Introduction

Many fatigue designs, in quite diversified fields of engineering, must operate at temperatures below room temperature. These operating temperatures may be as low as 219 K (−54°C) for ground vehicles, civil structures, pipelines, and aircraft, 110 K (−163°C) for natural gas storage and transport, 77 K (−196°C) for liquid nitrogen storage and transport, 20 K (−253°C) for aerospace structures, and 4 K (−269°C) for superconducting electrical machinery. This volume brings together the latest basic and applied research on fatigue at these low temperatures.

There has long been a need for a publication such as this. An appreciable period of time has passed since the major reviews on the subject (Teed in 1950 and Forrest in 1963).[1] Also, a review of fatigue textbooks indicates that they give little attention (from zero to about four pages) to fatigue at low temperatures. Many of these textbooks have suggested that fatigue design at room temperature is very often satisfactory for low temperatures. Substantial fatigue data do exist that promote this concept; however, most of these data have been obtained under constant-amplitude conditions, which can lead to erroneous design decisions. Even with constant-amplitude tests, however, sufficient data exist that invalidate the general concept that fatigue resistance at low temperatures is equal to or better than fatigue resistance at room temperature. In addition, variable-amplitude low-temperature fatigue behavior data are quite scarce. Thus a general lack of complete confidence in and understanding of fatigue behavior at low temperatures currently exists. It is hoped that this ASTM publication will lead to improving our knowledge concerning fatigue at low temperatures.

This volume consists of 16 papers on low-temperature fatigue. Seven papers involve cryogenic temperatures with liquid nitrogen (77 K), liquid hydrogen (20 K), or liquid helium (4 K), and nine papers deal with noncryogenic temperatures. The book is divided into two sections: (1) Mechanisms and Material Properties, and (2) Spectrum Loading, Structures, and Applications. Within each section, the cryogenic temperature papers have been separated from the noncryogenic papers.

[1] Teed, P. L., *The Properties of Metallic Materials at Low Temperatures,* Chapman and Hall, London, 1950; Forrest, P. G., *Fatigue of Metals,* Pergamon Press, Elmsford, N.Y., 1963.

The international flavor of this volume should be noted. Papers have been contributed by authors from the United States, Japan, the Soviet Union, Israel, China, and the United Kingdom. The authors' affiliations include universities (Metallurgy, Material Science, and Mechanical Engineering Departments), industry (including aerospace, steel, and nuclear fields), and five different governmental research laboratories.

The principal aspect of fatigue at low temperatures studied in this volume is fatigue crack growth of metals using compact type, center cracked panels, or bend specimens under constant-amplitude loading. The fatigue crack growth rates investigated range from 5×10^{-11} to 10^{-4} m/cycle, with a fairly even distribution between threshold and near-threshold interests, to that above 10^{-8} m/cycle. Four papers discuss fatigue crack growth behavior under spectrum loading; one of these papers also studies fatigue crack initiation under spectrum loading using a notched specimen. Low-cycle strain-controlled fatigue using smooth uniaxial specimens with ϵ–N (strain versus cycles to failure) and cyclic softening/hardening behavior is covered in two papers, and fiberglass epoxy laminate S–N (stress versus cycles to failure) fatigue behavior is investigated in another. The metal alloy systems discussed include carbon or low alloy wrought and cast steels, austenitic stainless steels, high-manganese austenitic stainless steels, and base alloys of aluminum, magnesium, titanium, and nickel. Analysis of fatigue behavior has relied heavily on electron fractography, especially in the areas of ductile- and cleavage-type fatigue crack growth. Crack closure, crack-tip plasticity, yield strength, ductile/brittle transitions, and dislocation dynamics are the principal means of discussing the test results.

It is believed that this volume, with its wide-ranging coverage of materials processing, loading types, temperatures, fractographics, mechanisms, and its 325 cited references (some repeated in different papers), provides an important contribution to the subject of fatigue at low temperatures. This publication will be beneficial to material scientists, metallurgists, and engineers involved in research and design under fatigue conditions at both cryogenic and noncryogenic low temperatures.

R. I. Stephens
Mechanical Engineering Department,
The University of Iowa,
Iowa City, IA; symposium
chairman and editor