAPACITY OF EACH LINE.

**LAST NAME** ________ **FIRST NAME** ________ **INITIAL** __

**COMPANY NAME** ________

**FACILITY** ________

**STREET** ________

**P.O. BOX** ________

**CITY** ________ **STATE** __ **ZIP** ________ – ____

**PHONE** ( ) — **EXTENSION** ____

**FAX** ( ) —

**COUNTRY** ________

**JOB TITLE** ________

PARENT COMPANY (IF DIFFERENT FROM ABOVE) ▶ ________________________

OFFICIAL REPRESENTATIVE (ORGANIZATIONAL MEMBERSHIP ONLY)

**LAST NAME** ________ **FIRST NAME** ________ **INITIAL** __

**TITLE** ________

IF HOME ADDRESS IS TO BE USED FOR ALL MAILINGS & PUBLICATIONS, PLEASE COMPLETE BELOW (AFTER COMPLETING ABOVE).

**ADDRESS** ________

**CITY** ________ **STATE** __ **ZIP** ________ – ____

*** ALL CHECKS MADE PAYABLE TO ASTM IN U.S. FUNDS ON U.S. BANKS**

*** OPTIONAL METHODS OF PAYMENT:** ☐ **AMERICAN EXPRESS** ☐ **MASTER CARD** ☐ **VISA**

ACCOUNT NO. (ALL DIGTS) ________ EXPIRATION DATE ________ SIGNATURE ________

**ONE FREE VOLUME — BOOK OF ASTM STANDARDS — YOUR CHOICE — VOLUME #** ____

**MAIL TO: ASTM ATTN: MEMBER SERVICES**

## BENEFITS AND FEES FOR 1992

| | Organizational | Member |
|---|---|---|
| Annual Fee | $350.00*† | $50.00**† |
| Participation on ASTM Technical Committees | One Official Rep. Only | Member Only |
| Annual Book of ASTM Standards | One Free Volume | One Free Volume |
| Complete Set of Book of ASTM Standards (Vols. 1–68) | $3,500.00 (Prepaid)† | $3,900.00 (Prepaid)† |
| Individual Book of Standards at Member Price | No Limit | None |
| Complete Sections at Member Price (Prepaid) | No Limit | No Limit |
| Other Publications at Member prices | No Limit | No Limit |
| Annual Subscription to *Standardization News* | 1 Free | 1 Free |

* Of the $350 Administrative fee payment, $300 is tax deductible as a charitable contribution for federal tax purposes. The remaining $50 may be deducted as an ordinary and necessary business expense.

** Administrative fee payments made to ASTM are not tax deductible as charitable contributions for federal income tax purposes. They may be deductible as ordinary and necessary business expense.

† Canadian Prospective Members – Please add 7% GST – Registration Number R129162244.

### MEMBERSHIP

- Membership year is January 1 to December 31. Fees are payable in advance and are not prorated. Membership will become effective upon payment of fees.
- Organizations applying for membership should select one official representative qualified to exercise the rights and privileges of membership. This includes voting on Society Ballot, and if appropriate, on technical committee matters.
- Only the official representative may participate on committees under the organizational membership. All others must maintain individual memberships in order to participate on committees.
- The official representative for the organizational membership may be changed as needed by notifying ASTM Headquarters. Committee participation is not transferable. An application will have to be submitted by the new representative for the appropriate committees. A member not officially serving on ASTM committees may not vote in committee matters.
- For members serving on technical committees, each organization may ask that the membership be transferred without payment of additional fees, if the fees were paid by the company. However, no additional free volume of the Book of ASTM Standards will be allowed. Committee participation is not transferable. An application will have to be submitted by the new member of the appropriate committee.

### PUBLICATIONS

- All publications must be shipped to the member.
- Shipping and handling costs will not be charged for prepaid orders shipped to the U.S. and Canada.

NOTE: Membership benefits and publication prices are subject to change.

Printed in the USA.