Overview

Structural fatigue, or simply, *fatigue,* has been of interest to civil and mechanical engineers, materials scientists, applied mathematicians, plant managers, and the public for a long time. In 1978, at the ASTM International Symposium on Fatigue Mechanisms held at Kansas City, Missouri, an *ad hoc* estimate was made of the annual world-wide cost of fatigue testing and research at about one billion 1978 U.S. dollars (*see* pp. 730–731, *ASTM STP 675*).

Undoubtedly, most of that effort each year is on fatigue testing with perhaps only a few percent of that effort on research. Nevertheless, the total effort on fatigue research over a period of, say, 20 to 30 years, may be looked upon as a sizable investment by both the private and the public sectors to the tune of many thousands of person-years. At that level of effort, members of the public, the technical community, and the next generation of engineers and materials scientists about to enroll in a course on fatigue, have a right to ask some obvious questions on the state of fatigue research such as:

(*a*) Has the concept of fatigue evolved over the past 30 years from an empirical subject of engineering practice to a well-defined discipline of materials science?
(*b*) Are the methodologies of fatigue research sufficiently scientific to yield a core of knowledge known as "fatigue science?"
(*c*) Are the current procedures for predicting the fatigue lives of structures in ordinary and severe environments based on sound theories and credible experiments?

In an attempt to shed some light on this and to ascertain whether there indeed existed a "scientific basis" of fatigue, the ASTM Committee E-9 on Fatigue initiated as early as 1982 the planning of a unique 5-day international symposium entitled:

"Fundamental Questions and Critical Experiments on Fatigue."

The symposium was held in October 1984 at Dallas, Texas, and was attended by over 250 researchers, engineers, and managers from 14 countries. Co-sponsoring the symposium were the ASTM Committee E-24 on Fracture and the U.S. National Bureau of Standards (NBS).

The symposium consisted of a 3-day workshop (18–20 Oct.) at Arlington, a suburb of Dallas, and a 2-day conference (22–23 Oct.) at Dallas, Texas, during a scheduled Committee Week of ASTM. Of the 43 contributed papers that were presented, 37 manuscripts were eventually submitted for inclusion in the two-volume proceedings. The papers in these two volumes represent the bulk of deliberations by some of the most distinguished and knowledgeable researchers from the international fatigue community.

To appreciate the significance of these papers, it is useful to recall some of the statements made in the original Call for Papers. In that document, which was released in the summer of 1983, potential contributors were advised that the symposium was a *new forum* designed

for researchers to meet and exchange *not necessarily* their recent results, as would normally be expected of them at traditional symposia, but rather their *burning questions* on some aspects of fatigue so long as the questions were "basic" and were aimed toward a better understanding of fatigue.

To guide the contributors in preparing their abstracts, the Call for Papers stipulated that each abstract must contain the following items:

1. A clear statement of the fundamental question and its importance.
2. A well-defined critical experiment to answer, unequivocally, the question posed.
3. Measurements to be made in the proposed critical experiment.

The goals of the symposium, as stated in the Call for Papers, were:

Goal 1—To Advance the Understanding of Fatigue

By emphasizing the coupling of fundamental questions with critical experiments, the multidisciplinary nature of fatigue may be brought into sharper focus in order to accelerate the understanding of fatigue in the following four subareas (for both metals and nonmetals):

1. Nucleation of fatigue damage.
2. Transition between nucleation and propagation.
3. Propagation of fatigue damage.
4. Environmental effects.

Goal 2—To Lay the Foundation for a Scientific Basis of Fatigue

Invited researchers from around the world will contribute open questions and critical experiments, including new results, for an intensive discussion and debate, thereby providing the framework for a scientific basis.

Goal 3—To Mold a Consensus on Research Priorities

Leading experts and practicing engineers will discuss and debate on the merits of a list of open questions and ideas for experiments. It is expected that a consensus on research priorities may be reached in time for inclusion in the symposium proceedings to guide the research direction of major fatigue laboratories.

To achieve the goals of the symposium, the Program Committee adopted a 3-part format for each accepted paper, namely: (i) presentation, (ii) invited official discussion, and (iii) general discussion. To preserve a continuity in technical discussion and debate leading to a consensus on a scientific basis of fatigue, the Committee also adopted a policy of not scheduling any parallel sessions.

Both the format and the single-session policy placed a severe restriction on the number of papers that could be scheduled in the final program. For a 10-session symposium lasting a total of 5 days, the upper bound of that number was somewhere between 40 and 50. This was about half of the 96 questions submitted to the Program Committee from authors of 14 countries (Austria, Canada, China, Finland, France, F.R. Germany, Italy, Japan, Korea, Sweden, Switzerland, U.K., U.S.A., and U.S.S.R.).

Fortunately, a good number of researchers were still able to contribute as invited official discussors. This led to a new activity of the Program Committee by introducing the concept of an *open preview*, where the extended abstract of every accepted paper was reviewed by

two or more invited discussers, and both the abstracts and the discussers' comments were sent to all pre-registrants one month before the meeting in the form of a 426-page symposium preview. This had the advantage that by the time the symposium opened, most of the participants had already digested the pros and cons of the relevance of each fundamental question and were able to zero in on the central issues of each paper as soon as it was presented.

So much for the background of the symposium. The two-volume proceedings is divided into eight sections of which five are in Volume I and three in Volume II. In the section on Introductory Remarks, we include the "Historical Account of the Symposium" by Dr. J. T. Cammett, then Chairman of ASTM Committee E-9. There are also two other remarks, one on "The International Role of ASTM" by Dr. D. R. Johnson of NBS, then a member of the Board of Directors of ASTM, and the other on "Experimentation and Measurement" by Dr. H. H. Ku, then Chief of the NBS Statistical Engineering Division.

In the next two sections, the questions of nucleation of fatigue damage in single crystals and polycrystals are addressed, with principal emphasis on the observation of damage at the microstructural level. Following these are sections dealing primarily with the role of mechanical variables on fatigue crack growth in ferrous and nonferrous alloys, and focus attention at the continuum level. This completes the contents of Volume I with three opening remarks and 20 contributed papers.

The remaining 17 contributed papers appear in Volume II, where the topics of research are more complicated, and the state of knowledge is very much in the formative stage. In the first section, the complex interactions associated with combined fatigue and creep damage are considered. The next section, by far the largest group of papers, deals with the questions of environmental effects. The last section contains the only papers that address fatigue of nonmetals. (It is recognized that fatigue research on nonmetals is customarily reported through a different forum.)

The 5-day symposium was well received and enthusiastically attended. The open preview concept, the single-session policy, and the 3-part presentation format, were most often cited as the principal factors in keeping everyone interested in the debate. The three questions posed earlier in this review were addressed throughout the symposium, and the final consensus appeared to be:

(*a*) The concept of fatigue did evolve over the last 30 years from an empirical subject of engineering practice to a well-recognized topic of materials science research, but the evolution fell short of reaching the goal of a mature discipline.

(*b*) The methodologies of fatigue research vary among researchers with some sufficiently scientific but others less so. A core of knowledge known as "fatigue engineering" already exists, but what may pass as "fatigue science" is yet to emerge.

(*c*) The current procedures for predicting the fatigue lives of structures in ordinary and severe environments are still based on a combination of empirical data, plausible theories, and experts' judgment. The day of making predictions from sound theories, credible experiments, and operational data, is still very much in the future.

The real value of the symposium lies in the searching questions and the critical experiments that are carefully laid out in these two volumes for the next generation of fatigue researchers to take advantage of. It is hoped that in a decade or two when we meet again to take stock of what we know, most of the questions listed in this book would be either fully or partially answered to yield a truly scientific basis of fatigue.

It gives us great pleasure in acknowledging the tremendous help and cooperation we received from hundreds of researchers all over the world in making this symposium a reality.

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