THE Mechanism of Fracture

Edited by V.S. Goel

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FOREWORD

This volume contains part of the total number of papers presented at the "International Conference on Fatigue, Corrosion Cracking, Fracture Mechanics and Failure Analysis," held in Salt Lake City, Utah, USA, from 2-6 December 1985. Response to this conference was so good that it resulted in a large number of papers. To satisfy the needs of different interest groups and to keep the proceedings of the conference in a manageable form, it was decided to publish it in four separate volumes:

Analyzing Failures: The Problems and The Solutions
Corrosion Cracking
The Mechanism of Fracture
Fatigue Life: Analysis and Prediction

The above paper collection volumes may be obtained from the American Society for Metals. This conference covered a wide range of topics, some of fundamental interest and some of application interest. To facilitate an early publication, the editing has been kept to a minimum. We hope the the technical merits of the papers outweigh any grammatical or minor stylistic deficiencies.

The advances in the concepts of design are pushing the operational limits of engineering materials and so maximum performance is expected out of the materials. Due to the general economic crunch, almost everyone wants the maximum life out of their equipment. The electric utilities want their plants to run more than the designed plant life (mostly 40 years), aircraft companies want their planes to fly longer, the transportation industry wants that its bridges last indefinitely, and the chemical industry wants their plants to keep on producing products. There is also an increased awareness on the part of the public for safety and reliability of components, because failure of components in large aircraft, nuclear plants or other large structures can lead to large-scale disasters like the Bhopal tragedy in India, the Three Mile Island accident in the USA and the string of airline disasters in 1985.

All of this shows that today materials are expected to show maximum performance, provide long life for maximum economy and at the same time ensure safety and reliability of components and systems. For all this, we need to understand the materials better and apply the principles of fracture mechanics, corrosion and fatigue to the solution of practical problems. This conference was planned to provide a forum for the exchange of ideas and allow a better understanding of the theory and applications of the materials science which can ensure safety in combination with the expected life and performance goals for materials.

The theme of this conference was "Technology Transfer" among the various groups who apply theory to the application of practical problems. There are many specialized meetings in this area which permit workers to come together and discuss problems in their specific application areas. However, there is no single meeting or conference which brings together workers in the various application areas such as Aerospace structures, Army-Navy Applications, Bridges and Architectural Structures, Transportation Industry and Nuclear Industry to learn what is being done in other areas which they may be able to utilize to their advantage. This conference was aimed at bringing together workers from different applications areas to give them a wider perspective. Hence, this conference was of interest to engineers, metallurgists and also to the engineering managers who remain concerned about product failure and liability.

The success of this conference was based on the contributions of the speakers, session chairmen and members of the Technical Review Committee and the Organizing Committee who generously supported this Conference. I would like to thank all the participants on behalf of the American Society for Metals and the co-sponsoring societies for their generous contribution of time and effort towards the success of this Conference.

Dr. V. S. Goel
Chairman, Organizing Committee

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PLENARY LECTURE: OUTLOOK ON FRACTURE MECHANICS

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ABSTRACT

Following a brief assessment of the on-going and past activities, this plenary lecture delves into the future outlook in fracture mechanics. The exhaustive amount of jargons, terminologies, symbols and subscripts presently adopted in the field are true evidence of the lack of a quantitative formalism of the material damage or failure process. Many of the empirical test methods and phenomenological approaches are not only costly and uninformative, they shed little or no light on prediction.

New approaches and ideas for treating the failure and fracture behavior of materials will be discussed both from the viewpoint of practical application and fundamental research. There is a wealth of scientific knowledge and technological know-how in related fields that can be used to further enhance fracture mechanics and to widen its application in engineering.

OWING TO THE international character of the Conference, this plenary lecture will begin with a few brief remarks on the historical background of fracture mechanics in the U.S., a discipline that has gradually fallen behind times. This is understandable that as codes and regulations are endorsed by professional societies, technical issues can no longer be clearly delineated from policy making and legal concerns. What was the state-of-the-art at one time can quickly become outdated. The outlook on fracture mechanics could be more encouraging if efforts were made on the part of the engineering community at large to keep the field in pace with modern technology, not merely in application but even more important in the development of new approaches.

Fracture mechanics grew out of necessity after World War II mainly because of the inability of continuum mechanics to address failure by fracture. The alarming numbers of fractured Liberty ships raised concern on the future design of welded structures. The susceptivity of brittle fracture in the high strength steels also indicated the need to understand how yield strength trades off with fracture toughness. Material characterization in the presence of defects became apparent as the existing theories were not able to predict fracture directly from uniaxial data.

The ASTM Committee E-24 on Fracture Testing of High Strength Materials* was thus established in 1959 in an attempt to launch a critical study of the fracture testing of high strength metallic materials. A symposium on Fracture Toughness Testing and Its Applications was held in 1964 at the 67th ASTM Annual Meeting. This resulted in the publication of STP 381 [1]. The majority of the effort at that time was to devise a valid fracture test and to obtain a parameter independent of loading and geometry. Hopefully, it can represent the fracture property of the material. Such a parameter is now known as the K_{1c} fracture toughness value. The specimen had to be sufficiently thick in order to enhance rapid fracture soon after the crack starts to grow. Such a condition was not difficult to be satisfied by the higher strength metals. Specimen size, however, had to increase many folds for those with lower strength that were proned to yielding and slow crack growth. This was a major concern to the U.S. nuclear industries in the 1960's as their valid K_{1c} specimen thickness matched that of the full size structure.

There was an urgency to develop the so-called small specimen test procedure allowing the deformation around the crack to become plastic. The crack opening displacement (COD) [2] and J-integral approach [3] were the two leading cindidates among many others proposed to characterize the behavior of ductile fracture. The former relied

*It was later changed to ASTM Committee E-24 on Fracture Testing of Metallic Materials.