Summary

There are now several well-established techniques available for characterizing various aspects of small-crack propagation. Some are more amenable than others for routine use; some require significant expertise. Some require almost no financial investment, while others require more significant expenditures. All are useful for measuring the growth of fatigue cracks on the order of 50 to 75 μm or greater, and some are applicable to even smaller cracks. There is little evidence the techniques yield da/dN versus ΔK data, which is technique dependent; however, extensive comparisons on a common set of material have not been conducted. Some techniques have relative limitations for use in characterizing three-dimensional shape changes (for example, replication), although all must make some assumptions about crack shape changes that require pre- or post-test verification. Shape changes may be deduced from the combination of some of the measurements.

Fatigue crack closure has been shown to be an important factor affecting small (and large) crack propagation. Some of the techniques reviewed here are very useful for characterizing crack compliance and closure (for example, ISDG and SEM) while others yield little or no quantitative closure information (for example, replication and photomicroscopy). Some techniques provide information that is clearly related to crack-closure behavior, however, the degree with which it can be used to quantify crack closure is open to interpretation (for example, ultrasonic and electric potential methods). Finally, novel techniques have been developed for conducting large-crack experiments (for example, constant-K_{max}), which may be closure free and thus may be useful for bounding those small-crack effects that are attributable to crack closure.

There is little disagreement that the small-crack effect exists and is important. However, in addition to the major and natural controversies regarding mechanistic interpretation, controversy exists in testing practice as well. These include the following:

1. Use of $\Delta\sigma = \sigma_{max} - \sigma_{min}$ where $\sigma_{min} < 0$ in calculating ΔK.
2. Use of established increments for data collection, fixed Δa versus fixed ΔN increments.
3. Methods for dealing with multiple cracks/rejection of data for crack interaction effects.
4. Use of large-crack procedures for bounding small-crack da/dN versus ΔK data.
5. Use of ultrasonic and electric potential, and perhaps even SEM, techniques for quantifying crack closure.

Future activity by ASTM Committees' E-9/E-24 Joint Task Group on Small Fatigue Cracks should concentrate on resolving these controversial measurement issues, which will pave the way to a recommended practice for small-crack test methods that is technique independent. In addition there is a need for more extensive comparison of da/dN versus ΔK data and closure data for a variety of techniques (for example, round-robin activity). Finally, research challenges exist in extending small-crack test methods to characterization of fatigue cracks less than 50 to 75 μm in size. Of obvious and general importance is research directed at understanding small-crack growth mechanisms, including environmental interactions, and characterizing/correlating small-crack behavior. This information is needed for development of more fatigue resistant and damage tolerant materials. In addition, as methods of nondestructive evaluation continue to improve, and the minimum detectable crack size decreases, a more thorough understanding of small-crack behavior will be needed for life prediction of high-performance structural applications.

Given the importance of small fatigue crack information for use in alloy development and the critical requirement for its use in component design, we are hopeful that this publication will be useful to students, researchers, and practicing engineers and will provide a means to make the experimental and analytical methods used to characterize small fatigue cracks more accessible.

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