World of Composites

EDITOR'S NOTE:
This issue of the World of Composites will feature details of the recent reorganization of ASTM's Committee D-30 on High Modulus Fibers and their Composites. In our continuing effort to provide a broad perspective of the composites scene, we will also highlight recent activities of the American Society for Composites, the American Society for Mechanical Engineers, and the Suppliers of Composite Materials Association. In addition, a major composites initiative by NASA, the Advanced Composites Technology Program, will be briefly reviewed. An update of activities at the University of Delaware’s Center for Composite Materials and our regularly featured notation of Recent Composites Publications will round out the section. Readers are, as always, invited to contact the editor with news items to be included in future issues.

ASTM COMPOSITES ACTIVITIES

D-30 reorganization detailed

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

On 24 July 1990 a special meeting of the D-30 Executive Committee was convened to discuss a possible restructuring of Committee D-30. The restructuring was proposed as a means to enable more effective functioning of the Committee in pursuit of its technical and standardization goals. The primary Committee functions were defined at this meeting as: (1) initiate standards, (2) develop and approve standards, (3) maintain standards, (4) promote technical exchange, and (5) conduct the business of the Committee. While technical exchange has been very effectively supported, the standards development is tedious and time-consuming work (see figure below for an outline of the process). These functions are best handled by small groups of knowledgeable members.

The proposed restructuring expands the responsibilities for standardization to a newly defined set of subcommittees with narrower scopes. The newly proposed structure, which is shown in the figure below, was presented to the membership and approved at the November 1990 Main Committee meeting.

The chairmen of these new subcommittees are listed in Table 1.

As a result of this change in ASTM Committee D-30, membership at the subcommittee level must be reorganized in accordance with the new structure. A draft scope for Subcommittee D30.04 is included (Table 2) to aid in subcommittee selection. The scopes of D30.04 through D30.08 are being drafted by the subcommittee chairmen. They will closely parallel that of D30.04. Current voting status in D-30 Main will not be changed by the restructuring, but members may apply for voting status at the subcommittee level in accordance with ASTM regulations and ASTM Committee D-30’s bylaws.

All D-30 members have been asked to declare their subcommittee voting status. This new subcommittee structure will be used at the next ASTM Committee D-30 meeting which is on 8–9 May 1990.

Standards Development Process

Steps in the Standards Development Process

New Committee Structure

Copyright ©1991 by ASTM International
TABLE 1—New ASTM Committee D-30 subcommittee chairmen.

<table>
<thead>
<tr>
<th>Subcommittee</th>
<th>Function</th>
<th>Chairman</th>
</tr>
</thead>
<tbody>
<tr>
<td>D30.01</td>
<td>Editorial and Terminology</td>
<td>Betsy Geoke</td>
</tr>
<tr>
<td>D30.02</td>
<td>Research and Mechanics</td>
<td>Glenn Grimes</td>
</tr>
<tr>
<td>D30.03</td>
<td>Constituent/Precursor Properties</td>
<td>Chris Spragg</td>
</tr>
<tr>
<td>D30.04</td>
<td>Lamina and Laminate Test Methods</td>
<td>Rich Fields</td>
</tr>
<tr>
<td>D30.05</td>
<td>Structural Test Methods</td>
<td>Edward Gonterman</td>
</tr>
<tr>
<td>D30.06</td>
<td>Interlaminar Properties</td>
<td>Kevin O'Brien</td>
</tr>
<tr>
<td>D30.07</td>
<td>Metal-Matrix Composites</td>
<td>Steve Johnson</td>
</tr>
<tr>
<td>D30.08</td>
<td>Thermophysical Properties</td>
<td>not yet selected</td>
</tr>
</tbody>
</table>

TABLE 2—Scope of Subcommittee D30.04—Lamina and Laminate Test Methods.

1. The focus of this subcommittee is on test methods associated with fundamental material properties of high-modulus fiber-reinforced composite materials; especially, but not restricted to, the elastic and mechanical properties of lamina and laminate forms of composite materials.

2. This subcommittee will stimulate and conduct research and development studies on test methods which might lead to new standards for the focus area.

3. Based upon these studies, as well as recommendations forwarded by the Research and Mechanics subcommittee, this subcommittee will develop new standards for the focus area, including the following steps in the standards development process:
   - drafting of new standard proposals, in coordination with the Editorial and Terminology subcommittee and ASTM editorial staff;
   - review, balloting, and revision of standard proposals;
   - conduction of round-robin studies; and
   - final revision of new standard.

4. Ongoing modernization, updating, and maintenance of existing standards under the jurisdiction of this subcommittee, in coordination with the Editorial and Terminology subcommittee and ASTM editorial staff.

5. Interface with national and international standards agencies, material trade groups, and industries on standards within the focus area.

SUPPLIERS OF ADVANCED COMPOSITE MATERIALS ASSOCIATION

SACMA highlights Flammability Task Force

**Flammability . . . the New Market Driver**

Air and marine transportation represent important markets for advanced composite structures. Just as transportation modes and missions vary—so, too, do their design requirements. The many factors that influence design of high performance composites in commercial and military markets include cost, performance, and safety.

Over the last ten years, safety has become a major driver in new product development and materials substitution. Of particular importance is materials and system flammability. Accordingly, government regulatory agencies have promulgated new fire, smoke, and toxicity (FST) standards which have had a dramatic impact on the advanced composites industry.

In response to this increasing emphasis on FST, SACMA organized a Flammability Task Force in 1988 comprised of flammability and advanced composites experts from member companies and testing facilities. The objectives of the Task Force are to improve communications and to maintain an ongoing dialogue with certifying bodies, for example, the Federal Aviation Administration (FAA), Department of Navy, and so forth, and prime contractors, in support of efforts to develop technically sound flammability requirements/regulations for advanced composites in shipboard and air transport applications.

**FAA Initiatives**

Commercial aircraft represent an important market for advanced composites, particularly in light of recent defense cuts in military spending. Interior applications characterize a major portion of the advanced composites used in commercial aircraft.

Although interior composite panels have had to meet federal flammability regulations for many years, the chief discriminating test before 1980 was the Bunsen Burner Vertical Burn Test.

In 1988, however, FAA upgraded its safety requirements by mandating that interior panels pass the Ohio State University
ASC Targets Students of Delaware's Center for Composite Materials. "Some of the role for undergraduates and students interested in direct industrial applications. But ASC can fill a very different niche for the importance of ASC student chapters," says ASC Editor of its sub and surface vessels through the use of composites, marine interiors. A first draft of the flammability, smoke, and toxicity test protocol was published in February 1987. The requirements have been modified and will be issued in a final form, that is, MIL-STD 2202, by the year's end.

Inasmuch as fire scenarios for submarines differ from fire scenarios for aircraft, Navy and FAA protocols for flammability testing differ as well. In fact, most materials and panel systems currently suitable for use in aircraft interiors would not pass the proposed Navy standard.

SACMA's Flammability Task Force has engaged in several proactive initiatives to clarify the proposed Navy protocol; to establish a communication network between prime contractors, materials suppliers, testing facilities, and Navy personnel; as well as to foster development of information on composites, generally, and flammability, particularly. In addition to developing consensus comments on the MIL-STD, the Task Force sponsored several flammability workshops and tours at the Naval Research Laboratory, David Taylor Research Center, Newport News Shipbuilding, and the National Institute of Standards & Technology (NIST). Presently, the Task Force is cooperating with the Naval Sea Systems Command in its program to develop a database on residual properties of composite materials after exposure to fire.

ASC Targets Students

Part of ASC's 1990 membership drive will be aimed at a special population—students. The Society's first student chapter has been established at the University of Utah, and efforts are underway to start them at other institutions, including the University of Delaware.

"I came back from the annual meeting with a new appreciation for the importance of ASC student chapters," says ASC Editor Jack Gillespie, Assistant Director for Research at the University of Delaware's Center for Composite Materials. "Some of the other engineering organizations like SAMPE play an important role for undergraduates and students interested in direct industrial applications. But ASC can fill a very different niche for graduate students who are looking for a more advanced scientific and engineering research environment. ASC is unique because here the whole conference—rather than just one or two isolated sessions—is devoted to composites. ASC activities are very focused on composites science and engineering, which can get lost in the bigger societies."

According to ASC Membership Secretary C. T. Sun, a professor at Purdue University's School of Aeronautics and Astronautics, "The Society is trying to encourage the establishment of more student chapters. Benefits to students include reduced conference fees, the newsletter and membership in an organization of common interest. Eventually, we may be able to offer special student sessions at the annual meeting, giving students an opportunity to present their work orally or in posters."

AMERICAN SOCIETY FOR COMPOSITES

ASC to initiate student chapters

Committee on Composite Materials meets at ASME 1990 Winter Annual Meeting

Committee on Composite Materials

Dr. Carl T. Herakovich of the University of Virginia chairs this committee which is a part of ASME's Applied Mechanics Division. He submitted this brief report summarizing committee activities at the 1990 Winter Annual Meeting in Dallas, Texas.

Report

The Committee was very active during 1990. Membership increased dramatically as a result of Chairman Forrestal's encouragement and the tear-out coupon in the Spring 1990 Newsletter. This resulted in a well-attended committee meeting in Dallas.
subcommittee on Honors and Awards was appointed at the Dallas meeting. The subcommittee members are Charles Bert, Dick Christensen, and George Dvorak. Members are encouraged to make nominations for the various ASME honors and awards to this subcommittee.

In an effort to provide better coordination with other committees and divisions, the persons listed below have volunteered to serve as liaison persons to these other groups. Hopefully this will result in more efficient organization and planning of future symposia.

<table>
<thead>
<tr>
<th>Committee</th>
<th>Liaison Person(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing in Applied Mechanics</td>
<td>J. N. Reddy</td>
</tr>
<tr>
<td>AMD-MD Constitutive Equations</td>
<td>Dusan Krajcinovic</td>
</tr>
<tr>
<td>Dynamics Structures &amp; Systems</td>
<td>Cornelius Horgan</td>
</tr>
<tr>
<td>Elasticity</td>
<td></td>
</tr>
<tr>
<td>Fracture Mechanics</td>
<td>Sherrill B. Biggers</td>
</tr>
<tr>
<td>Geomechanics</td>
<td>Dimitrios Karamanlidis</td>
</tr>
<tr>
<td>Materials Processing &amp; Manufacturing</td>
<td>Jack R. Vinson/ Ozden O. Ochoa</td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Wave Propagation</td>
<td></td>
</tr>
<tr>
<td>AD Strs/Mats</td>
<td></td>
</tr>
</tbody>
</table>

Volunteers are still needed for the open slots.

**Symposia**

A Symposium on Microcracking-Induced Damage in Composites was organized by George Dvorak and Dimitrius Lagoudas at the 1990 WAM in Dallas. The proceedings of the symposium were published in a bound volume (AMD-Vol. 111).

The Committee has also been very active in planning future symposia. Following is a list of future symposia and organizers.


**Advances in Finite Deformation Problems in Materials Processing & Structures.** Cosponsored with Committee on Computing in Applied Mechanics. Organized by J. N. Reddy (VPI) and N. Chandra (Florida State).


**Composite Materials in Transportation Systems.** Cosponsored with Transportation Committee. Organized by T. W. Chou (Dela-ware) and S. Biggers (Clemson).


1991 Summer, Ohio State, 16–19 June 1991

**Mechanics of Composites at Elevated and Cryogenic Temperatures.** Organized by Suren Singhal (Severdrup), Walter Jones (Oak Ridge), and Carl Herakovich (Virginia).

**Modelling of Smart Composite Structures Joint with Computing in Applied Mechanics.** Organized by J. N. Reddy (VPI) and G. L. Anderson (ARO).

**Micromechanical Modelling of Failure in Quasi-Brittle Materials.** Cospcomb with the Geomechanics Committee. Organized by Victor C. Li (University of Michigan).

**Special Conference**


---

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**NASA initiates ACT Program; holds first annual ACT Conference**

**Advanced Composites Technology (ACT) Program Summary**

Concerned with the United States' ability to maintain a leadership role and a competitive advantage over other nations in aircraft design, manufacture, and sales, the Aeronautics and Space Engineering Board (ASEB) of the National Research Council formed a committee to assess the status and viability of organic composites technology for aircraft structures. The committee provided recommendations for federally sponsored research and technology development programs that could produce a more rapid and timely translation of the potential of composite materials into production aircraft.

In response to the recommendations of the ASEB, NASA established an Advanced Composites Technology Program (ACT). A plan for the ACT Program was developed that includes basic research in materials and material forms to improve structural performance, particularly damage tolerance, while reducing processing and fabrication costs. Analytical methods will be developed to further the understanding of composite performance for both transport and fighter aircraft applications. The methods will be verified through tests at the element, sub-scale, and large-scale levels to raise the level of confidence in composite designs and remove costly conservatism. Innovative structural concepts and fabrication methods will be explored and selected concepts will be verified in large-scale tests.

Because of the importance of cost to the timely application of composites to the next generation of aircraft, the current program...
will place considerable emphasis on developing designs, materials processed, and fabrication methods that show promise of significant cost reductions.

The program is divided into three technical Work Breakdown Structure elements:

- Advanced Materials and Processes,
- Advanced Structural Mechanics, and
- Advanced Structural Concepts Development.

Brief summaries of these three program elements are presented below.

**Advanced Materials and Processes**

Advanced material forms and processes play a key role in improving both the performance and processability of composite materials. New material forms can improve the out-of-plane performance of materials and can reduce the part count of components. New material forms can also contribute to the development of innovative designs. The advanced materials and processes portion of the program is supported by work at the Langley Research Center as well as contracted research. The work is fundamental in nature and includes demonstrations of the technology on a modest scale. Promising materials and processes will be transferred to the contractors performing the concepts development phase of the program.

Automated textile processes such as two-dimensional (2-D) and three-dimensional (3-D) weaving, braiding, stitching, and knitting will be used to fabricate near-net-shape structural elements with multidirectional fiber architectures. Analytical methods will be developed to predict the stiffness, strength, and impact resistance of composites made from complex fiber architectures. Cost-effective resin application techniques, such as resin transfer molding, will be developed for use with the structural preforms. Cost-effective fabrication of damage-tolerant composite fuselage structures requires a major technology advance. A six-axis tow placement technique will be used to fabricate integrally stiffened flat and curved fuselage panels.

Models to predict damage initiation and growth in advanced composites under static and cyclic loading will be developed. Critical failure mechanisms will be identified by testing and microscopically examining woven, stitched, and braided composites. Specialized tests will be developed to isolate the effects of parameters such as fiber waviness, tow thickness, stitch spacing, and interfacial strength.

**Advanced Structural Mechanics**

The ASEB committee concluded that the application of composites has been hindered by lack of analytical methodology comparable to that of metals. The Structural Mechanics portion of the program will focus on developing and verifying analyses that describe the behavior of composites from the laminate level through built-up large-scale structure. The analyses will build on the growing understanding of composite behavior and will incorporate the important aspects of aircraft loads and operating environments. Analysis techniques will be developed to predict structural properties and, in particular, the residual strength after impact and cyclic loading of structures reinforced through the thickness by stitching.

The directional attributes of advanced composite materials will be exploited to develop advanced tailored structural concepts for wing and fuselage primary structures. The stiffness distributions for structural subcomponents and components will be tailored to control internal load paths and to provide desirable structural efficiency and performance characteristics.

**Advanced Structural Concepts Development**

The committee also specifically recommended that, in addition to the basic research and technology needed to expand the technical database of composites, the program must address cost reduction from material through design and construction, and should include the necessary large-scale fabrication and testing to validate the technology.

A major objective of the efforts in this portion of the program is to develop and demonstrate innovative structural concepts and material technologies for transcentury composite primary aircraft structures. Integrated design and manufacturing procedures, supported by a strong structural mechanics technology base, will be applied to achieve up to 50% weight reductions, 25% reduction in acquisition cost, 40% reductions in maintenance cost, and 50% reduction in parts count compared to current production aluminum aircraft. This phase of the program provides the needed integration of all disciplines.

The later phases of the program have been structured both in content and timing to incorporate new materials and concepts emerging from the fundamental research and technology activities included in the earlier elements of the program. Although the structures to be built and tested in this program are representative of actual aircraft structures, no attempt is being made to make them replicas of existing aircraft components. The structures will remain sufficiently generic to have broad applications and to support designs for the next generation of aircraft. This portion of the program will be implemented almost entirely through contracts with major airframe manufacturers.

**Technology Transfer**

Technology transfer within the U.S. aeronautics community is an essential element of the ACT Program. To promote rapid, real-time technology transfer between participants, the NASA-Langley Research Center Program Office will organize and coordinate scheduled meetings with participating members of government, industry, and universities. Informal workshops will be held at strategic times in the program. An annual conference will be held to provide a progress report for the U.S. composites community.

**First NASA Advanced Composites Technology Conference**

The First NASA Advanced Composites Technology Conference was sponsored by the NASA Langley Research Center to review recent advances in research and development of advanced composites technology for applications to military and commercial aircraft. The NASA Advanced Composites Technology (ACT) Program is a major new multiyear research initiative to achieve a national goal of technology readiness before the end
of the decade. This initiative is carried out through a cooperative program between industry, universities, and the Government conducting research in materials processing, analysis development, innovative designs, and manufacturing methods.

The First NASA Advanced Composites Technology Conference was held in Seattle, Washington, 29 Oct. through 1 Nov. 1990. The conference provided a forum for the composites community to exchange information and an opportunity to observe recent progress in advanced composites technology. A total of 52 papers were organized into sessions that emphasized composite transport technology development, advances in design and manufacturing, and research in materials and structural mechanics. In addition, a session sponsored by the Department of Defense emphasized lessons learned from current applications programs. This conference publication is a compilation which contains the papers presented in these sessions.

**CENTER FOR COMPOSITE MATERIALS UNIVERSITY OF DELAWARE**

*Sheet-forming technology highlighted; new industry interaction method noted*

**Research Team Develops Sheet-Forming Technology**

Sheet forming is a collection of processes for converting flat sheet stock into three-dimensional (3-D) curvilinear surfaces. Commonly used with metals, this technique is now the object of a major research effort aimed at gaining a fundamental understanding of its capabilities and limitations with thermoplastic composites. The following summarizes the recently completed research of three graduate students working in sheet forming under the advisorship of Engineering Dean R. Byron Pipes.

**Draping and Consolidation of Commingled Fabric Composites**

Supported by a Fellowship from BASF, Barry P. Van West recently completed a Ph.D. in Mechanical Engineering, with research on draping and consolidation of commingled fabrics. Van West's research resulted in a graphical simulation of the draping process that predicts fiber orientations and a consolidation model that predicts thickness, fiber volume fraction, and void content.

"Together, the two models give enough information to calculate mechanical properties at any point in a part formed to an arbitrary shape," says Van West. "Mechanical properties vary from point to point because of shear deformation in the fabric during draping leading to changes in the relative orientations of the fibers."

According to Van West, the draping simulation is potentially useful to the textile industry, particularly to those interested in determining how fibers align themselves relative to each other. It can also indicate whether or not a shape can be draped without wrinkling, an important feature in working with fabrics.

The consolidation model is different from previous models in that it treats discrete bundles rather than continuous fiber beds. "This part of the work is of value to anyone wanting to make parts from either commingled or co-woven materials," says Van West. He explains that co-wovens differ from commingled fabrics in that the former consist of bundles of reinforcement material next to separate bundles of matrix material; in commingled materials, each individual yarn contains both reinforcement and matrix fibers.

**Numerical Modeling of Sheet Forming for Thermoplastic Composites**

For sheet forming to make the transition from metals to fiber-reinforced thermoplastics, a better understanding of such issues as the control of fiber orientation and distribution, sheet thickness, materials properties, and influence of rate of forming on instability initiation is required. Alexandre Beaussart, who earned a master's degree in Mechanical Engineering in August, developed a finite element analysis to model the forming of thermoplastic sheets and predict fiber orientation and thickness in a formed part as well as the state of stress and strain rate during deformation. His work focused on a long-discontinuous-fiber (LDF) system, a technology recently developed by the Du Pont Company.

"The materials we worked with consist of aligned, long discontinuous fibers in a thermoplastic matrix," Beaussart says. "This structure allows an extensional deformation mode in the fiber direction not possible with continuous fibers. Sheets of this drawable material may offer better formability into complex geometries than continuous-fiber thermoplastics while maintaining comparable mechanical properties."

"Numerical simulation can make a significant contribution to a better understanding of this manufacturing method," says Pipes. "We need this information to determine optimum processing parameters and to design forming tooling equipment."

Beaussart adapted a finite element technique developed originally for large deformation of plastic metals to the case of composite materials by taking into account the change of orientation of the fibers during deformation. The feasibility of that method was first demonstrated for planar deformations. This 2-D work was then extended to a shell model to simulate the forming of sheets into arbitrary geometries through adaptation of a general-purpose finite element program.

Beaussart's work will be further extended by an incoming graduate student, Terry Creasy, who will work on a doctoral degree. Future research will include (1) extending the work to multidirectional laminates, (2) adding the treatment of tool contact to the shell program, and (3) comparing the numerical model to experimental results.
Diaphragm Forming of Thermoplastics

Researchers have been developing a new process for consolidation of continuous-fiber-reinforced thermoplastic-matrix composites, polymeric diaphragm forming, since 1987. Doctoral student Conchur M. O'Bradaigh has developed innovative analytical models and experimental work to verify the techniques.

In August, O'Bradaigh completed his doctoral work, which resulted in a new finite element analysis that takes into account the inextensibility of the fibers. “Continuous-reinforced thermoplastics are 60% by volume continuous carbon fibers which are essentially inextensible,” O'Bradaigh explains. “Because of that, previous work was purely kinematic; in other words, researchers looked at how the fibers moved during draping, for example.”

“Experimental work indicated that the instabilities which occur during diaphragm forming of composites are largely rate dependent,” he continued, “so a constitutive approach—taking into account stresses as well as deformation—was needed.”

The finite element analysis O'Bradaigh developed has now been compared with experimental results. Two types of instabilities were observed experimentally and verified by analysis. The first mode occurred in the plane of the fibers and appeared as a thin band of columnar buckling. The second occurred in an out-of-plane fashion and was shown to be a function of deformation rate, geometry, and diaphragm stiffness. The finite element formulation has been used to analyze the buckling problem, and it predicts correctly the occurrence of compressive stresses in the affected regions of the laminate.

Center Announces New Mechanism for Interaction with Industry

The Center for Composite Materials (CCM) at the University of Delaware has established a program of limited partnerships with composites-related companies interested in affiliation with a major academic research center. CCM has a 12-year history of interaction with industry through its University/Industry Research Consortium (UIRC), currently consisting of 30 companies representing material suppliers and end users in the automotive and aerospace industries. Establishment of the new program marks the first time that smaller companies will have access to the Center's resources and research.

Membership fees will provide partial support for graduate student fellowships in research areas based on priorities determined by the UIRC's Industrial Advisory Board. Members of the limited partners program will be eligible to attend CCM's annual workshop and symposium and select other limited benefits tailored to their specific needs. “We're very excited to have developed a new program in response to the many requests we've had over the past few years for this type of alliance,” says Program Manager Patricia M. Kraft.

According to CCM Associate Director John W. Gillespie, Jr., “Limited partners will benefit from interacting within the international forum represented by the UIRC as it establishes priorities and future directions for the composites industry.”

CONFEREE REPORT:

4th European Conference Materials

Introduction

The future in the materials sector has long since started and it belongs to fiber composites. The optimistic prognoses that foresee a very marked upward trend with annual growth rates of around 25% for these high-tech materials which offer simply unbelievable possibilities (sturdier than steel, lighter than aluminum) were further confirmed by the success of “Eurocomposites 90” and the “4th European Conference on Composite Materials (ECCM-4)” held at the Stuttgart trade fair complex on the Killesberg between 26 and 29 Sept. 1990. A total of around 3400 visitors attended the German premiere of the trade fair/congress combination in Stuttgart, almost 14% more than were present at the previous event in Bordeaux.

Many New Users

The 80 exhibitors who presented their products and services on a total exhibition area of around 2500 m² almost unanimously declared themselves satisfied with the way the trade fair went. Some companies underestimated the number of visitors and had to supplement their stand personnel during the event. One particularly positive note from the exhibitors was that “Eurocomposites 90” did not turn into an “insider meeting” of an already committed composites group. Instead, a remarkably large number of potential users participated and obtained information or concluded firm business agreements. In the heartland of the German mechanical engineering industry, the emphasis was on this field as far as visitors were concerned, but the variety of trade visitors spanned fields as diverse as electrical engineering and electronics, the leisure industry, and shipbuilding.

Favorable Surroundings

The success of “Eurocomposites 90” emphasizes the quality of Stuttgart's location as an ideal exhibition center for so-called “special interest” trade fairs in the field of high technology. The economically well-structured surrounding area with its future-oriented industries takes optimum advantage of the opportunity for technology transfer presented by events of this kind.

A Congress with Lively Discussions

The organizers of the “4th European Conference on Composite Materials (ECCM-4)” also drew a completely positive picture. More than 600 scientists, engineers, and technicians from 20 countries exchanged information in sometimes lively discussions on new products and new developments in the subject areas of fundamentals, properties, manufacturing, and inspection of
composite materials. There was a total of 160 speakers and 60% of Congress participants came from abroad. A very popular feature was the poster exhibition which allowed scientists to use large placards to report on the results of their work. A notable feature for a scientific conference was that in Stuttgart the participants came not only from universities or research institutes, but almost half were representatives of manufacturers and consumers.

The next "Eurocomposites" with "ECCM-5" will be held in Bordeaux again in 1992.

RECENT COMPOSITE PUBLICATIONS

Delaware Composites Design Encyclopedia, Volume Six Published


The final volume is now available in a new six-volume design encyclopedia for advanced composite materials and components. The Delaware Composites Design Encyclopedia will provide users with basic knowledge about the design and analysis of composite materials and structures. It is intended for use by engineers, material scientists, designers, and other technical personnel involved in the applications of composite materials to industrial products.

The material contained in the encyclopedia was written by international experts in the field and compiled at the University of Delaware's Center for Composite Materials (CCM). The CCM is supported by a university/industry consortium and several U.S. federal research agencies. The encyclopedia was originally offered as a special benefit to consortium members. It is now being offered for the first time to the composites community at large in an updated and expanded format.

Volume 6/Test Methods, authored by a distinguished set of international composites experts, contains a review of test methods (ASTM Standards and Guides) for characterizing constituent properties, composite thermomechanical properties, and physical properties. Because delamination represents one of the most prevalent life-limiting failure modes in laminated composite structures, one entire section is devoted to ultrasonic nondestructive evaluation techniques and equipment used to assess material quality and detect flaws that affect performance. The ultrasonic method is applied to numerous examples and types of composite materials. Finally testing issues and specimen design considerations are emphasized to provide a fundamental understanding of the underlying mechanics principles governing Mode I, II, and III interlaminar fracture characterization.

Engineers and materials scientists will find this information on test methods essential for materials evaluation and development, quality control assessment of manufacturing techniques, and the creation of material property databases for the design, analysis, and applications of composite materials to industrial products.

The authors of Volume 6 are R. Byron Pipes, Dean of the College of Engineering, University of Delaware, Robert A. Blake, Jr., ALCOA, Pittsburgh, and John W. Gillespie, Jr. and Leif A. Carlsson, Florida Atlantic University. The set is intended as an ongoing series to which new volumes will be added as needs arise and new knowledge is gained. Each volume is Smythe sewn for years of library and desktop use. An index to the entire set will be published later this year.

Fabrication of Particulates Reinforced Metal Composites


A review of the latest developments in the area of particulates reinforced composites is available from ASM International, the materials information society.

Fabrication of Particulates Reinforced Metal Composites is a 288-page compilation of the proceedings from the September 1990 conference of the same name, held in Montreal and sponsored by the National Research Council Canada and ASM.

Edited by Jacques Masounave and Francois G. Hamel, the book consists of 30 papers which provide a comprehensive review of particulates reinforced composites. Coverage includes not only those produced by the foundry process, but also those done by other fabrication processes, thus enabling a comparison of different elaboration techniques and their effect on the properties of the composites.

The book is divided into five major sections. The first group of seven papers addresses the fundamentals of elaboration—wettability, interface reaction, solidification, and kinetics.

The second section of eight papers, presented by composites manufacturers, details the different elaboration techniques. Information is provided on semisolid slurry processing, the investment casting process, and the bottom-mixing foundry process.

The following two sections are devoted to two aspects of postprocessing—heat treatment and mechanical treatments. The aging characteristics of particulates reinforced metal matrix composites is thoroughly covered by three papers. Extrusion, machining, and other forming processes are discussed in the section on mechanical treatments.

The final section of five papers deals with the mechanical properties of the composites, including strength, ductility, fracture, and wear behavior.
Calendar on Composites

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

1-4 April 1991
8th International Conference on Mathematical and Computer Modelling
College Park, MD
Contact: Dr. Xavier J. R. Avula, Chairman, Eighth ICMCM, P. O. Box 1488, Rolla, MO 65401; Telephone: 314-341-4585; FAX: 314-341-6026

8-10 April 1991
Baltimore, MD
Contact: Ron Kollmansberger, 16761 Via Del Campo Court, San Diego, CA; Telephone: 619-592-2423

14-18 April 1991
IMAC 9th International Modal Analysis Conference and Exhibit
Florence, Italy
Contact: Dominick J. DeMichele, Union College, Graduate & Continuing Studies, Wells House - 1 Union Avenue, Schenectady, NY 12308-363; Telephone: 518-370-6673; FAX: 518-370-6875

15-17 April 1991
Recent Advances in Active Control of Sound and Vibration
Blacksburg, VA
Contact: Ms. Nancy Feuerbach, Smart Materials & Structures Laboratory, Mechanical Engineering Department, Randolph Hall, Virginia Tech, Blacksburg, VA 24061-0238; Telephone: 703-231-3365; FAX: 703-231-9100

15-18 April 1991
Thirty-Sixth International SAMPE Symposium and Exhibition—Advanced Materials: How Concepts Become Reality
San Diego, CA
Contact: SAMPE, P.O. Box 2459, Covina, CA 91722; Telephone: 818-331-0616; FAX: 818-332-8929

16-18 April 1991
Third International Symposium Mechanics of Polymer Composites “MPC ’91”
Prague, Czechoslovakia
Contact: Secretariat of the MPC ’91, c/o Institute of Theoretical and Applied Mechanics, Czechoslovak Academy of Sciences, Vyšehradská 49, 128 49 Praha 2, Czechoslovakia; Telephone: 29 64 51, 29 91 71, 29 75 78.

21-25 April 1991
ICES ’91 International Conference on Computational Engineering Science
Patras, Greece
Contact: ICES ’91 Secretariat, % Professor S. N. Atluri, Computational Mechanics Center, Georgia Institute of Technology, Atlanta, GA 30332-0356

23-24 April 1991
Symposium on Constraint Effects in Fracture
Indianapolis, IN
Contact: Symposium Chairman E. M. Hackett, David Taylor Research Center, Code 2814, Annapolis, MD 21402; Telephone: 301-267-3755

28-30 April 1991
Woodfiber-Plastic Composites Conference: Virgin and Recycled Woodfiber and Polymers for High-Volume, Low-Cost Composites
University of Wisconsin-Madison, WI
Contact: Pat Gaitan, Wisconsin Center, 702 Langdon St., Madison WI 53706; Telephone: 608-262-6696, FAX: 608-262-8516

6-7 May 1991
Fourth ASTM Symposium on Composite Materials: Fatigue and Fracture
Indianapolis, IN
Contact: Dr. Wayne W. Stinchcomb, Engineering Science & Mechanics Department, 227 Norris Hall, VPI & SU, Blacksburg, VA 24061-0219; Telephone: 703-231-5316; FAX: 703-231-9452

12-16 May 1991
International Aerospace Congress 1991: Focus on the Future
Melbourne, Australia
Contact: Secretariat, International Aerospace Congress 1991, GPO Box 358F, Melbourne Victoria 3001 Australia; Telephone: 061 03 654 7533 or 061 03 654 8799; FAX: 03 654 8540

14-16 May 1991
2nd Annual BCC Conference on Recent Advances in Flame Retardancy of Polymeric Materials: Materials Applications, Industry Developments, Markets
Stamford, CT
Contact: Program Co-Chairman, G. S. Kirshenbaum, Manager, Standards, Codes, and Technical Support, Engineering Plastics Division, Hoechst Celanese, 26 Main St., Chatham, NJ 07928; Telephone: 201-635-4217; FAX: 201-635-4330

20-24 May 1991
AeroMat ’91: Advanced Aerospace Materials/Processes Conference and Exposition
Long Beach, CA
Contact: ASM International, Materials Park, OH 44073; Telephone: 216-338-5151; Telex: 98-0619 ASMINT; FAX: 216-338-4634

Summer 1991
American Society of Composites 6th Technical Conference
Telephone: 513-255-9080

16-19 June 1991
Mechanics of Composites at Elevated and Cryogenic Temperatures: ASME Applied Mechanics Meeting
Columbus, OH
Contact: Professor Carl T. Herakovich, Civil Engineering Dept., Thornton Hall, University of Virginia, Charlottesville, VA 22901; Telephone: 804-924-3605

16–19 June 1991
Modelling of Smart Composite Structures: ASME Applied Mechanics Meeting
Columbus, OH
Contact: Professor J. N. Reddy, Engineering Science and Mechanics Dept., 227 Norris Hall, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0219; Telephone: 703-231-6744, FAX: 703-231-4574

16–19 June 1991
Micromechanical Modelling of Failure in Quasi-Brittle Materials: ASME Applied Mechanics Meeting
Columbus, OH
Contact: ASME, 345 East 47th St., New York 10017; Telephone: 212-705-7722

16–19 June 1991
Symposium on Dynamics of Bubbles and Vortices Near a Free Surface
Columbus, OH
Contact: Iskender Sahin, Department of Mechanical Engineering, Texas Tech University, P.O. Box 4289 MS1021, Lubbock, TX 79409

18–20 June 1991
ASTM 23rd National Symposium on Fracture Mechanics
College Station, TX
Contact: Dr. Ravinder Chona, Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843-3123; Telephone: 409-845-1531; FAX: 409-845-3081

8–10 July 1991
The 6th International Conference in Australia on Finite Element Methods
Sydney, Australia
Contact: Dr. Colin McIvor, Organising Committee, Department of Aeronautical Engineering, The University of Sydney, Sydney, NSW 2006, Australia; Telephone: 02-692-2850; FAX: 02-692-2012

8–12 July 1991
The 7th International Conference on Numerical Methods for Thermal Problems
Stanford, CA
Contact: Meeting Coordinator, Mrs. Lindi Bauman, Thermal Conference, Department of Chemical Engineering, Stanford University, Stanford, CA 94305-5025; Telephone: 415-723-0153; FAX: 415-725-7294; E-Mail: LINDI@DELLA.STANFORD.EDU

15–17 July 1991
International Conference on Mixed-Mode Fracture and Fatigue
Vienna, Austria
Contact: Doz. Dr. H. P. Rossmanith, Institute of Mechanics, Technical University of Vienna, Wiedner Hauptstraße 8-10/325, A-1040 Vienna, Austria; Telephone: 0222-58801-5514, 5519; Tlx: 61-3222467 = TUW; Telefax: 0222-5871020

15–19 July 1991
The Eighth International Conference on Composite Materials (ICCM/VIII)
Honolulu, HI
Contact: Profs. Stephen W. Tsai and George S. Springer, Department of Aeronautics and Astronautics, Stanford University, Stanford, CA 94305; Telephone: 415-725-3305; FAX: 415-725-3377

15–19 July 1991
The 7th International Conference on Numerical Methods in Laminar and Turbulent Flow
Stanford, CA
Contact: Meeting Coordinator, Mrs. Lindi Bauman, Thermal Conference, Department of Chemical Engineering, Stanford University, Stanford, CA 94305-5025; Telephone: 415-723-0153; FAX: 415-725-7294; E-Mail: LINDI@DELLA.STANFORD.EDU

21–24 July 1991
First U.S. National Congress on Computational Mechanics
Chicago, IL
Contact: Professor Wing Kam Liu, Department of Mechanical Engineering, Robert R. McCormick School of Engineering and Applied Science, The Technological Institute, Northwestern University, Evanston, IL 60208-3111; Telephone: 708-491-7094; FAX: 708-491-4133

24–26 July 1991
The Third International Conference on Residual Stresses (ICRS -3)
Tokushima, Japan
Contact: Prof. R. W. Hendricks, Department of Materials Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; Telephone: 703-231-6917; E-MAIL: HENDRXXR@VTVM1.CC. VT.EDU

29 July–2 August 1991
The Sixth International Conference on Mechanical Behaviour of Materials (ICM - 6)
Kyoto, Japan
Contact: The Society of Materials Science, Japan, Att. Prof. T. Inoue, Secretary General, ICM-6, Yoshida-Izumidono-cho 1-101, Sakyo-ku, 606 Kyoto, Japan; Telefax: 075-761-5325

6–8 August 1991
Joint ICF/FEFG International Conference on Fracture of Engineering Materials and Structures
National University of Singapore
Contact: Dr. S. H. Teoh, Conference Director, Dept. of Mechanical & Production Engineering, National University of Singapore, 10 Kent Ridge Crescent, Singapore 0511; Telephone: 65-7722212; FAX: 65-7791459; Tlx: UNISP0RE RS33943; Tlgm: UNIVSPORE

12–16 August 1991
Plasticity '91 Symposium
Grenoble, France
Contact: Professor Akhtar S. Khan, School of Aerospace and Mechanical Engineering, The University of Oklahoma, 865 Asp Avenue, Room 212, Norman, Oklahoma 73019-0601; Telephone: 405-325-5011; FAX: 405-325-1088 or 405-325-5068
20–22 August 1991
Computational Structures Technology
Edinburgh, Scotland
Contact: Professor B. H. V. Topping, Department of Civil Engineering, Heriot-Watt University, Riccarton, Edinburgh EH14 4AS, United Kingdom; Telephone: 031-449-5111; FAX: 031-451-3170

20–22 August 1991
Conference on Materials for Electronic Packaging
Buffalo, NY
Contact: Professor D. D. L. Chung, Department of Mechanical and Aerospace Engineering, State University of New York at Buffalo, Buffalo, NY 14260; Telephone: 716-636-2520

4–6 September 1991
First Canadian International Composites Conference and Exhibition
Montreal, Quebec, Canada
Contact: Dr. S. V. Hoa, Conference Chairperson, Department of Mechanical Engineering, Concordia University, 1455 de Maisonneuve Blvd. West, H 929-11, Montreal, Quebec, Canada H3G 1M8; Telephone: 514-848-3139; FAX: 514-848-3494

9–11 September 1991
Sixth International Conference on Composite Structure (ICCS/6)
Paisley, Scotland
Contact: Dr. I. H. Marshall, Department of Mechanical and Production Engineering, Paisley College of Technology, High Street, Paisley PA1 2BE, Scotland; Telephone: 041-887-1241; FAX: 041-887-0812

9–11 September 1991
Third ASTM International Symposium on Computerization and Use of Materials Property Data
Cambridge, England
Contact: Keith W. Reynard, Symposium Co-Chairman, Wilkinson Consultancy Services, Stable Cottage, Broad Lane, Newdigate, Surry RH5 5AT, United Kingdom; Telephone: 44(0)-306-77247; FAX: 44(0)-306-77247

16–20 September 1991
International Conference of Nonlinear Engineering Computations
Split, Yugoslavia

17–19 September 1991
Interfacial Phenomena in Composite Materials (IPCM '91)
Leuven, Belgium
Contact: Janeil Miles, Conference Organiser, Butterworth Scientific Ltd., P.O. Box 63, Westbury House, Bury Street, Guildford, Surrey GU2 5BH, United Kingdom; Telephone: 0483 309966; Telex: 859556 SCITEC G; FAX: 0483 301563

6–9 October 1991
6th American Society for Composites Technical Conference on Composite Materials
Albany, NY
Contact: Professor Sanford S. Sternstein, Rensselaer Polytechnic Institute, Center for Composite Materials and Structures, JEC 5003, Troy, NY 12180; Telephone: 518-276-2792; FAX: 518-276-8788

7–9 October 1991
22nd Midwestern Mechanics Conference
Rolla, MO
Contact: Professor Romesh C. Batra, Department of Mechanical and Aerospace Engineering and Engineering Mechanics, University of Missouri-Rolla, Rolla, MO 65401-0249; Telephone: 314-341-4589

9–11 October 1991
3rd International Congress on the Entire Composite Technology: Design and Manufacturing Technology of Composites/Recycling Starting with Design
"VERBUNDWERK 91"
Wiesbaden, Germany
Contact: Diana Schnabel, DEMAT, Postbox 110 611, 6000 Frankfurt 11, West Germany; Telephone: 069/23 43 31; FAX: 069/25 30 71

14–15 October 1991
ASTM Symposium on Multiaxial Fatigue
Philadelphia, PA
Contact: Laurel Davis O'Brien, ASTM, 1916 Race St., Philadelphia, PA 19103; Telephone: 215-299-5524

15–16 October 1991
ASTM Symposium on High Temperature and Environmental Effects on Polymeric Composites
San Diego, CA
Contact: Dr. Charles E. Harris, NASA-Langley Research Center, Mail Stop 188E, Hampton, VA 23665-5225; Telephone: 804-864-3449, FAX: 800-864-7729

16 October 1991
Symposium on Thermo-Mechanical Fatigue Behavior of Materials
San Diego, CA
Contact: Professor Huseyin Sehitoglu, Department of Mechanical Engineering, University of Illinois, 1206 W. Green, Urbana, IL 61801; Telephone: 217-333-4112

22–24 October 1991
Twenty-Third International SAMPE Technical Conference: Advanced Materials/Affordable Processes
Kamesha Lake, NY
Contact: SAMPE International Headquarters, P.O. Box 2459, Covina, CA 91722; Telephone: 818-331-0616; FAX: 818-332-8929

27 October–1 November 1991
IUTAM Symposium on Local Mechanics Concepts for Composite Materials Systems
Blacksburg, VA
Contact: J. N. Reedy and K. L. Reifsnider, Department of Engineering Science and Mechanics, Virginia Tech, Blacksburg, VA 24061-0219; Telephone: 703-231-6744; FAX: 703-231-4574

6 November 1991
ASTM Symposium on Characterization and Testing of Composite Materials for Implant Applications in the Human Body
San Diego, CA
Contact: Russell D. Jamison, Smith & Nephew Richards Inc., 1450 Brooks Rd., Memphis, TN 38116; Telephone: 901-396-2121
6–8 November 1991
Conference on Active Materials and Adaptive Structures
Washington, DC
Contact: ASME, 345 East 47th St., New York 10017; Telephone: 212-705-7722.

6–8 November 1991
28th Annual Meeting of the Society of Engineering Science
Gainesville, FL
Contact: Dr. Martin A. Eisenberg or Dr. Bhavani V. Sankar, Department of Aerospace Engineering, Mechanics & Engineering Science, 231 Aerospace Building, University of Florida, Gainesville, FL 32611-2031; Telephone: 904-392-0961; FAX: 904-392-7303.

1–6 December 1991
Advances in Finite Deformation Problems in Materials Processing & Structures: ASME Winter Annual Meeting
Atlanta, GA
Contact: Prof. J. N. Reddy, Engineering Science and Mechanics Dept., 227 Norris Hall, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0219; Telephone: 703-231-6744, FAX: 703-231-4574.

1–6 December 1991
Enhancing Analysis Techniques for Composite Materials: ASME Winter Annual Meeting
Atlanta, GA
Contact: Prof. J. N. Reddy, Engineering Science and Mechanics Dept., 227 Norris Hall, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0219; Telephone: 703-231-6744, FAX: 703-231-4574.

1–6 December 1991
Materials and Materials Concepts for Aerospace Structures: ASME Winter Annual Meeting
Atlanta, GA

1–6 December 1991
Mechanics of Plastics and Plastic Composites: ASME Winter Annual Meeting
Atlanta, GA
Contact: ASME, 345 East 47th St., New York, NY 10017; Telephone: 212-705-7722.

1–6 December 1991
Recent Developments in Elasticity: ASME Winter Annual Meeting
Atlanta, GA

1–6 December 1991
Symposium on the Use of Composite Materials in Transportation Systems: ASME Winter Annual Meeting
Atlanta, GA
Contact: Sherrill B. Biggers, Department of Mechanical Engineering, Riggs Hall, Clemson University, Clemson, SC 29634-0921; Telephone: 803-656-0139, FAX: 803-656-2698, E-Mail: BIGGERS@ENG.CLEMSON.EDU.

Summer 1992
American Society of Composites 7th Technical Conference
Telephone: 513-255-9080.

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@VTVMI.CC.VT.EDU
New ASTM Publications

**ASTM Standards and Literature References for Composite Materials, 2nd Edition**

This newly revised publication includes standard test methods for high modulus fibers and composite materials reinforced by high modulus fibers, as well as applicable standards used to support standard tests on high modulus fibers and composites. This compilation features: several new standards, including a guide for testing automotive/industrial composite materials; 13 standards for sandwich constructions; and an updated Literature References section that references all new ASTM books on composites and the latest papers published in the *Journal of Composites Technology & Research*. This edition is available in soft cover or loose-leaf formats. *Soft cover*: 512 pages, list price, $69.00, ASTM member price, $55.20, ISBN: 0-8031-1230-0, and PCN: 03-430090-33. *Loose-leaf*: 512 pages, list price, $74.00, ASTM member price: $49.20, ISBN: 0-8031-1231-9, and PCN: 03-430190-33.

**Plain Talk: The Legacy of William T. Cavanaugh at ASTM**

*by Henry J. Stremba and Wayne P. Ellis*

The outstanding success of the ASTM consensus process is not something Bill Cavanaugh (ASTM's chief executive from 1970–1985) inherited. In the 1960s, ASTM's finances were dire, its mission muddled, and its future bleak. It lacked, in Cavanaugh's plain talk, "management." "Management" is what Cavanaugh supplied—in abundance. This book recounts Bill Cavanaugh's successful management of the consensus process to make ASTM the world's largest, most successful developer of voluntary consensus standards. It serves not only to record the history of a remarkable manager in a remarkable institution, but to provide for future ASTM participants—both volunteers and staff—and for managers in not-for-profit enterprises in general, guidelines for the positive use of consensus in reaching public service objectives. *Hard cover*: 354 pages, list price: $18.00, ASTM member price: $15.00, ISBN: 0-8031-1234-3, and PCN: 13-600001-64.
The Ship Structures and Protection Department (SSPD) at the U.S. Navy's David Taylor Research Center is responsible for executing a full spectrum of technical programs from basic research through fleet support. Its principal product lines are submarine and surface ship structures and protection against the effects of weapons. To accomplish its mission, the SSPD has approximately 175 scientists and engineers and 50 support personnel. Experimental facilities include a series of high-pressure hydrostatic tanks capable of applying both static and cyclic loads, a structural test bed 12.2 by 30.5 m (40 by 100 ft) for conducting static and fatigue tests of large and full-scale structures or components, and a battery of fatigue testing machines for conducting constant and random amplitude cyclic tests of various sizes of structural elements.

The development of composites technology and its application to ship structures has been singled out as a growth area for the SSPD. As a result, many initiatives have been taken over the past couple of years to meet this challenge. Increased emphasis has been given to expanding in-house expertise, formulating new research and development programs, and establishing cooperative efforts with industry, academia, and appropriate agencies in friendly foreign countries. The number of scientists/engineers working on composites programs in the SSPD has grown from about 25 to 60 in the past 5 years.

Current composites work within the SSPD is primarily supported by the Navy's exploratory development programs for surface ships and submarines. These efforts have focused on exploiting technology developed by the aerospace community, filling technology gaps which are critical to the successful application of composites to ship structures, and demonstrating the feasibility of composites for ship structures through the design, fabrication, and physical testing of composite models and components. The approach has been similar to that used by the aerospace community in the sense that initial attention was given to nonprimary structural applications. Examples include the deckhouse or superstructure of a surface ship, small- and medium-sized foundations for electronic equipment and machinery, masts, and control surfaces. There is a need for additional program support beyond the exploratory development phase to demonstrate fully the integrity, reliability, and benefits of composites for specific applications; this will pave the way for increasing transitions to the fleet. A recent example involved the application of composites to control surfaces of submersibles. Technology developments and a one-quarter scale feasibility demonstration funded under the Navy's exploratory development program provided the basis for follow-on full-scale development and evaluation under one of the Navy's advanced development programs. As a result, composite diving planes are now deployed on one of the Navy's deep-diving submersibles. Total time from development through application was roughly five years.

Several key technical issues remain to be resolved before the Navy deploys composites in primary ship structures such as the main loading-carrying members of a surface combatant or a submarine. Failure modes and strength of thick-section composites
under compressive loading is at the top of the list for submarine pressure hull applications. Behavior and strength under dynamic loading such as underwater shock require further thorough investigation before reliable design criteria can be formulated. For internal applications on ships it is imperative that the fire/smoke/toxicity characteristics of candidate composite materials be adequately defined. Residual strength after representative fire insults also requires definition and quantification. Finally, cost to fabricate and cost to maintain and repair will be key issues upon which the future application of composites to ships will strongly depend. These and other technical issues can be resolved given adequate time and resources.

The outlook for continued composite developments and applications for naval structures appears promising. Despite shrinking Department of Defense budgets, it is the author's belief that composites offer sufficient benefits over current ship structural materials such that programs which support their development will escape the budget axe for the foreseeable future.