

Chapter 1—Introduction

1.1 Purpose

Over the past quarter-century, since the *Manual on Fatigue Testing, ASTM STP 91* was published, the study of materials fatigue has grown to such an extent, that following only one of its ramifications can be the lifework of a large number of researchers. Materials fatigue is a hybrid science, having to draw heavily on several traditional sciences, such as metallurgy, statistics, and dynamic analysis. Rarely does one hear of a student studying “Fatigue Engineering” or some such direct approach to the problem. It is more likely that the researcher’s background was one of the supporting sciences. For this reason, the present *Handbook of Fatigue Testing* was prepared as a source of information for the person who finds himself becoming a fatigue engineer.

Fatigue strength is probably the most quality-sensitive of the engineering properties, because the imperfections of real-life processes have a vital effect on the fatigue performance of the material. Man’s inability to manufacture the material perfectly (flawlessly, free of residual stresses, etc.); his inability to fabricate the structures from the materials without using somewhat primitive joining methods, involving geometrical and metallurgical notches, etc.; and finally, his inability to define completely the environment (loadings, etc.) that the structure must experience in its lifetime—all these inabilities accumulate their uncertainties to cause the problems associated with fatigue life prediction.

It is necessary, however, to know something of the nature of fatigue in order to plan and conduct tests intelligently. Fatigue failures generally start as minute surface cracks which grow under the action of a fluctuating stress until a dominant crack attains critical size, causing failure. The stress necessary to initiate fatigue cracks is often less than that required to cause gross plastic deformation of the material. There is often little relief of the stress concentration at discontinuities, and cracks will generally start at such stress-raisers. Because of the inhomogeneity of real-life materials, this usually results in a wide dispersion of fatigue test results from nominally identical specimens and conditions. This fact must be kept in mind from the initial design of the fatigue experiment to the final evaluation of the test results.

Fatigue tests are conducted for a wide variety of purposes and the specimens tested range all the way from tiny samples of thin foil to complete aircraft weighing many tons. This handbook will point out the principles and techniques of fatigue testing, so that the reader will be assisted in defining his problem accurately, choosing an effective testing method, avoiding pitfalls in conducting the test program, and evaluating the results realistically.

1.2 Scope

No attempt will be made in this handbook to cover areas outside the general area of fatigue testing. Complete books (and indeed several manuals) have now been written on specific aspects of material fatigue (for example, low cycle fatigue, fatigue at elevated temperature, etc.).

By restricting the scope to testing itself, it is possible to attempt an in-depth study of testing that will be reasonably up-to-date at the time of publication. Such an objective is absolutely essential in a field that is changing as fast as that of fatigue testing. Gone are the days when very simple questions such as, "Will it stand one million constant amplitude (rotating beam) load reversals?" are asked of the fatigue engineer. Now he is asked to determine the actual fatigue life, often under complex service conditions. For this reason, this handbook may appear rather different from earlier manuals.

While material fatigue behavior in itself is not studied in this manual, there remains the question, "How is the fatigue resistance of materials most usefully characterized?" To answer this question, careful judgement has to be exercised in the selection of the test method, the specimen, and the procedure appropriate to the situation, so that the designer avoids the generation of test data not relevant to his purposes. In this sense, knowledge of material fatigue behavior has guided the writing of the manual.

In the present decade, the field of fatigue testing is seen to be rapidly maturing. The earlier years can be looked upon as a time when fatigue testing suffered from an isolation from many disciplines which could have helped it to develop at a faster rate. To name but a few of these disciplines, one would include servocontrol, electronics, digital techniques and computer science, and transducer (sensor) technology. Of course, these fields were rapidly developing themselves. Presently, however, fatigue testing is flourishing from its ability to incorporate new developments in these related primary fields, almost as quickly as they are introduced.

This handbook contains illustrative descriptions of several types of equipment, of important concerns in specimen design and preparation, and of items important in monitoring tests and recording test data. In describing equipment, it was not feasible to include actual details of the immense variety of testing equipment presently available, nor of all the

special tests that are conducted for various reasons. Rather, the emphasis is upon principles in the "art" of fatigue testing, so that the engineer can choose wisely among alternatives available to him and appropriate to his objectives.

The layout of the handbook has been organized so that the inexperienced fatigue test engineer can obtain the information he needs to carry out his test with the degree of precision and care pertinent to his objective. Early emphasis is placed on the necessity to design the experiment carefully. Then a consideration of the test apparatus required is given, then the design of the specimen, and incorporation of an environment. The references at the end of each chapter are related to the testing topic of that chapter.

It is recognized that the scope of activity in fatigue is so great at present, that no single source can call itself definitive. Indeed, many standing professional committees and government bodies throughout the world are continuously at work on the problem of generating standards, specifications, norms for fatigue testing. Appendix C will indicate as many of the groups as possible so that the reader can look into their work further, if he desires.

Consideration should be given to the social impact of the technical discipline of fatigue testing. There is a very definite social responsibility on the part of those who manufacture products for man's use, that they be safe to use either indefinitely or for a specified lifetime. Fatigue testing plays a key role in estimating this lifetime and thus can lead to better product reliability. For this reason, the potential user of this handbook must realize that carefully controlled tests and service simulation can be achieved with equipment available today, so that reasonable estimates of fatigue behavior of materials and products can be obtained. Of course, much fatigue research is involved very indirectly with the social problem of structural integrity (for example, fundamental studies of pure materials, etc.), and requirements in this area also will be covered. It is probably no exaggeration, at the present time, to state that fatigue testing capability has actually advanced beyond the imagination of many workers in the fatigue field. The main limitation now is essentially one of economics.