World of Composites

EDITOR'S NOTE:
This issue of the World of Composites will begin with a review of a variety of recent activities at ASTM. First, the proceedings of the Spring meeting of Committee D-30 on High Modulus Fibers and Their Composites will be summarized. A joint symposium sponsored by Committee D-30 and Committee E-8, on Fatigue and Fracture, will then be outlined. This will be followed by the announcement of the formation of a Task Group on Mechanical Testing of Metal Matrix Composites in Committee E-28 on Mechanical Testing. Activities at the Suppliers of Advanced Composite Materials Association will then be reviewed. Finally, several recent composites publications will be outlined.

ASTM COMPOSITES ACTIVITIES

Activities at D-30’s Spring Meeting Summarized; D-30 and E-8 to Hold Joint Symposium on Life Prediction Methodology; E-28 Forms Task Group on Testing Metal Matrix Composites

Committee D-30 Spring Meeting Summary

ASTM Committee D-30 on High Modulus Fibers and Their Composites held its last meeting in May 1993 in Atlanta, Georgia. In addition to sponsoring a symposium, the 5th Symposium on Composite Materials: Fatigue and Fracture, the committee held a series of subcommittee meetings to develop and update its test standards. Summaries of the subcommittee meetings follow.

D30.01 EDITORIAL—Elizabeth C. Goeke
U.S. Army Materials Technology Lab
A variety of committee ballot items was resolved during the committee meeting. They included revisions to D 3878-87, Terminology Relating to High-Modulus Reinforcing Fibers and Their Composites.

D30.02 RESEARCH AND MECHANICS—Roderick H. Martin
Analytical Services and Materials, Inc.
Dr. Martin opened the meeting by reviewing the scope of the subcommittee. Briefly stated, all work on new test methods which have no ongoing test standards activity within D-30 and hence are still in the research stage will belong in Subcommittee D-30.02. If a proposed test method has an obvious home in an existing subcommittee then it may be assigned by D-30 to that subcommittee for research and development. In addition, any dissemination of technical knowledge such as workshops and symposia is coordinated through this subcommittee.

Task Group Reports

Task Group on Symposium Planning—Robert Croman
It was announced that Robert Croman of Du Pont will take over as the new task group leader. A request to include a student session at the 6th Symposium on Composite Materials: Fatigue and Fracture was then discussed. Since there is no clear D-30 policy on student sessions, the ASTM symposium manager will be asked to instruct the symposium chairman accordingly. A report on the recently completed 5th Symposium on Composite Materials: Fatigue and Fracture was then presented. Finally, Kathie Schaaf, the D-30 ASTM staff manager, reviewed the status of the Committee’s Special Technical Publications (STPs). STP 1174, High Temperature and Environmental Effects on Polymeric Composites, had been released. STP 1156, Composite Materials: Fatigue and Fracture, Fourth Volume, has since been released. Two others, STP 1203, Fractography of Modern Engineering Materials: Composites and Metals, Second Volume and STP 1206, Composite Materials: Testing and Design, Eleventh Volume are to be published by the end of the year.

Task Group on Long Term Durability—Thomas Gates
This task group considered expanding its scope to include fatigue. It is currently investigating thermal issues such as thermal oxidative stability, isothermal aging, and physical aging.

Task Group on International Standards Harmonization—Rod Martin
Approximately ten labs have agreed to provide in-kind testing support testing for the international round robin of a harmonized standard of ASTM D 3039, Test Method for Tensile Properties of Fiber-Resin Composites, and ISO 527-5. Up to eight different material types with five replicates of each material and three different layups (0°, 90°, 0/90), totaling 120 specimens per lab, will be tested. A further four organizations agreed to provide in-kind support for five materials. Approximately, 45 lb (20 kg) of material was requested to support 30 international labs. Four companies agreed to cut the laminates into specimens and a
further seven labs agreed, either firmly or tentatively, to provide in-kind support of specimen preparation including tabbing and gaging, if required. Many labs were still considering support and several organizations were considering financial support. Several issues still require harmonizing between the two standards, particularly the differences in strain ranges, force calibration techniques, the use of strain gages, and the use of tabs.

Task Group on Textile Composites—John Masters

This task group reported on the effects of strain gage size on modulus determination in textile composites. To keep the coefficient of variation of modulus measurement below 5% a gage length to unit cell ratio of over 100% was recommended.

Task Group on Impact—Wade C. Jackson

A workshop was held to obtain and discuss ideas relevant to the development of a test method to measure impact damage resistance. The consensus from the workshop was to use force as an impact parameter rather than kinetic energy which is used in the Compression-After-Impact test (CAI). It was also decided that a need existed to establish a test to isolate damage resistance. The test would measure the damage resistance of a certain laminate rather than measure a basic property of the material system. The static indentation test was considered to be the easiest way to apply the impact force. The impact energy, if required, can then be determined from a record of force and displacement of the indenter. In many cases, the plate deformation and impact damage from a static indentation test have been shown to be equivalent, when compared on the basis of force, to large mass impacts on relatively small plates. Although the static indentation test has been shown to be relatively insensitive to specimen size and shape, a preliminary test configuration was selected as 5 in. by 10 in. (12.7 cm by 25.4 cm) to allow a compression test of residual properties. Two knife-edge supports spaced 5 in. apart and perpendicular to the longer side of the specimen would be used to hold the specimen in place. This setup produces a configuration with known boundary conditions (two simply-supported and two free). A steel 1.0-in.-diameter (25.4 mm) hemispherical indenter was selected and a stroke rate of 0.1 in. per min. The damage resistance of a laminate will be characterized by residual dent depth, damage initiation force, penetration force, force-displacement response, and delamination size determined by NDI methods. The impact force would be varied between that required to initiate damage and that required to penetrate the laminate. The onset of damage could be detected by the onset of audible noise or by acoustic emission techniques.

D30.03 CONSTITUENT PROPERTIES—Christopher J. Spragg

Amoco Performance Products

The chairman reported on the status of two of the Subcommittee's test methods: D 5300-92, Test Method for Measurement of Resin Content and Other Related Properties of Polymer Matrix Thermoset Prepreg by Combined Mechanical and Ultrasonic Methods; and D 4018, Test Methods for Properties of Continuous Filament Carbon and Graphite Fiber Tows. Both methods have passed Society Ballot.

Task Group Reports

Task Group on NDE of Composites—Don Pettit

The previously completed survey of NDE methods was reviewed and discussed in terms of future direction of the task group. One area of concern was the wide range of equipment and calibration procedures in use. Following the discussion, it was agreed to conduct a preliminary round robin consisting of composite specimens containing manufacturing defects such as porosity or impact damage, or both, to determine the variability of ultrasonic inspection results from different companies/institutions. Chris Spragg of Amoco agreed to supply the prepreg material, and Wayne Stinchcomb of Virginia Tech agreed to fabricate the panels and coordinate the round robin program. An instruction list will be prepared giving the pertinent information on the panels (material, thickness, etc.) and the information to be documented and recorded regarding the ultrasonic inspection process. A reference panel will also be fabricated with grafoil or other insert targets to aid in calibration and setup. Anyone interested in participating should contact Wayne Stinchcomb at 703-231-5316.

Two other topics were discussed: (1) image analysis of composite materials for porosity determination and (2) visual inspection criteria, particularly for impact damage of composites detection.

Image analysis for determination of the level of porosity in a composite part is a procedure a number of companies are currently exploring. However, everyone is suffering from the lack of a consistent procedure or any information other than what they have developed. It was decided that this would be appropriate to conduct a follow-on round robin on selected sections of the specimens from the ultrasonic inspection round robin. This will not only provide ready samples for the image analysis round robin, but the results of image analysis round robin will provide valuable feedback to the ultrasonic round robin participants. Anyone interested in participating in the image analysis for porosity determination round robin should contact Don Pettit at 404-494-1224 or FAX 404-494-1243.

The subject of visual inspection criteria was discussed at length. While the need for some quantitative basis for visual inspection was agreed to by all present, exactly how to start to get a handle on the subject remains to be determined. One possibility discussed was to approach the D30.02 Impact task group to see if this is an area of joint interest regarding definition/detection of impact damage by visual means.

D30.04 LAMINA/LAMINATE PROPERTIES—Richard E. Fields

Martin Marietta

The chairman reviewed the results of several standards. Two standards, D 5379, Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method, and D 3039, were approved at the D-30 Main Committee. ASTM E 1434, Guide for the Development of Standard Data Records for Computerization of Mechanical Test Data for High-Modulus Fiber-Reinforced Composite Materials, will be revised.

Section Reports

D30.04.01 Peter Sjoblom reported on the Tension Task Group and discussed efforts toward ISO harmonization.
D30.04.02 Eugene Campioneschi Jr. reported on the Compression Task Group. He will reballot D 3410 in a joint subcommittee and main committee ballot. The two negatives on the Sandwich Beam method were withdrawn so it will go to Society Ballot. He also discussed efforts toward ISO harmonization.

D30.04.03 Sotiris Kellas reported on the Shear Task Group. There is general agreement that the ultimate shear strength cannot be attained by present methods. Shear stress at 5% strain will be reported in its place. To enable more meaningful material comparisons, a 0.2% offset strength will be added. Chord modulus will only focus on the 0.1% to 0.6% strain range. The ongoing revision to the +45° test (D 3518) will be the first to include these changes. Similar revisions to the V-notched beam test (D 5379) and rail-shear test (D 4255) will follow. They also discussed ISO harmonization.

D30.04.04 Dr. Roderick Martin reported that Jeffery Schaff will begin work on the Fatigue method which has been inactive.

D30.04.05 Richard Fields reported that the Filament Winding Task Group did not meet. They are looking for volunteers to work on the NOL Ring and Filament Wound Pressure Vessel methods which need revisions or they will be withdrawn.

D30.04.07 Dr. Crystal Newton reported on the Data Reporting Task Group. They have reached a consensus and are coordinating D 3410 with D 1434.

D30.04.08 James Ferrel reported on the Specimen Preparation Task Group. He will concurrently ballot the revised Specimen Preparation document at the Main and Subcommittee levels.

D30.05 STRUCTURAL PROPERTIES—Ed Gonterman Integrated Technologies, Inc.

This subcommittee is currently developing four test methods: Open-Hole Tension; Open-Hole Compression; Compression after Impact; and Bolt Bearing Strength. The status of each effort was reviewed. The Open-Hole Tension and the Open-Hole Compression Test Methods have been submitted to concurrent main and subcommittee ballots. Rich Fields of Martin Marietta and Jim Ferrel of Hercules have, respectively, volunteered to manage the Compression After Impact Task Group. He will concurrently ballot the revised Specimen Preparation document at the Main and Subcommittee levels.

D30.06 INTERLAMINAR PROPERTIES—T. Kevin O'Brien

U.S. Army Aeronautical Directorate

The results of the concurrent main and subcommittee ballots of the draft standard for the Double Cantilever Beam Test Method were discussed. Two negative votes were resolved and the subcommittee voted to resubmit the revised method for another concurrent subcommittee/main committee ballot.

Rod Martin presented a table outlining the future planned round robins, material requirements, and current material commitments. BP and Ciba Geigy materials will be used to conduct preliminary and full round robins, respectively, for the ENF and MMB tests (static and fatigue) and DCB fatigue tests. Hexcel material will be used to fabricate DCB specimens for expanding the scope of the DCB standard to materials with multiple phase toughened epoxy matrices.

Kevin O'Brien led a discussion of a list of parameters, prepared by Rod Martin, for consideration in preliminary round robin testing of the ENF and MMB tests. Rod indicated that specimens will be fabricated that are 25 mm wide and both 24 and 36 plies thick. Some committee members expressed the desire to include some measurement of delamination growth in the test data to address the issue of delamination growth between the load at onset of nonlinearity and the max load. Professor Kageyama noted that the actual crack length should be used in the analysis rather than the original crack length where $P_{\text{max}}$ is used to determine $G_{\text{IC}}$. Rod Martin expressed a desire to investigate the effects of varying the load rate during some of the round robin testing. During a discussion regarding precracking, Rod indicated that both 13 and 7 μm inserts and shear precracks were used in previous ENF round robin testing. The Japanese currently measure $G_{\text{IC}}$ from a tension precrack. Kevin O'Brien mentioned that this technique was discussed in previous D30.06 meetings and was dismissed as not being representative of a true $G_{\text{IC}}$ value due to the presence of fiber bridging from the precrack. Kevin also reminded the subcommittee that it was necessary to use Teflon® inserts with epoxy matrix materials because the sprayed Kapton inserts often bonded to the matrix.

Kevin O'Brien related James Reeder's request that more data points be collected during MMB round robin tests at high $G_{\text{IC}}/ G_{\text{IC}}$ ratios. Steve Hooper reviewed the status of the compliance calibration data reduction technique for the MMB specimen. He indicated that both LVDTs were used so that both $G_{\text{IC}}$ and $G_{\text{IC}}$ could be evaluated from the data. Anoush Poursartip indicated that he has developed a compliance calibration technique using a single LVDT to obtain a total $G_{\text{IC}}$. The subcommittee briefly discussed two options for presenting mixed-mode data, the first as $G_{\text{IC}}$ versus $G_{\text{IC}}$ and the second as $G_{\text{IC}}$ versus $G_{\text{IC}}$.

Next on the agenda were two presentations on Mode III testing. First, Paul Robinson from Imperial College, London, presented his work on a modified Split Cantilever Beam (SCB) Specimen. Then, Shaw Ming Lee from Ciba Geigy, Anaheim, presented his work on a torsion loaded edge delamination specimen. Following the presentations, Kevin O'Brien appointed a committee consisting of Shaw Ming, Paul, and Mark Kortschot from the University of Toronto to identify an appropriate chairman for a Mode III testing task group. The new chair will be identified at the next D30.06 meeting in Fort Worth, Texas, 11-15 October 1993.

Finally, Ron Zabora from Boeing discussed his desire for the subcommittee to evaluate a (0/90)° configuration for the ENF test that Boeing has been using for qualifying toughened matrix composites. The motivation for this configuration is for process control verification on a single panel using a variety of tests to monitor critical properties. The cross-ply layup originally was chosen for compression strength testing. Boeing has found that $G_{\text{IC}}$ values measured on this configuration agree well with their unidirectional data. Kevin O'Brien passed around an example of a data sheet using this layup in an ENF test conducted by Gretchen Murri at Langley. Kevin also showed a summary of the data Gretchen generated using specimens supplied by Boeing. Concerns expressed by subcommittee members were (1) the unbalanced sublaminates may result in a mixed-mode fracture, (2) the compliance may be large enough to cause geometric nonlinearity, and (3) matrix cracking may be a problem for certain types of materials. Doug Getz expressed the concern about considering nonunidirectional laminates for these standard test methods because they introduce too many unknown variables. Others suggested that we should compare $G_{\text{IC}}$ data from this layup and a unidirectional layup of the same material. This could be done as part of a preliminary round robin. Steve Hooper
volunteered to conduct a 3-D finite element analysis of this layup
and Anoush Poursartip volunteered to look into the effects of
residual stresses, which was a fourth concern that surfaced. The
results of these evaluations will be reported at the next D30.06
meeting in Fort Worth.

D30.07 METAL MATRIX
COMPOSITES—W. Steven Johnson
NASA Langley Research Center

A status report on the round robin activity of Task Groups
D30.07.01 and D30.07.02 on Static and Fatigue Tensile Testing
was given by Dave Harmon. The round robin consisted of a
series of tests that were performed at room and elevated tem-
perature on several different layups of SCS-6/Timetal 21S tita-
nium matrix composites. A statistical evaluation of the static
tensile results was performed to determine if there were signif-
icient differences due to specimen geometry. No difference was
statistically evident. Therefore, either straight sided or dog bone
specimens are acceptable for tension testing. The analysis indi-
cated some lab-to-lab variations for the elevated temperature
tests. Only three of the six labs had sent their fatigue data in
early enough to perform the statistical analysis. Some early ob-
servations on this data were presented but final conclusions will
be held until all the data can be analyzed. At this time, only the
room temperature fatigue tests at McDonnell Douglas have yet
to be performed.

Boyet Stevens of Atlantic Research Corporation (ARC) led a
discussion on a future round robin test program for notched
tension and compression tests. Members expressed interest in
developing an unnotched compression test for MMCs, before
pursuing a notched compression method. The result of the sub-
sequent discussion was to concentrate on a notched tension test
program examining effects of width to diameter ratio and speci-
men scaling. There seem to be many issues dealing with compres-
sion testing of MMCs to pursue that course at this time. Stevens
is going to prepare a questionnaire for potential labs to determine
their capabilities. This questionnaire and a more formal round
robin test program will be presented at our next meeting.

Another potential test that could be included in the next round
robin is unnotched thermomechanical fatigue. Notched fatigue
tests are considered too controversial at this time, since there
are many unresolved issues associated with defining and tracking
the variety of damage modes that can appear.

Dr. Stuart Stock, Georgia Institute of Technology, gave a very
informative presentation on his work in computer tomography
(CT). CT is a form of X-ray radiography which can provide a
cross-sectional view of a specimen and therefore allow for 3-D
mapping. Dr. Stock has used this method to examine breaks in
silicon carbide fibers in an aluminum matrix composite. In fact,
the CT results indicated that the carbon core is fragmented after
load application. The break in the fibers correlated very well with
composite modulus reduction during fatigue testing. Dr. Stock has
also used this technique to examine crack openings in round bar
fatigue aluminum lithium specimens and as a means of investigating
infiltration processing of ceramic matrix composites.

D30.08 THERMOPHYSICAL
PROPERTIES—Thomas S. Gates
NASA Langley Research Center

The subcommittee reviewed the status of several task group
standards. As a result of the discussion, it was decided to ballot
D 4102, Test Method for Thermal Oxidative Resistance of Car-
bon Fibers, for reapproval. The subcommittee also reviewed
D 3171, Test Method for Fiber Content of Resin-Matrix Com-
po-ites by Matrix Digestion. A comparison of this method to
European standards and a SACMA method of computing fiber
volume is underway.

The limitations of two additional test methods, D 792 and
D 696, were also discussed. The need to update these documents
was identified. Volunteers are being sought for these activities
and others involving the measurement of fiber and composite
thermophysical properties. Interested individuals are asked to
to contact the subcommittee chairman at 804-864-3400.

Symposium on Life Prediction Methodology
for Titanium Matrix Composites

22–24 March 1994; Hilton Head Island, South Carolina

The purpose of this focused symposium is to bring together
the research conducted for various government sponsored pro-
sgrams such as the National Aerospace Plane (NASP) and the
Enabling Propulsion Materials (EPM) Programs with that from
other research centers such as the University of California-Santa
Barbara and RPI. Some very exciting work in this area is also
being conducted in the United Kingdom. The research will be
from universities, government labs, and industry. The sympos-
um will be a definitive collection of the state of the art in the
understanding required to develop a life prediction methodology
for titanium matrix composites (TMCs).

Chairmen: W. Steven Johnson, NASA Langley Research Cen-
ter; James M. Larsen, USAF Wright Laboratories; Brian N. Cox,
Rockwell International Science Center.

Steering Committee: Paul Bowen, University of Birmingham;
Dave Buchanan, McDonnell Aircraft; Rod Ellis, NASA Lewis;
Tony Evans, University of California-Santa Barbara; Ted Nicholas,
USAF Wright Laboratories.

Agenda

Tuesday, 22 March 1994

Session 1—Interface Properties and Microstructure

Session Chairman—Ted Nicholas

Interfacial Mechanics and Macroscopic Failure in Titanium-Based
Composites—T. W. Clyne, Cambridge University, England
Interfacial Strength of Ti Alloy Matrix Composites—C. Masuda,
National Research Institute for Metals, Japan
Fiber-Matrix Micromechanics and Microstructural Observations
Under Tensile and Cyclic Loading—D. L. Davidson, South-
west Research Institute
Interface Properties and Transverse Failure of Titanium Matrix
Composites—D. B. Marshall, M. C. Shaw, B. N. Cox, and
W. L. Morris, Rockwell Science Center
The Effect of Fatigue Loading and Environment on the Inter-
facial Shear Properties of SCS-6/Ti-based MMCs—P. Kantzos
and J. Telesman, NASA Lewis Research Center
On the Mechanics of Fiber Interaction: Transverse Loading of
Intermetallic Composites—D. Kouris, Arizona State University
Issues Related to Prediction of Residual Stresses in Titanium
Alloy Matrix Composites—N. Jayaraman and P. Rangasamy, University of Cincinnati

Session 2—Fiber Bridging Behavior
Session Chairman—Tony Evans

Stress Transfer Mechanisms: Models that Should be Used for Life Prediction Methodology—L. N. McCartney, National Physical Laboratory, England
Prediction Methodology for the Influence of Cyclic Degradation of Reinforcement on Fatigue Crack Growth—I. R. F. Rose, DSTO Aeronautical Research Laboratory, Australia, and B. N. Cox, Rockwell Science Center
Aspect of High Temperature Fatigue Crack Growth in Titanium MMCs—D. Zheng and H. Ghonem, University of Rhode Island
Effect of the Environment and Temperature on Fiber Bridging in Titanium Based Composites—J. Telesman, P. Kantzos, and L. Ghosn, NASA Lewis Research Center

Wednesday, 23 March 1994

Session 3—Inelastic Material Behavior and Modeling
Session Chairman—Rod Ellis

Sustained Load Behavior of SCS-6/Timetal 21s Composites—M. Khobaib, University of Dayton Research Institute
Creep Properties of a Titanium MMC Subjected to Thermo-mechanical Loading—S. Jansson and F. A. Leckie, University of California—Santa Barbara
A Fully Associative, Nonlinear Kinematic, Unified Visco-plastic Model for Titanium-Based Matrices—S. M. Arnold, A. F. Saleed, and M. G. Castelli, NASA Lewis Research Center
Inelastic Deformation of TMC Under Multiaxial Loading—C. J. Lissenden, M. J. Pindera, and C. T. Herakovich, University of Virginia
Creep and Creep Crack Growth Behavior of Fiber-Reinforced Titanium-Based Composites—J.-M. Yang, S. M. Yang, P.-C. Wang, and H.-P. Chiu, University of California—Los Angeles
Time-Dependent Deformation at the Fiber-Matrix Interfaces in Titanium Matrix Composites Due to Thermomechanical Loading—C. A. Bigelow, Y. A. Bahai-El-Din, and M. Mirdamadi, NASA Langley Research Center and The University of Cairo, Egypt
Discrete and Continuum Damage Modeling of a Titanium-Based Composite—J. A. Sherwood and H. M. Quimby, University of New Hampshire
Time and Temperature-Dependent Behavior of a SiC/Ti Composite—G. J. Dvorak, H. Nigam, and Y. Bahei-El-Din, Rensselaer Polytechnic Institute

Session 4—Fatigue
Session Chairman—Paul Bowen

Prediction of Matrix Crack Initiation from Notches—D. J. Herrmann, G. T. Ward, and B. M. Hillberry, Purdue University
Fatigue Cracking of Fiber-Reinforced Titanium-Based Composites—J.-M. Yang and S. M. Jeng, University of California—Los Angeles
Alpha-2 TMC Fatigue Failure Mechanisms in NASP Applications—J. Gayda and T. Gabb, NASA Lewis Research Center
A Comparison of Thermomechanical Fatigue Damage Mechanisms in Sigma and SCS-6 Fiber Reinforced Titanium Matrix Composites—M. G. Castelli, Sverdrup Technology, Inc., LeRC Group
On the Mechanisms and Mechanics of Fatigue Damage in Titanium Matrix Composites—F. W. Zok, University of California—Santa Barbara
Characterization, Modeling, and Life Prediction in Fiber-Reinforced Titanium Matrix Composites Under Cyclic Loading in the Presence of an Unbridged Defect—P. Bowen, University of Birmingham, England

Thursday, 24 March 1994

Session 5—Life Predictions
Session Chairman—Dave Buchanan

A Methodology to Predict Crack Initiation, Crack Growth and Residual Strength in Titanium Matrix Composites—J. G. Bakuckas, Jr. and W. S. Johnson, NASA Langley Research Center
Simulation of Fatigue Behavior of High-Temperature Metal Matrix Composites—M. T. Tong and C. C. Chams, NASA Lewis Research Center
Life Prediction for Bridged Cracks—B. N. Cox, Rockwell Science Center
Modeling and Life Predictions for TMCs Subjected to Mission Profiles—M. Mirdamadi and W. S. Johnson, NASA Langley Research Center

GROUP DISCUSSION: Where do we go from here?
Chairmen—Jim Larsen and Brian Cox

New Task Group on Mechanical Testing of Metal Matrix Composites Formed

A new task group, titled Metal Matrix Composites, has been formed by Subcommittee E28.03 on Elastic Properties, a subcommittee of ASTM standards-writing Committee E-28 on Mechanical Testing. The group will develop standard methods for the mechanical testing of such materials.

The task group will deal with metal matrix composites rein-
forced with discontinuous particles; that is, composites reinforced with ceramic particles or whiskers, or chopped fibers. Initially, it will focus on test methods for modulus which are suitable for lot acceptance testing. Test methods for shear strength will then be developed for sheet and other thin-gage products. The standards developed will interest engineers and designers in the automotive and aerospace industries, as well as producers and other users of these materials.

All interested individuals are welcome to participate in the work of this task group and of Committee E-28 and its subcommittees.


SUPPLIERS OF ADVANCED COMPOSITE MATERIALS ASSOCIATION

Environmental Regulatory Information Presented to Composites Manufacturers at Seminar

SACMA and CECMT Sponsor Environmental Seminar

On 20 May 1993, SACMA (Suppliers of Advanced Composite Materials Association) and CECMT (Center of Excellence for Composite Manufacturing Technology) sponsored the first of a possible series of environmental seminars at Carthage College in Kenosha, Wisconsin. The seminar, "Tap Dancing Through Minefields: Fundamentals of Environmental Regulations for the Composites Industry," was primarily targeted at small composite manufacturing businesses that do not have an environmental staff or access to important regulatory information. Approximately 60 people attended the day-long seminar including individuals from composite supplier and manufacturing companies, aerospace companies, the U.S. Navy, the U.S. Army, consulting firms, as well as colleges and universities.

The seminar was divided into five sessions to help address the different aspects of today's regulatory maze. These included Materials Procurement, On-Site Usage of Composites, Disposal of Composite Materials, Waste Management, and EPA Basic Areas Reviewed.

The first session consisted of three speakers who provided general information on Materials Procurement. Mark Scoville, Technology Sciences Group, Inc., presented the primary activities of the Toxic Substances Control Act (TSCA) as it relates to new and existing chemicals. Dr. Janos Schulze, Ciba-Geigy Corporation, followed and informed the audience on Hazard Communications including information on MSDSs and labeling. Dick Sayad, Dow Chemical Company, closed the session with information on how to carry out a successful Product Stewardship program including a life-cycle assessment program.

The following three sessions dealt directly with the usage and disposal of composite materials. Information regarding the On-Site Usage of Composites was given by Ray Huntington from Grumman Aerospace and Electronics Division. He discussed the present methods of cleaning advanced composite tools and products, how this will change in the future because of new regulations, and how Grumman is making the adjustment. Joel O'Connor, McDonnell Douglas, under Disposal of Composites, prepared information on the impact of RCRA on Composite Wastes. His section covered details on waste stream identification, treatment, storage and disposal facility standards, generators and transporters, land disposal restrictions, and, finally, information on alternative treatment technologies. Dr. Joe Camahort, Lockheed Missiles & Space Company, initiated the next session on Waste Management. He presented information on Lockheed's uses and disposal practices for composite materials as it pertains to California regulations. Subsequently, Tom Hahn, representing Day & Zimmerman, Inc., offered information on the recycling of composite waste, and in particular the NAVIRSA/GLCC Prepreg Recycling Program.

Lastly, the Environmental Audit/Inspections session was represented by two speakers who informed the audience of what to expect when the EPA inspects a facility and what can be done to keep that facility in compliance. Uylaine McMahan, Section Chief for RCRA (Resource Conservation and Recovery Act) EPA's Region 5, provided an overview of RCRA, its enforcement program, and how it affects your company. In closing, Pat Waldo from Ariel Research Corporation introduced a self-auditing program to assist companies in complying with governmental requirements.

Rounding out the seminar was the keynote speaker, Dr. Philip Broudy from the Naval Industrial Resources Support Activity. Dr. Broudy discussed the Navy's perspective on environmental concerns and potential Navy environmental programs, as well as the Navy sponsored Scrap Reclamation Program.

To provide additional support, a resource center containing literature and other sources of information was set up at the college. In addition, a resource manual was distributed to all participants. The manual, which contains regulatory information, an environmental service and resource directory, an environmental glossary, and speaker notes, is available for purchase by contacting CECMT at 414-947-8900 or 414-947-8919 by FAX or SACMA at 703-841-1556 or 703-841-1559 by FAX.
RECENT COMPOSITES PUBLICATIONS

New Edition of Composites Text Published; Thermoplastic Composites Discussed in New Text; Handbook on Failure Analysis of Composites Published

Fundamental Principles of Fiber Reinforced Composites, Second Edition


Written by Ken Ashbee, Ph.D., D.Sc., formerly a professor at the University of Tennessee, the book uses an interdisciplinary approach with emphasis on analytical methods for better understanding of key concepts such as anisotropy of stress, anisotropy of elasticity, and anisotropy of strength.

Many case histories, fully worked examples, and laboratory projects illustrate concepts. The book also includes information on nondestructive testing, in-service monitoring, and failure analysis. Materials covered in the book include plastic, metal, and ceramic matrix materials.

Chapter titles of this second edition include: Specific Strength and Specific Modulus; Materials and Processing; Anisotropy of Stress; Anisotropy of Elasticity; Elasticity of Orthotropic Laminates; Anisotropy of Thermal Expansion; Stresses in a Plate Arising from the Presence of a Hole; Fracture and Fracture Mechanics; Anisotropy of Strength; Environmental Degradation; Joining and Repair; and Non-Destructive Evaluation.

High Performance and Engineering Thermoplastic Composites


Over 200 pages, *High Performance and Engineering Thermoplastic Composites* covers all aspects of this important area—from resins and reinforcements to the many available manufacturing methods and finishing techniques.

Written by A. Brent Strong, Ph.D., Brigham Young University, the book examines design, testing and quality control, repair, and applications of thermoplastic composites.

Numerous schematics throughout the text illustrate manufacturing methods, design, and testing. The many tables provide needed data in convenient form. Plus, extensive references list sources of additional information.

Chapter titles in this new book include: Thermoplastic Resin Properties; Fiber/Matrix Interactions; Composite Properties; Manufacturing by Traditional Thermoset Methods; Injection Molding and Extrusion; Forming of Thermoplastic Sheets; Molding/Forming Preshaped Thermoplastics; Molds and Tooling; Finishing and Repair; and Design, Applications, and Costs.

Composite Failure Analysis Handbook

(USAF WL-TR-91-4032, DOT/FAA/CT-91/23)

REFERENCE: *Composite Failure Analysis Handbook*, CINDAS/USAF CRDA Handbooks Operation, Purdue University, West Lafayette, IN 47907-1293.

This comprehensive handbook documents the techniques, fractographic and material property data, and case histories currently being used in the analysis of failed composite structure. This program, conducted by Northrop Corporation over the period January 1987 to October 1990, covered the development of the following:

1. Procedural guidelines for field investigation techniques.
2. Expanded fractographic database for carbon/epoxy materials tested under known conditions.
3. Fractographic database for resin-based composite materials other than carbon/epoxy.
4. Fractographic documentation of composite materials and processing defects.
5. Documentation of fracture characteristics in adhesive and mechanical joint failures.
6. Compilation of material property data for composite materials.
7. Documentation of case histories recently conducted on failed composite structure.

Approval has been received from the U.S. Air Force to proceed with the publication and marketing of the subject Handbook through Purdue University's Cooperative Research and Development Agreement (CRDA).

For further information, contact:

CINDAS/USAF CRDA Handbooks Operation
Purdue University
1293 Potter Engineering Center, Room 316B
West Lafayette, IN 47907-1293
Telephone: 317-494-7756; FAX 317-494-2351
ASTM Committee D-30 Best Presentation Award

John W. Gillespie, Jr. of the University of Delaware Center for Composite Materials is a recipient of the D-30 Best Presentation Award for his presentation entitled "Design, Analysis, and Hydrotesting of a Composite-Aluminum Cylinder Joint for Pressure-Hull Applications" at the Symposium on Compression Response of Composite Structures held in November 1992 in Miami, with Dr. Scott Groves and Dr. Alton Highsmith as the Symposium co-chairmen. The Symposium was sponsored by ASTM Committee D-30. The presented paper was co-authored by Stephen M. Andersen, Mark A. Lamontia, Barry D. Olson, Jay G. Sloan, Keith E. Newman, and George K. A. Kodokian. The recipient of this award is selected based upon evaluations of all the symposium speakers by five members of the audience.

Design, Analysis, and Hydrotesting of a Composite-Aluminum Cylinder Joint for Pressure-Hull Applications

Stephen M. Andersen,1 John W. Gillespie, Jr.,1 Mark A. Lamontia,2 Barry D. Olson,2 Jay G. Sloan,2 Keith E. Newman,2 and George K. A. Kodokian2

ABSTRACT: The design, analysis, and hydrotesting of a composite-aluminum cylinder joint subjected to external hydrostatic pressure is presented. This study addresses the feasibility of utilizing an adhesive bond to join composite and metallic pressure hull components. A preliminary design methodology is outlined and applied to the joint. The design provides for axial load transfer through shear in the adhesive and bearing in the butt end of the cylinder. A thickened area of aluminum in the vicinity of the joint serves as a king frame to enhance stability of the structure. Detailed finite element analysis is performed to provide accurate failure predictions. Dimensional details of the joint are designed to obtain the desired ratio of shear/bearing load transfer and to minimize bending of the shell over the joint to delay interlaminar shear failure. An in-situ thermoplastic filament filament-wound cylinder is manufactured and adhesively bonded to an aluminum cylinder. The instrumented structure is then tested to failure through application of external hydrostatic pressure. Experimental results including collapse pressure, failure mode, and strain field are compared with predictions to verify finite element model accuracy and validate the design methodology. The results of this study demonstrate both accurate predictive capability and use of an effective design methodology for composite pressure-hull joints.

About the Author

Dr. Gillespie joined the University of Delaware Center for Composite Materials in 1981. He is currently the Associate Director, a member of the Board of Directors, and Senior Scientist of the Center. He is also Research Associate Professor of Mechanical Engineering and a member of the Materials Science Faculty. Dr. Gillespie has served as faculty advisor for more than 30 graduate and 40 undergraduate students during this period.

Dr. Gillespie has more than 120 technical publications in composites science and technology, including three book chapters on interlaminar fracture of composites. Dr. Gillespie's areas of specialty include continuum mechanics, experimental mechanics, fracture mechanics, and design and analysis of composite structures. His current research thrusts are in the areas of process-induced residual stress, joining and welding of composites, process automation, and the design, analysis, and characterization of filament-wound structures.

Dr. Gillespie is editor of the Journal of Thermoplastic Composites Materials and of the six-volume indexed Delaware Composites Design Encyclopedia. He is also the American Society for Composites editor, as well as secretary of the Society of Plastics Engineers Special Interest Group on Joining of Plastics and Their Composites. He was the subject-matter expert for an interactive videodisc course, Experimental Mechanics of Composite Materials.
Mode III Delamination Using a Split Cantilever Beam

Farhad Sharif, M. T. Kortschot, and R. H. Martin

ABSTRACT: Although tests for Mode I, Mode II, and mixed-mode delamination of laminated composites are relatively well established, to date there is no generally accepted method for measuring the Mode III (tearing mode) interlaminar critical strain energy release rate ($G_{III}$). The objective of this study was to develop such a test in order to complete the characterization of the delamination phenomenon.

Donaldson [1] and others have attempted to use the split cantilever beam (SCB) for a Mode III delamination test by introducing scissoring action as illustrated in Fig. 1a. Unfortunately, finite element analysis performed by Martin [2] indicated that the bending moment on the arms at the delamination front generates a substantial Mode II strain energy release rate near the free edges.

In this study, a simple modification of the original Mode III SCB test was developed (Fig. 1b). The Mode II strain energy release rate is eliminated by imposing two loads on each arm of the SCB specimen such that the net bending moment at the delamination front is zero. A simple loading rig capable of inducing the required loads was developed and is presented in Fig. 2.

FIG. 2—The required loads are introduced through a set of identical (not mirror symmetric) grips loaded in tension. Following Robinson [3], a longitudinal moment balance around the long axis of the specimen can also be achieved by partially withdrawing the loading noses $b$ as illustrated (c).

About the Author

Mark T. Kortschot is an Associate Professor in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto. He obtained his B.A.Sc. (1984) and M.A.Sc. (1985) degrees in the Faculty of Applied Science and Engineering at the University of Toronto, specializing in mechanics and materials science. He then went to Cambridge University as a Commonwealth Scholar and obtained his Ph.D. in 1988. Professor Kortschot is interested in the relationship between microstructure and material properties, with particular emphasis on the fracture toughness of fibrous materials such as long and short fiber reinforced polymers and paper. He supervises a large research group and is active in both ASTM and the Canadian Association for Composite Structures and Materials.
designed and built (Fig. 2), and the system was used to measure the Mode III delamination toughness of 48-ply AS4/3501-6 carbon fiber-reinforced epoxy specimens. Finite element analysis on a three-dimensional mesh confirmed that the strain energy release rate, determined using the virtual crack closure technique, was dominated by the Mode III component for the new loading configuration.

Scanning electron microscopy of the delaminated surfaces revealed matrix cracking at 45° to the plane of the delamination but parallel to the fiber direction. These cracks, termed shear crevices, form on the plane of maximum tension, and it is suggested that they are characteristic of Mode III crack propagation parallel to the fiber direction. Shear crevices are analogous to shear hackles which are generally found on a Mode II delamination surface.

References

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

26–30 September 1993
First International Symposium on Structural Intermetallics
Seven Springs Mountain Resort, Champion, Pennsylvania
Contact: TMS Meeting Services Department, 420 Commonwealth Dr., Warrendale, PA 15086; Telephone: 412-776-9050, FAX: 412-776-3770

27–29 September 1993
Second Canadian International Conference on Composite Structures and Materials (CANCOM ’93)
Ottawa, Ontario, Canada
Contact: Dr. W. Wallace, Cochairman, Institute for Aerospace Research, National Research Council Canada, Ottawa, Ontario, Canada K1A 0R6; Telephone: 613-993-2469, FAX: 613-952-7136

5–7 October 1993
Introduction to Advanced Composites Workshop
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441, FAX: 702-827-6599

5–14 October 1993
Composite Tooling—Design & Fabrication Workshop
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441, FAX: 702-827-6599

13–15 October 1993
Verbundwerk ’93 International Trade Fair for Reinforced Materials/Composites, Applications and Processing Equipment
Rhine-Main-Halls, Wiesbaden, Germany
Contact: Diana Schnabel, DEMAT Frankfurt, D-6000 Frankfurt Main 11, Postbox 110 611; Telephone: 0-69-23-43-31, FAX: 0-69-25-30-71

14–15 October 1993
ASTM Committee D-14 and Subcommittee D14.40 Symposium on Composites Bonding
Fort Worth, Texas

18–22 October 1993
Composite Structures: Fabrication and Damage Repair—Phase I Workshop
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441, FAX: 702-827-6599

19–21 October 1993
14th International SAMPE European Conference and Exhibition—Broadening Horizons with Advanced Materials & Processes
Birmingham, England
Contact: Birmingham Convention & Visitor Bureau, National Exhibition Centre, Birmingham B40 1NT, England, United Kingdom; Telephone: 021-780-4321, FAX: 021-780-4260

25–29 October 1993
Composite Structures: Fabrication and Damage Repair—Phase II Workshop
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441, FAX: 702-827-6599

26–28 October 1993
First International Workshop on Composite Materials for Offshore Operations
Houston, Texas
Contact: Prof. S. S. Wang, Mechanical Engineering Dept., University of Houston, 4800 Calhoun Rd., Houston, TX 77204-4729; Telephone: 713-743-4516

1–5 November 1993
Adhesive Bonding of Advanced Composite Materials Workshop
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441, FAX: 702-827-6599

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

3–5 November 1993
Instrumental Analysis of Thermoplastic and Thermoset Polymers Standards Technology Training Course (ASTM)
Tulsa, Oklahoma

3–5 November 1993
International Symposium on Polymer Surface Modification: Relevance to Adhesion
Las Vegas, Nevada
Contact: Dr. K. L. Mittal, Organizer, Skill Dynamics, An IBM Company, 500 Columbus Ave., Thornwood, NY 10594; Telephone: 914-742-5747; FAX: 914-742-5594
8–10 November 1993  
Las Vegas, Nevada  
Contact: Dr. K. L. Mittal, Organizer, Skill Dynamics, An IBM Company, 500 Columbus Ave., Thornwood, NY 10594; Telephone: 914-742-5747; FAX: 914-742-5594

8–12 November 1993  
*Repair Design for Composite and Bonded Structures Workshop*  
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441; FAX: 702-827-6599

15 November 1993  
*ASTM Committee E08.05/.09 Workshop on Fatigue of Ceramics and Ceramic Composites*  
Fort Worth, Texas  
Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

15–19 November 1993  
*Ultrasonic Inspection of Advanced Composites Workshop*  
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441; FAX: 702-827-6599

15–18 November 1993  
*Blueprint Reading for Advanced Composites Workshop*  
Contact: Kathleen H. Thomas, Administrator, Abaris Training, 5401 Longley Lane, Suite 49, Reno, NE 89511; Telephone: 1-800-638-8441; FAX: 702-827-6599

28 November–3 December 1993  
*Dynamic Characterization of Advanced Materials (ASME Winter Annual Meeting)*  
New Orleans, Louisiana  
Contact: Professor P. K. Raju, 202 Ross Hall, Dept. of Mechanical Engineering, Auburn University, Auburn, AL 36849-5341; Telephone: 205-844-3301, FAX: 205-844-3307, E-MAIL: PKRAJU@eng.auburn.edu, Telex: 59304WAREAGEL1AUBN

7–10 December 1993  
*3rd Japan International SAMPE Symposium and Exhibition*  
Chiba, Japan  
Contact: Japan Chapter of SAMPE, Meguroeki Higashiguchi Bldg., 3-1-5 Kamiosaki, Shinagawa-ku, Tokyo 141, Japan; Telephone: 3-3449-0091, FAX: 3-3445-8013

18–20 January 1994  
*Second Asia Pacific Conference on Materials Processing*  
Singapore  

23–26 January 1994  
*ASME-ETCE Composites Symposium*  
New Orleans, Louisiana  
Contact: Prof. David Hui, University of New Orleans, Department of Mechanical Engineering, New Orleans, LA 70184; FAX: 504-286-7413; E-MAIL: dxhme@uno.edu

13–18 March 1994  
*Symposium on High-Temperature Properties and Applications of Polymers and Polymer Composites*  
San Diego, California  
Contact: Martin R. Tant, Research Laboratories, Eastman Chemical Co., P.O. Box 1972, Kingsport, TN 37662; Telephone: 615-229-2147; FAX: 615-229-4558

22–24 March 1994  
*Life Prediction Methodology for Titanium Matrix Composites*  
Hilton Head Island, South Carolina  
Contact: W. Steven Johnson, NASA Langley Research Center, Mail Stop 188E, Hampton, VA 23681-0001; Telephone: 804-864-3463

11–14 April 1994  
*9th International Conference on Deformation, Yield and Fracture of Polymers*  
Cambridge, United Kingdom  
Contact: Mrs. Debbie Schorer, Conference Department (C406), The Institute of Materials, 1 Carlton House Terrace, London SW1Y 5DB, United Kingdom; Telephone: 071-839-4071, 071-976-1339, FAX: 071-839-3576, Telex: 881-4813

18–20 April 1994  
*35th AIAA Structures, Structural Dynamics, and Materials Conference*  
Hilton Head, South Carolina  
Contact: Meetings Department, AIAA, 370 L'Enfant Promenade, SW, Washington, DC 20024; Telephone: 202-646-7463

16–17 May 1994  
*ASTM Committee D-30 12th Symposium on Composite Materials: Testing and Design*  
Montreal, Canada  
Contact: Ravi Deo, Northrup Corp., 1 Northrup Ave., Dept. 3853/MF, Hawthorne, CA 90250; Telephone: 310-332-2134, FAX: 310-332-1481, or Charles R. Staff, McDonnell Douglas Corp., Bldg. 32 Post 365, P.O. Box 516-Dept. 337, St. Louis, MO 63166; Telephone: 314-233-8624, FAX: 314-777-1171

18–19 May 1994  
*ASTM Committee D-30 on High Modulus Fibers and Their Composites Meeting*  
Montreal, Canada  
Contact: Katharine Schaaf, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5529

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

29 August–1 September 1994  
First International Conference on Composites Engineering (ICCE/1)  
New Orleans, Louisiana  
Contact: Prof. David Hui, University of New Orleans, Department of Mechanical Engineering, New Orleans, LA 70148; FAX: 504-286-7413, E-MAIL: dxhme@uno.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

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 Behaviour of Materials  
The Hague, The Netherlands  
Contact: ICMI Secretariat, c/o Congress Office ASD, Avest 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

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

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:  
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