Astm E 647

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Fracture Mechanics
USAF Damage Tolerant Design Handbook
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Evaluation of Fatigue Crack Thresholds Using Various Experimental Methods
Fracture Mechanics
Pitfalls to Avoid in Threshold Testing and Its Interpretation

FREEMAN DAISY

POTEND.ROP ASTM International
Life predictions for small cracks emanating from material inhomogeneities or small flaws caused by manufacturing or corrosion damage are becoming increasingly important for several reasons, including: concerns over widespread fatigue damage; a shift in philosophy for fatigue initiation design from stress-life (S-N) to the equivalent initial flaw

size (EIFS) approach; and the greater usage of unitized structure. For these reasons, development of accurate fatigue crack growth rate (FCGR) data in the near threshold region is needed, which is not influenced by closure or residual stress. Threshold data ARE often generated from long crack specimens by load shedding as outlined in ASTM E 647. However, this data can be non-conservative and variable due to load history effects caused by crack closure. Generating closure-free short crack FCGR data requires much more sophisticated instrumentation and testing techniques than long crack testing, making it prohibitively expensive to perform on a routine basis. Small crack tests also sample only a small volume of material and typically exhibit large scatter, so multiple tests must be performed in order to determine the typical or average behavior of the material. As a result of these disadvantages, use of long crack tests to estimate short crack behavior is the preferred approach.

Fracture Mechanics

Elsevier

Examples are given where influence of residual stress leads to erroneous interpretation of fatigue crack growth rate measurements made in accordance with ASTM Method E 647-78T. The experimental data presented form a basis for modification of applicable ASTM documents to give recognition to problems caused by residual stress, and to suggest guidelines for minimization of their effect on fracture property measurement.

USAF Damage Tolerant Design Handbook ASM International

Fatigue crack growth rate testing is performed using automated data collection systems that assume straight crack growth in the plane of symmetry and that use standard polynomial solutions to compute crack length and stress-intensity factors from compliance or potential drop measurements. Visual measurements used to correct the collected data typically include only the horizontal crack length, which underestimates the crack growth rates for cracks that propagate out-of-plane. The authors have devised an approach for correcting both the crack growth rates and stress-intensity factors based on two-dimensional mixed mode-I/II finite element analysis (FEA). The approach is used to correct out-of-plane data for 7050-T7451 and 2025-T6 aluminum alloys. Results indicate the correction process works well for high ?K levels, but it fails to capture the mixed-mode effects at ?K levels approaching threshold (da/dN ~ 10-10 meter/cycle). Based on the results presented in this paper, the authors propose modifications to ASTM E 647: to be more restrictive on the limits for out-of-plane cracking (15°); to add a requirement for a minimum of two visual measurements (one at test start and one at test completion); and to include a note on crack twisting angles, with a limit of 10° being acceptable.

Advances in Fatigue Crack Closure Measurement and Analysis ASTM International

This book contains the fully peer-reviewed papers presented at the Third Engineering Foundation Conference on Small Fatigue Cracks, held under the chairmanship of K.S. Ravichandran and Y. Murakami during December 6-11, 1998, at the Turtle Bay Hilton, Oahu, Hawaii. This book presents a state-of-the-art description of the mechanics, mechanisms and applications of small fatigue cracks by most of the world's leading experts in this field. Topics ranging from the mechanisms of crack initiation, small crack behavior in metallic, intermetallic, ceramic and composite materials, experimental measurement, mechanistic and theoretical models, to the role of small cracks in fretting fatigue and the application of small crack results to the aging aircraft and high-cycle fatigue problems, are covered.

Automated Fatigue Crack Growth Monitoring ASTM International

Contains more than 500 fatigue curves for

industrial ferrous and nonferrous alloys. Also includes an explanation of fatigue testing and interpretation of test results. Each curve is presented independently and includes an explanation of its particular importance. **Effect of Residual Stress on Fatigue Crack Growth Rate Measurement** ASTM International
The accurate representation of fatigue crack threshold, the region defining crack growth as either very slow or nonexistent, is extremely important. If the experimentally measured threshold is unconservatively high, a structural component designed with this data may fail long before the fatigue analysis predicts. The fatigue crack growth threshold is experimentally defined using ASTM standard E 647, which has been shown to exhibit anomalies. Alternate test methods have been proposed, such as the constant Kmax test procedure, to define the threshold regime without ambiguity. However, only the current test method defined by ASTM is designed to produce the range of fatigue crack thresholds (e.g., low and high R) needed to characterize an acrospace loading environment. It is the scope of this paper to determine the fatigue crack growth threshold of a well characterized aerospace alloy, 7075-T7351 aluminum, using different methods, to compare the results,

and to draw conclusions.

ASTM E647 - 13ae1t Standard Test Method for Measurement of Fatigue Crack Growth Rates ASTM International

The scope of the study is to investigate the fatigue strength and fatigue crack growth of railway rail steel grade 900A International Union of Railways (UIC 54) profile. The UIC 54 profile has been used to manufacture the rail by Malaysian railway for several decades. The 3D finite elements analysis is performed between wheel and rail to analysis maximum stress field distribution at rail inside curve region. Apart from that, the hardness measurements testing on UIC 54 profile at used and unused rail profile head. Furthermore, the hardness testing is conduct according to ASTM E 92-16 Standards. The dog-bone specimen and CT specimen experimental setup and testing are conducted according to ASTM E 466-15 and ASTM E 647-15 Standard, respectively. The fatigue strength (S-N) curve is plotted using seven dog-bone specimens with variable stress amplitude and with constant stress ratio of 0.1.

An Investigation of Fatigue Crack Growth Behavior of UIC 54 Profile in High Speed Railway Applications ASTM International

The results of the Second Round-Robin on Opening-Load Measurement established the basis for a recent addition to ASTM E 647--"Recommended Practice for Determination of Fatigue Crack Opening Load from Compliance." The technique involves characterizing the deviation in linearity of a load-displacement curve and reporting, as a minimum, the opening load corresponding to a 2% slope offset. The opening load and associated ?Keff values reported showed significant scatter although this scatter was reduced when the data were subjected to a rigorous accept/reject criterion. Refinements in the method of handling data with high "noise" have further reduced scatter compared with the original analysis. Since each participant provided digitized load-displacement curves, the data from 17 test samples (10 participants) were reanalyzed using the "adjusted compliance ratio" (ACR) technique to evaluate ?Keff. A comparison between the two methods shows that the ACR technique gives a higher mean value of ?Keff than does the ASTM procedure. The ACR technique also shows a stronger correlation with crack growth rate data than does the ASTM procedure, with a slope comparable to that of a typical fatigue crack growth rate test. However, the mean value of ?Keff based on the ASTM procedure shows better agreement with high stress ratio "closure free" data than does the ACR technique. This seemingly contradictory result can be partially explained in terms of second-order effects not normally considered significant.

Fracture Mechanics ASTM International Annotation Contains 24 papers from the November, 1998 symposium of the same name, sponsored by the ASTM Committee E8 on Fatigue and Fracture, and presented by Newman and Piascik (both of the NASA Langley Research Center). The papers focus on such areas as fatigue-crack growth threshold mechanisms, loading and specimen-type effects, analyses of fatigue-crack-growth-threshold behavior, and applications of threshold concepts and endurance limits to aerospace and structural materials. Annotation copyrighted by Book News, Inc., Portland, OR.

A Low-Cost Microcomputer Data Acquisition System for Fatigue Crack Growth Testing CRC Press A proposed round compact specimen was evaluated for its suitability for fatigue-crack growth rate testing. The results were compared to results from standard compact specimens (per ASTM E647-78T), and the two specimens were found to yield equivalent results. A number of K-solution have also been proposed for the round compact specimens, and these are reviewed. The agreement between the various solutions was quite good, and the Newman Equation was used to evaluate the present results.

Minimization and Quantification of Error Associated with the K Gradient and the Interval of Crack Length Measurement in Fatigue Crack Growth Testing ASTM International

The objective of this work has been to characterize the fatigue crack growth rate of Inconel 718 in the elastic and elastic-plastic regimes. The major new contribution here is to develop fatigue crack growth rate data on this alloy using shallow crack specimens subjected to cyclic loadings that involve material plasticity exceeding what is allowed by the standard Linear Elastic Fracture Mechanics (LEFM) procedures of ASTM E 647.

Corrosion Tests and Standards ASTM International

Eccentrically-loaded single-edge crack tension, ESE(T), specimens made of A36 structural steel were tested over a wide range in stress ratios (R = 0.1 and 0.7) in laboratory air. Two test methods were used: (1) ASTM Standard E647 load-reduction method and (2) compression precracking. After compression precracking (CP), three different loading sequences were used: (1) constant amplitude (CPCA), (2) load reduction (CPLR), and (3) constant stress-intensity factor (CPCK). The crack-compliance method was used to determine that the specimens had no residual stresses; and that the effects of tensile residual stresses from compression precracking dissipated in about 2 compressive plastic-zone sizes. Agreement was found between the A36 and TC-128B steel ?K-rate data tested at both low and high stress ratio (R) conditions. At R = 0.1 loading, the CPCA and CPLR tests generated lower thresholds and faster rates than using the standard ASTM load-reduction method. All load-reduction tests exhibited an accumulation of debris at the crack front near threshold conditions. A crack-closure analysis was preformed to calculate the effective stress-intensity factor range (?Keff) against rate using measured 1 % offset (OP1) values for all R = 0.1 tests. The ?Keff-rate data correlated well with the high-R results.

A Framework for a Standardization Effort for Fatigue Crack Growth Testing Under Variable Amplitude Spectrum Loading

ASTM International

This bestselling text/reference provides a comprehensive treatment of the fundamentals of fracture mechanics. It presents theoretical background as well as practical applications, and it integrates materials science with solid mechanics. In the Second Edition, about 30% of the material has been updated and expanded; new technology is discussed, and feedback from users of the first edition has been incorporated.

Fatigue Crack Growth Thresholds, Endurance Limits, and Design

The purpose of this report is to documents the fatigue crack growth (FCG) testing that was accomplished in conjunction with various other labs to meet the objectives of the ASTM E647 FCG Round Robin Testing. Three M(T) panels each of 2024-T351 and 7O75-T6 aluminum were tested. with a different configuration for each-thick panels (0.375") for 2024-T351 and thin panels (0.125") for 7075-T6. The goal of the testing was to develop da/dN vs. Delta k curves for low load ratio testing (R= 0.1), focusing on DeltaK> 10 ksi(square root of)in.

Round Robin Fatigue Crack Growth Testing Results

Fatigue crack initiation in notched members is controlled by local strains at the notch root. A number of approaches have been developed for calculating local notch-tip stresses and strains from nominal stress and notch geometry considerations. One such approach uses the parameter ?K/?1/2, where ?K is the fracture mechanics stress intensity range and ? is the notch root radius. The parameter ?K/?1/2 has been shown to correlate with local notch-tip strain and provide a means of normalizing cycles-to-initiation, Ni, data for various notch-tip geometries. Fatigue crack growth rate specimens described in ASTM Test Method for Plane-Strain Fracture Toughness of Metallic Materials (E 399), ASTM Test Method for Measurement of Fatigue Crack Growth Rates (E 647) and elsewhere can be used for fatigue crack initiation testing if they have blunt notches. Data in the form of parameter ?K/?1/2 versus Ni has the same units as the traditional S-N curves. The advantage of having data in the form parameter parameter ?K/?1/2 versus Ni is that information is available on ?K and ? . As in all fracture mechanics testing, data obtained on one specimen geometry can be applied to a wide variety of structural geometries. This approach can be used in conjunction with commercially available software for fatigue crack growth rate testing, servohydraulic testing equipment, and modified fracture mechanics specimens to automate fatigue crack initiation testing. The combination of all of these elements represents a new test method. Results are presented for aluminum alloy 7075, where the effects of corrosion pits were studied and for titanium alloy Ti-6A1-4V, where the effects of heat treatment on initiation were studied.

Crack Growth Behavior Under Creep-fatigue Conditions Using Compact and Double Edge Notch Tension-

compression Specimens

The impact of a number of testing variables on the measurement of fatigue crack growth thresholds is discussed. References are made to the original works from which the current recommendations for measurement of threshold in ASTM E 647 were derived. The applicability of these original recommendations in light of advances made since that time is discussed. In addition, the effects of some commonly overlooked parameters and features, such as residual stress and environment, on the measurement and interpretation of crack growth thresholds are presented.

Development and Validation of Advanced Test Methods to Generate Fatigue Crack Growth and Threshold Data for Use in Damage Tolerance Analysis

With the advent of ASTM Test Method for Measurement of Fatigue Crack Growth Rates (E 647-91) and the associated annexes for nonvisual methods of monitoring crack length, there exists a need to address many aspects of the role that automation plays in generating fatigue crack growth rate data. The current ASTM standard provides primary guidance for visual methods of monitoring crack length and manual control of the test. The associated annexes provide guidance for two common nonvisual methods of monitoring crack length. Although they are good guides for both manual and automated control, they lack detail on many important considerations related to stress intensity (K) control, crack length precision, and load precision. This paper will emphasize the effect of sampling rate and resolution on crack length precision, dynamic load precision, and control. The issues will include analog-to-digital conversion resolution, digital filtering, peak reading, and multichannel phase considerations.

Automation in Fatigue and Fracture

A data acquisition system has been designed and assembled to allow automated, unattended fatigue crack growth testing. The system employs a low-cost micro-computer and analog-to-digital converter interfaced to a standard MTS servohydraulic fatigue machine. The system is designed to comply with ASTM Test for Constant-Load-Amplitude Fatigue Crack Growth Rates Above 10-8 m/Cycle (E 647). High-performance data are obtained by the crack-opening displacement method.

Evaluation of the Effect of Crack Tip Constraint on Fatigue Crack Growth Rate in Inconel 718

The American Society for Testing and Materials (ASTM) has recently developed a new standard for creep-fatigue crack growth testing, E 2760-10, that supports testing compact specimens, C(T), under load controlled conditions. C(T) specimens are commonly used for fatigue and creep-fatigue crack growth testing under constant-load-amplitude conditions. The use of these specimens is limited to positive load ratios. They are also limited in the amount of crack growth data that can be developed at high stress intensity values due to accumulation of plastic and/or creep strains leading to ratcheting in the specimen. Testing under displacement control can potentially address these shortcomings of the load-controlled tests for which the C(T) geometry is unsuitable. A double edge notch tension-compression, DEN(T-C), specimen to perform displacement controlled creep-fatigue crack growth testing is developed and optimized with the help of finite element and boundary element analyses. Accurate expressions for estimating the fracture mechanics crack tip parameters such as the stress intensity parameter, K, the crack mouth opening displacement (CMOD), and the load-line displacement (LLD) are developed over a wide range of crack sizes for the DEN(T-C) specimen. A new compliance relationship for use in experimental testing has been developed by using the compliance form available in ASTM E-647 standard.

Experimentally determined compliance value compared well with the new relation for C15 steel (AISI 1015) and P91 steel tested at room and elevated temperature conditions respectively. Fatigue crack growth rate data generated using the DEN(T-C) specimens on the two metallic materials are in good agreement with the data generated using standard compact specimens; thus validating the stress-intensity factor and the compliance equation for the double edge notch tension-compression specimen. The testing has shown that the DEN(T-C) specimen is prone to crack asymmetry issues. Through inspection of fatigue surfaces, it has been found that that better alignment control procedures are needed to ensure symmetric crack fronts for the DEN(T-C) specimen. Creep-fatigue crack growth tests were conducted on 9Cr-1Mo (P91) steels at 625°C with various hold times. These tests were conducted using C(T) specimens under constant load amplitude conditions (tension-tension) and DEN(T-C) specimens under displacement like conditions (tension-compression). Crack growth data generated under creep-fatigue conditions using standard C(T) specimens correlated well with crack growth data generated using DEN(T-C) specimens. The crack growth rates per cycle increased significantly with increase in hold time when crack growth data were plotted with the cyclic stress intensity parameter, Delta-K. A transient behavior in the initial portion of da/dN versus Delta-K plots were observed for the hold time tests, as reported previously by several other researchers. It is shown for the C(T) specimens that the creep-fatigue interactions during crack growth for various hold times are represented better by the (Ct)avg parameter implying that the P91 steel behaves in a creep-ductile manner. Significant differences (factors of 2 to 5) were observed between the calculated values of (Ct)avg and those based on measured values of force-line deflection. It is also shown that there is a high risk of obtaining invalid data in longer hold time tests under force-control conditions. The usefulness of DEN(T-C) specimens for crack growth studies under displacement controlled conditions to combat ratcheting problems in tests conducted under load conditions is established. The tests conditions for the round-robin program on creep-fatigue crack growth testing in support of ASTM E-2760 are finalized. Further developments needed in creep-fatigue crack growth testing are also presented.

Fatigue Testing of High-density Polyethylene and Polycarbonate with

Crack Length Measurement Using Image Processing Techniques

A software has been developed to conduct constant amplitude fatigue crack growth tests on the lines of a standard test method proposed by the American Society for Testing and Materials (ASTM E 647).