Overview

With the rapid advances in the incorporation of automated data acquisition and processing capabilities into many mechanical testing laboratories, it has become increasingly possible to conduct many experiments entirely under computer control. Computers, data loggers, and measurement and control processors, together with load cells, displacement gages, and their conditioning circuits, or electric potential-drop systems, have created an entirely new set of opportunities for the improvement of fatigue and fracture tests that were formerly conducted under essentially manual control using optical or simple analog methods of data acquisition. The existing ASTM standards for fatigue and fracture testing, while they are carefully worded so as to allow incorporation of automated techniques, do not specifically set down the methods for performing tests with fully automated test facilities. Since automated testing is possibly the present, or certainly the future, for many laboratories, many of the applicable standards face rewriting, or will require annexes (appendices) to specifically establish the requirements for automated methodologies.

The Symposium on Automated Test Methods for Fracture and Fatigue Crack Growth was held in Pittsburgh, PA on 7-8 November 1983 to provide a forum for researchers using automated systems to describe their techniques, and to discuss especially the methods used to establish conformance to, or exceed the requirements of, the various ASTM standards for fatigue and fracture which were used as the basis for the test. The contributors were asked to provide descriptions of the techniques used in their test systems, and to address how they qualified their systems to assure that the data conformed to the existing ASTM standard test practices. The contributions to the symposium covered a wide range of techniques and test objectives, and were provided by scientists from laboratories all over the world. The symposium was very well attended at all three sessions. The first two sessions addressed techniques used for fatigue and fatigue crack growth rate testing, and the final session dealt with techniques for fracture testing.

The arrangement of contributions to this STP follows the order of presentation at the symposium. In the final analysis, the authors provided more description of their test systems, and somewhat less description of the ways in which the systems conformed to, or exceeded, the requirements of the applicable ASTM standards. Thus, techniques for assuring accuracy and precision of these automated methods have still not been subjected to the kind of open forum which may be required before there is general acceptance of a particular methodology.

Systems for Fatigue and Fatigue Crack Growth Testing

Thirteen papers have been contributed in this category.

The paper by Miller and co-authors from the University of Illinois takes advantage of this university's long involvement in the development of computerized test control and data acquisition instrumentation. The history of laboratory computers is reviewed, and a description of a current system design is provided. Several computer-to-computer communication protocols are mentioned, since these are necessary for passing data from one laboratory location to another. Lastly, the general impact of these current advances on standards writing is discussed.

The use of a personal computer to monitor sustained load cracking test progress at several test stands is described by Meyn et al. This system has the advantage that data are acquired in proportion to the rate of change of the test specimen response; that is, when the loads or displacements of the specimen are changing rapidly, data acquisition is frequent, but when crack extension in the specimen is in an incubation stage, data acquisition is quite infrequent. The criteria for rejection of false data are discussed.

Vecchio and colleagues describe an automated system for fatigue crack growth that has been used on compact and three-point bend specimens over a wide range of growth rates, for both metals and polymers. The influence of overloads on crack closure, and therefore on the compliance technique for monitoring crack extension, is discussed.

Catlin and co-workers discuss a novel approach to the use of direct-current potential-drop methods in aqueous environments. Careful consideration has been given to the possibility that the currents and voltage levels used to provide the potential-drop capability might interfere with the corrosion potential of the specimen. This paper also describes the techniques used to assure that the systems have long-term stability, low noise, and can be applied to a number of specimen geometries and crack shapes.

Scientists at larger laboratories may be interested in the discussion of a distributed system approach to computerized test practice described in a contribution by Topp and Dover. In particular, the authors discuss their application of an alternating-current method of crack extension determination, and its application to somewhat large test specimens and nonstandard geometries, such as tubular joints, and threaded sections.

One of the most tedious of the fatigue crack growth experiments is the determination of near-threshold data. Systems for this application are described in contributions by Sooley and Hoeppner and by McGowan and Keating. The McGowan/Keating system measures crack extension by both the compliance and potential-drop methods, and controls the rate of change of applied cyclic stress-intensity factor, ΔK, to a user-selected value. The procedures for selecting the locations for the potential probes, and the methods for assuring that the crack is fully open, before making a potential measurement, are pointed out. Sooley and Hoeppner discuss their approach to the near-threshold growth rate test practice using a very inexpensive controller. The authors indicate that this system meets the existing requirements of the ASTM Test Method for Constant-Load-Amplitude Fatigue Crack Growth Rates Above 10^{-8} m/Cycle (E647-83), and the proposed requirements for threshold testing.

Fatigue crack initiation from a blunt notch is a study requiring extremely high sensitivity measurement techniques, and a paper by Kondo and Endo presents a unique approach to this problem. Compact specimens were instrumented with back-face strain gages, and a special analog processing circuit was constructed to subtract an offset voltage from the resultant signal output, thus allowing high amplification of the incremental output from the gage. Using this system, the authors were able to detect extremely small crack extensions, and found that initiation from a blunt notch occurred much earlier in the specimen life than had been expected.

There are some attractive advantages to conducting a constant ΔK experiment, making it easier to concentrate on the other critical variables that may affect fatigue crack growth rates. Van Der Sluys and Futato review their experiences with a four-station data acquisition system that controls all the aspects of test practice, from setup through test termination, including changes in test frequency and loading parameters that may be required at various intervals in the test schedule.

Fatigue crack growth of part-through cracks in flat specimens, sometimes called surface-defected panels, is very applicable in the sense that these flaws are more geometrically similar to those that actually occur in service. Van-Stone and Richardson describe very carefully the experimental methods and calculations which are involved in the testing of such specimens, and discuss some of the techniques needed to derive the crack aspect ratio. They also discuss the effect of net section stress on aspect ratio and growth rates.

The use of surface-bonded resistance gages to measure crack extension is described in a contribution by Liaw and co-workers. Various forms of these gages have been used in air, salt water, and wet hydrogen, and a plasma-sprayed version is being evaluated for high-temperature testing. The gages have been used to monitor growth of short cracks, and have also been shown to generate, for longer cracks, data that are in good agreement with data from compliance and optical methods of crack length determination.

Testing of irradiated materials is the subject of a paper by Tjoa and co-authors. Of necessity, these specimens must be tested remotely, and use of both compliance and potential-drop methods are described. The discussion focusses on the computer algorithm used and on the errors which may be incurred in either method.

Cheng and Read discuss a system for high-frequency constant-amplitude and near-threshold testing that has been used for testing cast stainless steels at liquid helium temperatures. This system utilizes a digitizing oscilloscope to capture the rapidly varying load and displacement signals. The use of an effective modulus to match the computer calculated and optically measured crack lengths is discussed, along with the requirements for overprogramming the servohydraulic system to achieve the high test frequencies.

Systems for Fracture Testing

Four papers have been contributed in this category.

The first paper provides an interesting crossover since it discusses the elastic plastic parameter, J-integral, as it can be used in low-cycle fatigue. Joyce and Sutton describe the automated test method used to calculate and apply the desired J-integral range, and to measure and correct the loads for crack closure, in real time.

Jolles describes an automated system for R-curve measurement using either compact or bend specimens. The criteria for hardware selection based on the required sensitivity are discussed, and the use of the direct-current electric potential-drop method is presented. The potential-drop technique eliminates the need for frequent partial unloadings in order to obtain a compliance measurement.

Saario and co-workers present results on the elastic-plastic fracture testing of compact, round compact, and three-point bend specimens. An automated system has been used to carry out these tests in accordance with the proposed ASTM R-curve test procedures. The rate of load application has been shown to affect the correlation coefficient of the unloading compliance.

The final paper in this section presents a methodology for measuring the errors involved in automated systems used for fracture testing. Jablonski shows how the various contributions to errors in the load, crack opening displacement, and specimen modulus enter into the J-integral and crack extension calculations. A comparison of the results from compact and three-point bend specimens shows that the tearing modulus is different in the two geometries. The effect of side grooves and a/W ratio on the R-curve is also described in some detail.

The overall evaluation of this symposium is that there were a number of contributions which described interesting and unique approaches to the topics of automated testing, and indirect measurement of fatigue and slow-stable crack growth. However, it is obvious that there is no consensus about the exact procedures, calibration methods, or post-test data processing that would be necessary before standards can be drafted for the test methods involved in this research. However, the editors are certain that standardized test methods are feasible at this time, and in fact, at the time this overview was drafted, an effort to write an appendix for ASTM Method E 647 to incorporate compliance methods of crack length determination was underway. On the fracture side, a full-fledged standards writing effort for J-R curve determination, using the unloading compliance method, is nearing completion. It seems likely that, as time goes on, other standards for mechanical test practice will be modified or created to take advantage of computerized laboratory techniques.

W. H. Cullen

Materials Engineering Associates, Lanham, MD 20706; symposium cochairman and coeditor.