

# World of Composites

---

## EDITOR'S NOTE:

*This issue of the World of Composites begins with a summary of activities of ASTM's Committee D-30 on High Modulus Fibers and Their Composites, and a call for papers from Committee E-28 on Mechanical Testing. Activities at the Suppliers of Advanced Composite Materials Association will then be reviewed. This will be followed by news from the Canadian Association for Structures and Composite Materials. Finally, several recent composites publications will be outlined.*

---

## ASTM COMPOSITES ACTIVITIES

### *ISR and D-30 Secure International Harmonization Support*

#### **National Science Foundation and the Naval Surface Warfare Center to Provide Funds**

The ASTM Institute for Standards Research in cooperation with ASTM Committee D-30 on High Modulus Fibers and Their Composites has recently secured full funding from the National Science Foundation and the Carderock Division of the Naval Surface Warfare Center to move forward on a first phase of an international effort to harmonize composite materials standards.

The objectives of the new ISR program are to:

- A. Harmonize ASTM's D 3039 tension test with its ISO counterpart.
- B. Validate these methods through an international interlaboratory testing program.
- C. Develop the basis for a critically needed composite material database that can be used by U.S. industry for improving the engineering design of advanced composites.

The need to harmonize standards is vital to keep the U.S. composites industry competitive internationally. ASTM has some of the best composite material test methods in the world. It is important that these tests become the basis of international documents. Failure to do so could easily result in another country's technology providing the basis for standards being adopted by ISO and U.S. industry being forced to use them. Without rapid harmonization the U.S. composites industry could be placed in an unfair competitive position by foreign competitors.

Phase 1 of the harmonization effort involves a round robin testing program to validate ASTM D 3039-93, Test Method for Tensile Properties of Polymer Matrix Composite Materials. ASTM D 3039 has been chosen as the first standard in this effort because soon it should be deemed technically equivalent to ISO CD 527-5 (Plastics Determination of Tensile Properties, Part 5: Test Conditions for Unidirectional Fiber Reinforced Plastic

Composite). ISO CD 527-5 is being reviewed by ASTM, SACMA, Mil Handbook 17, and AIA to ensure its technical merit and equivalence to current U.S. tension tests including ASTM D 3039.

ASTM D 3039 is perhaps the most commonly used ASTM composite material test method. It is used to establish the tensile modulus and strength of composites, properties which are generally the first given in material property data sheets and are required for most types of analysis. ASTM D 3039 provides the basis for other ASTM composite material standards such as ASTM D 3479 on fatigue and ASTM D 3518 on in-plane shear.

Validating the precision of ASTM D 3039 and ISO CD 527-5 will enhance their technical equivalence and establish them as internationally accepted documents for trade. The new ISR program will ensure that the ASTM D 3039 round robin will be conducted at the same time with the same materials as a similar round robin planned for ISO CD 527-5.

Ten labs have already agreed to voluntarily participate for the U.S. part of the ASTM D 3039 round robin program. They include Ciba Composites, Cincinnati Testing Laboratories, University of Dayton Research Institute (UDRI), Martin Marietta, Hexcel, Texas A&M, DuPont, U.S. Army Research Laboratory, Integrated Technologies, and L. J. Broutman.

The following eight materials have been proposed for the program: carbon/thermoplastic tape, carbon/epoxy tape, glass/epoxy tape, carbon/toughened epoxy tape, carbon/thermoplastic fabric, carbon/epoxy fabric, glass/epoxy fabric, and aramid/epoxy. Hercules, 3M Aerospace, Ciba Composites, and VPI have agreed to contribute five of these materials for the ASTM D 3039 round robin. The remaining will be supplied by international participants.

For more information, please contact: Kathleen Riley, Executive Director, ASTM Institute for Standards Research at 215-299-5527, or Dr. Peter Sjoblom, Project Manager, University of Dayton Research Institute at 513-229-3812.

*D-30, E-8, and NASA Sponsor Symposium***Life Prediction Methodology for Titanium Matrix Composites**

Thirty-three papers were presented at the symposium which was held on 22-24 March 1994 at Hilton Head Island, SC. The papers were divided into five sessions representing all aspects of damage mechanics associated with life prediction methodology required for titanium matrix composites (TMCs). The sessions were as follows:

- Session I: Interface Properties and Microstructure—Chaired by Jim Larsen, USAF Wright Laboratories
- Session II: Fiber Bridging Behavior—Chaired by Tony Evans, University of California—Santa Barbara
- Session III: Inelastic Materials Behavior and Modeling—Chaired by Rod Ellis, NASA Lewis Research Center
- Session IV: Fatigue—Chaired by Paul Bowen, University of Birmingham, U.K.
- Session V: Life Predictions—Chaired by Dave Buchanan, McDonnell-Douglas Aircraft.

The papers covered most of the work conducted as part of the National Aerospace Plane Program and part of the work

conducted in the United States for the high-performance aircraft engine programs at NASA Lewis and the Air Force. These collective papers represent the current state of the art and should be a valuable reference for scientists and engineers working in this area.

The audience consisted of representatives from the major engine companies (G.E., Pratt & Whitney, Rolls Royce, etc.), several airframers, many government labs (including Japanese and U.K.), and universities both in the United States and abroad.

Lively discussions were held after each session. In particular the debates on appropriate fiber bridging analysis and time/rate/temperature dependent property modeling were informative. Other discussions centered around future applications of TMCs and areas of needed future research.

All submitted papers will be peer-reviewed by three reviewers. Those papers accepted will be published in an ASTM Special Technical Publication (STP). The anticipated date for publication is Summer 1995. For information pertaining to the STP, contact Ms. Kathy Dernoga at ASTM, 215-299-5581. This symposium was chaired by W. Steven Johnson of NASA Langley Research Center, James M. Larsen of USAF Wright Laboratories, and Brian N. Cox of the Rockwell International Science Center.

*E-28 Issues Call for Papers***Symposium on M<sup>3</sup>D III: Mechanics and Mechanisms of Material Damping**

Papers are invited for a Symposium on M<sup>3</sup>D III: Mechanics and Mechanisms of Materials Damping, sponsored by ASTM Committee E-28 on Mechanical Testing. The symposium will be held 15-16 November 1995 in Norfolk, VA in conjunction with the 13-15 November 1995 standards development meetings of Committee E-28.

The main objective of this symposium, as a sequel to M<sup>3</sup>D held in Baltimore, MD in 1991 and to M<sup>3</sup>D II held in Pittsburgh, PA in 1993, is to continue to bring about a synergistic interaction between researchers in the fields of mechanics of solids and materials science. The symposium is intended to foster a better understanding of the fundamentals of material damping, leading to design of materials with enhanced intrinsic damping. It is hoped that this symposium will promote an increased collaboration between the two disciplines.

Technical papers are invited on all aspects of innovative methods for enhanced material damping including:

Mechanics of Material Damping  
 Mechanisms of Material Damping  
 Measurement of Material Damping (Relaxation Mechanisms; The Zener Relaxation; The Snoek Relaxation; Grain Boundary Relaxation; Point-Defect Relaxation; Dislocation Damping; Phase Transformations; Magnetoelastic Relaxation; Interfacial Damping)

Analytical Modeling in Multiphase Materials (Correspondence Principles; Viscoelasticity of Heterogeneous Media; Anelasticity; Irreversible Thermodynamics; Internal State Variables; Plasticity: Micro and Macro; Metallic Foams)

Novel Techniques for the Measurement of Damping (Nonlinear Damping; Composite Materials: Metal-Matrix, Polymer-Matrix, Ceramic-Matrix, Carbon-Carbon; Damage-Induced Damping; Porous Materials).

Prospective authors must submit a title and a 250 to 300 word abstract by **15 November 1994**. The abstract must include a clear definition of the objective and approach of the work discussed, pointing out material that is new, and present sufficient details regarding results. Your presentation and manuscript must not be of a commercial nature nor previously published. Submit the abstract to Dorothy Savini, Symposia Operations, ASTM, 1916 Race St., Philadelphia, PA 19103-1187, Telephone: 215-299-2617. More information is available from Symposium Co-Chairmen Dr. A. Wolfenden, Mechanical Engineering Department, Texas A&M University, College Station, TX 77843-3123, Telephone: 409-845-4835, Fax: 409-845-3081, E-mail: A1W3405@ZEUS.TAMU.EDU; or Dr. V. K. Kinra, Aerospace Engineering Department, Texas A&M University, College Station, TX 77843, Telephone: 409-845-1667, Fax: 409-845-6051, E-mail: VKK8691@ZEUS.TAMU.EDU; or Professor R. de Bastist, IMS, Technologie van de Materialen, RUCA, Middelheimlaan 1, B-2020 Antwerpen, Belgium Belgie, Telephone: (03) 2180 675, Fax: (03) 2180 652; or Dr. L. Kabacoff, Office of Naval Research, Code 1131, 800 North Quincy St., Arlington, VA 22217-5000, Telephone: 703-696-0283, Fax: 703-696-0934; or Ms. C. Wong, Carderock Division, Naval Surface Warfare Center, Code 612, Annapolis, MD 21402-5067, Telephone: 410-267-2835, Fax: 410-267-4885.

## SUPPLIERS OF ADVANCED COMPOSITE MATERIALS ASSOCIATION

### *Conference to Address Environment, Health, and Safety Concerns*

SACMA believes that the key to the success of any business is keeping abreast of the latest industry developments, innovative approaches, and advances in emerging fields, particularly environmental, safety, and health technology and research. The prominence of these issues in today's world is mirrored by the federal government's daily development of initiatives to regulate how businesses address these issues. With the rapid commercialization and expanding applications of composite materials, particularly in the aerospace community, paying attention to safety and environmental issues is becoming increasingly more important for the industry.

Historically, the Suppliers of Advanced Composite Materials Association has taken a proactive stand in these areas. Most recently, SACMA decided to co-host a conference entitled Environmental, Safety, and Health Considerations for Composite Materials in the Aerospace Industry, to be presented in the fall of 1994. The conference is cosponsored with the Aerospace Industries Association (AIA) and National Aeronautics and Space Administration (NASA); the Department of Defense has been invited as a cosponsor as well.

The conference is part of the Association's continuing effort to identify, confront, and communicate the latest developments in health and environmental issues. It is designed to be a unique forum for exchanging state-of-the-art environmental and pollution prevention technology developments within the advanced composite industry, aerospace community, and related federal agencies.

The conference will feature significant research and technological advancements in critical areas such as Pollution Pre-

vention; Product Safety and Stewardship; Hazardous Materials Substitutions; Methods for Hazard Evaluation; Composite Dust Studies; Off-Gassing Studies; Industrial Hygiene; Ergonomic Concerns with Composites; Safe Handling of Materials; Ventilation; Hazard Communication Training; and Specific EH&S Problems and Case Studies.

The conference will be held 20-21 October 1994, in Mesa, AZ. SACMA, AIA, and NASA have issued a Call for Papers for the joint conference. Those interested in addressing these and other contemporary environment, health, and safety issues by presenting a paper or attending the conference should contact SACMA staff.

Although environmental, health, and safety concerns are more visible today than ever before, they are not new issues for SACMA. The Association has six established Working Groups under SACMA's Environment, Health and Safety Committee which track new developments and synthesize the latest advancements into current and credible industry literature. Some of the Committee's past success stories include publication of *Safe Handling of Advanced Composite Materials*, and the *SAVE YOUR SKIN!* booklet and video series. As part of SACMA's continuing proactive efforts on environmental, health, and safety matters, the information gleaned from the fall conference will be incorporated into a format that provides readily available technical information for communication throughout the advanced composite industry and to allied interests.

For more information on SACMA's environmental, health, and safety initiatives, contact SACMA staff at 703-841-1556 or Fax: 703-841-1559.

## CANADIAN ASSOCIATION FOR STRUCTURES AND COMPOSITE MATERIALS

### *International Conference on Composite Materials and Energy Announced*

Enercomp 95 will bring together the energy industry and the composite materials sector with a view to developing strategic alliances for the future and to promote the transfer of know-how within the scientific community of these two industries.

From 8-10 May 1995, Montreal will be the crossroads for these two industries when the Canadian Association for Structures and Composite Materials (CAC SMA) will become host to Enercomp 95, the first international conference on the use of composite materials in the generation, storage, distribution, and utilization of energy.

Enercomp 95 will unite specialists in the fields of ceramic, metal, and polymer composites as well as international leaders in the energy sector in all its forms: electricity, gas, petroleum, nuclear, solar, and wind power. The event will combine two aspects. The first, more scientific, consists of the presentation of some 200 technical papers, a dozen or so to be delivered by invited speakers, all renowned experts in their respective fields. The second aspect involves a technology transfer activity in the

form of a poster session where 100 participants will present their products, technologies, and applications in an atmosphere favoring communication and exchange.

Enercomp 95 has been made possible by the collaboration of Hydro-Québec, the Quebec and Canadian governments, the Canadian composite-materials manufacturing and utilization industry, and a number of other partners. It has the full support of a competent technical committee and an advisory committee whose members represent the world's best known researchers, scientists, and technology specialists in their respective fields. In all, eleven countries from Europe, Asia, and America will be sending participants to this event.

The major themes to be covered by the technical papers and poster sessions include:

- new use of composites in the different energy sectors (oil extraction and transportation, gas bottles and tanks, electric power line hardware, wind turbine blades, photocell plates)

- contribution of composites to energy savings in transportation, construction, and other fields (insulating panels, piping, refractory cooling towers, all lighter structural materials for transportation)
- use of composites in all types of energy storage (batteries, flywheels)

- promising new materials (nanocomposites, selective glasses)
- rupture, degradation, and durability of composites and energy savings
- design methods and energy-efficient manufacturing processes.

## RECENT COMPOSITES PUBLICATIONS

*ASTM Publishes Two STPs; Dekker Prints Second Edition of Composites Text; Woven Fabric Composites Text Published*

### Fractography of Modern Engineering Materials: Composites and Metals, Second Volume

**REFERENCE:** *Fractography of Modern Engineering Materials: Composites and Metals, Second Volume, ASTM STP 1203*, J. E. Masters and L. N. Gilbertson, Eds., American Society for Testing and Materials, Philadelphia, 1993, 224 pp., hard cover, ISBN 0-8031-1866-X, \$63 (\$57 ASTM members).

Failure analysis of composite materials and metals is the subject of the eleven papers in this new volume, covered in three sections:

- Unique Fractographic Techniques
- Metallic Materials
- Polymeric and Composite Materials.

The section titles reflect the diversity of materials discussed, including crosslinked polyethylene, AISI 52100 steel, 2024 aluminum, and a variety of organic and metal matrix fibrous composites. Case studies also cover a wide range, including failure investigations of an antenna used in deep space exploration and chemical storage tanks. Papers range from theoretical to applied.

This book will aid investigators in conducting failure investigations. It is useful to metallurgists, ceramists, composite material specialists, researchers, and engineers actively involved in failure analysis of materials.

#### CONTENTS:

Recent Developments in Quantitative Fractography  
Computerization of Fracture Features and Failure Analysis of Automotive Composite Materials  
Statistical Analysis of Profilometric Sampling for Roughness Parameters  
Quantitative Fracture Surface Analysis of Fatigue Crack Propagation Under Variable Amplitude Loading  
Deep Space Network 70-Meter Antenna Elevation Bearing Failure Investigation  
Fractographic Study of Notch Fatigue Crack Closure and Growth Rates  
Effect of Oxidizing Environments on Long-Term Performance of Rotationally Molded XLPE Storage Tanks  
Tensile and Tension-Tension Fatigue Fracture Behavior of  $\gamma = \text{Al}_2\text{O}_3/\text{Al}$  Metal Matrix Composite at Room and Elevated Temperature  
Failure Analysis of Aramid Fiber Reinforced Aluminum Laminates with Surface and Through Thickness Fatigue Cracks

Fractographic Analysis of Quasi-Isotropic Laminates Loaded in Compression  
Quantitative Fractography of the Cracked Lap Shear Composite Specimen

### Composite Materials: Testing and Design, Eleventh Volume

**REFERENCE:** *Composite Materials: Testing and Design, Eleventh Volume, ASTM STP 1206*, E. T. Camponeschi, Jr., Ed., American Society for Testing and Materials, Philadelphia, 1993, 365 pp., hard cover, ISBN 0-8031-1879-1, \$100 (\$90 ASTM members).

This book gives you access to current design, test, and analysis techniques and data for composite materials. Twenty-two peer-reviewed papers cover:

- Materials Testing and Response (transverse tension and shear properties; compression test methods; multiaxial stress state response; other properties)
- Design and Analysis
- Interlaminar Fracture and Strength

It is useful to composite materials suppliers fabricators, DoD contractors, aerospace contractors, university professors in materials and mechanical engineering, and Army, Navy, Air Force, and NASA research labs.

#### CONTENTS:

##### Material Testing and Response

*Transverse Tension and Shear Properties*

Matrix-Dominated Mechanical Properties of a Fiber Composite Lamina

Scale Effects on the Transverse Tensile Strength of Graphite/Epoxy Composites

Inelastic Shear Response of Unidirectional Composites from Torsion of Solid Bars

Composite Material Shear Property Measurement Using the Iosipescu Specimen

##### Compression Test Methods

Compression of "Thick" Composites: Two Test Methods  
Evaluation of Compression Specimens and Fixtures for Testing Unidirectional Composite Laminates

*Multiaxial Stress State Response*

Measurement of Multiaxial Ply Strength by an Off-Axis Flexure Test

Biaxial Testing and Failure Mechanisms in Tubular G-10 Composite Laminates

*Other Properties*

Elastic Constants of Isotropic and Orthotropic Composite Materials from Plate Vibration Test Data

High Strain Rate Effects for Composite Materials

Matrix-Dominated Stress/Strain Behavior in Polymeric Composites: Effects of Hold Time, Nonlinearity, and Rate Dependency

Thermomechanical Fatigue Behavior of SiC/Ti-24-Al-11Nb[O]<sub>2</sub> In Air and Argon Environments

**Design and Analysis**

Micromechanical Analysis of Fiber-Matrix Interface Stresses Under Thermomechanical Loadings

Bearing Strength Behavior of Clearance-Fit Fastener Holes in Toughened Graphite/Epoxy Laminates

Experimental Determination of the Effect of Hole Interaction on Stress Concentrations in Angle Ply Graphite/Epoxy Composite Panels

Design and Testing of Composite Laminates for Optimum Extension-Twist Coupling

Modeling of the Thermo-Elastic Properties of Woven Fabric Composites in Complex Shapes

Analysis of Thick-Sectioned Composite Cylindrical Shells Under Hydrostatic Pressure

**Interlaminar Fracture and Strength**

The Effect of Mixed-Mode Loading on Delamination Fracture Toughness

A Bilinear Failure Criterion for Mixed-Mode Delamination

Delamination of Ply-Drop Configurations

An Interlaminar Tensile Strength Specimen

**Fiber-Reinforced Composites: Materials, Manufacturing, and Design**

**REFERENCE:** Mallick, P. K., *Fiber-Reinforced Composites: Materials, Manufacturing, and Design*, Marcel Dekker, Inc., New York, 1993, 576 pp., ISBN 0-8247-9031-6, \$150 (\$65 classroom orders).

Maintaining the broad, interdisciplinary perspective that made the first edition so popular, this second edition of an invaluable reference/text provides comprehensive discussions of all aspects of fiber-reinforced composites, including materials, mechanics, properties, test methods, manufacturing and design.

Written from a conceptual point of view and emphasizing fundamentals, *Fiber-Reinforced Composites, Second Edition* offers fully up-to-date, thoroughly expanded sections on

- fibers and matrix, including thermoplastic matrices
- discontinuous fibers and laminated structures
- static mechanical properties, fatigue properties, and damage tolerance

- resin flow, bag molding, filament winding, and resin transfer molding
- environmental effects.

With over 1000 literature citations, figures, tables, and display equations, this book is an incomparable reference for mechanical, manufacturing, materials, aerospace, automotive design, and structural engineers, and the text of choice for upper-level undergraduate and graduate students in these disciplines.

**CONTENTS**

Introduction

Materials

Mechanics

Performance

Manufacturing

Design

Metal and Metal Ceramic Composites

Appendixes:

Woven Fabric Terminology

Residual Stresses in Fibers and Matrix in a Lamina due to Cooling

Alternative Equations for the Elastic and Thermal Properties of a Lamina

Halpin-Tsai Equations

Typical Mechanical Properties of Unidirectional Continuous Fiber Composites

Properties of Various SMC Composites

Typical Mechanical Properties of Metal Matrix Composites

Determination of Design Allowables

Useful References

Selected Computer Programs

**Woven Fabric Composites**

**REFERENCE:** Naik, N. K., *Woven Fabric Composites*, Technomic Publishing Company, Inc., Lancaster, PA, 1993, 204 pp., soft cover, ISBN 0-87762-990-0, \$65 (brochure available).

Although fiber-reinforced composites have long been recognized for their applications in load-bearing structures, the understanding of the thermomechanical behavior of these materials is still deficient.

This new book presents a unified, quantified examination of the thermomechanical behavior of an important class of composites—woven fabric composites.

Written by Niranjana K. Naik, Aerospace Engineering Department, Indian Institute of Technology, the book includes models for elastic analysis of a variety of laminae and laminates with experimental validation. Experimental investigations explore the effect of stacking sequence on strength and failure, and the book presents guidelines for optimum stacking sequence.

Chapters in the book include: Woven Fabric Composites; Elastic Analysis of a Plain Weave Fabric Lamina; Elastic Analysis of a Plain Weave Fabric Laminate; Elastic Analysis of Mixed and Satin Weave Fabric Laminates; Thermal Expansion Coefficients of a Plain Weave Fabric Lamina; Compact Plain Weave Fabric Laminates; Prediction of Notched Strength of Laminates; Effect of Stacking Sequence on Notch Sensitivity of Woven Fabric Laminates; and Failure Behavior of Woven Fabric Composites Under Off-Axis Loading.

# Best Presentation Award

## ASTM Committee D-30 Best Presentation Award

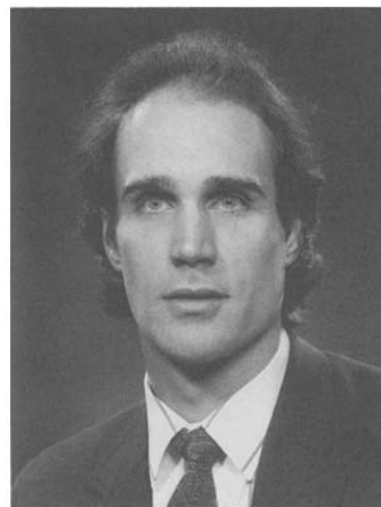
Mr. Kevin Koudela of the Applied Research Laboratory at the Pennsylvania State University is a recipient of the D-30 Best Presentation Award for his presentation entitled "A Novel Joining Method for Smooth-Bore Pressure Hulls" at the Symposium on Bolted and Bonded Joints in Composite Materials held during November 1993 in Fort Worth, Texas. The Symposium was sponsored by ASTM Committee D-30 on High Modulus Fibers and Their Composites. The paper presented was coauthored by Jim Sabo, Larry H. Strait, and Mark L. Karasek. The recipient of this award is selected based upon evaluations of all the symposium speakers by five members of the audience.

### A Novel Joining Method for Smooth-Bore Composite Pressure Hulls

*Kevin L. Koudela, Jim Sabo, Larry H. Strait, and Mark L. Karasek*

Although the filament winding process has been successfully used to fabricate light weight composite shells, weight savings and structural performance attainable is generally limited by the type of interface between the composite and metal components. While significant work has been done in composite-to-metal joining, developmental thrusts have not focused on problems specific to the design and fabrication of low-cost circular joints. This paper discusses the development of a novel circular composite-to-metal joint for a filament wound composite pressure hull. The concurrent engineering approach, fabrication methodology, and validation testing of the novel circular composite-to-metal joint are presented.

The design of the circular end attachment was initiated by prescribing the material type(s), number of plies, and ply orientations of the skin laminates. The candidate skin configuration was input to a point stress lamination algorithm and effective laminate properties calculated including directional strengths, stiffnesses, and coefficients of thermal expansion. The effective laminate properties were, in turn, used as inputs to Hart-Smith's double-lap joint design methodology [1] for prediction of the minimum required joint length and the resultant joint strength. To ensure that the maximum adhesive joint shear strength was achieved, the net longitudinal stiffness of the metal end ring "transition zone" was designed to be within 5% of the stiffness of the mating composite shell. This was accomplished by using double aluminum tangs separated by a low modulus potting material to form the transition zone of the double lap joint. The relative thicknesses of the aluminum tangs and potting material as well as the modulus of the potting material were iterated until the longitudinal stiffness of the composite skins were matched. An additional consideration in the design was the circumferential stiffness mismatch between the composite section and metal end ring. The transition zone of the aluminum end ring was designed to minimize the circumferential stiffness mismatch. This also required iterating on the aluminum tang and potting material thicknesses and potting material moduli.



### About the Author

Kevin Koudela is a member of the Materials Technology Group at the Applied Research Laboratory at the Pennsylvania State University. He graduated from the University of Akron with a B.S. and M.S. in Mechanical Engineering. He is currently pursuing his Ph.D. in Engineering Science and Mechanics. Since joining the Applied Research Laboratory in 1990, Mr. Koudela has conducted research in areas of computational mechanics, fatigue, shock, fabrication, passive control, and active control of composite materials and their structures. He is currently involved in the design and fabrication of large scale components for undersea structures. He has published several articles related to these topics.

After the composite-to-metal joint details were finalized, the global collapse pressure of the sandwich pressure hull was predicted using the simple closed form buckling equations developed by Koudela et al. [2]. In addition to the global instability calculation, several local buckling phenomena were checked including local buckling of the aluminum end joint, intracell buckling of the core, face sheet wrinkling of the inner and outer skin laminates, and shear crimping of the core. In order to assess the integrity of the core material and composite face sheets, through-the-thickness and discontinuity stresses were predicted for each candidate pressure hull design using a simplified version of the general Lekhnitski solution [3]. The three-ply Lekhnitski solution was then modified to include thermal effects due to operation of temperatures other than the laminate's stress-free temperature. Discontinuity stresses generated as a result of the circumferential stiffness mismatch between the composite shell and bonded end joint were predicted from a closed-form solution based on the method prescribed by Ugural [4]. Thermal effects were also included in the discontinuity stress calculations. Two composite pressure hulls were then fabricated to the final design.

© 1994 by American Society for Testing and Materials

In order to validate the integrity of the composite pressure hull design and specifically the robustness of the circular joint, several structural tests were conducted. First, the composite pressure hull was successfully proof tested to 3.497 MPa or two times the expected service pressure. The second pressure hull was fabricated for destructive testing purposes to evaluate the performance of the novel circular bonded end attachment. This shell was water-jet cut into longitudinal specimens and special tensile grips were designed and fabricated to facilitate tension testing in an Instron test machine. The results of the tests demonstrated an apparent (includes peel moment) tensile strength of the as fabricated joint of 10 510 N/cm. Validation test results demonstrate that the novel circular joint described in this paper

is a viable alternative to more complex and costly composite-to-metal circular joints.

### References

- [1] Hart-Smith, L. J., "Adhesive Bonded Double-Lap Joints," Douglas Aircraft Co., *NASA Langley Report CR-112235*, January 1973.
- [2] Koudela, K. L. and Strait, L. H., "Simplified Methodology for Prediction of Critical Buckling Pressure for Smooth-Bore Composite Cylindrical Shells," *Proceedings of the American Society for Composites 7th Technical Conference on Composite Materials*, October 1992.
- [3] Lekhnitski, S. G., *Anisotropic Plates*, translated by S. W. Tsai and T. Cheron, Gordon and Breach, New York, 1968.
- [4] Ugural, A. C., *Stresses in Plates and Shells*, McGraw-Hill, New York, 1981.

# Calendar on Composites

---

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

---

## **26 June–1 July 1994**

*Twelfth U.S. National Congress of Applied Mechanics*

Seattle, Washington

Contact: Engineering Continuing Education, University of Washington, GG-13, Seattle, WA 98195; Telephone: 206-543-5539, FAX: 206-543-2352

## **27–29 June 1994**

*ASTM Committee E-08 26th National Symposium on Fracture Mechanics*

Idaho Falls, Idaho

Contact: Dr. Walter G. Reuter, EG&G Idaho, Inc., P.O. Box 1625, Idaho Falls, ID 83415-2281; Telephone: 208-526-1708, FAX: 208-526-0690

## **18–22 July 1994**

*10th International Conference on Experimental Mechanics*

Lisbon, Portugal

Contact: Secretariat 10th Intl. Conf. on Exp. Mech. APAET, Laboratório Nacional de Engenharia Civil, Av. do Brasil, 101, 1799 Lisboa Codex, Portugal; Telephone: 351-1-848-21-31/7, FAX: 351-1-849-76-60

## **28 August–1 September 1994**

*First International Conference on Composites Engineering (ICCE/I)*

New Orleans, Louisiana

Contact: Prof. David Hui, University of New Orleans, Department of Mechanical Engineering, New Orleans, LA 70148; Telephone: 504-286-6192, FAX: 504-286-5539, E-MAIL: dxhme@uno.edu

## **13–15 September 1994**

*2nd European Conference on Composites (ECCM CTS 2) Testing and Standardization*

Hamburg, Germany

Contact: EACM, 2, Place de la Bourse, 33076 Bordeaux Cedex, France

## **20–22 September 1994**

*American Society for Composites' Ninth Technical Conference and the Center for Composite Materials' Twentieth Anniversary Research Symposium*

Newark, Delaware

Contact: Dr. Tsu-Wei Chou, Center for Composite Materials, University of Delaware, Newark, DE 19716; Telephone: 302-831-2904, FAX: 302-831-8525

## **10–12 October 1994**

*SES 31st Annual Meeting*

College Station, Texas

Contact: Dr. David H. Allen, Dept. of Aerospace Engineering, Texas A & M University, College Station, TX 77843; Telephone: 409-845-1669, FAX: 409-845-6051, E-MAIL: dha6186@zeus.tamu.edu

## **13–18 November 1994**

*ASME Winter Annual Meeting*

Chicago, Illinois

Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

## **14 November 1994**

*ASTM Committee D-30 Symposium on Fiber Matrix and Interphase Properties*

Phoenix, Arizona

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

## **14–15 November 1994**

*ASTM Committee E-8 Second Symposium on Thermomechanical Fatigue Behavior of Materials*

Phoenix, Arizona

Contact: Michael J. Verrilli, Co-Chairman, NASA, Lewis Research Center, 2100 Brookpark Rd., Cleveland, OH 44135; Telephone: 216-433-3337, FAX: 216-433-8011, or Michael G. Castelli, Co-Chairman, Sverdrup Technology, NASA, Lewis Research Center, Telephone: 216-433-8464

## **14–16 November 1994**

*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*

Phoenix, Arizona

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

## **1995**

*SES 32nd Annual Meeting*

New Orleans, Louisiana

Contact: Dr. David Hui, Dept. of Mechanical Engineering, University of New Orleans, New Orleans, LA; Telephone: 504-286-6192, FAX: 504-286-7413, E-MAIL: DXHME@jazz.ucc.uno.edu

© 1994 by the American Society for Testing and Materials



**8-10 May 1995**

*International Conference on Composite Materials and Energy (ENERCOMP '95)*

Montreal, Canada

Contact: Enercomp 95 Secretariat, 75, boul. de Mortagne, Boucherville, Quebec, Canada J4B 6Y4; Telephone: 514-641-5139, FAX: 514-641-5117

**14-16 May 1995**

*ASTM Committee D-30 6th Symposium on Fatigue and Fracture*

Denver, Colorado

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**14-17 May 1995**

*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*

Denver, Colorado

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**28 May-2 June 1995**

*7th International Conference on Mechanical Behavior of Materials*

The Hague, The Netherlands

Contact: ICM7 Secretariat, c/o Congress Office ASD, Asvest 22, P.O. Box 40, 2600 AA Delft, The Netherlands; Telephone: 31-15-120234

**5-7 June 1995**

*The First International Symposium on Thermal Stresses and Related Topics*

Hamamatsu, Japan

Contact: Prof. N. Noda, Chairman, Thermal Stresses '95, Dept. of Mechanical Engineering, Shizuoka University, 5-1, Johoku 3 chome, Hamamatsu, 432, Japan; Telephone: 81-53-471-1171, ext. 267, 268, FAX: 81-53-475-4794, E-MAIL: tmnnoda@mm.shizuoka.ac.jp

**5-7 June 1995**

*International Conference on Mechanics of Solids and Materials Engineering*

Singapore

Contact: Prof. F. W. Travis, School of Mechanical and Production Engineering, Nanyang Technological University, Nanyang Ave., Singapore 2263; Telephone: 7911744, ext. 5500, FAX: 7911859; Telex: RS 38851 NTU, E-MAIL: MFWTRAVIS@NTUVAX

**12-15 June 1995**

*1995 SEM Spring Conference and Exhibits*

Grand Rapids, Michigan

Contact: Society for Experimental Mechanics, Inc., 7 School St., Bethel, CT 06801

**14-18 August 1995**

*Tenth International Conference on Composite Materials (ICCM-10)*

Vancouver, Canada

Contact: Anoush Poursartip, Co-Chair, ICCM-10, c/o The University of British Columbia, Dept. of Metals and Materials

Engineering, Vancouver, B.C., Canada V6T 1Z4; Telephone: 604-822-3665, FAX: 604-822-3619 E-MAIL: anoush.poursartip@ubc.ca

**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

**14-15 November 1995**

*ASTM Committee D-30 Symposium on Environmental Effects on Polymeric Composites*

Norfolk, Virginia

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**14-16 November 1995**

*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*

Norfolk, Virginia

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**19-21 May 1996**

*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*

Orlando, Florida

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**25-31 August 1996**

*19th International Congress of Theoretical and Applied Mechanics*

Kyoto, Japan

Contact: Prof. Eiichi Watanabe, Secretary General, ICTAM 1996, Dept. of Civil Engineering, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan; Telephone 81-75-753-5079, FAX: 81-75-752-5296

**17-22 November 1996**

*ASME Winter Annual Meeting*

Atlanta, Georgia

Contact: ASME, 345 E. 47th St., New York, NY 10017; Telephone: 212-705-7722

**19-21 November 1996**

*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*

New Orleans, Louisiana

Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

**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*

**1916 Race Street**  
**Philadelphia, PA 19103**  
**Phone: (215) 299-2632**  
**FAX: (215) 977-9679**

**European Office**  
27-29 Knowl Piece, Wilbury Way  
Hitchin, Herts SG4 0SX, England  
Phone: 0462-437933  
FAX: 0462-433678

## 1994 MEMBERSHIP APPLICATION

THIS APPLICATION IS FOR SOCIETY MEMBERSHIP ONLY.

EACH TECHNICAL COMMITTEE REQUIRES A SEPARATE APPLICATION.

PLEASE SEND APPLICATIONS FOR THE FOLLOWING

COMMITTEE (S) \_\_\_\_\_

SEE BENEFITS AND FEES ON REVERSE SIDE

APPLICATION IS MADE FOR MEMBERSHIP IN ASTM:

<input type="checkbox"/>	<b>ORGANIZATIONAL MEMBERSHIP</b>	An organizational member shall pay an annual fee and can designate one official representative. This membership entitles your organization to the benefits listed on the reverse side.
<input type="checkbox"/>	<b>INDIVIDUAL MEMBERSHIP</b>	An individual member shall pay an annual fee and can join and participate on ASTM technical committees representing his or her employer unless unassociated with any organization. This membership entitles the individual to the benefits listed on the reverse side.

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

**NOTE:** IF YOUR AFFILIATION IS A SUBSIDIARY, PLEASE IDENTIFY THE PARENT ORGANIZATION.

LAST NAME																FIRST NAME											INITIAL								
AFFILIATION																																			
FACILITY																																			
STREET																																			
P.O. BOX																																			
CITY																					STATE			ZIP											
PHONE	(			)	-						EXTENSION																								
FAX	(			)	-																														
COUNTRY																																			
JOB TITLE																																			

☐ CHECK HERE IF HOME ADDRESS

OFFICIAL REPRESENTATIVE (ORGANIZATIONAL MEMBERSHIP ONLY)

[illegible]

☐ ENCLOSED IS PAYMENT. 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 DIGITS)

EXPIRATION DATE

SIGNATURE

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

MAIL TO: ASTM ATTN: MEMBER SERVICES

## BENEFITS AND FEES FOR 1994

	<u>Organizational</u>	<u>Member</u>
Annual Administrative 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. 1–70)	\$3,700.00 (Prepaid)†	\$4,100.00 (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 ASTM <i>Standardization News</i>	1 Free	1 Free

\* 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.
- Only the official representative of an organizational membership may participate on committees. All other employees of the organization must maintain individual memberships in order to participate on committees.
- An organizational membership may change its representative as needed by notifying ASTM Headquarters.
- An individual membership may be transferred without payment of additional fees, if the fees were paid by an employer, by notifying ASTM Headquarters. However, no additional free volume of the Book of ASTM Standards will be allowed.
- Technical committee participation is not transferable. A committee application will have to be submitted by the new individual member, or the new official representative of an organizational membership.

NOTE: Membership benefits are subject to change.

# Additional Information for Contributors

The *Journal of Composites Technology and Research* (JCTR) is a quarterly publication sponsored by ASTM technical Committee D-30 on High Modulus Fibers and Their Composites, and E08 on Fatigue and Fracture. Each published paper and technical note has been peer-reviewed. Papers and technical notes are open to brief written comments in the Discussion section of the *Journal*, which also includes authors' written responses.

While the majority of articles appearing in the journal are full papers, Technical Notes are also welcome. A paper will be considered as a Technical Note if: it gives a reasonably brief description of ongoing studies with or without providing interim, tentative data and/or conclusions; it reports phenomena observed in the course of research requiring further study; it provides mathematical procedures for facilitating reduction and analysis of data; or it reports promising new materials prior to undertaking extensive research to determine their properties. The final decision as to whether a manuscript is published as a paper or a technical note resides with the Editorial Board (an Editor and at least one Board Member is assigned to each paper).

The guidelines below describe our manuscript selection, peer review, revision, and publication processes. Following these guidelines will ensure expeditious handling of submitted material.

## Submission

The name, mailing address, position, affiliation, and telephone and fax numbers of each author must be supplied in a cover letter. A statement is to be included that the paper has not been published and is not under consideration for publication elsewhere. All permissions for previously published material used in the paper must be submitted in writing at this time.

The submitting author must also affirm that all those listed as co-authors have agreed (a) to be listed and (b) to submit the manuscript to ASTM for publication.

Five copies of the manuscript with clear copies of each figure are required. Original art work and computer disks should accompany the revision.

## Copyright

ASTM requires that the submitting author shall return the completed "Paper Submittal Form" with the revised paper assigning copyright to ASTM. For U.S. government employees whose manuscript has been prepared as part of their official duties, it is understood that copyright in the United States is not transferrable.

## Manuscript Instructions\*

### Word Processing Instructions

The hard-copy text can be produced on any letter-quality printer. Text is to be printed double-spaced with left and right

\*For complete manuscript instructions, which include a sample manuscript, call Barbara Stafford, Administrative Assistant, ASTM Journals, 215/299-5424 or FAX 215/299-5511.

margins of 1 in. (25.4 mm) using left justification. New paragraphs are to be indented five spaces and end-of-line returns are not to be used.

The *revised* manuscript is to be sent on a 5<sup>1</sup>/<sub>4</sub> in. (133 mm) or 3<sup>1</sup>/<sub>2</sub> in. (89 mm) disk, preferably in WordPerfect 5.1, with the corresponding hard copies. ASTM can convert from other word-processing packages as well.

### Abstract and Keywords

An abstract of 100–150 words and a list of 5–10 keywords that can be used to index the manuscript are required.

### Trademarks

Commercialism is to be avoided by using generic terms whenever possible. Trademarks and trade names are to be capitalized if their use is unavoidable.

### SI Units

Society policy requires the use of SI units in all publications (including figures and tables). If in.-lb units must be used to describe materials and present test results, SI equivalents must follow in parentheses. (See ASTM E380, Standard Practice for Use of the International System of Units (SI) (The Modernized Metric System) for further information on SI units.)

### Figures

Each figure is to be simple and uncluttered. A separate sheet of "Figure Captions" followed by the illustrations are to be placed together at the end of the paper. Consecutive Arabic (not Roman) numerals are required. The size of type in illustrations must be large enough to be legible after reduction. All lettering, lines, symbols, and other marks must be drawn in India ink on white paper. Computer graphics must be produced by a laser printer. Photographs must be high-contrast black and white. **SCALE MARKERS MUST BE SHOWN ON ALL PHOTO-MICROGRAPHS AND ALL FIGURES THAT ARE REPRESENTATIONS OF EQUIPMENT OR SPECIMENS.**

### Tables

All tables are to be placed together at the end of the manuscript preceding the illustrations. Tables are to be numbered in Arabic and are cited in numerical order in the text. It is better to use several small simple tables than one large, complex table.

### References

References shall be cited in the text in numeric order. Type the numerical citation on the line, not as a superscript, and enclose in brackets. References should be listed together at the end of the paper in numeric order. They must contain enough information to allow a reader to consult the cited material with reasonable effort.

## Manuscript Review

Each new paper, fitting the scope of the journal, of interest to the readership, and well written, is processed for peer-review. A Board Member (MEB) is assigned by the Editor to each paper. A minimum of three reviews are required for papers, and two for technical notes. Reviewers, chosen by the MEB, base their reviews on technical content, originality, logical conclusions, sound data, reproducibility of results, and clarity of presentation.

The reviewers' comments are compiled and evaluated. Papers receiving two or more rejecting recommendations are automatically rejected for publication in the *Journal*. The reviewers' anonymous comments, and any other comments from the Editor and/or the MEB are returned to the author(s) for revision.

A total of five copies of the revised manuscript is required; one original with original figures; two highlighted, indicating where each revision has been made and identifying which reviewer's comment the revision is in response to; and two plain copies. A completed "Authors' Response Form," provided during revision, should detail which revisions were made and where, as well as any explanations why a change was not made.

After the revised manuscript is evaluated, the Editor and MEB may (1) accept the revised manuscript for publication, (2) require further revision or explanation, or (3) reject the revised manuscript. A revised manuscript may be sent for re-evaluation to a reviewer who had found major flaws in the original manuscript.

## Editorial Review by ASTM

Each accepted paper is edited by the ASTM staff for style, format, and proper English usage. The edited manuscript is returned to the author before typesetting. The typeset page proof is also sent to the author and the Editor for final review prior to printing.

If ASTM does not hear from the author by the time designated

for return of the edited paper and/or page proof, ASTM will proceed with the publication process.

## Book Reviews

ASTM receives books from other publishers requesting book reviews. The books are available to potential reviewers in exchange for publishable reviews. Book reviews are screened and edited by the Editor and staff without peer review.

## Other Features

*World of Composites*—Covers ASTM's Committee D-30 meetings, highlights of other activities in the composite community, summaries of research activities, and outlines of recent composite publications. Please send items of interest to Dr. John Masters.<sup>+</sup>

*Composites Contents*—A listing of current literature of interest to the composite community as a service to our readers. Please send items of interest to Dr. Ronald F. Gibson.<sup>+</sup>

*Calendar on Composites*—Meetings of interest to researchers in the field of composite materials. Please send items of interest to Dr. Michael W. Hyer.<sup>+</sup>

W. Steven Johnson, Ph.D.  
Editor-In-Chief

<sup>+</sup>See Editorial Board Listing (inside front cover) for addresses.