FRETTING FATIGUE

Current Technology and Practices

David W. Hoeppner
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EDITORS

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David W. Hoeppner, V. Chandrasekaran, and Charles B. Elliott III, editors

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Foreword

This publication, Fretting Fatigue: Current Technology and Practices, contains papers presented at the symposium held at the University of Utah, Salt Lake City, Utah on Aug. 31, 1998. The symposium was sponsored by University of Utah, United Technologies Research Center, MTS Systems Corporation, FASIDE International, INC. and co-sponsored by Committee E8 on Fatigue and Fracture. The symposium was chaired by David W. Heoppner, V. Chandrasekaran, and Charles B. Elliott III served as co-chairmen. They all served as STP editors of this publication.

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Overview

The Second International Symposium on Fretting Fatigue was held at the University of Utah August 31–September 2, 1998. This symposium was held to continue the exchange of information on the subject of fretting fatigue that was accelerated within the ASTM Symposium on *Standardization of Fretting Fatigue Methods and Equipment* held in San Antonio, TX on November 12–13, 1990 (see *ASTM STP1159* edited by Attia and Waterhouse, ASTM, 1992) and the International Symposium on Fretting Fatigue held at the University of Sheffield in April, 1993 (see *Fretting Fatigue*, ESIS Publication 18, edited by Waterhouse and Lindley, 1994). The contribution of fretting to nucleating fatigue failures, often well before they were expected to occur is well known now even though the phenomenon had not been formally identified until the 20th century. A great deal of progress dedicated to understanding the phenomenon of fretting fatigue has occurred within the past century. Thus, this symposium was organized to focus on the progress and to continue the extensive interchange of ideas that has occurred—particularly within the past 50 years.

Fifty-six delegates from ten countries attended the symposium to present papers and participate in lively discussions on the subject of fretting fatigue. The attendees included Dr. Waterhouse and Dr. Hirakawa who did pioneering research and development from the 1960's to the present. Technical leaders in the area of fretting fatigue were in attendance from most of the leading countries that are currently involved in fretting fatigue research, development, and engineering design related matters as well as failure analysis and maintenance engineering issues. ASTM Committee E08 provided the ASTM organizational support for the symposium. The collection of papers contained in this volume will serve as an update to a great deal of information on fretting fatigue. It contains additional contributions that may prove useful in life estimation. More applications of these methods are required. The damage mapping approach presented in some of the papers should assist the community in developing more understanding of fretting fatigue and also provide significant guidance to developing fretting fatigue design methods, and prevention and alleviation schemes. This volume thus serves engineers that have need to develop an understanding of fretting fatigue and also serves the fretting fatigue community including both newcomers and those that have been involved for some time.

The Symposium was sponsored by the following organizations: 1) The Quality and Integrity Engineering Design Center at the Department of Mechanical Engineering at the University of Utah—Dr. David Hoeppner—contact. 2) MTS Systems Corporation—Mr. Arthur Braun—contact. 3) United Technologies Research Center (UTRC)—Dr. Donald Anton—contact and 4) FASIDE International Inc.—Dr. David Hoeppner—contact.

All of the above organizations provided valuable technical assistance as well as financial support. The Symposium was held at the University Park Hotel adjacent to the University of Utah campus. Many of the delegates took part in pre- and post-symposium tours of area National Parks and other sites. Sally Elliott of Utah Escapades, Part City, UT, coordinated the activities and program.

The organizing committee was formed at the conclusion of the International Symposium of Fretting Fatigue held at the University of Sheffield in Sheffield, England April 19–22, 1993. The committee members were: Dr. David Hoeppner, P.E., Chair (USA), Dr. Leo Vincent (France), Dr. Toshio Hattori (Japan), Dr. Trevor Lindley (England), and Dr. Helmi Attia (Canada). Forty papers were presented and this volume contains 36 of those papers.

At the conclusion of the symposium the planning committee for the next two symposia was formed. Dr. Mutoh of Japan will coordinate and chair the next meeting with support from the fretting fatigue community of Japan. Another symposium will be held a few years after the Japan symposium in France with Dr. Vincent as coordinator and chair.

Editing and review coordination of the symposium was done with the outstanding coordination of Ms. Annette Adams of ASTM. The editors are very grateful to her for her extensive effort in assisting in concluding the paper reviews and issuing this volume in a timely manner.

The symposium opened with remarks by the symposium chair. Subsequently, Dr. Robert Waterhouse gave the Distinguished Keynote Lecture. A session of six keynote papers followed the paper of Dr. Waterhouse and is included as the Background Section in this volume.

The papers enclosed in this volume cover the following topics: Fretting fatigue parameter effects, environmental effects, fretting fatigue crack nucleation, material and microstructural effects, fretting damage analysis, fracture mechanics applied to fretting fatigue, life prediction, experimental studies, surface treatments, and applications.

The symposium involved the presentation of methods for studying the phenomenon and for analyzing the damage that fretting produces. It is now very clear that fretting is a process that may occur conjointly with fatigue and the fretting damage acts to nucleate cracks prematurely. More evidence of this is presented in the papers presented in this volume. Although a few laboratories are expending significant efforts on the utilization of fracture mechanics to estimate both the occurrence of fretting fatigue and its progression, there was lively discussion of when cracks are actually nucleated during the fretting fatigue process. As with many of the symposia held on topics related to fatigue over the past 40 years, part of the problem stems from the use of the conceptual view on "initiation of cracks" rather than on the processes by which cracks nucleate (e.g., fretting), and grow in their "short or small" stage and in their long stages where LEFM, EPFM, or FPFM are directly applicable. Even though ASTM committee E 8 has attempted to have the community use the term crack formation or nucleation rather than initiation, this symposium had several papers that persist in this conceptual framework and thus a great deal of discussion centered on this issue. As well, some investigators simply substitute the word nucleation or formation for "initiation." This also resulted in lively discussion at the Symposium, and readers of this volume will find this aspect most interesting. The papers will, when taken as a whole, assist the community in expanding our understanding of fretting fatigue a great deal. This will undoubtedly assist engineers in both the prevention and control of fretting fatigue and in formulating standards to deal with experimentation related to it in the future.

Extensive progress has been made in understanding the phenomenon of fretting fatigue. Even though analytical techniques have emerged to assist in life estimation for fretting fatigue and the analytical techniques also provide guidance for alleviation of fretting fatigue, it is still necessary to conduct experiments to attempt to simulate the fretting fatigue behavior of joints. New experimental techniques have emerged that allow characterization of fretting fatigue in much greater detail than at any time previous to this and new testing techniques are emerging. A standard to assist in development of fretting fatigue data still has not emerged, but one of the participating countries has made an effort to attempt to develop a standard. As well, a manual of standard terminology for fretting fatigue still has not emerged. ASTM E 8 was asked by the planning committee to ask their fretting fatigue subcommittee to undertake to develop the list of terms and phrases and come up with a manual of these within the next two years—hopefully, before the next symposium in Japan.

Several papers dealt with the application of fracture mechanics to fretting fatigue. This is not new but some newer computational models are discussed, and these applications provide a means by which to manage the occurrence of fretting fatigue induced cracks in practice. Thus, the crack propagation portion of cracks induced by fretting is manageable as was shown in works as early as 1975. Some papers herein provide additional insight into the application of fracture mechanics to fretting fatigue. One of the areas that has not received as much interest and study as it should is the area of

surface treatments (coatings, self-stresses, diffusion layers, and implanted layers, etc.). This is regrettable since one of the most important ways to prevent fretting degradation is to provide a change in the surface behavior. Hopefully, more effort will be expended on this aspect, and more results will be presented at the next symposium. It is suspected that the scientific community of the USA, for example, does not view this as a new science area to be studied. If this is true and extends to other countries, this would slow the development of fretting fatigue prevention schemes. Another area that has not received anywhere near the attention needed, even though Waterhouse and Hoeppner both have emphasized the need for additional effort and study to adequately understand the phenomenon, is the area of environmental effects on fretting fatigue. The review of this subject by D. Taylor in the 1993 discussed this issue in depth but little progress seems to have occurred in this area. This is regrettable since it is very likely that the environmental (both chemical and thermal) contribution to fretting fatigue is substantial. Thus, more effort needs to be directed at this area in the future.

Work in France, Japan, and two US laboratories (UTRC and the University of Utah) is progressing on a more holistic, systems oriented approach to fretting fatigue. This includes damage characterization during the process, the development of fretting maps and/or damage maps, attempting to characterize the physics of the crack nucleation and propagation processes as well formulate mechanics based formulations of life estimation. These papers are reflected in this volume. It is clear that additional progress will be made in the next several years to assist the engineering and science community in understanding and dealing with fretting fatigue. The papers contained herein will assist in this endeavor.

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University of Utah
Symposium Chairman, Co-chairmen, and STP Editors

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