MANUAL ON LOW CYCLE FATIGUE TESTING

STP 465

AMERICAN SOCIETY FOR TESTING AND MATERIALS

MANUAL ON LOW CYCLE FATIGUE TESTING

ASTM SPECIAL TECHNICAL PUBLICATION 465

List price $12.50

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

Library of Congress Catalog Card Number: 70-97730
SBN 8031-0023-X

NOTE

The Society is not responsible, as a body,
for the statements and opinions
advanced in this publication.

Printed in Baltimore, Md.
December 1969

Foreword

The *Manual on Low Cycle Fatigue Testing* has been compiled by Subcommittee VIII on Fatigue Under Cyclic Strain of ASTM Committee E-9 on Fatigue. The editorial work was coordinated by R. M. Wetzel, Ford Motor Co. L. F. Coffin, Jr., General Electric Co., is chairman of Subcommittee VIII.

Related ASTM Publications

Fatigue Crack Propagation, STP 415 (1967), $30.00

Electron Fractography, STP 436 (1968), $11.00

Bibliography on Low Cycle Fatigue 1957–1967

(microfiche), STP 449 (1969), $3.00

Fatigue at High Temperature STP 459 (1969) $11.25

Contents

Introduction

In the course of the last 15 years a very considerable interest has developed in the testing of metals where the controlling variable is cyclic strain rather than cyclic stress. Commonly referred to as low cycle fatigue testing, it has now developed to a state of refinement such that a "discipline" exists, at least among those working actively in the field. This special technical publication has been prepared to share the accumulated knowledge on the procedures, techniques, and skills now employed by several experts in the field. It is a collection of individually prepared papers describing the practices and viewpoints which each of the several authors feels best answer his particular testing requirements. Although there is much in common in many of the papers, there is no attempt made here to express a consensus; the reader is left to determine for himself which approach or combination of approaches is best suited to his particular needs. It should be further emphasized that the subject is specimen testing rather than component testing, an important distinction which must be reckoned with in relating the fruits of this work to the design of real parts.

The interest in low cycle fatigue testing stems directly from the need for information on metals when subjected to relatively few cycles of controlled cyclic strain. It may come from a search for methods to study the behavior of metals basically, where the interest is in developing mechanisms for explaining how microstructural and atomic effects can lead to the observed deformation and fracture characteristics, or it may come from the search for quantitative information to predict the life of engineering components subjected to a cyclic history similar to that produced in the laboratory. The latter has become the principal driving force for the development of low cycle fatigue testing methods.

Technological advance in the past 15 years has moved toward the use of higher and higher temperatures in materials for engineering structures, accompanied by an increase in the severity and frequency of thermal transients during operation. This trend is translatable into cyclic thermal stresses, or other cyclic loading, which fall directly in the category of controlled strain behavior. Some examples of components subject to these conditions include steam turbine rotors and shells, aircraft or land gas turbine buckets and wheels, and nuclear pressure vessels and fuel elements. Design procedures based largely on experimental information attained in laboratory testing have evolved for treating these problems. Hence, low cycle fatigue testing has played an important role in our technological advance.

Since this publication is devoted to fatigue testing in the low cycle regime, it is necessary to distinguish between it and fatigue testing more generally. By definition, failure in low cycle fatigue occurs in fewer than 50,000 cycles. It is further characterized by the existence of a stress-strain hysteresis loop and by the measurement of a plastic strain range in the test specimen. To meet these requirements certain special testing techniques not generally considered in high cycle fatigue testing assume importance. To produce failure in a few cycles, strain rather than stress must be controlled. This places special emphasis on strain-detecting devices and accompanying instrumentation for measurement and control. Further, the loading is nearly always fully reversed, since, with the plastic strain ranges experienced, mean stresses are quickly relaxed. Thus nearly equal tensile and compressive loads are encountered, requiring gripping systems capable of transmitting these loads from machine to specimen without slippage or misalignment. Specimen configuration becomes important, since buckling or bending must be avoided and reliable strain measurements must be made. While these problems exist to some extent in all fatigue testing, they are of special importance in low cycle fatigue.

In selecting subdivisions for this publication, one basis has been the choice of loading, that is, whether it be by uniaxial loading, bending, torsion, or otherwise. Most work was carried out either on uniaxial loading (push-pull) or in bending. More space has been given to push-pull loading, with only one contribution directed to bending. The reader should not infer from this emphasis that a preference in fact exists; rather, he should select the test best suited to individual needs.

Controlled strain testing can also be subdivided into constant temperature and cyclic temperature (thermal fatigue). In cyclic temperature the mechanical strain imposed on the specimen is derived entirely or in part from thermal expansion. Although this is a more complex test to conduct in the laboratory, it may in fact be more realistic in its representation of service conditions. One chapter is devoted to this important subject.

The balance of the papers deal with uniaxial testing: from the viewpoint of metals research, from a mechanics of materials view, and from the viewpoint of high temperature testing. While some duplication in technique appears, we believe this emphasizes the areas of general agreement among the investigators and the laboratories they represent. It also illustrates, the several ways of tackling the same problem: choice of grips, specimen design, strain measurement, instrumentation, testing machine, etc.

This publication is a contribution of Subcommittee VIII on Fatigue Under Cyclic Strain of ASTM Committee E-9 on Fatigue. As chairman of the subcommittee I should like to acknowledge the contributions made by the several authors. Such a publication could not have been undertaken without the help of many others, among whom I should like to thank R. S. Carey who has prepared the Index, and the editorial committee coordinated by R. M. Wetzel and ably supported by J. A. Dunsby and V. Weiss. Finally, the full support of Committee E-9, H. F. Hardrath, chairman, is gratefully appreciated.

L. F. Coffin, Jr.,
Metallurgy and Ceramics Laboratory,
General Electric Co., Schenectady, N.Y.;
Chairman, Subcommittee VIII,
ASTM Committee E-9