World of Composites

News articles and announcements of interest to the composites technical community

Eighth Symposium on Composite Materials: Testing and Design

ASTM Committee D-30 on High Modulus Fibers and Their Composites is sponsoring the Eighth Symposium on Composite Materials: Testing and Design to be held 29 April through 1 May 1986 at Charleston, SC. The symposium chairman is J. D. Whitcomb, NASA Langley Research Center, Hampton, VA. The program for the symposium is as follows:

Tuesday, 29 April 1986

8:15 a.m.: Welcome and Introduction—J. D. Whitcomb, Symposium Chairman

Session I: Analysis

CHAIRMAN: D. W. Uplinger
Army Materials & Mechanics Research Center
Watertown, MA

8:30 a.m.: A Computer-Based Design Environment for Composite Material Structures—J. R. Zumsteg and F. W. Crossman, Lockheed Palo Alto Research Laboratory, Palo Alto, CA

9:00 a.m.: Automated Design of Composite Plates for Improved Damage Tolerance—Z. Gurdal and R. T. Haftka, Virginia Polytechnic Institute and State University, Blacksburg, VA

9:30 a.m.: Composite Interlaminar Fracture Toughness: 3-D Finite Element Modeling for Mixed Mode I, II, and III Fracture—P. L. N. Murthy, Cleveland State University, Cleveland, OH; and C. C. Chamis, NASA Lewis Research Center, Cleveland, OH

10:00: Break.

10:15 a.m.: Ply Substructuring Theory—C. C. Chamis, NASA Lewis Research Center, Cleveland, OH; and P. L. N. Murthy, Cleveland State University, Cleveland, OH

10:45 a.m.: A Damage Model for Continuous Fiber Composite Laminates with Matrix Cracks and Interlaminar Delaminations—S. E. Groves, D. H. Allen, C. E. Harris, and I. Georgiou, Texas A&M University, College Station, TX

11:15 a.m.: Interlaminar Fracture Analysis of Composite Laminates under Bending and Combined Bending Extension—E. A. Armanios and L. W. Rehfield, Georgia Institute of Technology, Atlanta, GA

11:45: Lunch.

Session II: Impact and Compression

CHAIRMAN: D. J. Wilkins
General Dynamics
Fort Worth, TX

1:15 p.m.: Impact Damage Characterization of Multidimensionally-Braided Graphite/Epoxy Composites—E. T. Camponeschi, Jr. and R. M. Crane, David Taylor Naval Ship Research and Development Center, Annapolis, MD

1:45 p.m.: Effect of Adhesive Layers on Impact Damage in Composite Laminates—C. T. Sun and S. Rechak, Purdue University, West Lafayette, ID

2:15 p.m.: The Correlation of Low Velocity Impact Resistance of Graphite Fiber Reinforced Composites with Matrix Properties—K. J. Bowles, NASA Lewis Research Center, Cleveland, OH

2:45 p.m.: Break.

3:00 p.m.: The Sandwich Column As a Compressive Characterization Specimen For Thin Laminates—P. A. Lagace and A. J. Vizzini, Massachusetts Institute of Technology, Cambridge, MA

3:30 p.m.: Instability Related Delamination Growth In Thermoset and Thermoplastic Composites—R. J. Rothschilds, J. W. Gillespie, and L. A. Carlsson, University of Delaware, Newark, DE

4:00 p.m.: 2-D Delamination Growth in Composite Laminates Under Compression Loading—G. Flanagan, Grumman Aerospace Corporation, Bethpage, NY

4:30 p.m.: An Experimental Study of a Composite Panel with a Cutout—A. N. Palazotto, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH

5:00 p.m.: Adjourn.

Wednesday, 30 April 1986

Session III: Materials Characterization

CHAIRMAN: J. M. Whitney
Air Force Wright Aeronautical Laboratories/Materials Laboratory
Wright-Patterson Air Force Base, OH

8:30 a.m.: Measuring the Stress-Strain Nonlinearity of Carbon Fibers—I. M. Kowalski, Union Carbide Corporation, Parma, OH

9:00 a.m.: Development of a Standard Quality Control Test Method For Determining the Fiber Strength of Roving—S. L. Kirshenbaum, Avco Speciality Materials Division, Lowell, MA

9:30 a.m.: Shear Fatigue of UD Glass/Epoxy—R. J. Butler and P. M. Barnard, Cranfield Institute of Technology, Cranfield, Bedfordshire, England; and P. T. Curtis, Royal Aircraft Establishment, Farnborough, Hants, England

10:00 a.m.: Break.

10:15 a.m.: Impact Behavior of PET Fiber Reinforced Epoxies—A. Mazor, Illinois Institute of Technology, Chicago, Illinois; and L. J. Broutman, L. J. Broutman & Associates, Chicago, IL

10:45 a.m.: Height-Tapered Double Cantilever Beam Specimen for Study of Rate Effects on Fracture Toughness of Composites—G. Yaniv and I. M. Daniel, Illinois Institute of Technology, Chicago, IL

11:15 a.m.: A Constant G Test For Measuring Mode I Interlaminar

Fatigue Crack Growth Rates—A. J. Russell and K. N. Street, Defence Research Establishment Pacific, Victoria, British Columbia, Canada

11:45 a.m.: Lunch.

Session IV: Failure Mechanisms

CHAIRMAN: W. W. Stinchcomb
Virginia Polytechnic Institute & State University
Blacksburg, VA

1:15 p.m.: Growth of Elliptic Delaminations in Laminates Under Cyclic Transverse Shear Stresses—S. N. Chatterjee and V. Ramnath, Materials Sciences Corporation, Spring House, Pennsylvania; and W. A. Dick and Y. Z. Chen, University of Delaware, Newark, DE

1:45 p.m.: Analytical Predictions of the Notched Strength of Thick Laminates with Surface Flaws—C. E. Harris, Texas A&M University, College Station, TX; and D. H. Morris, Virginia Polytechnic Institute and State University, Blacksburg, VA

2:15 p.m.: Analysis of Delamination Growth from Matrix Cracks in Laminates Subjected to Bending Loads—G. B. Murri, NASA Langley Research Center, Hampton, VA; and E. G. Guynn, Kentron Technical Ctr., Hampton, VA

2:45 p.m.: Break.

3:00 p.m.: Interlaminar Fracture Processes in Resin Matrix Composites Under Static and Fatigue Loading—A. D. Reddy, L. W. Rehfield, F. Weinstein, and E. A. Armanios, Georgia Institute of Technology, Atlanta, GA

3:30 p.m.: Failure Mechanism of Delamination Fracture—S. M. Lee, Ciba-Geigy Corporation, Fountain Valley, CA

4:00 p.m.: Study of Stacking Sequence Effects Near a Laminated Composite Free Edge—M. E. Tohlen, LTV Aerospace and Defense, Vought Aero Products Division, Dallas, TX; R. D. Goolsby, University of Texas, Arlington, TX; and J. R. Eisenmann, General Dynamics, Ft. Worth, TX

4:30 p.m.: Edge Delamination of $(\pm\theta_m/90_n/\pm\theta_m)$ Laminates Subjected to Tensile Loading—R. S. Sandhu and G. P. Sendeckyj, Air Force Wright Aeronautical Laboratory, Wright-Patterson Air Force Base, OH

5:00 p.m.: Adjourn.

Thursday, 1 May 1986

Session V: Nondestructive Evaluation

CHAIRMAN: S. W. Beckwith
Hercules Aerospace Division
Magna, UT

8:15 a.m.: The Use of Acoustic Emission to Detect the Onset of Interlaminar Shear Failure in Short Beam Fatigue Specimens—J. H. Edwards, Testwell Limited, Daventry, Northants, England

8:45 a.m.: Measurement of Strain in Layered Media Using Optical Fibers—P. A. Carroll, K. D. Bennett, and R. O. Claus, Virginia Polytechnic Institute and State University, Blacksburg, VA

9:15 a.m.: Damage Assessment in Composite Materials by Acousto-Ultrasonic Technique—L. Lorenzo, Servico Naval de Investigacion y Desarrollo, Buenos Aires, Argentina; and H. T. Hahn, Washington University, St. Louis, MO

9:45 a.m.: Break.

Session VI: Filament Wound and Woven Composites

CHAIRMAN: S. W. Beckwith
Hercules Aerospace Division
Magna, UT

10:00 a.m.: Viscoelastic/Damage Modeling of Filament-Wound Cylindrical Pressure Vessels: R. M. Hackett, Ohio University, Athens, OH, and J. L. Prater, U.S. Army Missile Laboratory, Redstone Arsenal, AL

10:30 a.m.: Residual Stress and Strength Loss in Filament-Wound Composites—C. E. Knight, Virginia Polytechnic Institute and State University, Blacksburg, VA

11:00 a.m.: Notched Strength of Woven Fabric Composites with Molded-In Holes—L. Chang and T. Chou, University of Delaware, Newark, DE

11:30 a.m.: Mechanical Behavior of Braided Composites—R. A. Simonds, W. W. Stinchcomb, and R. M. Jones, Virginia Polytechnic Institute and State University, Blacksburg, VA

12:00: Adjourn.

New ASTM Publications

Delamination and Debonding of Materials

The latest technology on the analysis, testing, and detection of the delamination of composite materials and debonding of adhesive joints is presented in a new ASTM Special Technical Publication.

STP 876, *Delamination and Debonding of Materials*, is sponsored by ASTM Committees D-30 on High Modulus Fibers and Their Composites and E-24 on Fracture Testing. Twenty-five peer-reviewed papers thematically unite these two areas.

Central to STP 876's focus is its recognition that both the delamination of composite materials and the debonding of adhesives involve the separation of materials held together by polymer resins. Another consideration given to the delamination/debonding problem is that a composite is nothing more than a complex adhesive joint that bonds together high-strength fibers in an orderly predetermined arrangement.

The papers in STP 876 are classified into three categories: stress analysis, mechanical behavior, and fractography/NDI. Aircraft, advanced structure, composite, and adhesive manufacturers can all benefit from this book.

To order STP 876, contact ASTM Customer Service Department, 1916 Race Street, Philadelphia, PA 19103, 215/299-5585. Editor: W. S. Johnson. Publication Code Number: 04-876000-33.

Multiaxial Fatigue

The international schools of thought on the behavior of materials subjected to various forms of multiaxial fatigue are discussed in a new ASTM Special Technical Publication.

STP 853, *Multiaxial Fatigue*, was developed through ASTM Committees E-9 on Fatigue and E-24 on Fracture Testing, in cooperation with the American Society of Mechanical Engineers, the American Society for Metals, and the Society of Automotive Engineers. The book provides simplified methods of analysis that are applicable to practical situations involving complex stress cycling. The introduction of stresses on two or three axes in fatigue experiments provides valuable information on micromechanisms of fatigue crack formation and growth and on the uses and limitations of multiaxial correlation factors.

STP 853 shows that significant progress has been achieved towards predicting finite fatigue failure. It also provides a useful aid in interpreting failures and understanding the mechanics of fatigue.

This book will aid designers, production engineers, failure analysts, and researchers who need to evaluate the effects of complex loading situations that frequently occur in engineering practice.

To order STP 853, contact ASTM Customer Service Department, 1916 Race Street, Philadelphia, PA 19103, 215/299-5585. Editors: K. J. Miller and M. W. Brown, University of Sheffield. Publication Code Number: 04-853000-30.

Conference Report

Forum on Composite Materials Research and Technology

A Forum For Composite Materials Research and Technology was held on the campus of George Mason University on 1 May 1985. The Forum was organized by the Composites Committee of the Southeastern Universities Research Association. Financial support was provided by the Office of Naval Research, Virginia Polytechnic Institute and State University, and the George Mason University. Other support was provided by organizations associated with the individuals involved in various committee activities as described in the Appendix of this document.

The objectives of the Forum were as follows:

- To identify issues that control the development of the composites enterprise in the United States.
- To present perspectives on these issues.
- To identify collective needs and opportunities.
- To establish consensus directions for planning and action.
- To improve our sense of community.

The Forum itself was an experiment, a first attempt to bring together three principal components of the composites community—the government, industry, and university sectors—to address not only what is being done in various technical areas, but also how and why that research and development is being done, and what issues are involved in the general enterprise. Indeed, the Forum was intended to address the general condition of composites research and technology in the United States and to identify collective needs and opportunities associated with that condition.

The greatest challenge of such an objective is to maintain a level of attention that is sufficiently general to avoid having paradigms obscured by tedia, and sufficiently specific to insure that cosmic conclusions are firmly supported by technical reality. Given that challenge, and various constraints, the Forum was organized around six principal speakers, two each from the government, industrial, and university communities. In the summer of 1984 those speakers were asked to identify critical issues to be addressed by Forum participants. When lists of those issues had been collected, a panel of discussers was appointed, and the issues were forwarded to them for their comments. The critical issues and summaries of the panel comments are enclosed in this document, along with other information associated with the Forum.

Plenary discussions were provided by the principal speakers who addressed the Forum. However, most of the afternoon was used for discussion. Panel members were called on to lead discussion on various topics, but it was the intent to hear from as many of the attendees as possible. Indeed, the number of attendees was held to a minimum to insure that an effective working discussion involving most of the participants could be conducted.

A preliminary document was circulated to all participants to provide a basis for that discussion by providing a summary of the thoughts and perspectives identified by representatives of the three primary communities. While it was hoped that this information would stimulate questions and comments from participants, it was also hoped that participants would identify issues and perspectives not addressed by the principal speakers and panel members, and give careful thought to the needs and opportunities that might be common to the group.

The following perspectives were formed as the Forum on Composite Materials Research and Technology was being planned, conducted, and discussed. The perspectives are pictures of issues whose images are formed by ideas, concepts, and facts contributed by participants in the Forum as I recounted them. A number of the associated interpretations and prejudices are (however unfortunately) my own.

As a general principle, I have always believed that it is necessary for each one of us to accept some responsibility for the direction and welfare of those enterprises and institutions with which we are concerned. That idea is one of the basic precepts of the social system in this country and it is equally true for technical institutions and activities. For a scientific/technical enterprise such as composite materials, this is an extraordinary challenge. The field of composite materials is high technology and highly interdisciplinary. In fact, in order to pursue this field we must attempt to embrace disciplinary perspectives as broad as mathematics and physics, and circumstances as diverse as material synthesis and product retirement-for-cause. The creation of successful composite systems, components, and structures requires that we fully integrate these areas and allow a creative flow of ideas in all technical directions, not just from the materials supplier to the product salesman.

While these technical issues are commonly addressed in a staggering array of technical meetings concerned with composite materials, there is considerably less attention given to the general direction of things, how it is determined, and what it should be. Moreover, it is important to establish the issues associated with our enterprise, and to determine the general opportunities for exploitation and growth of the field of composite materials and structures in the context of personal, institutional, and national interests. Finally, we need to develop a sense of community, to understand our activities and responsibilities as part of the corpus of people and events that define progress in this field. Finally, let me add a clearly labeled prejudice. It would appear that universities as a group are poorly represented in collective community activities in this field, especially those associated with planning at the national level. This is somewhat distressing since universities must bear the primary responsibility for providing a foundation of understanding and education on which we must build scientific and technical progress. Universities provide the service of education and training for the scientists and engineers of tomorrow. Their responsibility cannot be properly executed without significant interaction with other elements of the technical and scientific community.

With these generalities as a starting point, let us turn our attention to more specific matters. The Forum on Composite Materials was organized around issues which were identified by Principal Speakers, as mentioned in the Preface. These issues and a number of discussions provided by Forum participants are presented in the present document. Using that information combined with comments and discussions heard at the Forum, (and some license of interpretation allowed for the Forum Chairman) the following comments are offered.

Figure 1 provides a listing of some of the plenary issues identified at the Forum. A general summary of these issues is provided by Joe Lees, Chairman of the Recommendations Committee, as the last en-

- MATERIAL DEVELOPMENT AND CHARACTERIZATION
- INNOVATIVE EXPLOITATION
- RESOURCES FOR RESEARCH AND DEVELOPMENT
- PERSONNEL AND EDUCATION
- HOW TO WORK TOGETHER BETTER
- HOW TO DRIVE RESOURCE ALLOCATION WITH SCIENCE AND TECHNOLOGY AS WELL AS WITH ECONOMIC OPPORTUNITY
- HOW TO PRESERVE OUR UNIVERSITY RESEARCH SYSTEM, ITS' IDENTITY, ITS' DEDICATION TO THE SERVICE OF EDUCATION
- TECHNOLOGY / INFORMATION TRANSFER
- EXISTING TECHNICAL, EDUCATIONAL INFRASTRUCTURE
- ECONOMIC VS. MILITARY TECHNOLOGY FOCUS
- INDIVIDUAL INITIATIVES, RESPONSIBILITIES
- DEFINITION OF PROPERTIES, RELATIONSHIP TO PERFORMANCE

FIG. 1—*Plenary issues.*

try in this document. While several of the specific issues overlap, several categories of concern can be discerned. One category has to do with the development and characterization of materials. Composite material development in the United States is conducted by a relatively small number of corporate laboratories which face intense international competition, limited financial support, poor transfer of information, insufficiently detailed definitions of long-term goals, and innumerable constraints including those imposed by various government agencies. Inadequate characterization of material systems, even those commonly available, frequently makes even a definition of those systems nebulous, a design of components or structures based on material properties difficult, and the design level predictions of long-term performance of composite components much more of an art than a science. There was a clear identification of the issue of (need for) a much stronger organizational interaction between the university, government, and industrial communities. At the same time, it was recognized that the specific roles of these communities, and their identities, need to be preserved and strengthened rather than merged and weakened. There was a considerable amount of discussion regarding the focus of technological development, especially along two major lines loosely defined as an economic focus and a military technology focus. The point was clearly made that the best interests of those two foci are not always served by the same activities, cost being the most obvious factor which separates the two objectives. This last matter is of very great consequence to the development of optimization philosophies, which are so critical to the successful design, development, and exploitation of composite material systems. Another issue and concern defined by the Forum participants was the need for highly technical personnel. This issue has to do not only with education and training but also with reeducation and retraining. Comprehensive composite education and training programs exist in only a small number of universities in the United States; that number must be increased. At the same time, the need for large scale university research programs which address specific classes of technical problems associated with composite materials and structures was also identified. Finally, various organizational structures and infrastructures at the national level were discussed and proposed to serve the general purpose of identifying scientific and technical opportunities in the national interest.

In the course of discussion of these and other issues, a variety of points were made which were peculiar to the three communities involved—industry, government, and universities. I have summarized these points in a series of figures divided into two categories—opportunities and needs. Figure 2 summarizes some of the opportunities discussed for industry. It is no surprise that the role of industry was clearly identified as the developer of technology for specific applications. Certainly short-term interests are defined by these immediate applications and associated objectives. However, it is somewhat surprising to find that a significant portion of the industrial community is attempting to identify long-term opportunities and objectives. This is particularly true of material suppliers, but this terminology leads us to another very important point. The industrial community of composite material suppliers is undergoing a dramatic and dynamic change. This change is best illustrated by the example of companies that used to regard themselves as being in the "chemical business" who now regard themselves as being in the "composite materials and components business." This is another reflection of the need for integration of technologies and disciplines for the successful development and use of composite materials.

Figure 3 identifies several needs associated with industrial activity as identified by the Forum. Most of these needs are self-evident, but the last item on the list bears special mention. There are some elements of similarity in the details of transfer of research technology associated with composite materials and the circumstances associated with the "semi-conductor revolution" experienced in this country over the last 10 to 15 years. One similarity is the fact that opportunities for exploitation and application of composite materials appear to be almost unlimited. Another similarity is that technology is moving more quickly than the associated science. The author is aware that throughout recorded history art has always led science. Such is the nature of man. However, building large expensive technological structures on small foundations of understanding is inherently an unstable enterprise subject to great dangers and many unexpected events. If the failure of large composite structures is to be avoided, the details associated with such failures must be understood not just described; nothing can be reliably avoided that cannot be reliably predicted. In view of the complexity of composite materials, there is a growing realization that the industrial community

- DATA BASE DEVELOPMENT AND EXCHANGE
- TECHNOLOGY DEVELOPMENT
- PRODUCT INNOVATION
- IDENTIFICATION OF PERFORMANCE LIMITS AND CONSTRAINTS
- CONTEXT FOR IDENTIFYING SHORT-TERM PRIORITIES AND LONG-TERM OPPORTUNITIES

FIG. 2—*Industry opportunities.*

- STANDARDIZATION
- LOWER COST MATERIALS AND MANUFACTURING
- TRANSPORTABLE DATA BASES
- PERSONNEL AT ALL LEVELS
- RETOOLING AND RETRAINING
- COMPREHENSIVE DATA FOR PROPERTIES AND RESPONSE (VARIOUS ENVIRONMENTS, DYNAMIC, LONG-TERM)
- TRANSFER OF UNIVERSITY (OTHER INSTITUTIONAL) RESEARCH TO TECHNOLOGY

FIG. 3—*Industry needs.*

(along with everyone else) must actively pursue and support research and vigorously pursue the transfer of the results of that research to the technological objectives at hand.

The list of government opportunities given in Fig. 4 is deceptively short. Several of the list items are extremely broad and pervasive. Certainly the government agencies must bear a major responsibility for the encouragement and support of research and development from the basic to the applied levels, given our national organization of the scientific community. In particular, it would be difficult for any other organization to foster large-scale programs which involve multiple institutional participants. Obviously the government is responsible for defining certain long-term national needs. And as the largest sponsor of research, the government is a natural repository and distributor of information and perpetrator of technology transfer. However, assignment of other general responsibilities beyond these levels is surprisingly difficult. It is not at all clear that the government should assume the role of a technical coordinator at the most general level. Nor is it clear that the present organizations and institutions associated with the government are or would be capable of conducting such a total coordination. It should be noted that there are counter examples to this observation in other countries where, for example, a specific ministry is assigned the responsibility of coordinating all research in that country associated with composite materials and structures, and collecting and disseminating information associated with that research. In the United States, the most noticeable national leadership at the general level appears to

- LARGE-SCALE, MULTIPLE PARTICIPANT INITIATIVES
- DEFINE LONG-TERM NATIONAL NEEDS
- TECHNOLOGY TRANSFER
- SUPPORT OF R&D FROM BASIC TO APPLIED LEVELS

FIG. 4—*Government opportunities.*

be associated with regulations which constrain information exchange and control the nature of information export for many subjects associated with composite materials. This latter subject was the basis of much intensive discussion at the Forum.

Figure 5 reflects the question of whether the government should indeed develop a general policy for composites research in the United States, and focuses on the need for help from the government in our effort to forge a strong relationship between the government-university-industry communities. Another need identified with the government was a need for a certification philosophy and, in particular, the need to identify an appropriate approach to the determination and specification of the reliability of composite structures. This is a particularly acute challenge for composite materials and structures since so many factors play a significant role in reliability considerations.

Figure 6 lists opportunities associated with university institutions. The university community must assume primary responsibility for basic research and education, and secondary responsibility for applied research and training. More than any other institution, universities must take (and must be able to take) a long-term view of the development and dissemination of knowledge. They must be able to address high-risk high-payoff technical objectives of a general or specific nature. They must also be free to provide the service of education with the objective of developing the comprehension and understanding of individuals. At the same time, universities must provide the opportunity for the development of certain skills, an activity

- COMPOSITES POLICY OBJECTIVES, PLAN FOR GOVERNMENT-UNIVERSITY-INDUSTRY EFFORT)
- CERTIFICATION PHILOSOPHY
- RELIABILITY PHILOSOPHY
- COMPREHENSIVE DATA (STATISTICALLY SOUND)

FIG. 5—*Government needs.*

- LONG-TERM GENERIC RESEARCH (HIGH-RISK, HIGH-PAYOFF, RIGID SCIENCE / TECHNOLOGY)
- TECHNICAL / ACADEMIC BREADTH (SUPPORT OF DEVELOPMENT)
- SERVICE OF EDUCATION
- COORERATIVE R&D (UNIVERSITY-GOVERNMENT-INDUSTRY)
- COMPREHENSIVE CHARACTERIZATION
- CONCEPTUAL SYNTHESIS (PHILOSOPHY)
- ACCELERATE TECHNOLOGY

FIG. 6—*University opportunities.*

commonly called training. However, in general, education must be viewed as a service; universities must not be asked to "produce a product" or we will do our country and ourselves the disservice of producing a mass of mioptic specialists who have no comprehension or understanding of themselves, of others, or of the world around them. One of the new horizons discussed at the Forum for the university community was a rapidly growing role in the development of technology. Universities are forming new and substantial relationships with government and industrial laboratories and playing a significant role in the acceleration of technology. This is easily the most rapidly growing and most dramatic facet of the university community in the present context at this time. At the same time, it was recognized that this new role presents an enormous challenge to faculty and administrative groups who are traditionally not well prepared and frequently poorly organized to function in this capacity.

Figure 7 lists a few salient needs identified by the discussions at the Forum. In general, universities are able to provide only a modest amount of support for research activities. As a consequence, major research expenditures, such as those associated with modern equipment, must usually be sustained from outside grants and contracts. This is an acute and continuing need. However, perhaps the most serious and pressing need in the university community is the need for a larger number of technically strong (and highly motivated) faculty members, staff members, and students (especially graduate students) for programs in composite materials and structures. Actually, this pressing need is not peculiar to the field of composite materials and structures. It is endemic to the engineering community in the university system. Nevertheless, it is a pressing national need. Another matter identified at the Forum had to do with the need for sustaining support. Universities suffer a particularly severe loss of faculty time and effort associated with the yearly pursuit of research funding and the crush of administrative detail associated with the large number of relatively small contracts normally granted to a majority of university investigators. In the opinion of the author, this is a truly suicidal system. It has the archane feature of most severely penalizing those who are most successful at identifying research support and conducting research. This situation contributes to another need identified by the Forum, the last item on the list in Fig. 7. Universities have a growing tendency to reward entrepreneuralship among their faculty members. A consequence of this is the fact that we are "raising a generation" of faculty members with a Pavlovian-type tendency to pursue dollars and an incidental or nonexistent tendency to pursue understanding.

Figure 8 lists a summary of some of the major obstacles that were identified during the Forum. Certainly the single most obvious obstacle is cost: cost of materials, processing, manufacturing, repair, and design of composite materials and structures. However, a significant part of this obstacle appears to be the common lack of generality of approach to this problem. In many cases, significant advantages and opportunities can be identified if total life cycle cost considerations are included in such an analysis. Another general obstacle identified was the basic nature of the response of many composite material systems. Many systems currently in use and those planned are "brittle" in the sense that their strain to failure is small. In addition, these systems are generally complex so that it is usually difficult to generate understandings and philosophy, which can be used to predict long-term strength, stiffness, life, and reliability of structures constructed from these materials. In another vein, the current policies on export control of information associated with composite material systems was identified as an obstacle in many regards. An interesting aspect of this issue has been identified by recent studies, which indicate that, in general, export controls tend to suppress the foreign sales of rélated hardware items. Another interesting issue highlighted by the Forum had to do with a contrast in the direction and focus of research activities between the immediate application of composite material systems to high technology hardware and the thrust of fundamental research aimed at broadening understandings of present material systems and developing new ones. While this subject was not well developed by the Forum, it is clear that there is at least a gentle struggle between what is sometimes called "high tech hype" and basic or fundamental research. Another issue had to do with the fact that many new material systems cannot be manufactured in sufficient volume and with sufficient reproducibility of properties to support general applications, and indeed, the development of new material systems is greatly dependent upon the development of appropriate manufacturing processes. This is especially true for the new categories of high temperature composites. Finally, one of the salient obstacles identified was the current infrastructure associated with science and technology which was developed primarily for other materials such as common metals, and not easily adapted to the development and application of composite material systems. Perhaps the most difficult aspect of that obstacle has to do with the highly compartmentalized nature of that infrastructure whereby communication is inhibited between people who are

- EQUIPMENT
- PEOPLE (FACULTY, STAFF, STUDENTS)
- SUSTAINING SUPPORT
- FREEDOM OF PURSUIT (ABNORMAL EXCELLENCE)
- PROTECTION OF ACADEMICS FROM ENTREPRENEURALSHIP

FIG. 7—*University needs.*

- COST - MATERIAL, PROCESSING, MANUFACTURING, REPAIR ...
- "BRITTLE" RESPONSE - IMPACT, RELIABILITY, SENSITIVITY TO DAMAGE
- NO SCIENCE OR WELL GROUNDED TECHNOLOGY OF FAILURE ANALYSIS, OR DAMAGE TOLERANCE
- EXPORT CONTROL AND RELATED REQUIREMENTS
- STRUGGLE BETWEEN "HIGH-TECH HYPE" AND BASIC SCIENCE, FUNDAMENTAL RESEARCH
- MANUFACTURING PROCESSES, TECHNIQUES, AUTOMATION
- TRADITIONAL INFRASTRUCTURE DEVELOPED FOR OTHER MATERIALS

FIG. 8—*Major obstacles.*

associated with different aspects of composite material development and application.

Figure 9 presents a partial listing of consensus directions that were identified at the Forum. Like the other figures before it, no attempt has been made to be complete, that is, to include all of the details associated with the Forum or with the material submitted in support of that meeting. Salient directions however are provided in Fig. 9 as perceived by the writer in association with the Forum activities. The general trends associated with the list are particularly interesting. Many parts of the general field of composite materials can be said to be in a "building mode." Not only composite components but large composite structures, which have a primary function in common engineering devices such as vehicles, are being designed and built. Because of that, attendant issues, such as manufacturing of large-scale parts, component and structural durability, long-term behavior, life prediction, reliability, and certification, are becoming more prominent features of the technical landscape. There is every indication that this applications' thrust will continue and broaden. In this context, there is also a trend for growth in highly specialized areas such as high temperature applications and other specialized environments. In addition, applications which are peculiar to the tailored response, which can only be obtained with composite materials, are a particularly exciting growth direction. The forward-swept wing X-29 Grumman aircraft is an example of this type of application. In this association, another consensus direction of growth appears to be optimization, especially integrated optimization based on material-component-structural (performance) relationships motivated by long-term performance goals and cost. It appears likely that artificial intelligence activities are going to make a major impact on this particular area. There also appears to be a strong growth into the area of comprehensive characterization including efforts to establish not only properties of materials and material systems but also performance characteristics such as strength, stiffness, life, vibration response, and so forth. It is also clear that a major growth direction has to do with the corresponding growth in the capability and availability of computational hardware. The use of a variety of systems from mainframes to personal computers is bringing the level of analysis applied to composite materials and components up to a point where more complete and correct information about stress and strain distributions and even strength degradation can be used to design better and more reliable products. This particular growth area has also made a major impact on the educational community where the use of computers, especially personal computers, has greatly facilitated the introduction of courses dealing with composite materials, even at the undergraduate level. Even at this writing, codes are available which can be used to conduct three-dimensional static, transient, or steady state dynamic finite-element analysis of composite components with complex shapes which run on desktop personal computers. This is indeed a revolution that will certainly continue.

- PROCESSING AND MANUFACTURING SCIENCE - SMART SYSTEMS, QA AND NDT & E (IN PROCESS), ROBOTICS, AUTOMATION
- COMPONENT DURABILITY, LIFE PREDICTION, DAMAGE TOLERANCE, LONG-TERM RESPONSE
- FAILURE MODE CONTROL - TOUGHNESS, STRENGTH IN COMPRESSION, "BUILT-IN" FAILURE MODES, DESIGN FOR SECONDARY STRESSES
- HIGH TEMPERATUE MATERIALS
- REPAIR - SUPPORTABILITY
- JOINING TECHNOLOGY
- IN-SERVICE MONITORING - NDT & E, LARGE-SCALE SCANNING, INTERPRETATION
- MATERIAL-COMPONENT OPTIMIZATION BASED ON LONG-TERM PERFORMANCE GOALS
- COMPREHENSIVE CHARACTERIZATION - STRENGTH, STIFFNESS, LIFE, VIBRATION (DAMPING), TEMPERATURE / ENVIRONMENT, RELIABILITY (SAFETY), ECONOMY, CRASH WORTHINESS, ...
- ENGINEERED MICROSTRUCTURE - USE OF BRITTLE (HIGH TEMPERATURE) ABUNDANT ELEMENTS
- THREE-DIMENSIONAL APPROACH TO ANALYSIS, DESIGN, EVALUATION AND EXPLOITATION OF COMPOSITES

FIG. 9—*Consensus directions.*

It is difficult to summarize a field as diverse as this one. However, the Forum left the writer with several general impressions concerning the direction of development of the field of composite materials and structures. One has the feeling that we are moving from a position of "bragging to building," from highly compartmentalized design to integrated and optimized design, from "performance at any cost" to "lifetime" cost effective commercial exploitation. There is every indication that we are moving in the direction of a highly specialized material system design based on sophisticated algorithms, comprehensive mechanics analysis, and comprehensive characterization of the long-term response of material systems and components. Composite materials present us with the greatest opportunity in the history of man and his technical activities to tailor the properties and performance of manmade material systems to the specific engineering objectives of components and structures. In many regards, this opportunity has opened up a new era of science and technology, an era in which successful engineering will require the intensive integration of classical disciplines, in which creative synthesis and innovation must be fueled and supported by rigorous analysis, in which we must learn to recognize paradigms that may be obscured by great complexity and tedia, and in which our national economy and safety depends on our technical ability to produce composite materials and structures with superior performance at reasonable cost.

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Forum Chairman and Coeditor

Composites Contents

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

Introduction

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

- Journal of Composite Materials
- Journal of Reinforced Plastics and Composites
- Composites
- Composites Science and Technology
- Polymer Composites
- Composite Structures
- Journal of Materials Science
- Mechanics of Composite Materials (USSR)
- Experimental Mechanics
- Experimental Techniques
- Journal of Engineering Materials and Technology
- International Journal of Cement Composites
- Journal of Sound and Vibration
- International Journal of Solids and Structures
- Shock and Vibration Digest
- AIAA Journal
- SAMPE Journal
- SAMPE Quarterly
- Journal of Applied Mechanics
- International Journal of Fracture
- Engineering Fracture Mechanics
- Computers and Structures

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

Dr. Ronald F. Gibson, *Contents Editor*
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AIAA Journal

Composites

Fibre Science and Technology

Vol. 21, No. 4, 1984

International Journal of Cement Composites and Lightweight Concrete

Vol. 6, No. 3, Aug. 1984

Vol. 6, No. 4, Nov. 1984

Vol. 7, No. 1, Feb. 1984

Vol. 7, No. 2, May 1985

International Journal of Solids and Structures

Vol. 20, Nos. 9&10, 1984

Journal of Materials Science

Vol. 19, No. 12, Dec. 1984

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Analysis of Cellulose Networks by the Finite Element Method—M. Rigdahl, B. Westerlind and H. Hollmark, pp. 3945-3952
Reinforcement of Polyethylene With Polypropylene by a Blending and Deformation Process—E. S. Sherman, pp. 4014-4020
Effect of Temperature on the Strength and Fatigue Behavior of Optical Fibres—J. E. Ritter, Jr., G. S. Glaesemann, and K. Jakus, pp. 4087-4092
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Vol. 16, No. 2, Jan. 1985

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Vol. 17, No. 1, Jan. 1985

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17-18 April 1986
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Columbia, SC
Contact: Sectam III, Office of Continuing Engineering Education, College of Engineering,
University of South Carolina, Columbia, SC 29208

27-31 April 1986
Composite Materials Testing and Design: 8th Symposium
Charleston, SC
Contact: John D. Whitcomb, MS 188E,
NASA Langley Research Center, Hampton, VA 23665;
Telephone: 804-865-3012

19-21 May 1986
27th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Materials Conference
San Antonio, TX
Contact: AIAA, 1633 Broadway, New York, NY 10019

25-29 May 1986
International Conference on Computational Mechanics
Tokyo, Japan
Contact: Prof. G. Yagawa, Department of Nuclear Engineering,
University of Tokyo 7-3-1, Hongo, Bunkyo-ku,
Tokyo 133, Japan

8-12 June 1986
SESA Spring Conference on Experimental Mechanics and Exhibit
New Orleans, LA
Contact: SESA, 14 Fairfield Dr., Brookfield Center, CT 06805;
Telephone: 203-775-6373

10-13 June 1986
International Symposium on Composite Materials and Structures
Beijing, China
Contact: C. T. Sun, School of Aeronautics and Astronautics,
Purdue University, West Lafayette, IN 47906;
Telephone: 317-494-5130

23-25 June 1986
The Third Japan-U.S. Conference On Composite Materials
Tokyo, Japan
Contact: J. R. Vinson and M. Taya, University of Delaware
(302-451-2246) or Prof. K. Kawata and A. Kobayashi,
Institute of Interdisciplinary Research,
University of Tokyo, 4-6-1, Komaba, Meguro-ku
Tokyo 153, Japan

2-5 Sept. 1986
3rd International Conference on Computational Methods and Experimental Measurements
Porto Caras, Greece
Contact: Dr. G. A. Keramidas, Naval Research Laboratory,
Code 5841, Washington, DC 20375;
Telephone: 202-767-3389

10-11 Sept. 1986
Joining and Repair of Fibre-Reinforced Plastics
London, United Kingdom
Contact: Mr. F. L. Matthews, Aeronautics Dept.,
Imperial College, Prince Consort Rd.,
London S27 2BY, United Kingdom;
Telephone: 91 589-5111 X 4003

16-19 Sept. 1986
EUROMECH 214: The Mechanical Behavior of Composites and Laminates
Dubrovnik, Yugoslavia
Contact: Prof. M. Micunovic, Faculty of Mechanical Engineering, University "Svetozar Markovic," 34000 Kragujevac, Yugoslavia

22-25 Sept. 1986
1st World Congress on Computational Mechanics
Austin, TX
WCCM/TICOM Continuing Engineering Studies,
Cockrell Hall 10.324, University of Texas,
Austin, TX 78712;
Telephone: 512-471-3506

2-5 Nov. 1986
SEM Fall Conference and Exhibit: Optical Methods in Composites
Keystone, CO
Society of Experimental Mechanics, 14 Fairfield Dr.,
Brookfield Center, CT 06805;
Telephone: 201-775-7373

7-12 Dec. 1986
ASME Winter Annual Meeting
Anaheim, CA
Contact: ASME, United Engineering Center,
345 E. 45th St., New York, NY 10017

5-10 Jan. 1987
2nd International Conference on Constitutive Laws for Engineering Materials
Tucson, AZ
Contact: C. S. Desai, University of Arizona,
Department of Civil Engineering and Engineering Mechanics,
Tucson AZ 85721;
Telephone: 602-621-6569

15-20 Nov. 1986
ASME Winter Annual Meeting
New York, NY
Contact: ASME, United Engineering Center, 345 E. 45th St.,
New York, NY 10017

21-27 Aug. 1988

17th International Congress of Theoretical and Applied Mechanics
Grenoble, France
Contact: Prof. Germaine, Ecole Polytechnic, Paris, France

Calendar prepared by Prof. Michael W. Hyer,
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The University of Maryland,
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