Introduction

Multiaxial fatigue is a subject of concern to both engineers and research scientists. In the eventuality of failure, fatigue lifetime is determined in the majority of cases by the applied multiaxial stress-strain state, whether generated by multiple loading or the component geometry itself. Thus multiaxial stresses should be taken into consideration by the designer, and it is important to note that material data generated in laboratories under constrained situations (for example, uniaxial loading or Mode I crack growth specimens) cannot be used in practice without recourse to some multiaxial criterion. The introduction of stresses on two or three axes in fatigue experiments, therefore, can provide valuable insight concerning both the micromechanisms of fatigue crack formation and growth and also the uses and limitation of multiaxial correlation factors.

The multiaxial behavior of metals has been studied throughout the twentieth century, and the engineers concern with the fatigue limit in the design of safe structures has led to a number of useful criteria which were developed prior to 1960, based on, for example, the pioneering work of Gough and Sines. Two more recent developments associated with the finite life of structures are fracture mechanics and life prediction techniques for high-strain fatigue, both of which have required the development of additional criteria. In these cases a knowledge of the extent of plastic deformation is important since inelastic strains are used not only in low cycle fatigue analyses but also in advanced elastic-plastic fracture mechanics. However, a number of problems remain to be solved, since fatigue cracks are invariably associated with notches or surface defects, and frequently experience aggressive environments.

This volume presents a number of papers which were read at the International Symposium on Biaxial/Multiaxial Fatigue, sponsored by the American Society for Testing and Materials in collaboration with the American Society of Mechanical Engineers, the American Society for Metals and the Society of Automotive Engineers. The need for a conference was recognized in 1979 after preliminary discussions in Sheffield between the editors and European friends, but, because much new work in multiaxial fatigue had been funded by the Nuclear Regulatory Commission in Washington, it was thought proper to approach ASTM to see if they would sponsor the event in the USA. First contacts were made at the Bal Harbour meeting in Florida in 1980 via such people as Jane Wheeler and Don Mowbray. The three day meeting, held in San Francisco in December 1982, led to many stimulating discussions among the delegates from several
countries, many of whom are actively involved in different aspects of the multiaxial problem. It was apparent that a variety of approaches are now being developed, and this book summarizes the current state of the art in each area of concern.

The 38 papers have been divided into eight groups, of which the first two present the various tools available to the materials scientist, that is, laboratory testing followed by the characterization of cyclic deformation response and the stress analysis of cracks. The importance of fatigue crack development, in terms of both the propagation rate and the plane and direction of growth, is highlighted by papers on mixed mode cracking and short cracks in metals. The group of papers on composite materials illustrates other mechanisms of damage accumulation. Life prediction techniques have been broadly based on crack development concepts, and new methods are compared with the older criteria and current design codes, showing that the new methods have much potential. Two areas requiring more attention are nonproportional stressing and elevated temperature aspects such as creep fatigue. Apart from these topics many other problems remain, but this volume shows that significant progress has been achieved towards predicting finite fatigue life behavior, and it should provide a useful aid in interpreting failures and understanding the mechanics of fatigue.

The success of the symposium and the production of this book would not have been possible without the hard work and support of the ASTM staff. We would also like to thank our able cochairman, J. R. Ellis, and the invaluable assistance of B. N. Leis in editorial matters subsequent to the symposium. Both have given much time and generous advice. The detailed work of the reviewers has greatly strengthened many papers presented here, and we appreciate the assistance of session chairman, the international group of experts who supported the symposium, ASTM committees E-9, and E-24 who sponsored the conference, and the staff of the Mechanical Engineering Department of the University of Sheffield.

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