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Assessment of Damage Tolerance Standard Test Methods and Development of Crack Growth and Delamination Database for Composite Structures

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Final Report

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16. Abstract

This research was conducted as a part of the Federal Aviation Administration (FAA) damage tolerance technology development and database generation for composite materials used in rotorcraft and general aviation industries. The objectives of the research were to review the status of the fracture and fatigue testing of composite laminates, develop a total fatigue life prediction model, generate the database of delamination growth rates for mode I loading, determine constants in the total fatigue life model, and verify the model.

The present research proposed and developed three total life prediction models. They are (1) a log-log equation with resistance (G_R) normalization, (2) a log-linear equation with critical energy release rate (G_{IC}), and (3) a log-log equation with G_{IC} normalizations. All three total life equations were proposed and developed for the first time in the literature. The most promising total life prediction model is the G_R normalization.

Two material systems were considered in this research: (1) woven-roving Fiber Glass Industries, Inc. (FGI) 1854 E-glass/Dow 510A-40 vinyl ester and (2) unidirectional Toray's T800H carbon/3900-2 epoxy composites. The glass/vinyl ester composite panel was fabricated by North Carolina A&T developed vacuum-assisted resin transfer molding (VARTM) technique and carbon/epoxy panel by no-bleed autoclave processing. Fracture resistance test data was generated by ASTM D 5528 test method. The G_{IC} and G_{IR} data were reduced by modified beam theory, compliance, and modified compliance methods. An automated data reduction program was developed using the Microsoft® Excel® spread sheet. The program is included in the report.

Fatigue onset life and delamination growth rate tests were conducted as per the ASTM D 6115 standard. Either 2% or 5% compliance increase criteria was found to be appropriate for predicting the onset life. The asymptotic value of energy release rate from the data generated was about $0.22G_{IC}$ for glass/vinyl ester. The threshold G (G_{th}) will be less than the asymptotic value. Fatigue delamination growth rate tests were started with the $G_{I\max}$ loading equivalent to 0.8 G_{IC}.

For the glass/vinyl ester, the developed delamination growth rate equation was verified for two types of block fatigue loading with $R = 0.1$. One type of loading was typical service loading while the other was aggressive with high value of $G_{I\max}$. The block loading consisted of $G_{I\max}$ rising, constant, and decreasing segments. The G_{IR} normalized delamination growth rate equation agreed very well with experiment for the block loading 1 and reasonably well for block loading 2. The log-linear equation agreed very well with experiment for block loading 1 but was inaccurate for block loading 2. The verification was performed only for glass/vinyl ester composite but not for carbon/epoxy because of thermoplastic interlayer effect.

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LIST OF ACRONYMS

CC	Compliance calibration
DCB	Double canitlever beam
ENF	End-notched flexure
FAA	Federal Aviation Administration
FGI	Fiber Glass Industries, Inc.
MCC	Modified compliance calibration
MBT	Modified beam theory
SEM	Scanning electron microscopy
VARTM	Vacuum-assisted resin transfer molding

EXECUTIVE SUMMARY

This research was conducted as a part of the Federal Aviation Administration (FAA) damage tolerance technology development and database generation for composite materials used in rotorcraft and general aviation industries. The objectives of the research were to review the status of the fracture and fatigue testing of composite laminates, develop a total fatigue life prediction model, generate the database of delamination growth rates for mode I loading, determine constants in the total fatigue life model, and verify the model.

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Two material systems were considered in this research: (1) woven-roving Fiber Glass Industries, Inc. (FGI) 1854 E-glass/Dow 510A-40 vinyl ester and (2) unidirectional Toray's T800H carbon/3900-2 epoxy composites. The glass/vinyl ester composite panel was fabricated by North Carolina A&T developed vacuum-assisted resin transfer molding (VARTM) technique and carbon/epoxy panel by no-bleed autoclave processing. Fracture resistance test data was generated by ASTM D 5528 test method. The G_{IC} and G_{IR} data were reduced by modified beam theory, compliance, and modified compliance methods. An automated data reduction program was developed using the Microsoft® Excel® spread sheet. The program is included in the report.

Fatigue onset life test was conducted as per the ASTM D 6115 standard. Constant-amplitude cyclic displacement loading was used with an R ratio of 0.1. One percent compliance change criteria was found to be invalid for woven textile composites because a number of microscope cracking within the tow occurs before any propagation in the delamination front. That damage alone caused more than 1% compliance increase. Either 2% or 5% compliance increase criteria was found to be appropriate for predicting the onset life. The asymptotic value of energy release rate from the data generated was about 0.22 G_{IC} for glass/vinyl ester. The threshold G (G_{th}) will be less than the asymptotic value.

Fatigue delamination growth rate tests were conducted similar to ASTM D 6115 but started with the $G_{I\max}$ loading equivalent to 0.8 G_{IC}. Two types of data recording and reductions were used. One was the stepped number of load cycles approach, and the other was the compliance approach. In the stepped method, the test was conducted by incrementing the displacement at every specified number of load steps. Then the load and the delamination length were recorded at the maximum cyclic displacement. From this data all other required parameters were calculated. In the compliance approach, the compliance equation generated separately was used for calculation. The first method was used for both glass/vinyl ester and carbon/epoxy composites, while the second method was used only for carbon/epoxy composite.

For the glass/vinyl ester, the developed delamination growth rate equation was verified for two types of block fatigue loading with R = 0.1. One type of loading was typical service loading while the other was aggressive with high value of $G_{I\max}$. The block loading consisted of $G_{I\max}$

rising, constant, and decreasing segments. The G_{IR} normalized delamination growth rate equation agreed very well with experiment for the block loading 1 and reasonably well for block loading 2. The log-linear equation agreed very well with experiment for block loading 1 but was inaccurate for block loading 2. The verification was performed only for glass/vinyl ester composite but not for carbon/epoxy because of thermoplastic interlayer effect.

1. INTRODUCTION.

1.1 BACKGROUND.

Susceptibility to delamination is one of the major weaknesses of laminated composite structures. Knowledge of the laminated composite material's resistance to interlaminar fracture and fatigue life is essential to establish design allowables for damage tolerance analysis and structure design. The Technical Oversight Group for Aging Aircraft (TOGAA) recommended the Federal Aviation Administration (FAA) Rotorcraft Directorate to implement damage tolerance and fatigue life evaluation technology for composite structures so that the rotorcraft can be operated safely, inspected, and repaired as needed. In metallic structures, certain size cracks are assumed to be present. Using fracture mechanics methodologies and load spectrum, the crack propagation is determined. Based on the crack propagation life, suitable inspection intervals are established so that a crack can be found and repaired long before they become critical or exceed the residual strength of the component. This concept has been successfully used in fixed-wing aircraft designs. There, the majority of the work was based on mode I stress state. This methodology works well even for cracks subjected mixed-mode stress state because the cracks eventually turn and become perpendicular to the loading direction. Total life prediction models based on fatigue crack propagation rates that cover all three domains, namely, subcritical (or slow) growth, linear, and unstable fracture, have been developed for some metallic materials [1]. Currently, these methods are being investigated for rotorcraft materials and structures by the FAA. Figure 1-1 describes the three domains of crack propagation and their mechanisms [1 and 2]. The crack propagation rate depends on the microscope details of the material in domain 1, on the crack driving force (K or ΔK) in domain 2, which is defined by the famous Paris law [2] equation, and on the fracture characteristics of the material in the unstable domain 3. Such interlaminar delamination growth models do not exist for composite materials.

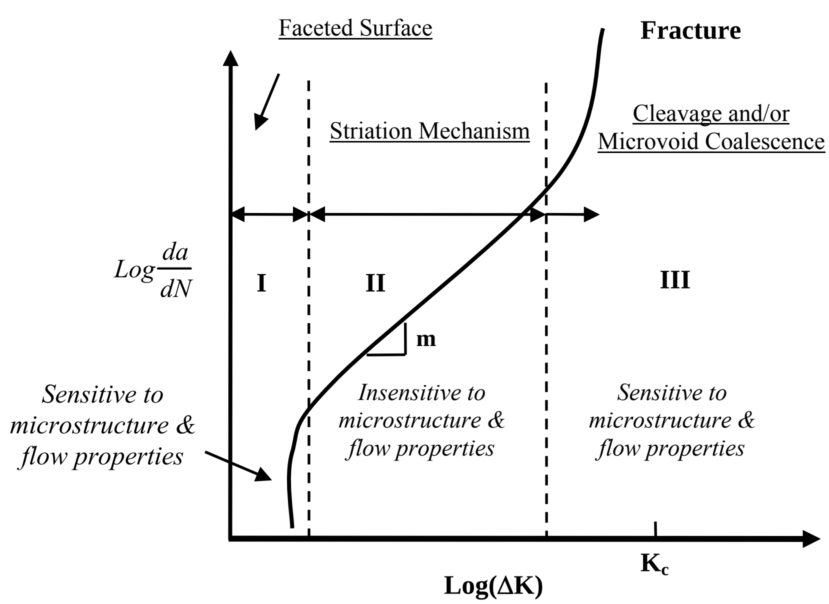


Figure 1-1. Typical Total Fatigue Propagation Model for Metallic Material

State of the art of fatigue design technology for rotorcraft components is far behind fixed-wing aircraft. The fatigue lives are still calculated based on the S-N (fatigue response) diagram. The fracture mechanics-based models need to be developed. One of the main issues in rotorcraft is the high number of load cycles (10 to 100 million). The rotorcraft have many components that are exposed to extensive vibrations resulting in millions of load cycles more than the fixed-wing aircraft components. Hence, a conservative approach is followed. While fracture mechanics-based life prediction models are being developed for metallic rotorcraft structures, the FAA rotorcraft directorate has also embarked on the development of a similar technology for composite structures.

The concept adapted to develop fatigue delamination propagation models for composite materials is similar to that of metals technology. The laminated composite structures are assumed to have certain delaminations. Using fracture mechanics methodologies and a load spectrum, the number of flights or some other measure, the delamination propagation life of the structural component can be determined. Based on this delamination propagation life, suitable inspection intervals are established so that delaminations can be found and repaired long before they become critical or exceed the residual strength of the component. The effectiveness of damage tolerance analysis depends on many factors, including fracture mechanics methodology, test methods, stress-state, material database, environmental factor, etc. Delamination fracture toughness, fatigue onset life, toughness thresholds, and fatigue propagation rates are required for damage tolerance analysis and design of laminated composite structures. Although the problem of delamination in composites has been widely studied for last 30 years, the technology to predict the total life is very limited or nonexistent [3]. Therefore, this research was focused on developing fatigue damage propagation technology that is similar to metallic materials for composite laminates. Fatigue delamination propagation rate is hypothesized to consist of three domains, namely subcritical, linear, and unstable fracture (as seen in figure 1-2). Delamination propagation rate depends on the microscopic details, such as fiber architecture, resin properties, and fiber-matrix interface characteristics in domain 1. In domain 2, propagation depends on driving force (energy release rate G or ΔG), and many studies have shown that the relationship [3-13] is similar to the Paris law for metals. In the unstable domain, delamination propagation rate depends on the fracture characteristics of the laminate. Early efforts [3-15] were focused on characterizing delamination rate in domain 2. Growth laws were established as a linear equation fit to $log(da/dN)$ versus $log(G_{I\max})$ or $log(\Delta G_{I\max})$. Studies included the effect of stress ratio [2 and 7], matrix toughness [9 and 10], and mixed-mode stress states [4, 6, 9, 11, and 13]. But no work has been reported that extended to other two domains (domain 1 and 3) or total life prediction results. Furthermore, these studies ignored the effect of increased fracture resistance as the delamination grows. Fracture test data of many composite laminates showed increased resistance as the delamination grows because of fiber bridging and matrix cracking. Ignoring the toughness increase could severely underestimate the fatigue life of a component.

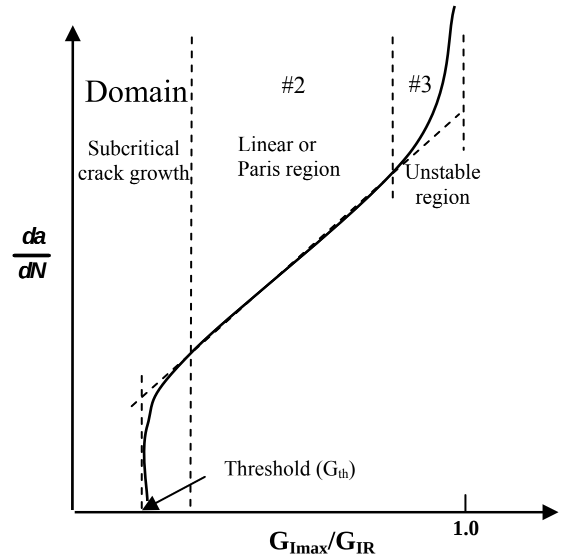


Figure 1-2. Three Domains of Fatigue Delamination Propagation Rate of Composite Laminates

Poursartip [14] was the first to recognize the importance of resistance curve and proposed a G_R normalization of *da/dN* equation for edge delaminated laminates. The G_R normalization resulted in change of exponent in the *da/dN* equation. Recently, Paris and O'Brien [15] proposed an approach for total *da/dN* equation covering all three domains and including the resistance effect. This concept will be evaluated and used to determine the delamination propagation rate equation for selected composite laminates.

1.2 RESEARCH OBJECTIVES.

Objectives of the research were to:

- Review the status of the fracture and fatigue testing of composite laminates.
- Develop a total fatigue life prediction model for composite laminates.
- Generate the database of delamination growth rates for mode I-loaded glass/vinyl ester and carbon/epoxy composites.
- Determine constants in the total fatigue life models through testing for the two material systems and verify these models for block loading.

2. STATUS OF DAMAGE TOLERANCE DATA GENERATION TECHNOLOGY.

2.1 STATE OF STRESS IN ROTORCRAFT COMPONENTS.

The three main structural components of rotorcraft (figure 2-1) are fuselage, flex beam, and rotor. These components, respectively, are subjected to membrane-bending, tension-bending, and tension-torsion loads. The states of stress at the delamination front of these components are mode I, II, I-II, I-III, or II-III. The total life concept envisioned in this research program can be developed to all these components, which cover the three mechanisms described in the previous section. However, the present focus was on mode I-loaded components.

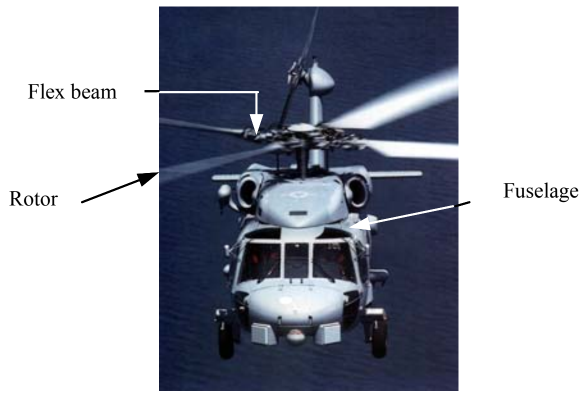


Figure 2-1. Primary Structural Elements in Rotorcraft

Test specimens, apparatus, and the testing methods that simulate pure mode I, II, and III, and mixed-mode (combination of pure modes such as I-II) stress states are needed to generate the database of fracture toughness and fatigue delamination propagation rates.

2.2 STATE-OF-THE-ART FRACTURE AND FATIGUE TESTING OF COMPOSITE LAMINATE.

The state-of-the-art fracture and fatigue testing of composite laminate was evaluated using the following methods.

- Literature search.
- Discussion with a number of researchers around the country who are working on damage tolerance of composite structures. (List of people are in the acknowledgement).
- Review of FAA reports by past contractors and grantees.
- Review of past data generated by the Center for Composite Materials Research at North Carolina A&T State University. Special attention was given to rotorcraft applications.

Based on this study, the following were found. Split beam specimens with different loading systems shown in figure 2-2 were used for various fracture and fatigue tests. They included a double cantilever beam (DCB) for mode I testing, end-notched flexure with three-point or four-point loading for mode II testing, and mixed-mode bending apparatus for mixed-mode (I-II) fracture. The same specimens with test apparatus with cyclic loading were used for fatigue testing. All these tests are in ASTM high-modulus composite materials test standard [16]. A split beam specimen with four-point loading was proposed for measuring mode III fracture toughness [7 to 21] and it had mixed success. The status of various test methods are summarized below.

Mode I—DCB Test

- Delamination fracture: ASTM D 5528—well established
- Delamination fatigue onset: ASTM D 6225—well established
- Delamination growth rate: preliminary tests underway

Mode II—End-Notched Flexure Test

- Fracture: 3 end-notched flexure (ENF) and 4ENF—reasonably well established
- Delamination onset: in development
- Delamination growth rate: in development

Mixed Mode I-II—Bending Test

- Fracture—well established
- Onset: very little

Mode III—Four-Point-Loaded Torsion Test

- Fracture—mixed results

A large body of work has been reported on edge-delaminated specimen [3 and 22] subjected to static and fatigue loading, but much needs to be done on fatigue of pure mode-loaded problems. The current research work focuses on fatigue delamination growth rate data generation for mode I-loaded DCB specimen and then development of an equation to represent the fatigue propagation rate.

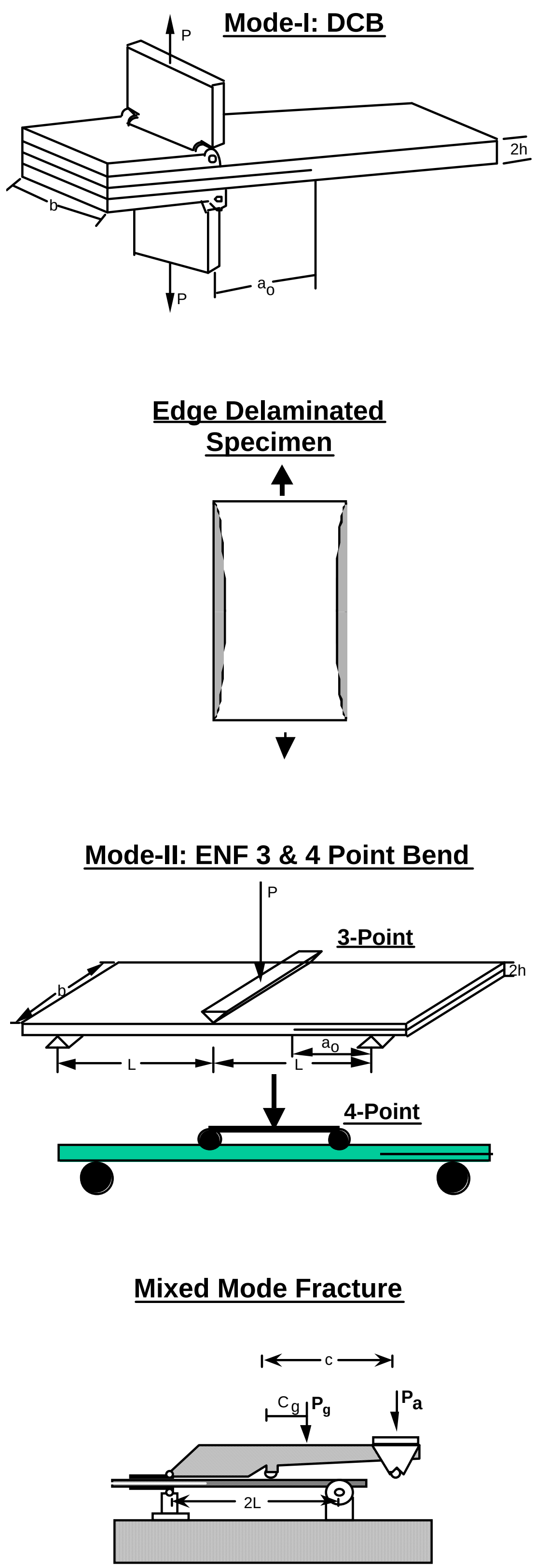


Figure 2-2. Fracture and Fatigue Test Specimen and Loading Apparatus

3. TOTAL LIFE METHODOLOGY FOR DELAMINATED PROPAGATION.

Three methods are proposed for establishing the delamination propagation rate equation. The first is based on the G_R (resistance curve) normalization similar to that proposed in reference 15. The second and third are based on G_{IC} (Initial fracture toughness) normalization. The second method uses the log-linear representation in the domain 2, while the third method uses the log-log representation. Other than these differences, the approach in the second and third methods is the same as the first method. The G_R normalization method is new and is described in detail below.

3.1 METHOD 1: EQUATION WITH G_R NORMALIZATION.

The methodology proposed is more general and is applicable to both pure and mixed-mode loading. However, the description presented here is for mode I loading for simplicity and clarity. The delamination driving force is expressed by energy release rate G_I, the material resistance by G_{IR}, and the delamination growth rate by da/dN.

3.1.1 Assumptions.

The following assumptions are made in developing the da/dN data and the equation.

- Interlaminar fracture resistance (G_R) of delaminated panel increases with delamination length (a) because of matrix cracking and fiber bridging in the case of unidirectional composites and tow cracking, multiple delaminations, tow bridging, and tow breaking in the case of laminated woven/braided fiber composites. The resistance G_R (a) equation can be expressed as a function of initiation fracture toughness G_{IC} and total delamination extension (a-a_0), as shown in figure 3-1.

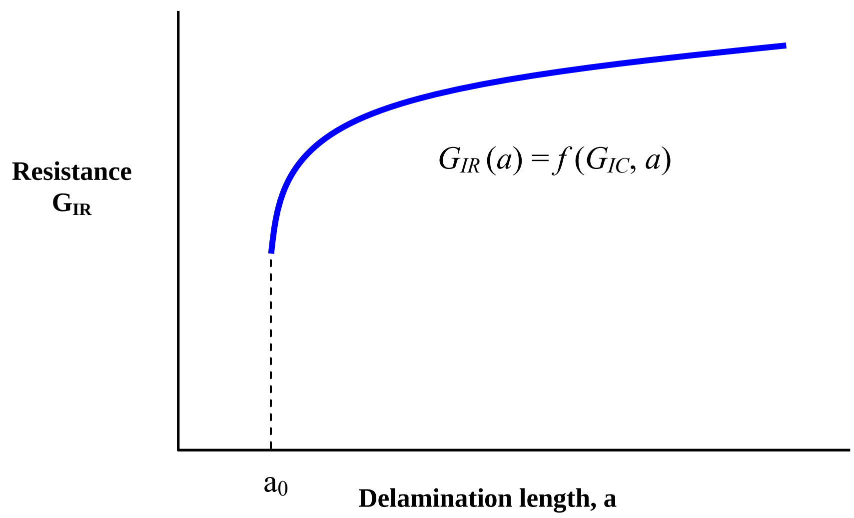


Figure 3-1. Typical Delamination Growth Resistance Curve

- The delamination growth rate (*da/dN*) is proportional to the cyclic maximum driving force $G_{I\max}$ and inversely proportional to the resistance $G_{IR}(a)$ at the current delamination length.

- The *da/dN* is bounded by two extreme values of $G_{I\max}$. One is the threshold energy release rate (G_{Ith}) below which the *da/dN* is zero, and the other is the G_{IR} at which the *da/dN* is infinite or unstable.

- The value of G_{Ith} can be determined by fatigue delamination onset test as per ASTM D 6115 or by displacement controlled fatigue delamination growth rate test. The $G_{Ith} = G_{I\max}$ when $da/dN \approx 0$ (or $<10^{-7}$ in./cycle). In the ASTM D 6115, $G_{Ith} = G_{I\max}$ when the compliance change is less than or equal to 2% in one million load cycles.

3.1.2 Approach.

A constant-amplitude displacement controlled fatigue test is conducted with maximum and minimum values of displacements δ_{max} and δ_{min}, respectively. The load ratio is $R = \delta_{min}/\delta_{max}$. The associated values of energy release rates are $G_{I\max}$ and $G_{I\min}$, respectively, at maximum and minimum values of displacements. The value of $G_{I\max}$ at the beginning of the test is nearly G_{IC} (typical value is about $0.8G_{IC}$). The fatigue test is continued until the *da/dN* drops to $\leq 10^{-7}$ in./cycle. This rate is arbitrary, one can choose a suitable criteria. Record maximum load P_{max} and delamination length *a* as a function of *N*. From this data and δ_{max} calculate *da/dN*, $G_{I\max}$, and $G_{IR}(a)$. Plot the data as *da/dN* versus $G_{I\max}/G_{IR}$ in a log-log scale.

As explained in section 1.1, the *da/dN* data also falls into the three domains, i.e., subcritical or slow growth domain, linear ($G_{I\max}$ controlled) domain, and the unstable fracture domain (see figure 1-2). Divide the *da/dN* versus $G_{I\max}/G_{IR}$ data into three domains. From assumptions *a* and *b*, the *da/dN* in domain 2 is written in a power law form similar to Paris law for metals as

$$\frac{da}{dN} = A\left[\frac{G_{I\max}(a)}{G_{IR}(a)}\right]^m \tag{3-1}$$

Where *A* and *m* are material constants that can be determined from curved fit to the experimental data.

In the subcritical domain, the *da/dN* (assumption c) varies between zero (when $G_{I\max} \leq G_{Ith}$) and a value that matches with the equation 3-1. The form of the *da/dN* equation can be written as

$$\frac{da}{dN} = A\left[\frac{G_{I\max}}{G_{IR}}\right]^m \left[1-\left(G_{Ith}/G_{I\max}\right)^{D_1}\right] \tag{3-2}$$

The exponent D_1 is determined from curve fit to the fatigue test data in domain 1.

In the unstable domain (domain 3), *da/dN* varies between ∞ (when $G_{I\max} = G_{IR}$) and a transition value that matches the upper end of second domain (equation 3-1). The form of the *da/dN* equation is written as

$$\frac{da}{dN} = A\left[\frac{G_{I\max}}{G_{IR}}\right]^m \frac{1}{\left[1-\left(G_{I\max}/G_{IR}\right)^{D_2}\right]} \tag{3-3}$$

The exponent D_2 is a material constant determined from the curve fit to the experimental data in domain 3.

Finally, the combined *da/dN* equation that covers all three domains is

$$\frac{da}{dN} = A\left[\frac{G_{I\max}}{G_{IR}}\right]^m \frac{\left[1-\left(\frac{G_{Ith}}{G_{I\max}}\right)^{D_1}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{IR}}\right)^{D_2}\right]} \tag{3-4}$$

The values of A, m, D_1, and D_2 are to be determined by curve fit to the fatigue test data.

3.1.3 Test Procedure for Establishing the Parameters.

a. Conduct mode I fracture test using the DCB specimen and establish resistance curve $G_{IR}(a)$, as per ASTM D 5528 [16]. Fit a G_{IR} versus a equation. Often a power law equation fits the data very well.

b. Conduct a fatigue test on a virgin DCB specimen with $G_{I\max}$ value about 0.3 G_{IC} until the compliance change is about 5%. This ensures the initiation of a natural delamination, yet the resistance change from G_{IC} is very little or $G_{IR} = G_{IC}$ can be assumed.

c. Conduct constant-amplitude displacement controlled fatigue tests starting with $G_{I\max}$ value that is slightly lower than G_{IC}. A good starting value is about $G_{I\max} = 0.8G_{IC}$. Continue the test until the delamination growth rate becomes very small (e.g., $da/dN \leq 10^{-7}$ in./cycle).

d. Repeat the test at least for three specimens and plot the data as *da/dN* versus $(G_{I\max}/G_{IR})$ on a log-log graph.

e. Divide the plot into three regions by visual inspection. The middle linear region and the subcritical and unstable regions.

f. Perform least square log-log equation fit to the middle region (domain 2) data to establish the constants A and m in equation 3-1.

g. Establish D_1 from equation 3-2 and using already determined values of A and m by fitting the curve to domain 1 and 2 data. A trial and error approach works well.

h. Finally, establish D_2 of the equation 3-3 using the data in domains 2 and 3 by trial and error approach to best fit the data.

i. Using the A, m, D_1, and D_2 values determined above, plot equation 3-4 and compare it with the test data. If the fit is not satisfactory, repeat steps e through i.

3.2 METHOD 2: LOG-LINEAR EQUATION WITH G_{IC} NORMALIZATION.

The test method and the data collection procedure remain the same as section 3.1, but the $G_{I\max}$ in normalized by G_{IC} instead of the resistance G_{IR}. The da/dN versus $G_{I\max}/G_{IC}$ data was fit to a log-linear equation in the domain 2. The total equation for delamination propagation rate is given by the form

$$\frac{da}{dN} = 10^{\left[A_l\left(\frac{G_{I\max}}{G_{IC}}\right) - m_l\right]} \frac{\left[1-\left(\frac{G_{I\mathrm{th}}}{G_{I\max}}\right)^{D_1}\right]}{\left[1-\left(\frac{G_{I\max}}{G_C}\right)^{D_2}\right]} \tag{3-5}$$

where A_l, m_l, D_1, and D_2 are material constants determined by fitting equation 3-5 to the test data.

3.3 METHOD 3: LOG-LOG EQUATION WITH G_{IC} NORMALIZATION.

The test method, the data collection, and the curve fit procedures remain the same as in section 3.1, but the $G_{I\max}$ is normalized by G_{IC} instead of the resistance G_{IR}. The total equation for delamination propagation rate is given in the form

$$\frac{da}{dN} = A_c\left(\frac{G_{I\max}}{G_{IC}}\right)^{m_c} \frac{\left[1-\left(\frac{G_{I\mathrm{th}}}{G_{I\max}}\right)^{D_1}\right]}{\left[1-\left(\frac{G_{I\max}}{G_C}\right)^{D_2}\right]} \tag{3-6}$$

A_c, m_c, D_1, and D_2 are the material constants determined from the curve fit to the fatigue data.

4. MATERIAL SYSTEM.

Two sets of materials were chosen: one that is suitable for affordable composites for general aviation (glass/vinyl ester) and the Bell Helicopter Co. approved T800H unidirectional carbon fiber with 3900-2 toughened epoxy.

4.1 GLASS/VINYL ESTER COMPOSITE.

The glass fiber material system chosen was woven-roving E-glass supplied by Fiber Glass Industries, Inc. (FGI) with FGI's super 317 sizing for ease of handling, fast wet-out, and compatibility with vinyl ester resins. The fabric designation was FGI 1854 with 18 oz/square yard areal weight and unbalanced construction. About 59% of fibers were in warp (0^o) direction and the remaining in fill (90^o) direction. The vinyl ester matrix used was Dow Chemicals Derakane 510A-40 brominated for fire resistance property. The vinyl ester had 350 cps viscosity at room temperature, which is ideally suited for vacuum-assisted resin transfer molding (VARTM). The Derakane 510A-40 can be catalyzed to give a wide range of pot life and cure time to suit the size of the panel to be fabricated. The 510A-40 matrix has specific gravity of 1.23, tensile modulus and strength of about 0.5 Msi (3.4 GPa) and 10.5 ksi (73 MPa) respectively, flexural modulus and strength of about 0.53 Msi (3.6 GPa) and 18 ksi (125 MPa), and heat distortion temperature of 22.5^oF.

4.2 CARBON/EPOXY COMPOSITE.

The carbon fiber chosen was Toray's PAN-based Torayca™ T800H, 12k size, impregnated with 3900-2 epoxy resin. The prepreg had a resin content of 40% by weight with an areal density of 190 grams/square meter. The prepreg was supplied by Toray Composites (America), Inc. as P2302-19-610 in a 24-inch-wide unidirectional roll. The 3900-2 epoxy resin is a proprietary resin that has been toughened by the addition of a thermoplastic powder during the prepreg manufacture. The thermoplastic particles form an interleaving layer when the composite is processed. The interlayers enhance the impact resistance of the material. Figure 4-1 shows the viscosity curve of this resin. This material is used by Bell Helicopter as per Material Standard BHTI 299, -947, -347, Revision E and The Boeing Corporation as BMS 8-276F, Type 35, Class 1, Grade 190, Form 1, Composition 2. A set of unidirectional composite mechanical properties provided by the manufacturer are listed in table 4-1.

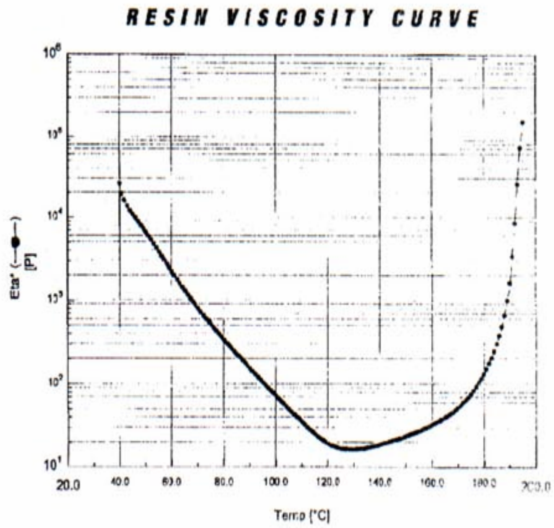


Figure 4-1. Viscosity Curve of 3900-2 Epoxy Resin

Table 4-1. Material Properties of Toray T800H/3900-2 Unidirectional Composite
(Data normalized to 56% fiber volume)

0^o Tensile	
Strength	400 ksi (2.8 GPa)
Modulus	24 msi (163 GPa)
0^o Compression	
Strength	210 ksi (1.5 GPa)
ILSS	13.0 ksi (90 MPa)
0^o Flexure	
Strength	190 ksi (1.3 GPa)
Modulus	19.3 msi (131 GPa)
G_{IC} (DCB)	1.5 in-lb/in^2
G_{IIC} (ENF)	13 in-lb/in^2

5. PROCESSING OF PANELS.

5.1 FABRICATION OF GLASS/VINYL ESTER COMPOSITE PANELS BY VARTM.

The VARTM process is an excellent process for producing large composite components with a minimum of capital equipment. The Swedish navy has recently constructed a 72-meter ship using this process extensively. Structures of such great size and complex geometry, as well as the need for relatively inexpensive equipment requirements, make this process of considerable interest for the fabrication of large components.

The main feature of the VARTM process (see figure 5-1) is the use of a flow media to allow for the relatively free flow of the resin along the surface of the fiber preform rather than along the axis of the preform. The resin flows along the flow media and impregnates the fiber preform by flowing from the flow media through a peel ply into the fiber preform. The whole assembly is in a vacuum bag, which draws in the resin together with the flow media, peel ply, and fiber preform. The flow media used in this work was Roxford-Fordell Lock-Knit 50% Shade Cloth. Many things can be used as a flow media as long as it provides a flow path under the compression pressure exerted by the vacuum and is inert to the liquid resin. As the resin is allowed to flow into the vacuum bag containing the preform assembly, it is desirable to control the resin flow front. This goal is accomplished by introducing the liquid resin into the assembly using a manifold along one edge. A 1/2-inch, high-density polyethylene tube with slots machined along the length with an end plug was used in this case. Likewise, the same type of tubing was used at the opposite edge of the preform to conduct the vacuum into the preform. A 800-ml Staco Tube was used for the liquid resin reservoir. The reservoir was connected to the resin manifold using Masterflex High Performance Tygon Lab (R-3603) Tubing. A peristaltic pump was positioned between the reservoir and the matrix manifold. The peristaltic pump was used to throttle-back the resin flow rate. Early work indicated that the resin would rush rapidly into the flow media and slow down as the flow media was filled. This resulted in excessive porosity in the composite panel. By using the peristaltic pump, the fill rate in the flow media and the preform are controlled to become constant. This technique results in resin impregnation both through-the-thickness and in the direction of flow front thus reducing the void and increasing fiber volume. In addition, it was determined that by alternating the on and off time of the peristaltic pump for brief periods further enhanced the results of the fill. Figure 5-1 describes the complete setup of VARTM process, and reference 23 provides the details.

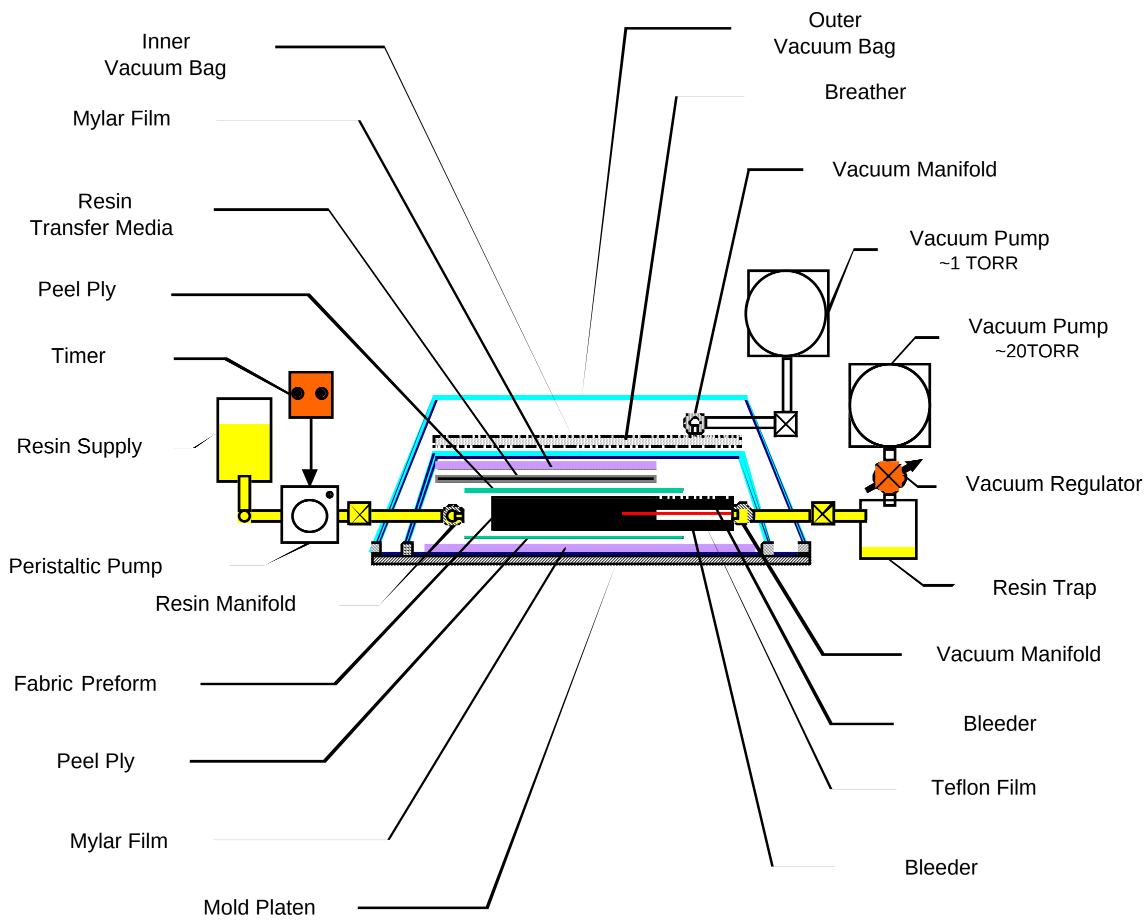


Figure 5-1. Vacuum-Assisted Transfer Molding Process Setup

5.1.1 Preform Preparation and Lay-Up.

The preform was prepared by cutting ten plies of 32- by 12.5-in. FGI 1854 woven-roving E-glass fiber fabric. Weft direction of the fabric was aligned with the axis of the specimen. A 0.5-mil Teflon release film is located between the fifth and sixth plies along one edge of the mold. The Teflon was long enough (38 in. long and 3 in. wide) to extend several inches beyond the panel edge. This provided the opportunity for the resin to fully impregnate the bottom five plies of the preform before the resin from the top plies returned to fill the lower plies. The film provides a debond about 3 inches in length along the edge of the panel. These unbonded plies were used to initiate the crack.

5.1.2 Preform Bag Assembly Preparation.

The mold plate was mold released to provide for easy cleanup of the plate for reuse. Two rows of vacuum bag sealing tape was applied around the perimeter of the mold plate (figure 5-2). The outside sealing tape line was about 2 inches from the inside line. The two rows of sealing tape accommodated two sealing bags, one inside the other. The outside bag is the vacuum compression bag, and the inside bag is the vacuum infiltration bag. The compression bag was evacuated to about 2 torr, and the infiltration bag was evacuated to about 20 torr. The outside bag is at maximum compression to obtain a high fiber volume and the inside bag is at a low vacuum to avoid resin boiling. The area inside the sealing tape was covered with a fitted piece of Mylar® film to further protect the mold surface. A rectangle of peel ply that was 2 in. wider and 4 in. longer than the preform is located near center of the Mylar film. The preform was laid on the peel ply and centered. The edge containing the Teflon release film was positioned at the matrix exit end of the mold. Another peel ply, the same size as the first peel ply, was laid over the preform. The peel ply was used between the preform and the flow media to enable the flow media to be easily removed from the molded panel. The flow media was cut to the size of the preform and layered over the peel ply, as shown in figure 5-1. The next ply used was a Mylar film. This restricts the vacuum pressure from restricting the matrix flow in the flow media. The connecting tubing for the matrix and vacuum manifolds must go through the vacuum bag seals without leaking. This was accomplished by wrapping the tubes with several turns of sealing tape. Then the tubing and sealing tape were placed on top of the perimeter sealing tape. The two areas of sealing tape were worked together to provide an effective seal. Then the inside infiltration bag was placed and all the seal joints were rubbed and mashed until an effective seal was established. The seal leak was tested to determine if the seal was effective. Pleats may be necessary to have the bag accept the deformations required when the vacuum pulls the bag tight. The bag seals should be loosely fitted to avoid shearing of the seals. A breather ply is added over the barrier film. This ply conducts the vacuum evenly across the surface of the preform. The preform bag assembly is shown in figure 5-2.

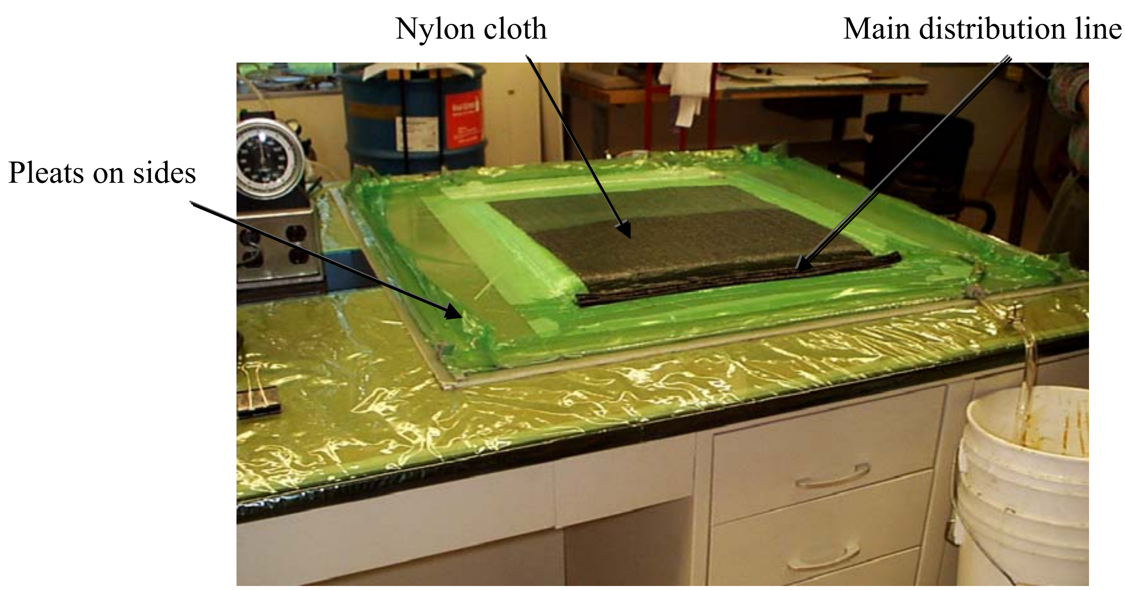


Figure 5-2. Preform Bag Assembly

5.1.3 Resin Preparation.

Dow Chemical's Derakane 510A-40 vinyl ester was mixed with accelerator CoNap in a ratio of 1% to 0.1% by weight (all percentages here are based on the weight of 510A-40 resin). To get longer gel time, a gel time retardant 2,4-P with 0.06% weight was mixed into the master batch. Finally, 1.0% of curing agent methylethelketone peroxide (MEKP) was added. The mixture was stirred for 2 minutes and was evacuated for 5 minutes to eliminate air bubbles in it. At room temperature, gel time of the mixture is about 2 hours. The mixture was transferred into the resin supply.

5.1.4 Preform Impregnation.

The vacuum pump was turned on and the vacuum bag and all its contents were evacuated. The integrity of the seals was checked for leaks by shutting off the vacuum and watching the vacuum gage to determine if there was a loss of vacuum. If a leak was found, the seals were reworked around the plumbing and along the edges and retested until good vacuum seals were obtained. After a stable vacuum was achieved in the bag, the matrix was allowed to slowly flow into the evacuated bag containing the preform. The flow rate was regulated by the peristaltic pump. A timer provided on and off times for the peristaltic pump. For these panels, the pump was set at 300 rpm; the on time cycle was 9 seconds and the off time cycle was 51 seconds. This pumping speed gave a flow rate in the panel of about 0.5 in./minute. The total fill time was approximately 1 hour.

5.1.5 Curing of Panels.

The panels were allowed to cure at room temperature for 72 hours under vacuum pressure. The peel plies were then stripped away and the panels postcured in an oven. The panel was heated at 0.2°F/min to 160°F, held at 160°F for 20 hours, and cooled down to room temperature at 1°F/min. The total postcure and cool down time was about 31 hours. Time-temperature plots of cure and postcure and alternate postcure cycles are shown in figures 5-3 and 5-4, respectively. The gradual postcure heating rate keeps the glass transition temperature of the composite panel above the oven temperature so that warping is minimized. Cured samples were inspected for any known defects.

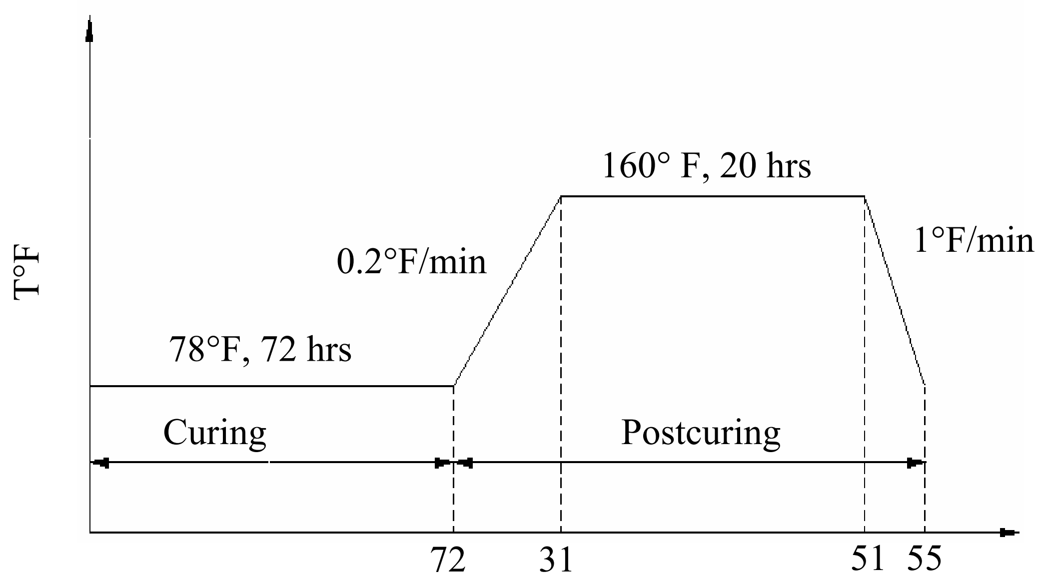


Figure 5-3. Cure and Postcure Cycle for Glass/Vinyl Ester Composite

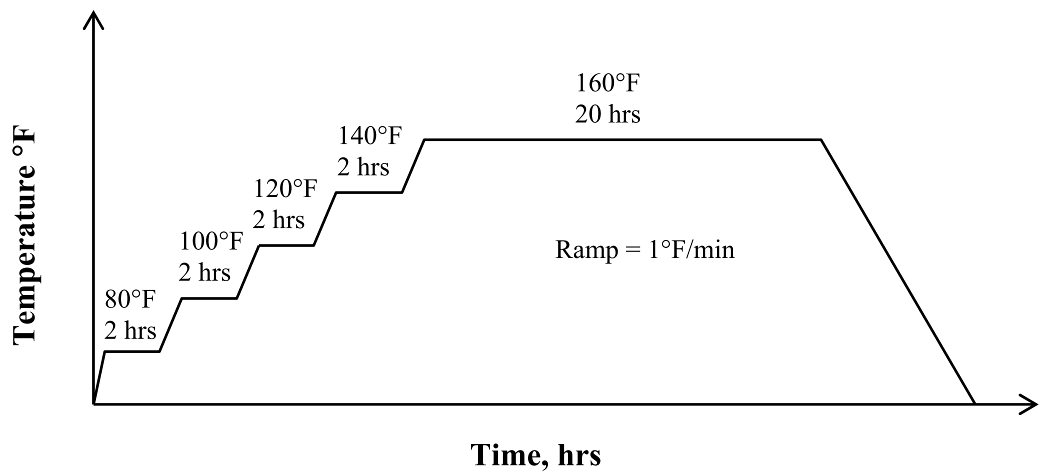


Figure 5-4. Alternate Postcure Cycle for Glass/Vinyl Ester Composite

5.2 FABRICATION OF T800H CARBON/3900-2 EPOXY COMPOSITE.

5.2.1 Autoclave Process.

Four panels were fabricated using a nonbleed autoclave process. In this process, the only resin bleed allowed was through a small fiber glass yarn at each corner of the prepreg preform. This process provided a better surface finish, less thickness variation, as well as better fiber volume control.

5.2.2 Prepreg Preparation.

The refrigerated prepreg is kept in a sealed bag until it warms above the ambient dew point to minimize moisture pickup. The prepreg is cut into 8″ by 12″ panels with the 12″ length of the prepreg being in the fiber direction. Twenty plies were required for each panel. Two plies are laid in place with the aid of a straight edge and put into a vacuum frame for compaction for about 2 minutes. The straight edge maintains the ply alignment within 1 degree. To minimize contamination, the separator paper is left on each surface of the prepreg until a bonding of plies is required. Another two plies are added to the stack until ten plies are compacted together; then, a 0.5-mil-thick Teflon® film is cut to 8″ by 3″ and laid at one end of the stack of ten compacted prepreg plies. The Teflon film provides a nonadhesion area to create the delamination. Another ten prepreg plies are compacted, as described above, and laid on top of the first group of compacted plies now containing the Teflon film required for crack initiation. The two ten-ply stacks containing the Teflon film at one end are put back in the vacuum frame and compressed by the evacuating the assembly. The prepreg preform is now complete.

5.2.3 Bagging.

A steel caul plate is used as the base for the bagging assembly. A 3/8-inch glass plate with a Teflon film taped to it is positioned on the steel plate to maintain their relative positions. The prepreg preform is placed in the center of the Teflon film. A resin dam is placed along each of the four edges adjacent to the prepreg preform to limit the flow of resin from the prepreg during the autoclave cycle as well as to maintain the integrity of the prepreg preform. A strand of fiber glass yarn is positioned at each corner of prepreg preform leading from the preform beyond the resin dam. This fiber glass yarn provides an opportunity for air to bleed from the prepreg preform during evacuation and resin to bleed during the autoclave cycle. Then another piece of Teflon film is placed over the prepreg preform similar to the Teflon sheet below the prepreg preform. Another glass plate is positioned over the Teflon film parallel to the bottom glass plate. The entire assembly is fitted along the perimeter with a Nylon film vacuum bag sealed along the edges with bag sealant tape.

The nonbleed bagging assembly is illustrated in figure 5-5. Figure 5-6 shows the bagging assembly of the prepreg preform with rubber dams, Teflon insert for delamination initiation, as well as the fiber glass yarn placement at the four corners.

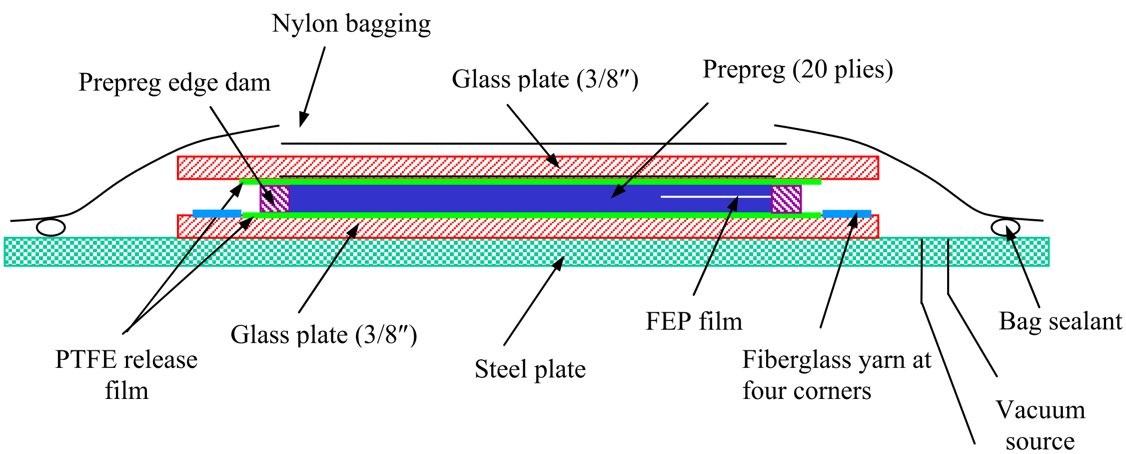
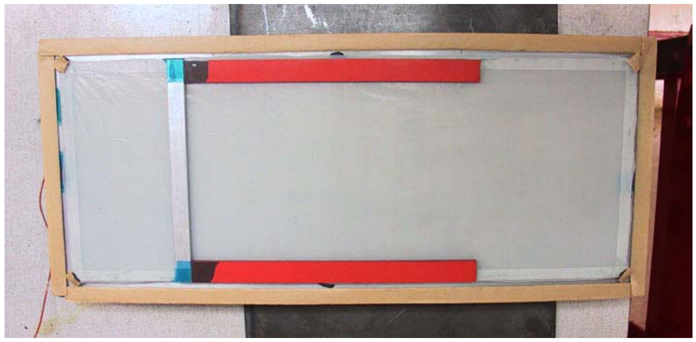
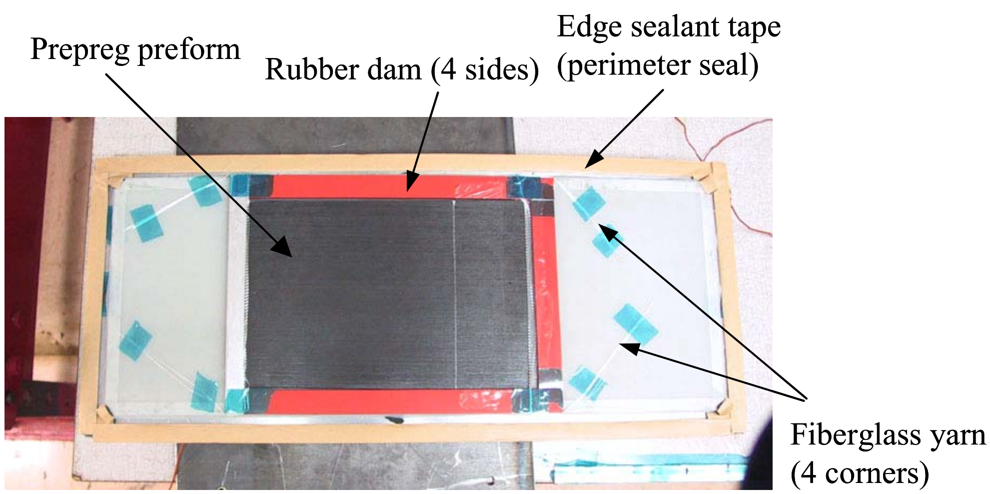


Figure 5-5. Nonbleed Bagging Assembly



3/8″ glass plate over steel mold with bottom PTFE release



Preform with FEP film delamination insert

3/8″ glass caul plate over top PTFE release and perform

Figure 5-6. Bagging Assembly

5.2.4 Autoclave Cycle.

The bagged assembly is positioned in the autoclave and the vacuum hose and temperature control thermocouples are attached. The vacuum sealing system is verified by checking for the ability of the bag and connections to hold a vacuum. While the assembly is under vacuum, any wrinkles or folds in the bag are removed before proceeding.

The bag is vented to the atmosphere and the autoclave is pressurized to 85-100 psig. The heating elements are activated and the autoclave is heated to 355°F at a rate of 3°F per minute. The 355°F cure temperature is held for 130 minutes and then allowed to cool at 3° per minute until 140°F or less is achieved. The autoclave pressure remains on until this temperature is reached. The autoclave door is opened and the bagging material is removed from the cured panel. The autoclave cure cycle is illustrated in figure 5-7.

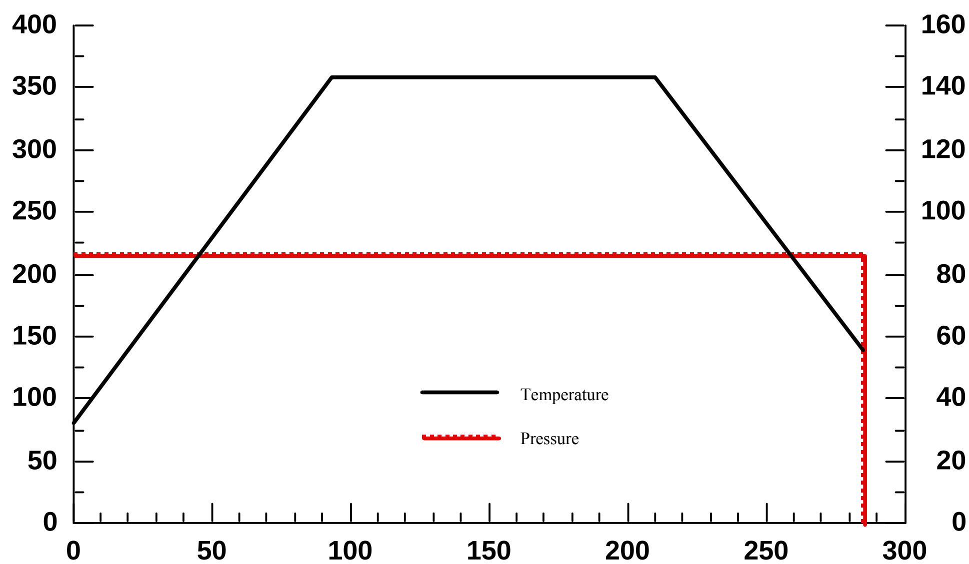


Figure 5-7. Autoclave Cure Cycle

6. SPECIMEN PREPARATION AND CONFIGURATION.

Figures 6-1 and 6-2 show the configurations of two panels of FGI 1854 glass/Dow 510A-40 vinyl ester (Gl/VE) and three panels of T800H carbon/3900-2 epoxy composites. The figures also show edge trimming pattern, delamination location, tab area, and the specimen layout. The Gl/VE panel was cut into test coupons of 10-in.-long, 1.5-in.-wide, and 1.5-in. nominal delamination length. A wider specimen configuration was chosen to accommodate at least three whole unit cells within the width to reduce edge effect. The T800H/3900-2 panel was cut into test coupons of 10-in.-long, 1-in.-wide, and 1-in. nominal crack length. Piano hinges were bonded to the outer faces of the specimen at the debond-end using 3M DP-460™ two-part epoxy. This adhesive was chosen because of its high peel and shear strength. The mounting procedure involved abrading the mating surfaces of the specimen and the tabs. The abraded areas were rinsed with acetone and air-dried. To maintain constant bondline thickness, 1μ glass beads were added to the adhesive in proportions of 5% by weight. After mixing, the epoxy was spread onto the aluminum tabs, which were then aligned symmetrically on the specimen and clamped in place. The adhesive was cured at 60°C for 2 hours. The edge of the coupon was painted with white-out to highlight the delamination tip while it is growing during the test. Reference marks were made on the white-out as per the ASTM D 5518 test standard [16]. The DCB specimen configuration is shown in figure 6-3. A list of specimen numbers and the tests conducted for glass/vinyl ester and carbon/epoxy are given in tables 6-1 and 6-2.

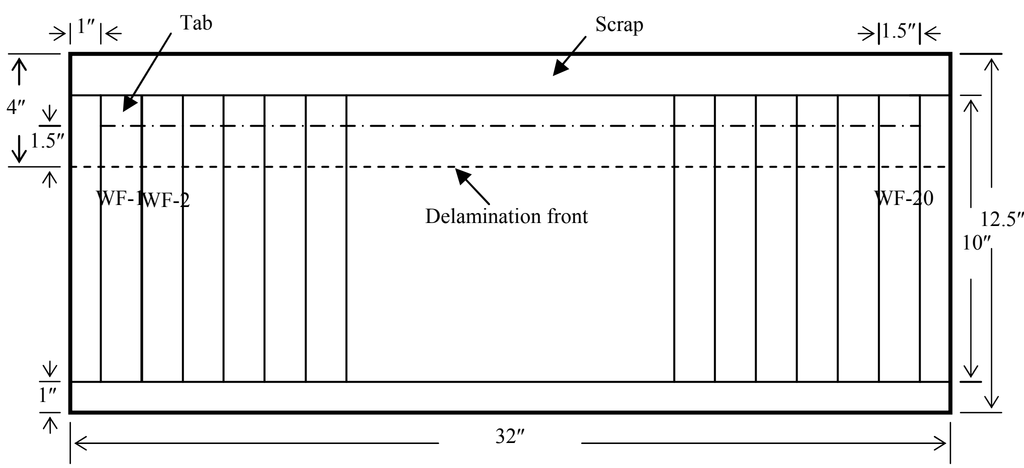


Figure 6-1. The FGI 1854/Dow 510A-40 Panel and Specimen Layout

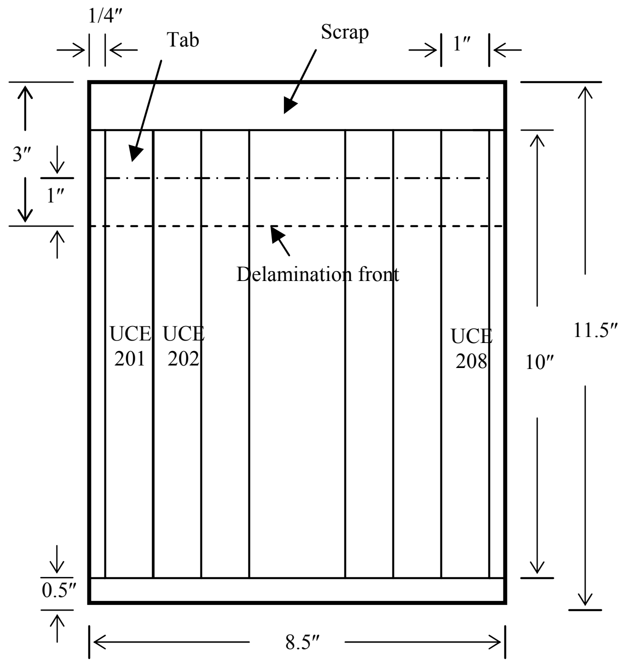


Figure 6-2. T800H/3900-2 Panel and Specimen Layout

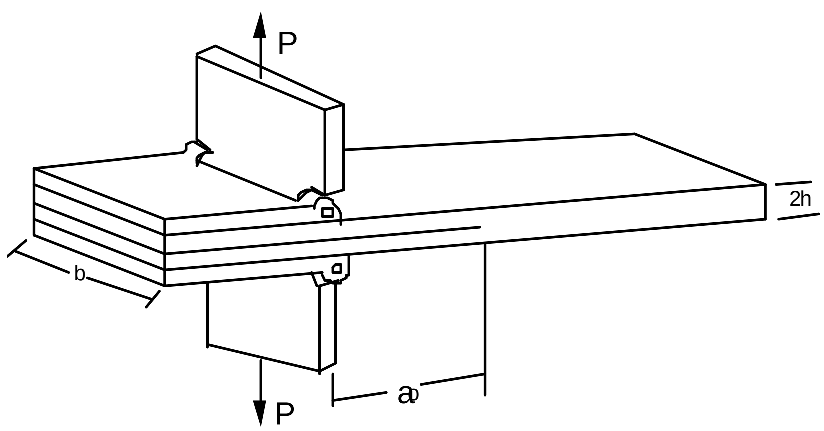


Figure 6-3. Specimen Configuration

Table 6-1. List of Specimen Numbers, Configurations, and Tests Conducted for Glass/Vinyl Ester

Test	Specimen Number	a_0 (in.)	b (in.)	2h (in.)
Fracture	W-1	1.455	1.497	0.195
	W-2	1.434	1.499	0.196
	W-3	1.475	1.497	0.195
	W-4	1.478	1.499	0.195
	W-5	1.488	1.498	0.199
Fatigue	WF-6	1.464	0.196	1.495
	WF-7	1.441	1.490	0.191
	WF-8	1.468	1.491	0.197
	WF-12	1.440	1.492	0.200

Table 6-2. List of Specimen Numbers, Configurations, and Tests Conducted for Carbon/Epoxy

Test	Specimen Number	a_0 (in.)	b (in.)	2h (in.)
Fracture	PN3S1	0.991	1.094	0.154
	PN3S2	0.995	1.090	0.152
	PN3S3	0.982	1.092	0.154
	PN3S4	1.000	1.095	0.155
	PN3S5	0.998	0.970	0.151
Fatigue	UCE203	0.995	0.982	0.148
	UCE204	0.989	0.995	0.154
	UCE205	0.992	0.936	0.152
	UCE206	0.974	0.936	0.155

7. FRACTURE TOUGHNESS MEASUREMENTS.

7.1 TEST PROCEDURE.

The fracture tests were performed in an MTS, Inc. test machine using a 200-lb (890 N) load cell. The piano hinge tabs of the specimen were mounted in the hydraulic grips of the load frame. The tests were conducted by stroke-controlled loading with a crosshead rate of 0.02 in./min (0.5 mm/min). Load and crosshead displacements were recorded throughout the test. A magnifying camera with a vernier scale was mounted on a traversing stand (both vertical and horizontal). The camera was connected to a TV monitor to locate and track the crack tip. The test setup is shown in figure 7-1.

Figure 7-1. Fracture Test Setup

At the start of each test, the delamination-tip location was noted. The crosshead displacement was started, and the delamination-tip propagation was monitored through the camera. The specimen was loaded at a constant crosshead rate and the load and displacement values were recorded continuously. The load-displacement data was recorded when the visual onset of delamination movement was observed on the edge of the specimen. The initial loading was stopped after an increment of delamination growth of about 0.2 in. (5 mm). The specimen was unloaded at a constant crosshead rate of up to 1 in./min (25 mm/min). After unloading, the position of the delamination tip was marked on both edges of the specimen. No specimen had the delamination length on the two edges that differed by more than 0.08 in. (2 mm). The specimen was reloaded at the same constant crosshead speed of 0.02 in./min (0.5 mm/min) without stopping or unloading until the final delamination length increment was reached. The load and displacement values were recorded at every 0.04-in. (1-mm) increment in the first 0.2-in. (5-mm) delamination growth increment. Subsequently, load and displacement data were recorded at every 0.2-in (5-mm) growth, until the delamination propagated at least 1.8 in. (45 mm) or the desired value, and again at every 0.04-in. (1-mm) increment for the last 0.2 in. (5 mm) of delamination propagation.

The total delamination extension criteria used for glass/vinyl ester composite was about 2.5 in. (64 mm) and for carbon/epoxy composite was about 4.0 in. (102 mm).

7.2 METHODS FOR COMPUTATION OF ENERGY RELEASE RATE.

Three methods of data reductions [16] were used to calculate energy release rate (G). These methods are explained below.

7.2.1 Modified Beam Theory Method.

The modified beam theory (MBT) expression for the energy release rate of a perfectly built-in (that is, clamped at the delamination front) double cantilever beam is

$$G_I = \frac{3P\delta}{2ba} \tag{7-1}$$

Where P = load, δ = load point displacement, b = specimen width, and a = delamination length. This expression will overestimate G because of a perfect built-in assumption. The rotation of debond tip decreases the beam stiffness. A number of studies can be found in the literature on how to account for this rotation [23-26]. The most simple and accurate method [26] is to treat the debond length as longer, $a + |\Delta|$, where Δ is determined experimentally by generating a least square plot of the cube root of compliance, $C^{1/3}$, as a function of delamination length 'a'. Figure 7-2 describes the determination of Δ. The compliance, C, is the ratio of the load point displacement to the applied load, δ/P. The values used to generate figures 7-3 was the load and displacement corresponding to the debond length measured on the edge of the specimen. The mode I energy release rate G_I is calculated from

$$G_I = \frac{3P\delta}{2b(a+|\Delta|)} \tag{7-2}$$

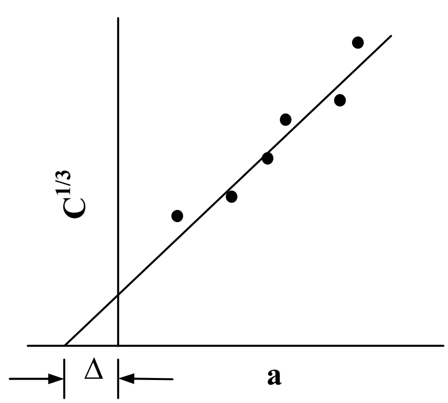


Figure 7-2. Determination of Parameter Δ

7.2.2 Compliance Calibration Method.

Compliance calibration (CC) is one of the oldest methods in fracture mechanics. Here, a plot of *logC* versus *loga* was generated using the visually observed debond growth onset and propagation values. Then, a least-square linear fit to the data was performed. The slope of the line gives the exponent *n* of the compliance equation. Figure 7-3 describes the determination of *n*. The Mode I energy release rate is given by

$$G_I = \frac{nP\delta}{2ba} \tag{7-3}$$

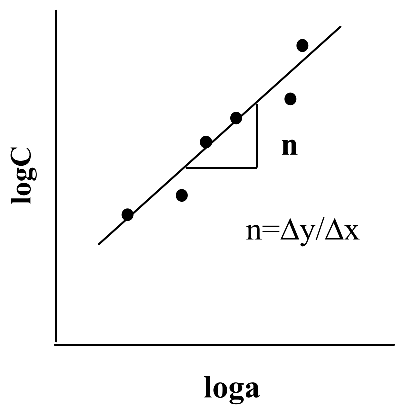


Figure 7-3. Determination of Parameter *n*

7.2.3 Modified Compliance Calibration Method.

An improved method of the CC method is the modified compliance calibration (MCC) method. Here, a least-squares fit of the debond length data normalized by specimen thickness, a/h, as a function of the cube root of compliance, $C^{1/3}$, using the visually observed disbond onset and all the propagation values, is performed. The slope of this line is A_1. Figure 7-4 describes the determination of A_1. The Mode I energy release rate is calculated using equation 7-4:

$$G_I = \frac{3P^2C^{2/3}}{2A_1bh} \tag{7-4}$$

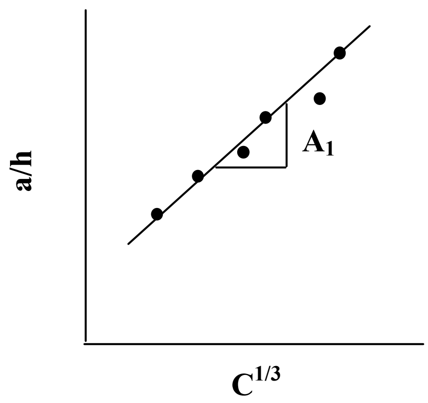


Figure 7-4. Determination of Parameter A_1

All three methods give nearly the same results. The authors' experience has been that MBT and MCC methods gives nearly equal G_I results, while CC method results, sometimes, vary as much as 5%. Therefore, the MBT method was chosen in this study for data reduction because of its simplicity and accuracy. Results from other methods are also presented in some cases.

7.3 AUTOMATED DATA REDUCTION BY MICROSOFT® EXCEL® SPREADSHEET PROGRAM.

All three methods of reducing the fracture resistance data of DCB specimens are programmed in an Microsoft Excel spreadsheet. All that is required from the user is to enter load (P), load-point displacement (δ), and delamination lengths (a). The width (b) and thickness ($2h$) are entered on the top row (figure 7-5). The program automatically performs the curve fit (figure 7-6) to extract delta (Δ), n, and A_1. The user enters these values in a specific cell of the spreadsheet (figure 7-5). All G_{IR} values are instantly calculated. A step by step procedure of how to use the program, employing an example data, is as follows.

- Double click the table in figure 7-5 so that the Microsoft Excel spreadsheet is opened showing the data.

- Enter crack length (a), load (P), and displacement (δ) from the row number labeled **Begin**. Choose appropriate units for load and linear dimensions. If lb and inch are chosen, then G_R will be in in.-lb/in^2. If N and m are chosen, then G will be in Joules/m^2.

- If the data is longer than the example data given between **Begin** to **End** rows, then insert additional rows in the middle by copying/duplicating rows. If the data set is smaller, then delete excess rows between **Begin** and **End**.

- Once all data are entered, the three charts in figure 7-6 are automatically updated to reflect the new values.

- Chart 1 gives the relationship between $C^{1/3}$ and a in a form $y = mx + c$. Then, calculate Δ=c/m and enter the value in Δ cell in figure 7-5.

- Coefficient of *x* in chart 2 is *n*, enter the value under cell *n* (figure 7-5).
- Coefficient of *x* in chart 3 is A_1, enter this value under cell A_1 (figure 7-5).
- Now *G* from all three methods are calculated, as well as cumulative delamination propagation length *Da* in the last column of figure7-5.

Specimen WF-1

h,in	b,in	Delta (□)	n	A1
0.1947	1.497	0.218	2.7426	46.223

	a	*P* (lb)*	disp (in.)*	*C=d/P*	*C*^1/3	*C*^2/3	G_MBT	G_CC	G_MCC	Da
Begin	1.455	26.89	0.1874	6.97E-03	0.19101	0.03648	3.02	3.17	2.94	0.0000
	1.655	25.94	0.2211	8.52E-03	0.20426	0.04172	3.07	3.17	3.13	0.2000
	1.695	27.77	0.2679	9.65E-03	0.21288	0.04532	3.90	4.02	3.89	0.2400
	1.735	28.11	0.2770	9.85E-03	0.21439	0.04596	3.99	4.11	4.04	0.2800
	1.815	29.46	0.2997	1.02E-02	0.21668	0.04695	4.35	4.46	4.54	0.3600
	1.855	26.07	0.3337	1.28E-02	0.23390	0.05471	4.21	4.30	4.14	0.4000
	2.055	29.49	0.4717	1.60E-02	0.25195	0.06348	6.13	6.20	6.15	0.6000
	2.255	24.54	0.4844	1.97E-02	0.27024	0.07303	4.82	4.83	4.90	0.8000
	2.455	21.35	0.5854	2.74E-02	0.30154	0.09093	4.69	4.66	4.61	1.0000
	2.655	22.96	0.7132	3.11E-02	0.31436	0.09882	5.71	5.65	5.80	1.2000
	2.855	19.52	0.7618	3.90E-02	0.33923	0.11508	4.85	4.77	4.88	1.4000
	3.055	17.59	0.8848	5.03E-02	0.36917	0.13629	4.76	4.67	4.69	1.6000
	3.255	16.83	1.0170	6.04E-02	0.39244	0.15401	4.94	4.82	4.85	1.8000
	3.455	16.07	1.0653	6.63E-02	0.40473	0.16381	4.67	4.54	4.71	2.0000
	3.495	16.94	1.1590	6.84E-02	0.40900	0.16728	5.30	5.14	5.34	2.0400
	3.615	16.85	1.2115	7.19E-02	0.41586	0.17294	5.33	5.17	5.46	2.1600
End	3.655	15.19	1.2308	8.10E-02	0.43272	0.18725	4.84	4.69	4.81	2.2000

**** Appropriate units***

Figure 7-5. G_{IR} Data Generation Microsoft Excel Spreadsheet Program

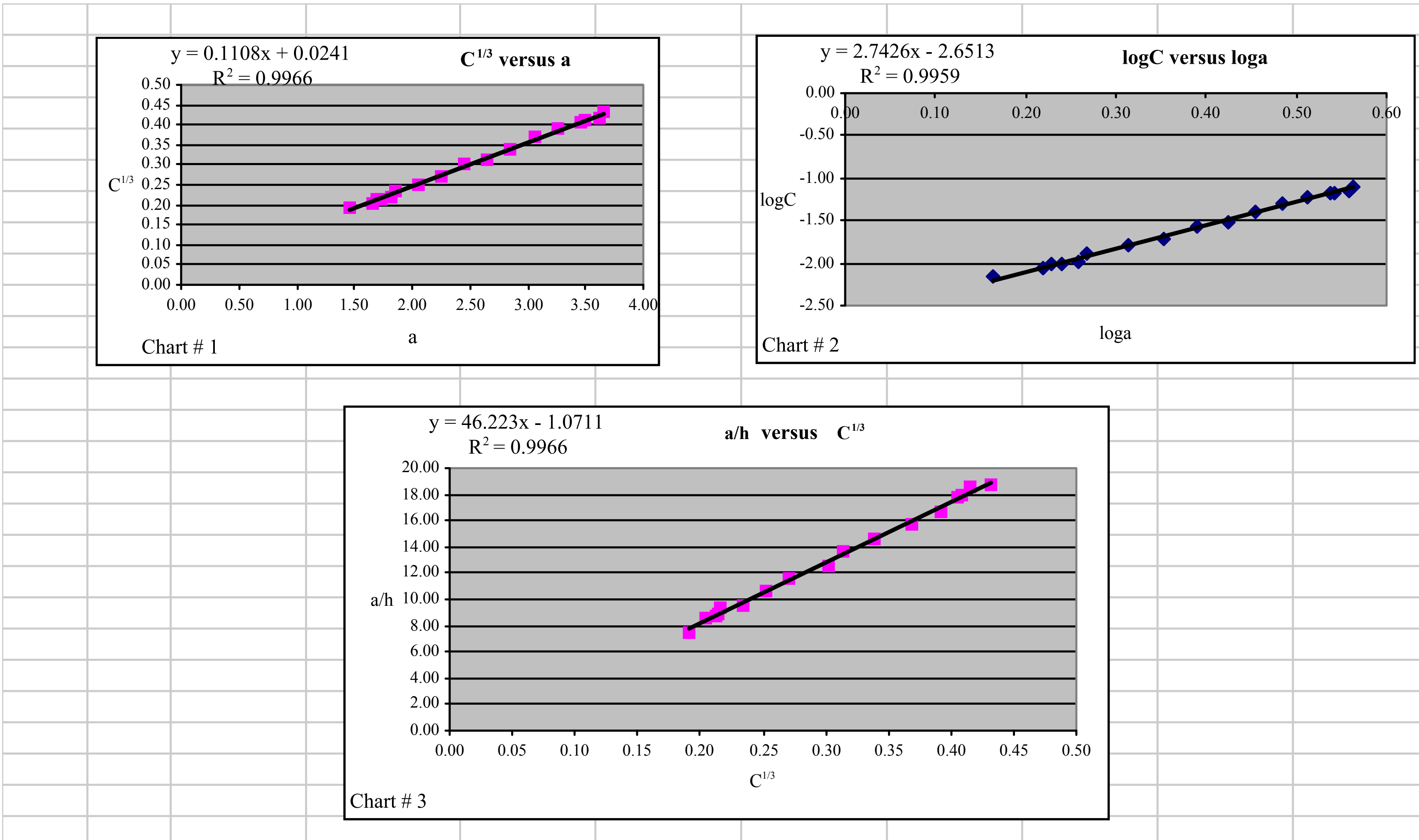


Figure 7-6. Plots for Determination of Δ, *n*, and A_1

7.4 FRACTURE RESISTANCE OF GLASS/VINYL ESTER LAMINATE.

7.4.1 Load Displacement Results.

The load versus displacement curves for all five FGI1854/Dow 510A-40 specimens are shown in figure 7-7. The initial slope of the curves is almost identical. The load displacement response is typical of brittle matrix composite laminates. The camera was mounted to capture the edge view of the specimen recorded interesting failure modes such as tow cracking/splitting and separation, fiber bridging, and fiber breakage. Figures 7-8 and 7-9 show the scanning electron microscope (SEM) images of fracture surfaces that reveal the fiber splitting, breakage, and fiber-matrix interfacial fracture.

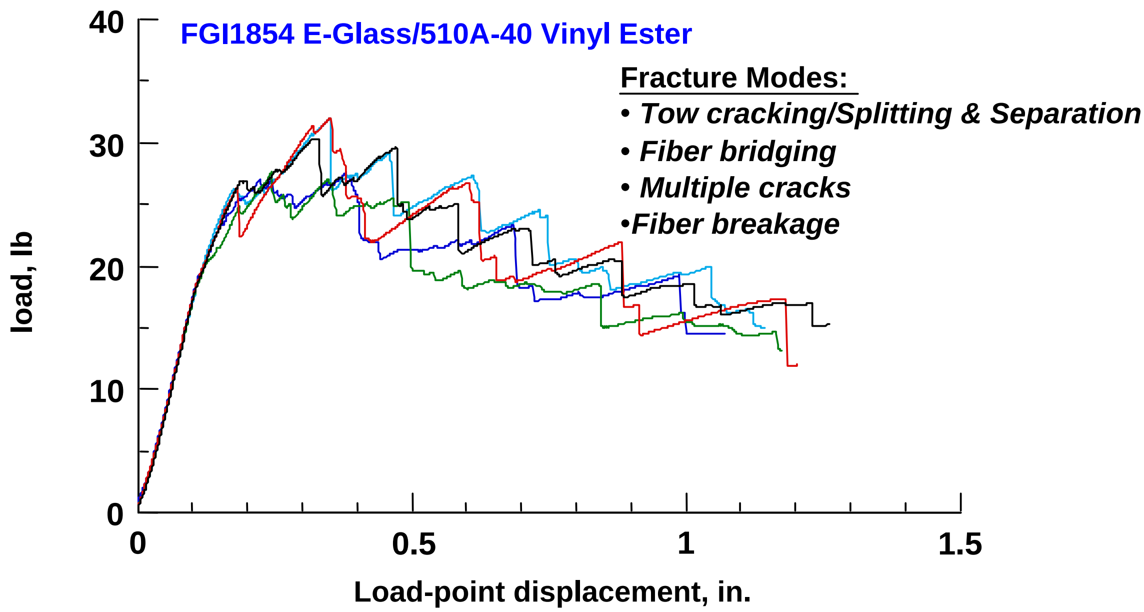


Figure 7-7. Load Displacement Response for Glass/Vinyl Ester Composite

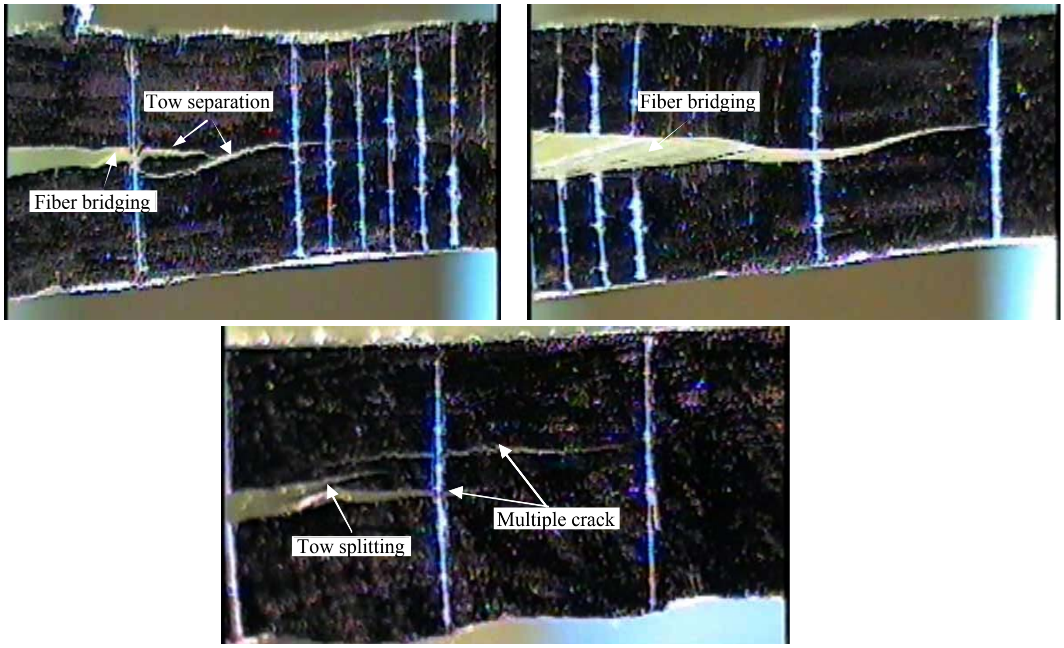
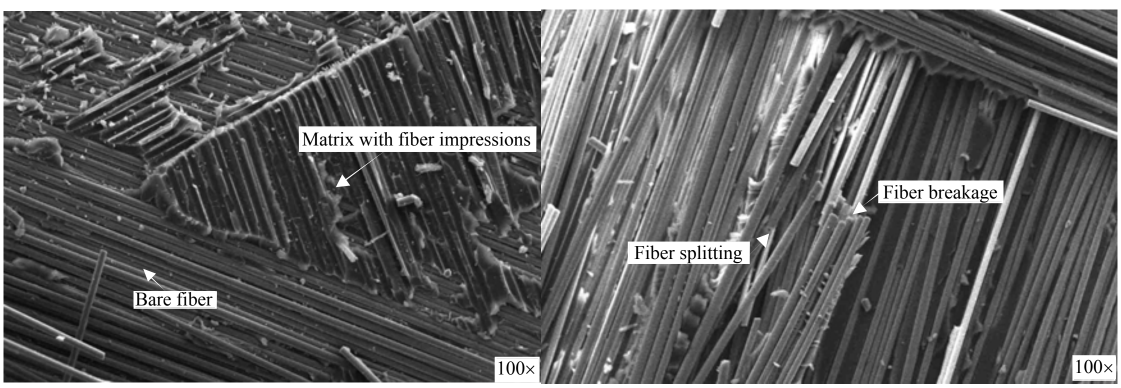


Figure 7-8. Edge Failure Modes of Woven-Roving Glass/Vinyl Ester Laminate



Interfacial fracture **Interfacial fracture and fiber breakage**

Figure 7-9. Fracture Surface of Glass/Vinyl Ester Laminate (SEM)

7.4.2 Fracture Resistance Results.

Energy release rate G_{IR} was calculated from the three methods explained in the previous section. The complete data reduction from load, load point displacement, and delamination lengths are given in appendix A, tables A-1 through A-5, for the five specimens from all three methods. The constants Δ, *n*, and *A*1 determined from the test data for all five specimens are listed in table 7-1. The G_{IR} versus $(a\text{-}a_0)$ results are shown in figures 7-10 through 7-12 for MBT, CC, and MCC methods. All three methods gave G_{IR} within 5% of each of other and MBT and MCC results differed by less than 2%. A simple power-law type of equation fitted through the G_{IR} data of the MBT method is given by

$$G_{IR} = 1.97 + 2.25(a - a_0)^{0.31} \qquad (7\text{-}5)$$

The constant is the initial fracture toughness G_{IC} that was determined from the data when the first visual extension of delamination front was observed. Equation 7-5 also agreed well with the G_{IR} data from CC and MCC methods (figures 7-11 and 7-12).

Table 7-1. Summary of Δ, *n*, and A_1 Parameters From Fracture Tests for Glass/Vinyl Ester Composite

Specimens	FGI 1854 E-Glass/510A-40 Vinyl Ester Laminate		
	Δ	*n*	A_1
W-1	0.218	2.74	46.22
W-2	0.040	3.00	40.45
W-3	0.165	2.80	45.60
W-4	0.113	2.86	46.14
W-5	0.110	2.85	45.06

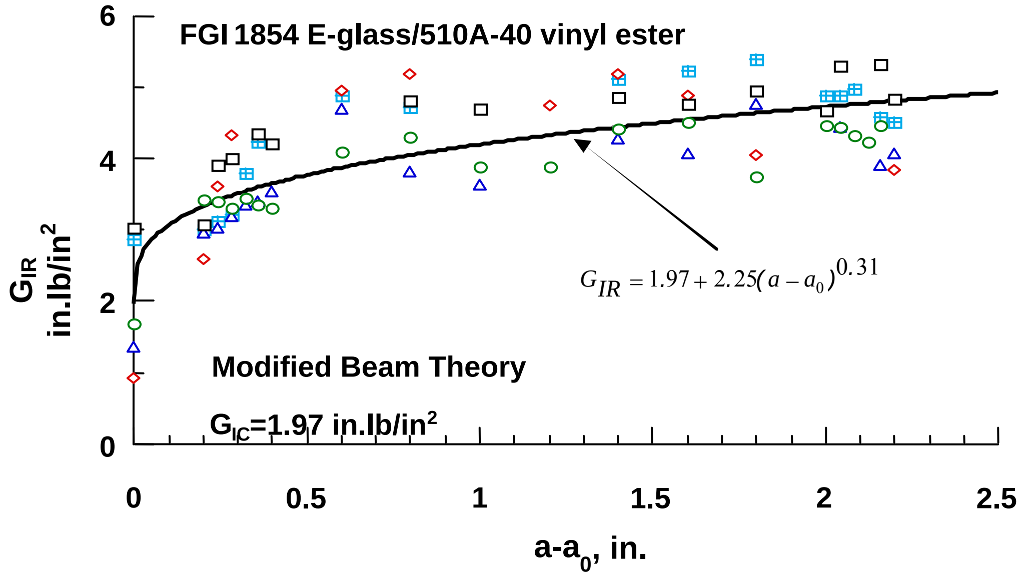


Figure 7-10. G_{IR} Versus Delamination Extension for Glass/Vinyl Ester Composite From MBT Method

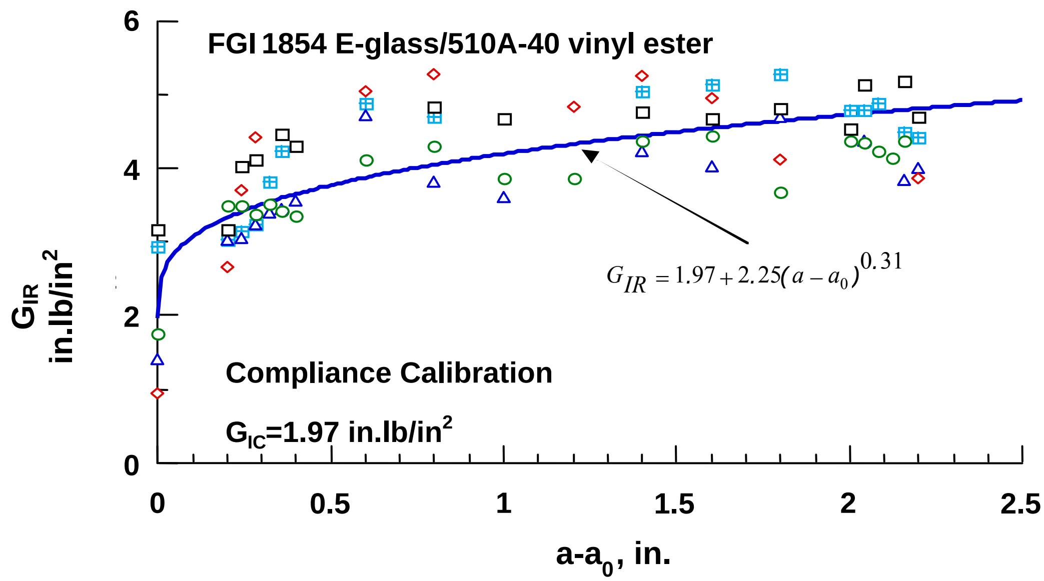


Figure 7-11. G_{IR} Versus Delamination Extension for Glass/Vinyl Ester Composite From CC Method

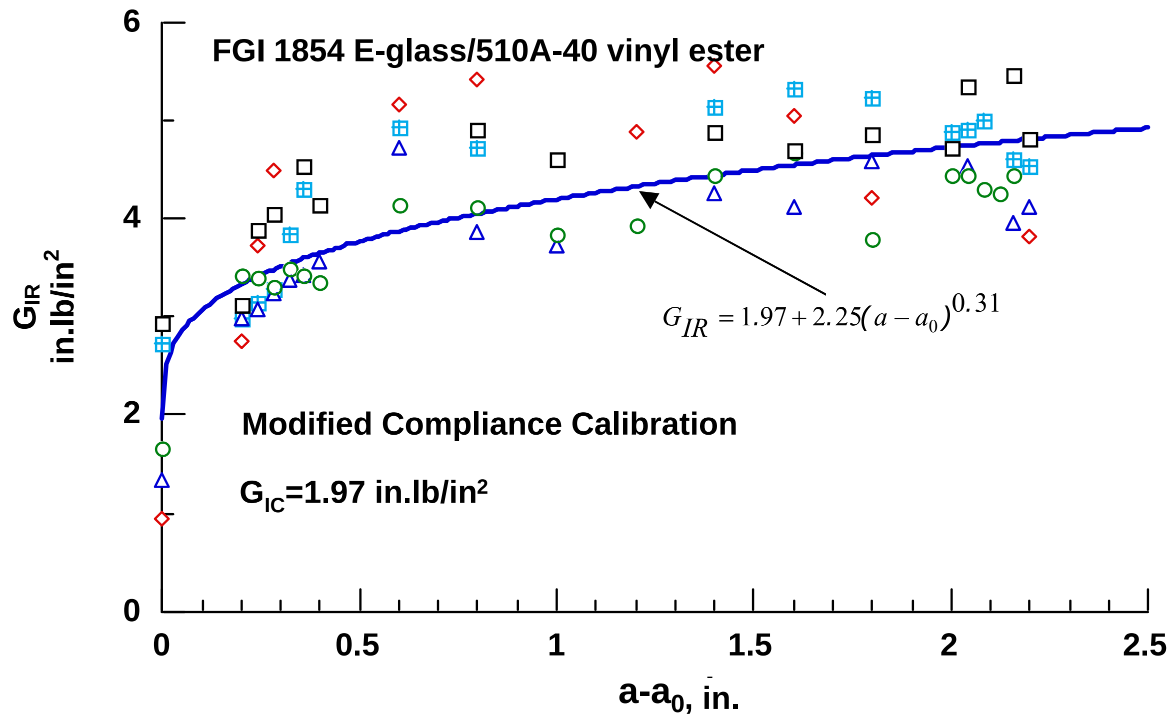


Figure 7-12. G_{IR} Versus Delamination Extension for Glass/Vinyl Ester Composite From MCC Method

7.5 FRACTURE RESISTANCE OF CARBON/EPOXY UNIDIRECTIONAL LAMINATE.

7.5.1 Load Displacement Results.

The load versus displacement curves for all five T800H carbon/3900-2 epoxy specimens are shown in figure 7-13. Responses of these specimens were significantly different from glass/vinyl ester (figure 7-7) and are not typical of brittle matrix composites.

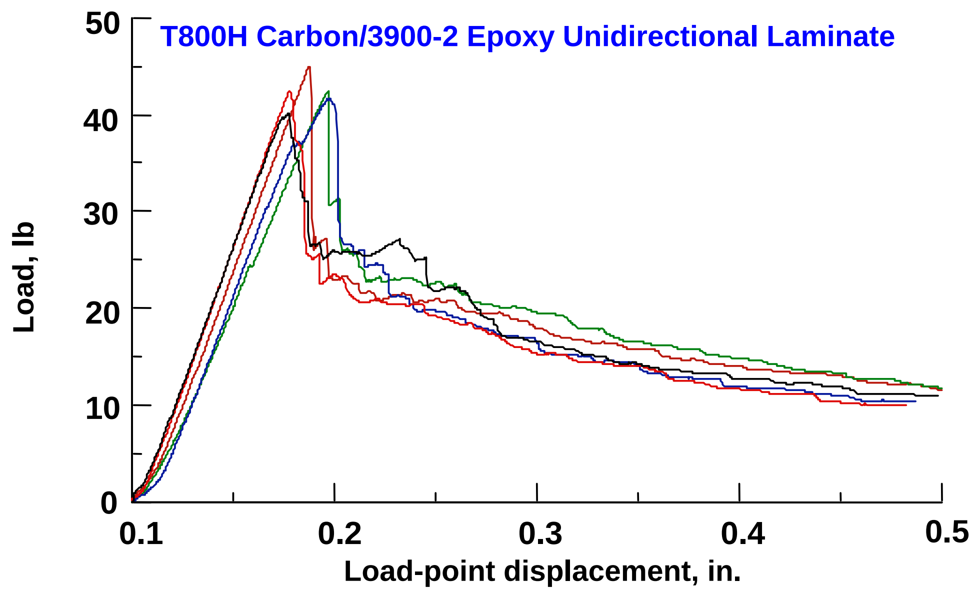


Figure 7-13. Load Displacement Response for T800H/3900-2 Composite

7.5.2 Fracture Resistance Results.

Energy release rate G_{IR} was calculated from the three methods explained in section 7.2. The complete data reduction from load, load point displacement, and delamination lengths are given in appendix A, tables A-6 through A-10, for the five specimens from all three methods. The constants Δ, n, and A_1 determined from the test data for all five specimens are listed in table 7-2. The resistance versus (a-a_0) for all five specimens are plotted in figures 7-14 through 7-16 for MBT, CC, and MCC methods, respectively. Unlike the glass/vinyl ester composite, which showed an increasing resistance curve, this material exhibited an unusual decreasing resistance. The energy release rate decreased from the beginning of crack growth until the crack was extended by about 2 in. and then, reached an asymptotic value of about 1.74 in.lb/in^2. A power-law type of equation fitted through the G_{IR} data of the MBT method is given by

$$G_{IR} = 1.74 + 0.29\left(a - a_0 + 0.06\right)^{-0.78} \tag{7-6}$$

Table 7-2. Summary of Δ, n, and A_1 Parameters From Fracture Tests for Carbon/Epoxy Composite

Specimens	T800H Carbon/3900-2 Epoxy Laminate			
	Δ	n	A_1	G_{IC}, in.lb/in^2
PN3S1	0.289	2.59	76.68	3.67
PN3S2	0.250	2.65	71.07	4.05
PN3S3	0.416	2.44	77.18	4.37
PN3S4	0.418	2.48	73.19	4.41
PN3S5	0.309	2.57	72.97	4.55

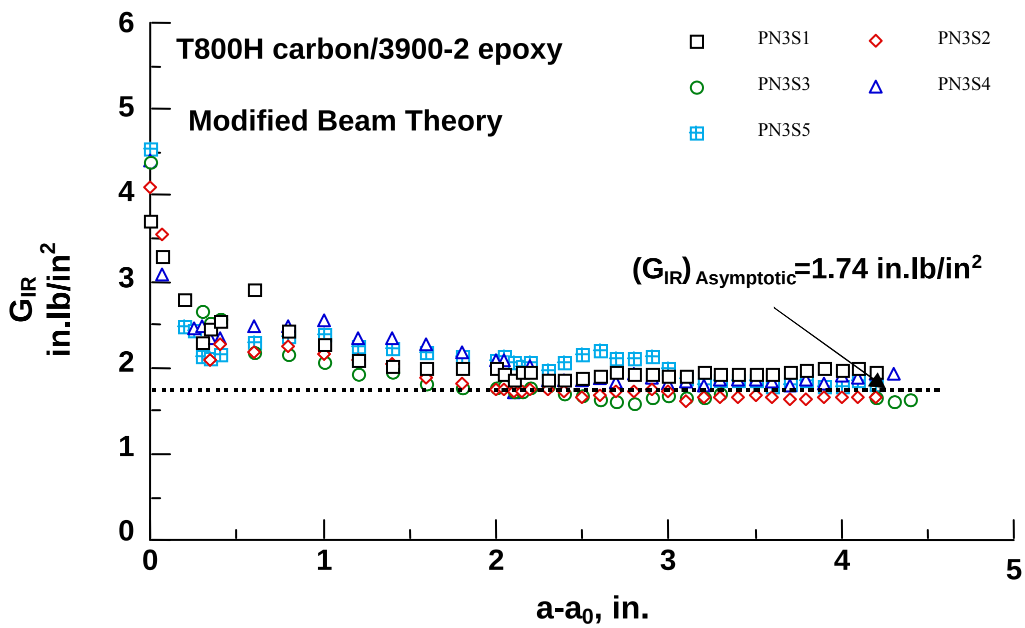


Figure 7-14. G_{IR} Versus Delamination Extension for T800H/3900-2 Composite From MBT Method

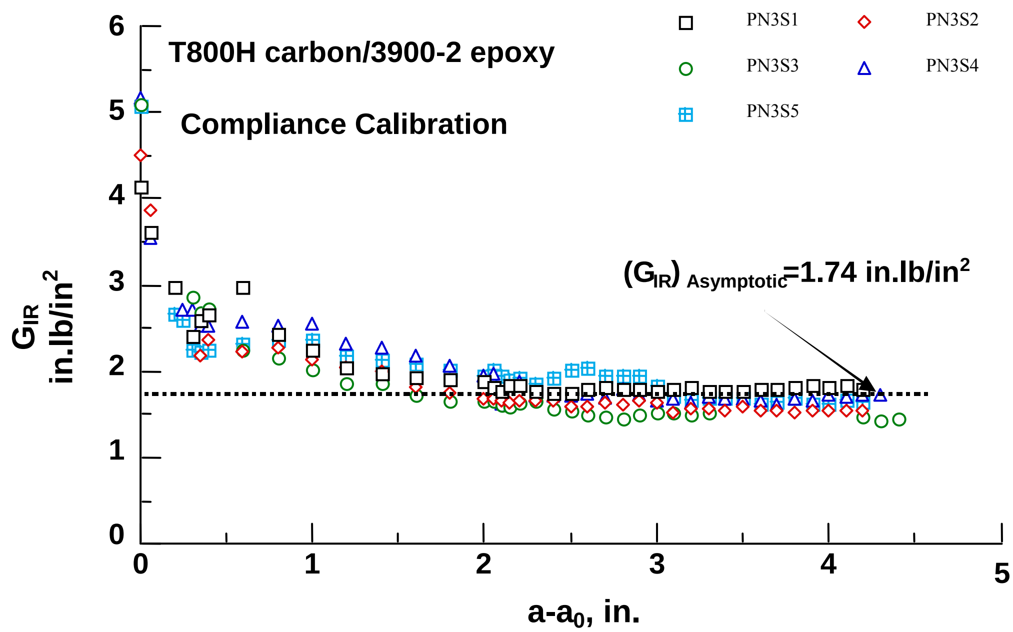


Figure 7-15. G_{IR} Versus Delamination Extension for T800H/3900-2 Composite From CC Method

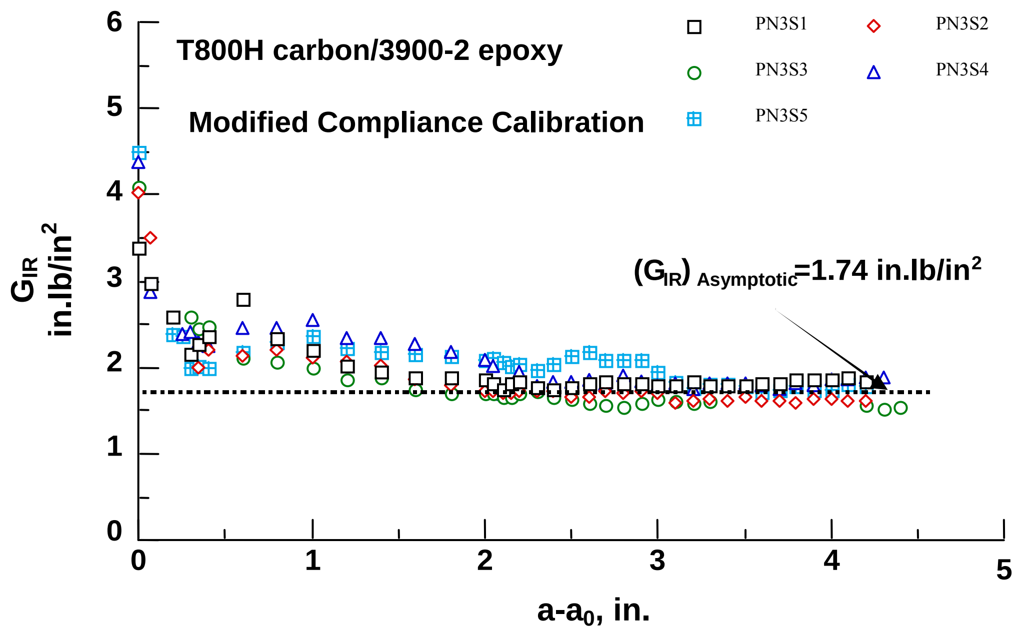


Figure 7-16. G_{IR} Versus Delamination Extension for T800H/3900-2 Composite From MCC Method

The initiation fracture toughness G_{IC} (based on visual point) values are listed in table 7-2. The average G_{IC} is 4.14 in.lb/in^2, while Toray Composites Inc. reported a value of 1.5 in.lb/in^2. The data reported by Davidson [28] was 4.43 and 4.48 in.lb/in^2 for 16- and 24-ply laminates, respectively, which agree well with the present data. Both tests were conducted at ambient conditions. The large difference between the supplier and the present data called for some explanation. Upon inquiry with Toray Inc., it was revealed that their specimens were conditioned and tested at low temperature, which may explain some of the differences. Further investigation is needed to assess the effect of material conditioning on the fracture properties.

Equation 7-6 and the experimental data are shown in figure 7-17.

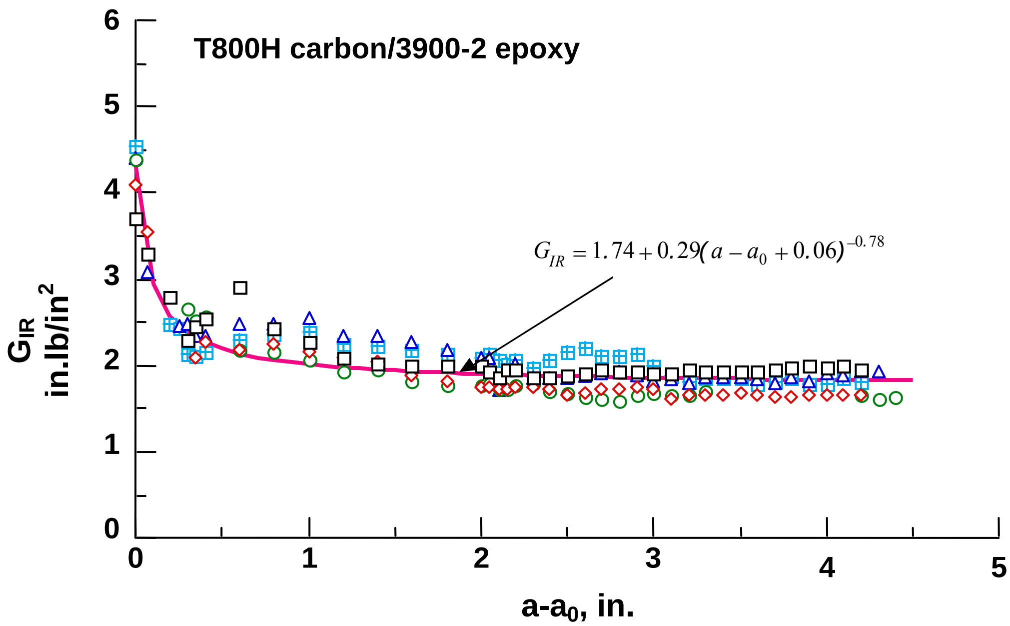
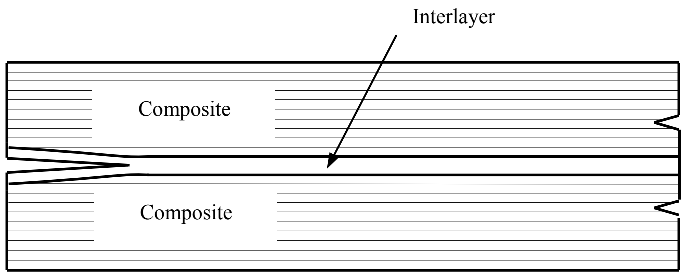


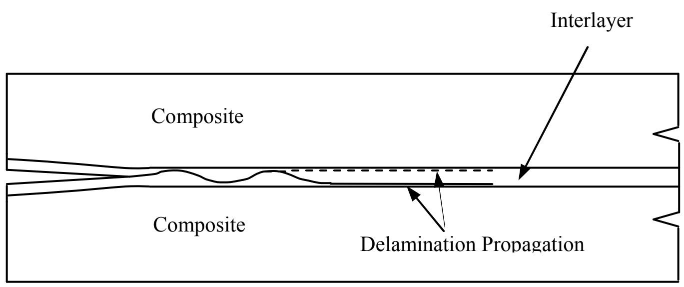
Figure 7-17. G_{IR} Versus Crack Extension Equation Fit With Experimental Data

<u>7.5.3 Fracture Mechanism and Morphology</u>.

T800H/3900-2 is an interleaved composite laminate to improve its impact resistance. The prepreg surface is sprinkled with thermoplastic particles. When the composite is cured, these particles form an interlayer between the plies. These interlayers offer improved impact resistance, but may change fracture and fatigue properties. Figure 7-18a illustrates a fracture possibility of a laminate with an interlayer. Ductility of the interlayer offers higher resistance to initial propagation of delamination front. Once the delamination starts propagating, the front may wander within the layer or may go to the one of the interface of the brittle parent matrix (figure 7-18(b)). Thus, the initiation fracture toughness is high, and after sufficient propagation of delamination, the fracture resistance drops to the bare matrix or interfacial property, as shown by the test results.



(a) Delamination within the interlayer

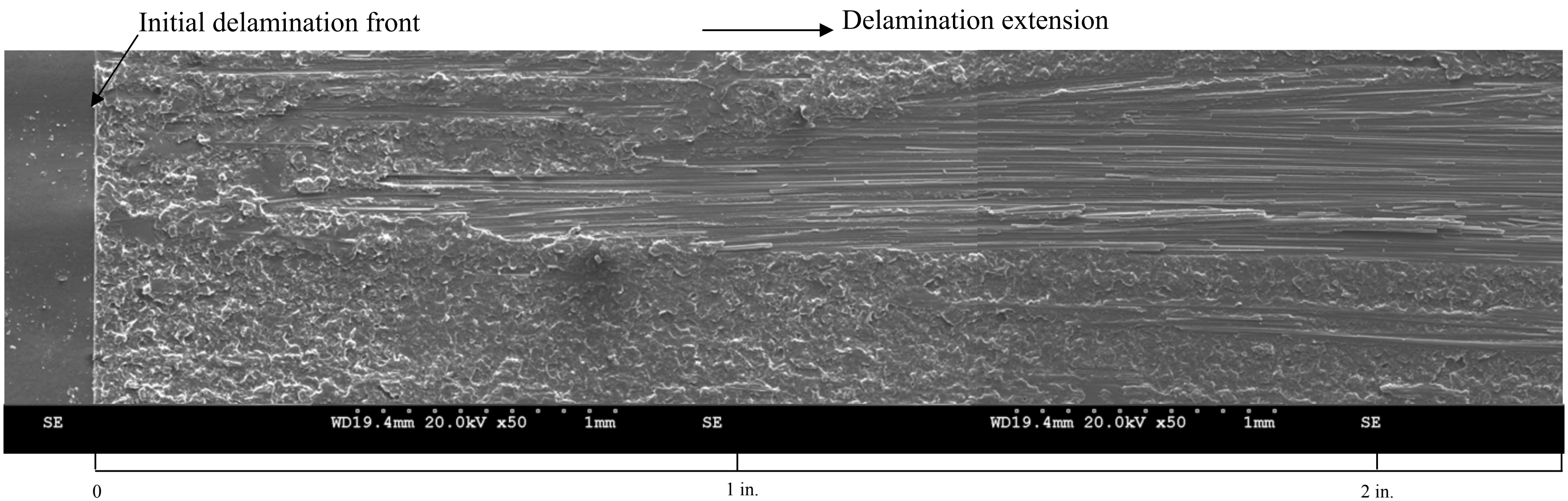


(b) Potential fracture mode

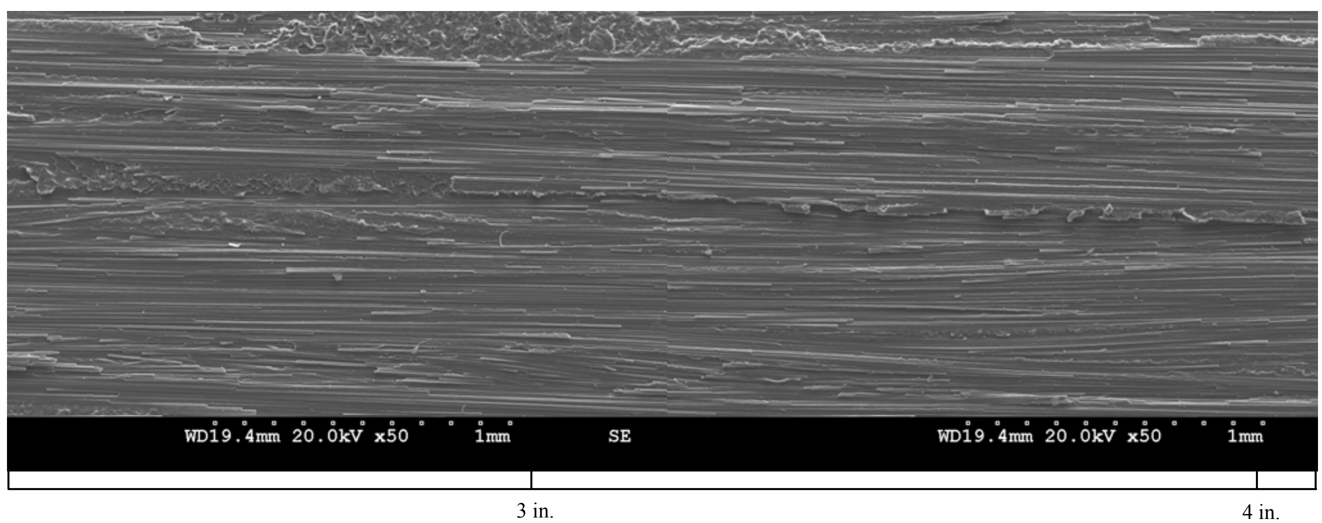
Figure 7-18. Potential Fracture Mechanism in T800H/3900-2 Composite Laminate

The SEM fracture surface of T800H carbon/3900-2 epoxy specimen PN3S3 is shown in figure 7-19. The figure shows a continuous fracture surface starting from the delamination initiation site to delamination growth of 4 in. At the beginning of delamination, growth occurs within the interlayer. As delamination extends, a strip of fiber-thermoplastic interface area begins to show up and grow to almost complete width by the time the delamination extended to 2.5 in.

1. The resistance data in figure 7-17 almost reached an asymptotic value by the time delamination propagation is about 2.5 in. The asymptotic value ranged between 1.5 to 1.8 in.lb/in^2 that is nearly same as the Toray-America's data. This interlayer could also complicate the delamination growth rate study. 2, December 2002.



(a) First part



(b) Continuation from (a)

Figure 7-19. Scanning Electron Microscopy of Fracture Surface of One Face of the T800H/3900-2 Specimen

8. FATIGUE ONSET LIFE MEASUREMENTS.

This study was conducted only on FGI 1854 glass/Dow 510A-40 vinyl ester composite laminate.

8.1 TEST PROCEDURE.

All fatigue tests were conducted using specimens made from the same panel (batch) that was used for fracture tests in section 7. An expression relating the load point displacement and the G_{IC} at the onset of fracture (or at the visible delamination propagation can also be used) was determined. The average values of load point displacement and G_{IC} are represented by $(\delta_{cr})_{av}$ and $(G_{IC})_{av}$, respectively. Then, for a chosen value of maximum cyclic energy release rate ratio $f = G_{I\max}/(G_{IC})_{av}$, the $\delta_{\max}$ was calculated from the equation [16].

$$\delta_{\max} = (\delta_{cr})\sqrt{\frac{G_{I\max}}{(G_{IC})_{av}}} \qquad (8\text{-}1)$$

The cyclic loading ratio (R) selected was 0.1, from that, $\delta_{\min}$ was determined ($\delta_{\min} = R\delta_{\max}$). Values of $\delta_{\max}$ for ($G_{I\max}/G_{IC}$) of 0.5, 0.4, 0.3, 0.25, and 0.2 were calculated and listed in table 8-1. The table also lists the width and delamination lengths of the specimen tested.

Table 8-1. Fatigue Onset Test Data for FGI 1854/510A-40 Glass/Vinyl Ester Composite

Samples	b, in.	a_0 in.	$G_{\max}/(G_{IC})$	$\delta_{\max}$	$N_{\max}$	da, in.	$P_{\max}$	$G_{\max}$	$G_{\max}/(G_{IC})_{calc}$
WF6A	1.495	1.464	0.40	0.0861	5,200	0.060	15.328	0.801	0.407
WF7A	1.490	1.441	0.40	0.0861	3,000	0.115	15.932	0.820	0.416
WF8A	1.491	1.468	0.30	0.0761	3,000	0.000	13.219	0.634	0.322
WF9A	1.493	1.443	0.30	0.0761	3,000	0.030	15.013	0.716	0.364
WF10A	1.494	1.443	0.25	0.0695	5,000	0.000	12.856	0.571	0.290
WF11A	1.491	1.420	0.25	0.0695	5,000	0.000	12.303	0.555	0.282
WF12A	1.492	1.440	0.20	0.0621	10,000	0.000	11.768	0.468	0.238
WF13A	1.495	1.447	0.20	0.0621	10,000	0.000	11.355	0.449	0.228

The loading hinges on the specimen were mounted in the loading machine grips and the specimen was aligned and centered. Before gripping, the end of the specimen opposite to grips was supported to assist in the mounting process. The test machine was set to the stroke loading at a frequency of 1 Hz between $\delta_{\max}$ and 0.1 $\delta_{\max}$. At first, the specimen was displaced to $\delta_{\max}$ and P_{max} was recorded. From these values and the specimen geometry, the initial compliance at N=1 and actual $G_{I\max}$ were calculated and tabulated (table 8-1). The machine displacement was slowly reduced to zero and the fatigue test was started. The load and displacement were recorded at every cycle using a Vishey 5000 data acquisition system. The test was continued for predetermined number (10,000) of cycles.

The fatigue tests were repeated for other values of δ_{max}. All the recorded and reduced data are listed in table 8-1. Note that only FGI 1854/510A-40 glass/vinyl ester composite was tested for onset life determination.

8.2 DATA ANALYSIS AND RESULTS.

The ASTM D 6115 recommends two criteria for determining the onset life, namely, 1% and 5% increase in the compliance at $N = 1$. Because the composite considered in this study is a woven preform fiber system, the 1% criteria is too conservative. Therefore, 2%, 5%, 7%, and 10% increases in compliance were chosen to establish the onset life. Figure 8-1 shows the variation of compliance with number of cycles N for a typical specimen (WF4). On this plot, horizontal lines corresponding to 1%, 2%, and 5% increase in compliance were drawn. The intersection of the horizontal lines and compliance versus N plot provide the onset lives. Table 8-2 summarizes the onset lives for the specimen tested at various values of G_{Imax}/G_{IC} ratios. The table includes the data based on 1%, 2%, 5%, 7%, and 10% criteria. Figures 8-2 through 8-5 show G_{Imax}/G_{IC} versus N for 2%, 5%, 7%, and 10% change in compliance criteria, respectively. From these figures, the asymptotic value of was found to be $(G_I)_{Asymptotic}$=0.22 G_{IC}.

Table 8-2. Fatigue Onset Lives for FGI 1854/510A-40 Glass/Vinyl Ester Composite

Samples	$G_{max}/G_{IC})_{calc}$	$N^{1\%}$	$N^{2\%}$	$N^{5\%}$	$N^{7\%}$	$N^{10\%}$
WF6A	0.407	19	149	507	863	1840
WF7A	0.416	10	36	193	234	435
WF8A	0.322	2	14	185	641	2850
WF9A	0.364	4	24	446	832	1817
WF10A	0.290	6	79	1389	2456	4830
WF11A	0.282	6	46	2653	4560	7941
WF12A	0.238	16	180	1930	4697	8585
WF13A	0.228	13	368	6713	-	-

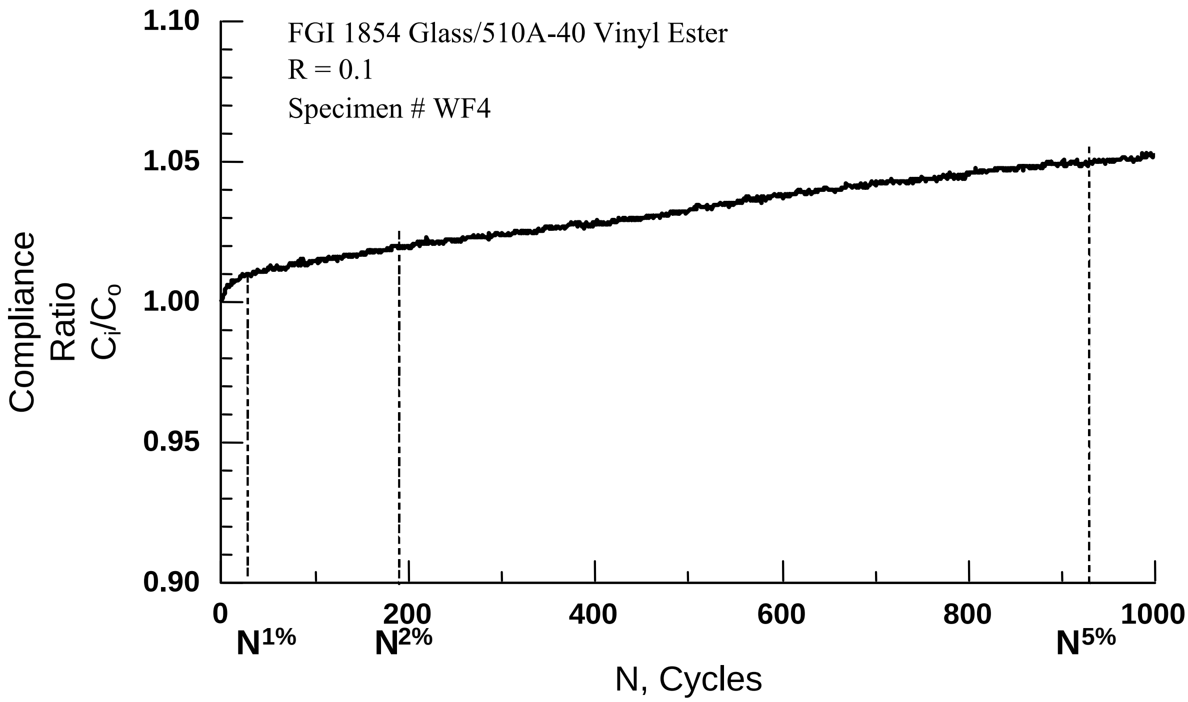


Figure 8-1. Onset Life Test's Compliance Versus Number of Load Cycles, *N* Plot

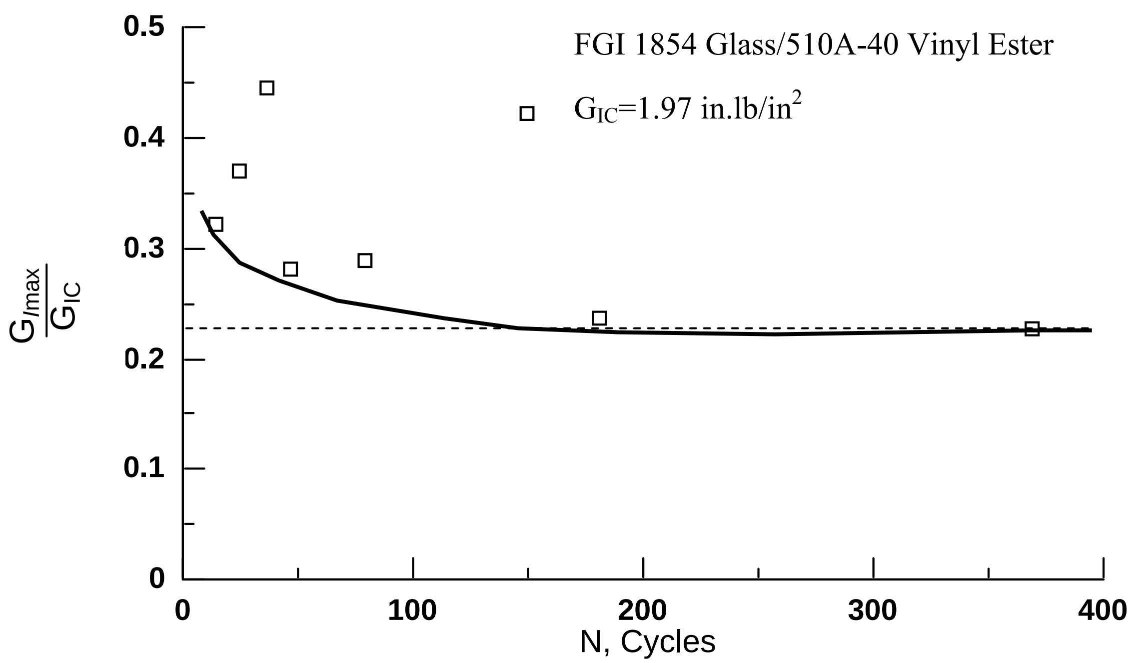


Figure 8-2. Variation of $N^{2\%}$ Onset Life With $G_{I\max}$

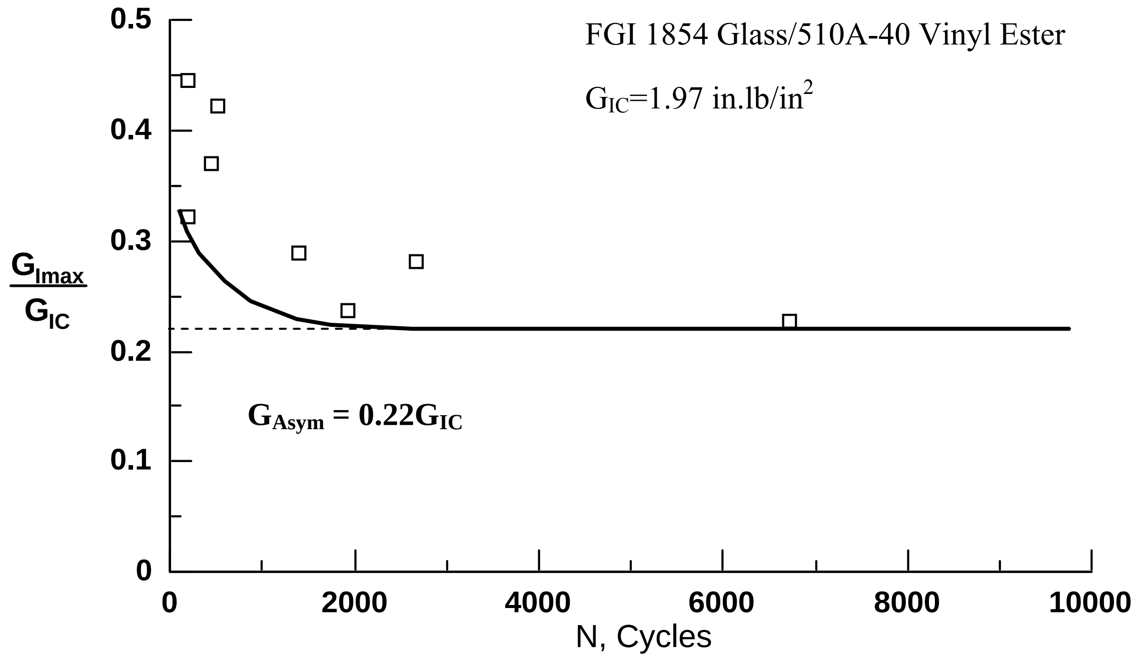


Figure 8-3. Variation of $N^{5\%}$ Onset Life With $G_{I\max}$

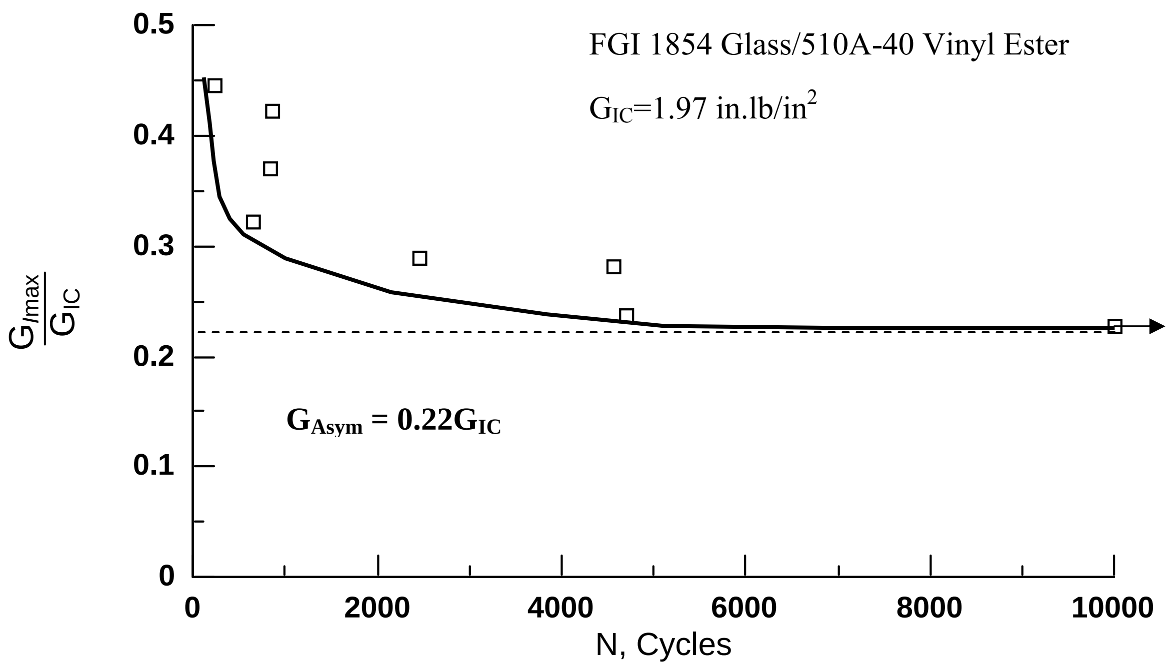


Figure 8-4. Variation of $N^{7\%}$ Onset Life With $G_{I\max}$

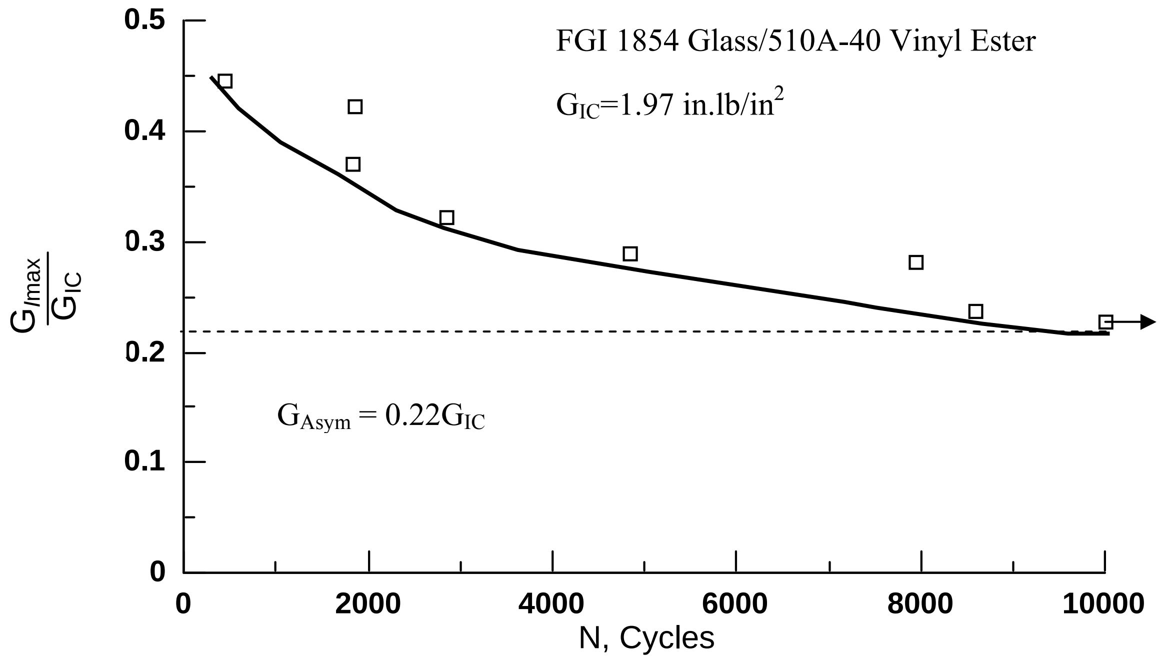


Figure 8-5. Variation of $N^{10\%}$ Onset Life With $G_{I\max}$

8.3 SUMMARY.

Fatigue onset life measurement was conducted on FGI 1854/Dow 510A-40 glass/vinyl ester composite. Stroke-controlled tests were conducted for $G_{I\max}/G_{IC}$ values ranged from 0.5 to 0.2 for cyclic displacement load ratio of 0.1. Each test was run for 10,000 cycles. In addition to 1% and 5% increases in compliance criteria, 2%, 7%, and 10% criteria were also used to establish the onset life. $G_{I\max}/G_{IC}$ versus N plots were generated for the last four onset life criteria. The asymptotic value of $G_{I\max}$ was found to be 0.22 G_{IC}.

9. FATIGUE DELAMINATION GROWTH RATE DATA.

Two types of testing approaches were used, namely, stepped and continuous or compliance. In the stepped approach, fatigue tests were conducted for a preselected value of N; and at each N, the test was stopped and the delamination length and P_{max} were measured. The compliance approach is similar to fatigue onset life test (ASTM D 6115), but the compliance equation is used to calculate P_{max} (corresponding to δ_{max}) and the delamination length. The stepped fatigue test was used for FGI 1854/Dow 510A-40 glass/vinyl ester composite, and both stepped and compliance test methods were used for T800H/3900-2 carbon/epoxy composite.

9.1 STEPPED FATIGUE TEST PROCEDURE.

The fatigue test setup was the same as the fracture test except that a cyclic loading was used. The test was conducted under constant-amplitude displacement loading at a cyclic load frequency range of 1-4 Hz with the ratio of minimum to maximum displacement ($R = \delta_{min}/\delta_{max}$) of 0.1. The maximum cyclic displacement δ_{max} was calculated from

$$\delta_{I\max} = \sqrt{\frac{G_{I\max}}{(G_{IC})_{av}}} \left(\frac{a_s + \Delta}{a_{IC} + \Delta} \right)^2 (\delta_{IC})_{av} \tag{9-1}$$

where $G_{I\max}$ is the applied maximum cyclic load and a_s is the starting delamination length. The parameters $(G_{IC})_{av}$, $(\delta_{IC})_{av}$, a_c, and Δ_{av} are the average fracture toughness, displacement, delamination length, and correction factor from the fracture tests (section 7). The starting values of $G_{I\max}/(G_{IC})_{av}$ was about 0.8. The procedure is described below.

The specimen was mounted on the test machine as explained in section 8.1. The traveling microscope was focused on the specimen, which was moved horizontally until the vertical crosshair was at the initial crack tip. The specimen was slowly opened to the δ_{max} displacement value for the test. This usually causes some delamination growth. The opening of the specimen also causes the specimen to move horizontally relative to the microscope. The microscope crosshair was realigned to the initial delamination mark and the horizontal scale position of the microscope was recorded. The microscope was then moved to the current delamination tip and the microscope position was recorded. The difference between these two microscope readings is the Δa for the first cycle. This Δa was added to the initial delamination length to get the current delamination length. The load P_{max} at δ_{max} was recorded for the first cycle. The displacement was then slowly moved back to zero.

The fatigue test was run for a predetermined number of cycles. The test was stopped, the microscope view was examined and moved to the new crack position. The position reading from the microscope scale was recorded. The difference between this reading and the previous reading was the Δa for the number of cycles just run (ΔN). Then, da/dN was calculated from the ratio of Δa and ΔN to get the current crack length. Δa was added to the previous crack length. The displacement was brought back to zero and the test was continued. This procedure was repeated. The values of N, dN, microscope reading, a, Δa, and P_{max} at δ_{max} were recorded and tabulated each time the cycling was stopped. From these, da/dN, $G_{I\max}$, and G_{IR} were calculated. Complete data tables are given in appendix A. The cumulative values of N selected for this test was N = 1, 2, 5, 10, 20, 50, 100,…up to 1 million. The equations used for calculation of $G_{I\max}$ and G_{IR} are

$$G_{I\max} = \frac{3P_{I\max}\delta_{I\max}}{2b\left(a+|\Delta|\right)} \tag{9-2}$$

$$G_{IR} = 1.74 + 2.25(a - a_0)^{0.31} \tag{9-3}$$

9.2 DELAMINATION GROWTH RATE DATA.

9.2.1 Fiber Glass Industries 1854/Dow 510A-40 Glass/Vinyl Ester Composite.

The complete fatigue test data and the reduced values of *da/dN*, $G_{I\max}$, G_{IR}, and ($G_{I\max}/G_{IC}$) are given in the appendix tables A-11 through A-14. The value of Δ used was 0.123 in. The *G* results were found to be insensitive to Δ varying from 0.10 to 0.15 for a delamination length of 1.5 in. Figures 9-1 and 9-2 show delamination growth rate for four specimens versus $G_{I\max}/G_{IR}$ and G_{Imax}/G_{IC}, respectively. Different symbols represent different specimens. Both data profiles show a nice S curve trend covering the all three domains of delamination growth rates.

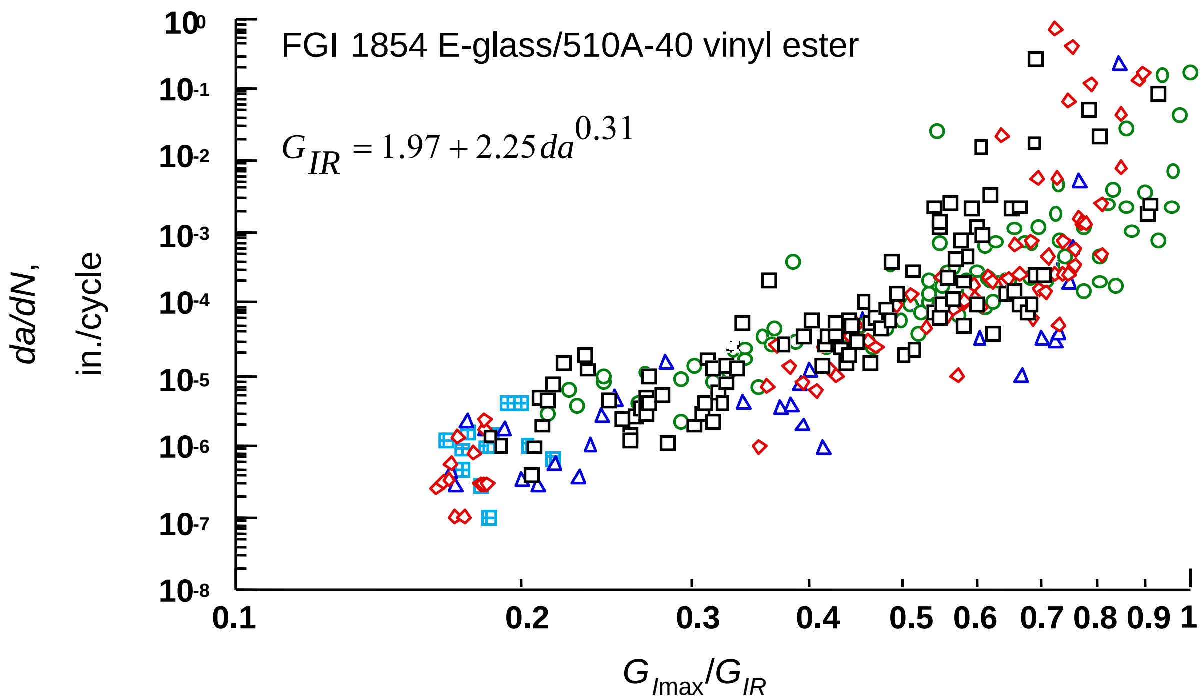


Figure 9-1. Delamination Growth Rate Data as a Function of $G_{I\max}/G_{IR}$

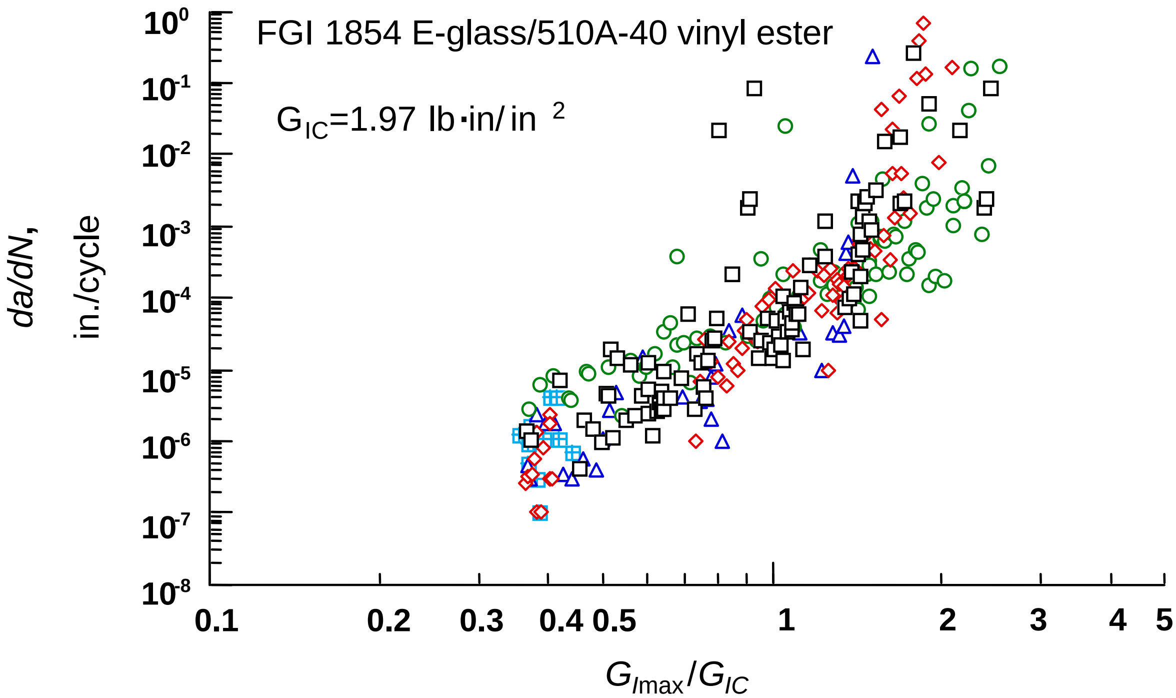


Figure 9-2. Delamination Growth Rate Data as a Function of $G_{I\max}/G_{IC}$

9.2.2 T800H/3900-2 Carbon/Epoxy Composite.

Test data based on the two test methods are generated and presented. Figures 9-3 and 9-4 show delamination growth rates from the stepped fatigue test approach. All four specimen tested were from the manufactured delaminated specimen. The data in figure 9-3 is for G_{IR} normalization while figure 9-4 is for $(G_{IR})_{Asym}$ value normalization. The data for the four specimens are in appendix tables A-15 through A-18. The $(G_{IR})_{Asym}$ used was 1.75 in.lb/in^2. Both plots show specimen dependency of the data. One possible reason is that the thermoplastic interleaving may be influencing the data. Therefore, tests for specimens UCE203 and 205 were redone after fracturing the specimen by 2 inches to eliminate the interleave effect. These tests were conducted using the compliance method. Figures 9-5 and 9-6 show the compliance versus N for the two specimens for total number of cycles up to 1.6 million cycles. For about 400 selected values of N, the delamination growth rate and $G_{I\max}$ were calculated and plotted in figure 9-7. The data are in appendix tables A-19 through A-20. The agreement between the specimens is much better than the test conducted from the manufactured specimen.

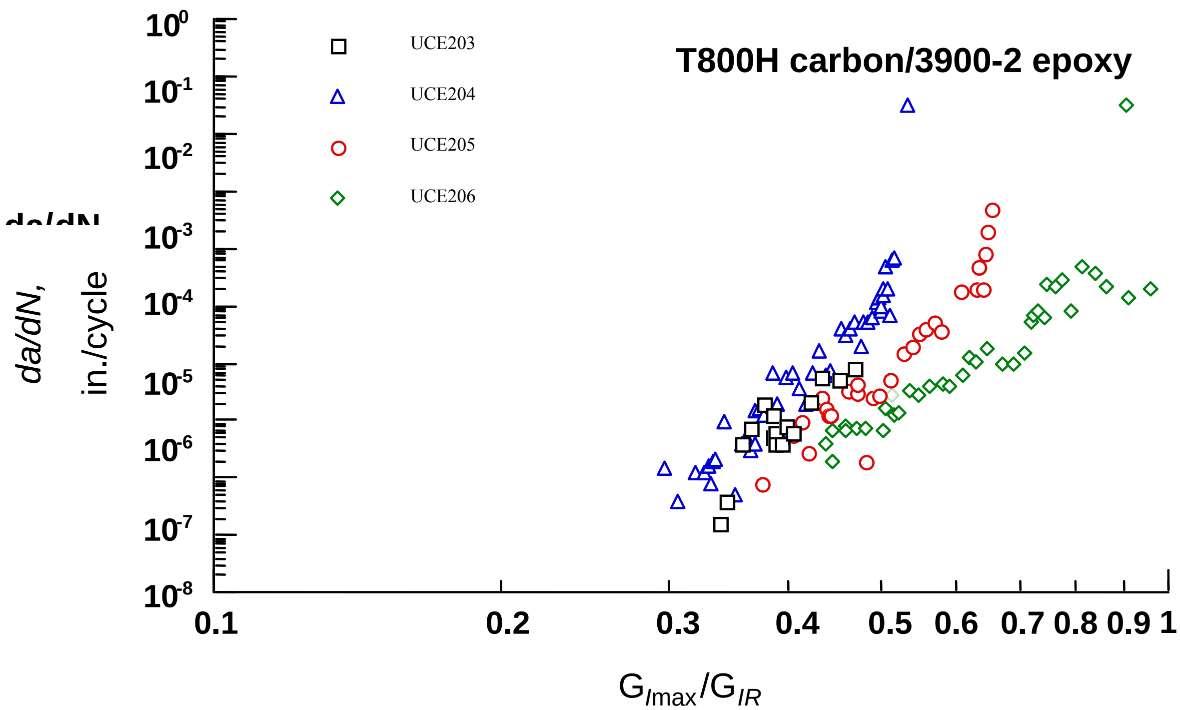


Figure 9-3. Delamination Growth Rate as a Function of G_{Imax}/G_{IR} for Carbon/Epoxy Composite

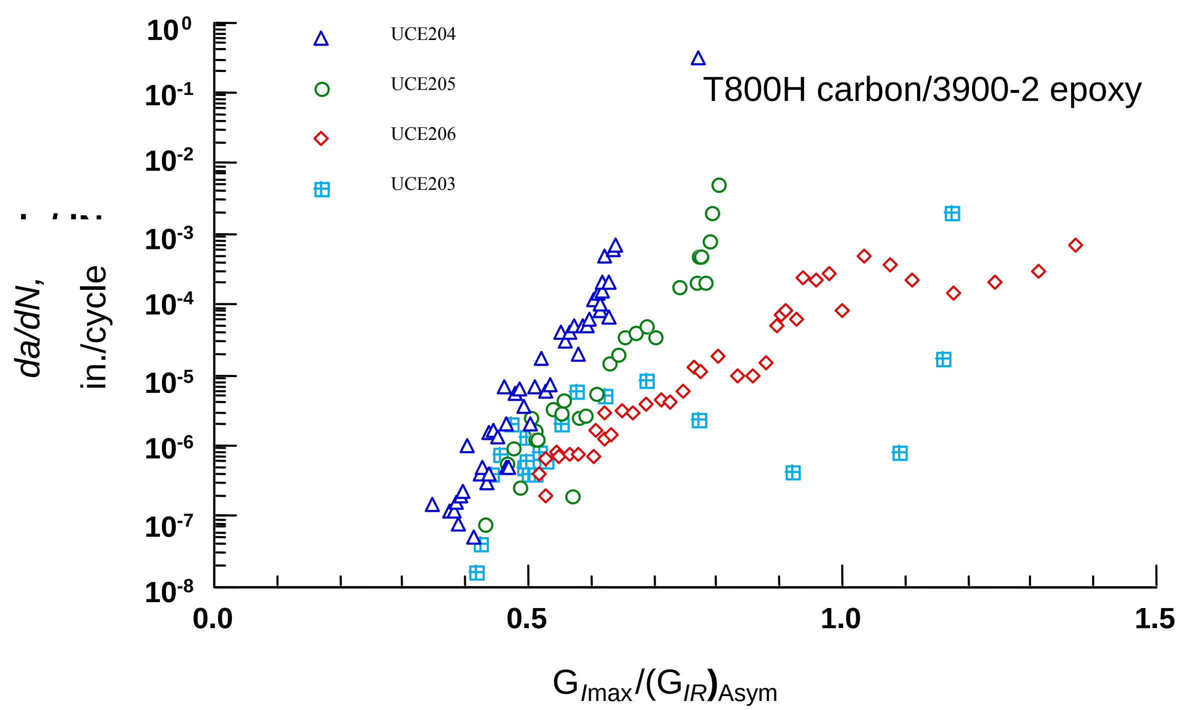


Figure 9-4. Delamination Growth Rate as a Function of $G_{Imax}/(G_{IR})_{Asym}$ for Carbon/Epoxy Composite

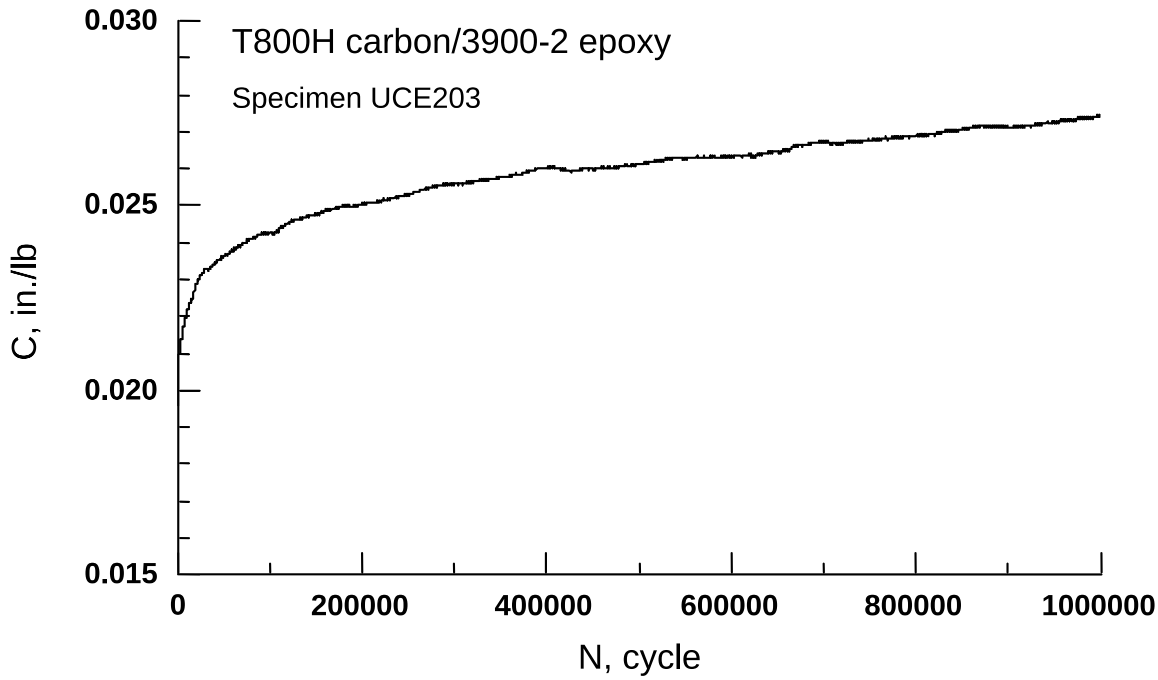


Figure 9-5. Compliance Versus *N* Data for Specimen UCE203

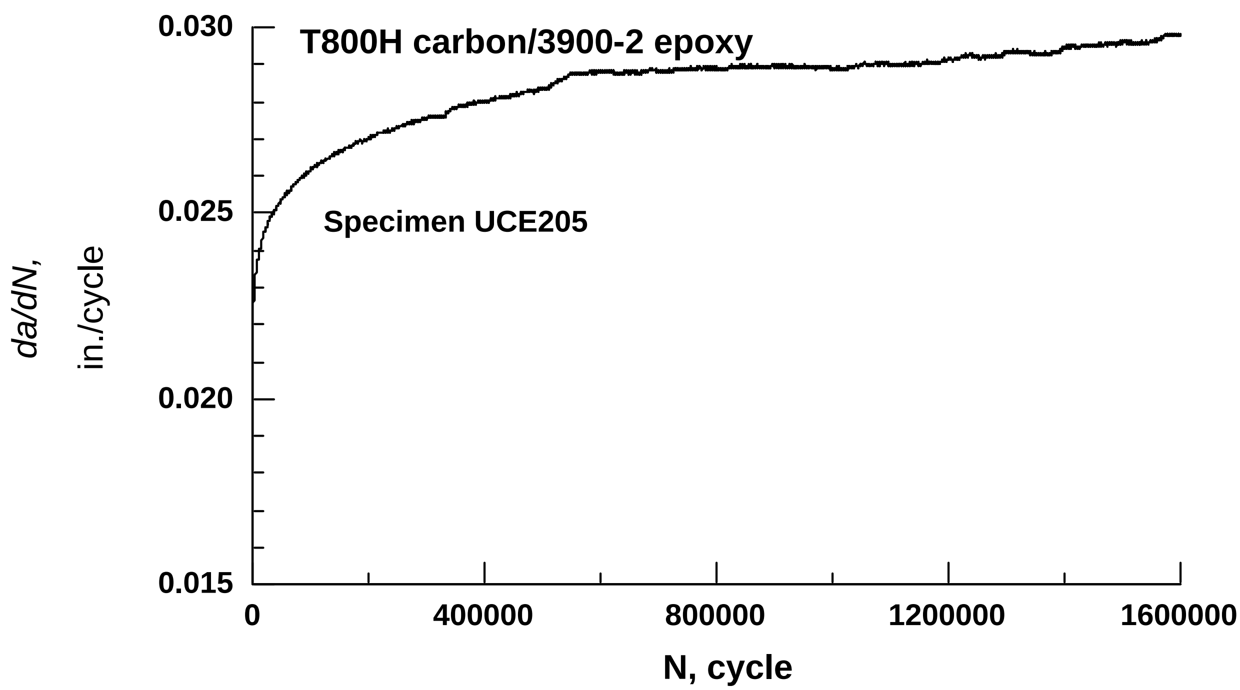


Figure 9-6. Compliance Versus *N* Data for Specimen UCE205

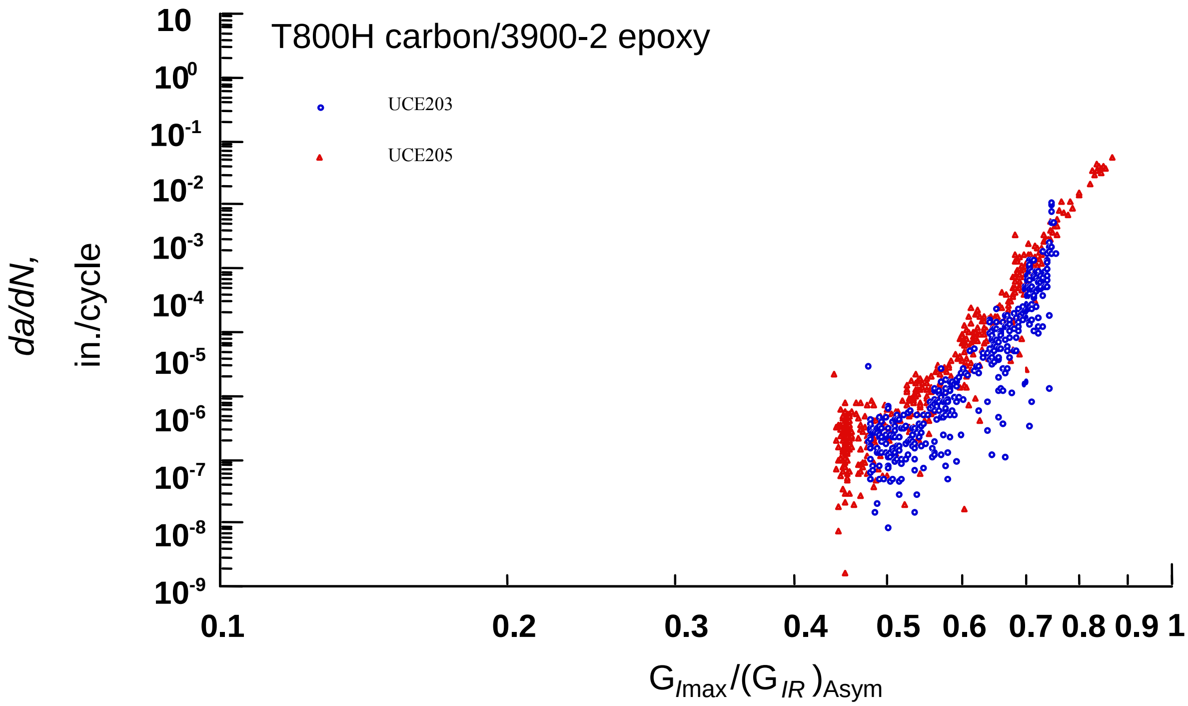


Figure 9-7. Delamination Growth Rate Data for Carbon/Epoxy After Removing the Interleaving Effect

10. FATIGUE DELAMINATION GROWTH RATE EQUATION.

10.1 FIBER GLASS INDUSTRIES 1854 GLASS/DOW 510A-40 VINYL ESTER COMPOSITE (G_{IR} NORMALIZED EQUATION).

Two methods of equation fit were performed. Details of the fit and comparison with the test results are presented.

10.1.1 G_{IR} Normalized Equation.

The delamination growth rate data (figure 9-1) were divided into three parts by visual inspection, the middle linear region (domain 2), and two ends, namely, subcritical (domain 1), and unstable regions (domain 3). A least square log-log equation fit was performed for the middle region. The equation fit was performed for $0.2 \leq G_{I\max}/G_{IR} \leq 0.7$ to determine *A* and *m* in equation 3-1. Values of *A* and *m* were 0.004 and 5.4 for a best fit. The *da/dN* equation (equation 3-1) reduced to

$$\frac{da}{dN} = 0.004\left(\frac{G_{I\max}}{G_{IR}}\right)^{5.4} \qquad (10\text{-}1)$$

Figure 10-1 shows the comparison between equation 10-1 and the test data.

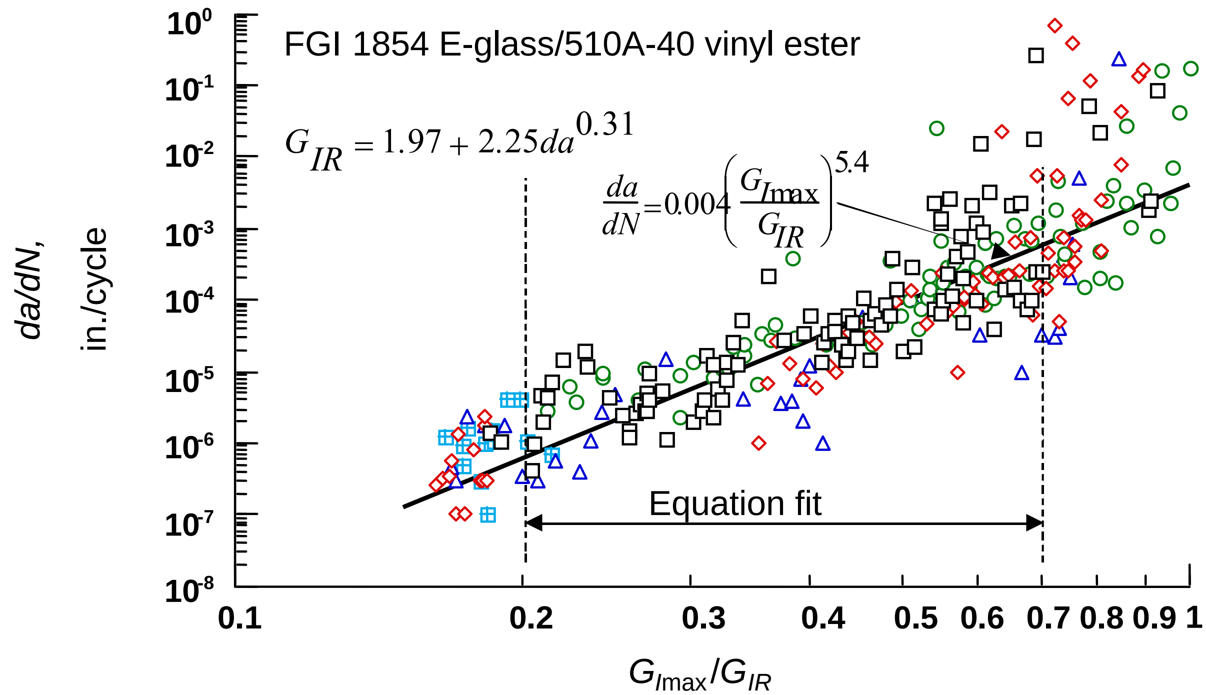


Figure 10-1. Equation Fit in the Domain 2

Equation 3-2 was fit to the data in domain 1 and domain 2, using the value G_{Ith} equal to 0.15 G_{IR}. The value of D_1 was determined to be 8 with resulting equation

$$\frac{da}{dN} = 0.004\left(\frac{G_{I\max}}{G_{IR}}\right)^{5.4}\left[1-\left(\frac{G_{I\text{th}}}{G_{I\max}}\right)^{8}\right] \tag{10-2}$$

Equation 3 was fit to the data in domain 2 and 3 and found D_2=2. Equation 3 reduced to

$$\frac{da}{dN} = 0.004\left(\frac{G_{I\max}}{G_{IR}}\right)^{5.4}\frac{1}{\left[1-\left(G_{I\max}/G_{IR}\right)^{2}\right]} \tag{10-3}$$

The final equation covering all three domains is

$$\frac{da}{dN} = 0.004\left(\frac{G_{I\max}}{G_{IR}}\right)^{5.4}\frac{\left[1-\left(\frac{G_{I\text{th}}}{G_{I\max}}\right)^{8}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{IR}}\right)^{2}\right]} \tag{10-4}$$

with A = 0.004, m = 5.4, D_1 = 8, and D_2 = 2.

A comparison of equation 10-4 and the data in figure 10-2 shows a good fit. The sensitivity of equation 10-4 to variation of parameters A and m is shown in figure 10-3. The value of A varied from 0.004 to 0.005 and m varied from 5.3 to 5.5. The effect of variation of parameters D_1 and D_2 while A and m are constant on the da/dN equation is shown in figure 10-4. D_1 varied from 4 to 8 and D_2 varied from 2 to 4. For this range of variation, equation 3-4 fits the test data very well. Thus, equation 10-4 is stable and agrees with the test data in all three domains.

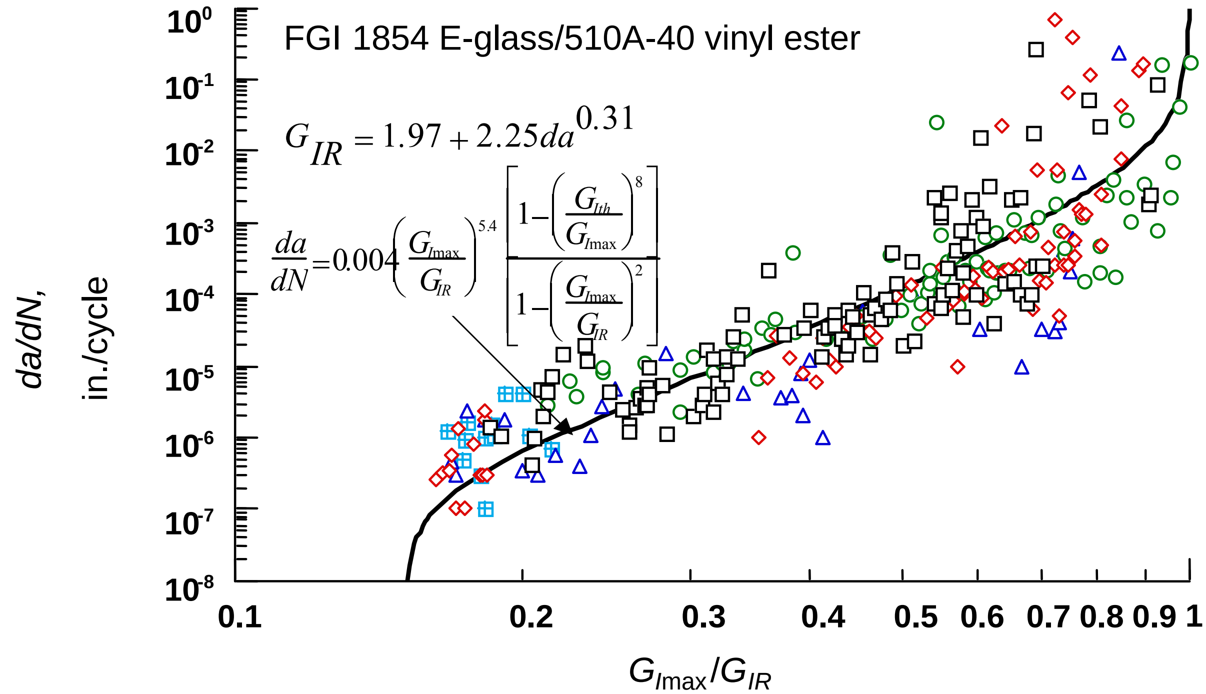


Figure 10-2. Comparison of Total Delamination Growth Rate Equation With the Test Data

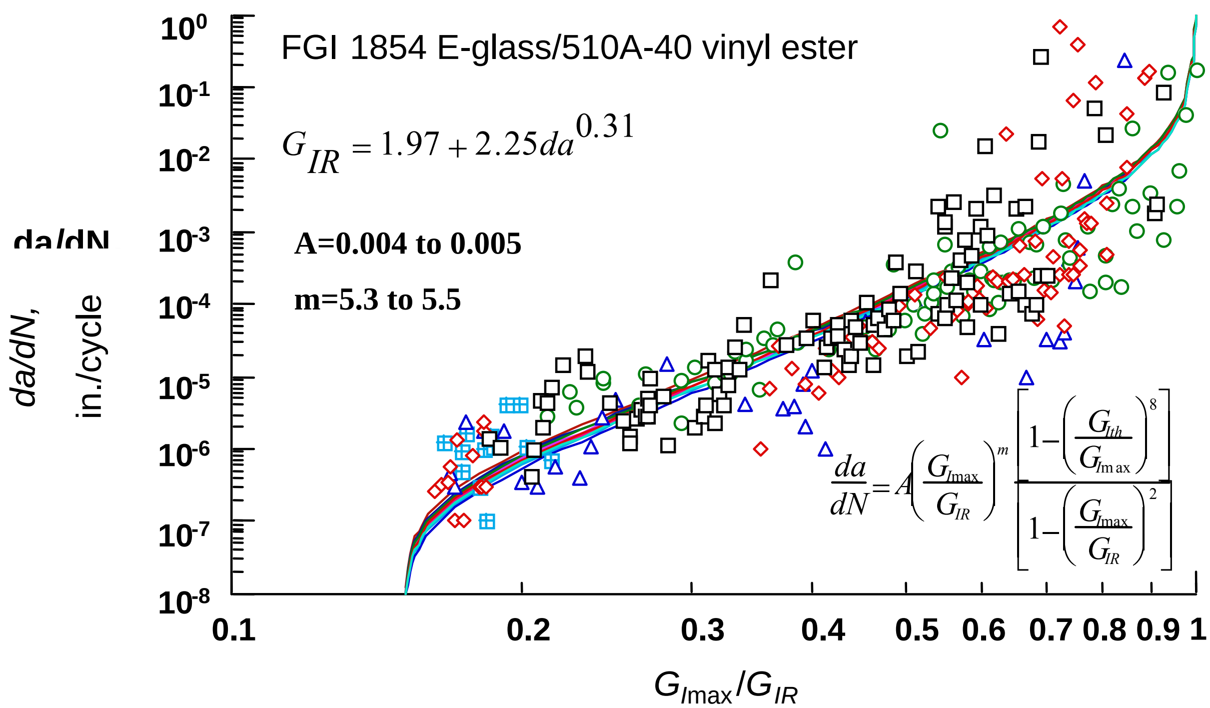


Figure 10-3. Sensitivity of *A* and *m* Parameters on Predicted Delamination Growth Rates

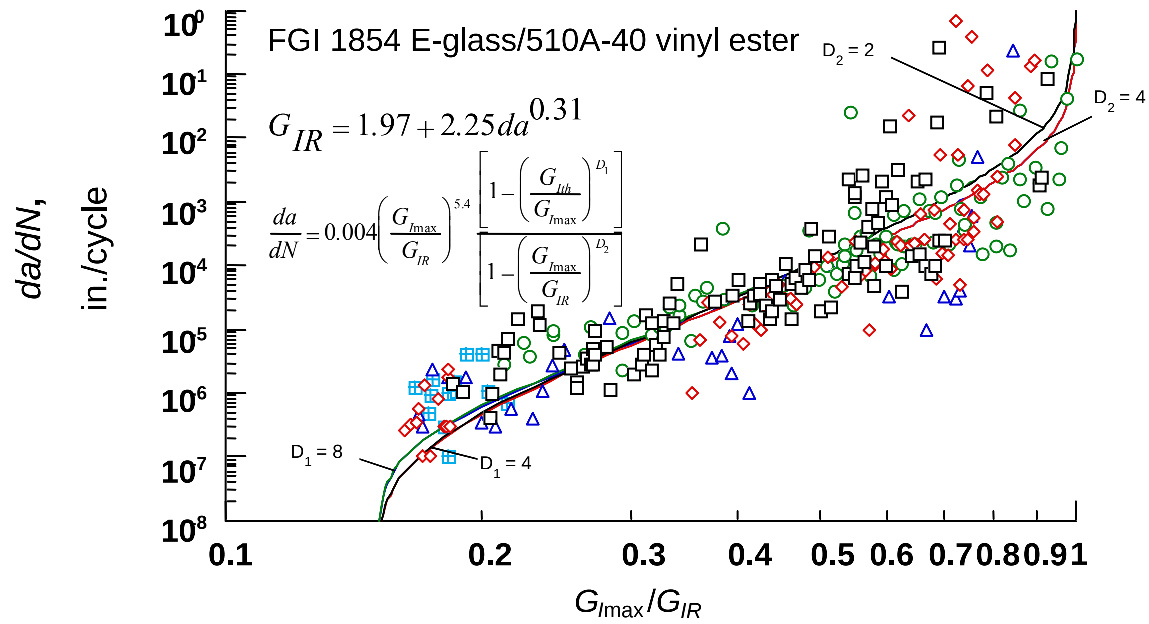
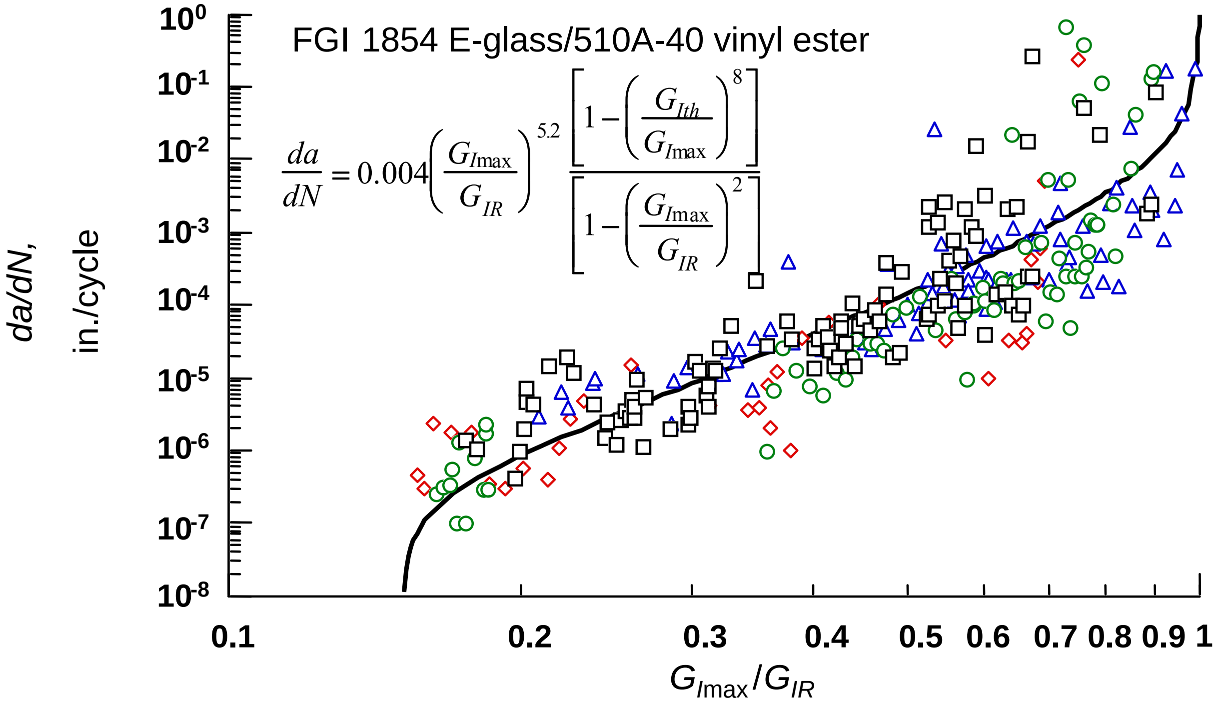


Figure 10-4. Sensitivity of D_1 and D_2 Parameters on Predicted Delamination Growth Rates

To evaluate the effect of variation of Δ on the resulting *da/dN* equation, the $G_{I\max}$ were recalculated using the true Δ for each of the fatigue test specimen. These results are shown in figure 10-5. Table 10-1 lists the values of Δ value for fracture and fatigue tests. Figure 10-5 compares the *da/dN* equation (equation 10-4) with *G* data calculated from true Δ value. The agreement is very good. Thus, for data reduction one can use *D* measured fracture specimen as long as the specimen for fatigue and fracture tests are taken from a same panel or batch.

Table 10-1. Comparison of Δ From Fracture and Fatigue Tests for Glass/Vinyl Ester Specimen

Specimen	Δ, in.	
	Fracture Test	Fatigue Test
W-1	0.218	
W-2	0.040	
W-3	0.165	
W-4	0.113	
W-5	0.110	
WF-6		0.230
WF-7		0.097
WF-8		0.148
WF-12		0.309
$\Delta_{fracture}$	0.129	



$$\frac{da}{dN} = 0.004\left(\frac{G_{I\max}}{G_{IR}}\right)^{5.2}\frac{\left[1-\left(\frac{G_{Ith}}{G_{I\max}}\right)^{8}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{IR}}\right)^{2}\right]}$$

Figure 10-5. Delamination Growth Rate Equation Based on Δ From Fatigue Tests (Glass/Vinyl Ester)

10.1.2 G_{Ic} Normalized Equation.

The delamination growth rate data (figure 9-2) was divided into three parts by visual inspection, middle linear region (domain 2), and two ends, namely, subcritical (domain 1) and unstable regions (domain 3). A least square log-linear equation fit was performed for the middle region also called as the Paris region. The equation fit was performed for $0.5 \leq G_{I\max}/G_{IC} \leq 1.5$. The values of A_1 and m_1 in equation 3-5 were found to be 2.3 and -6.65, respectively. The *da/dN* equation in domain 2 was found to be:

$$\frac{da}{dN} = 10^{\left[2.3\left(\frac{G_{I\max}}{G_{IC}}\right)-6.65\right]} \tag{10-5}$$

Figure 10-6 compares equation 10-5 with the test data for domain 2.

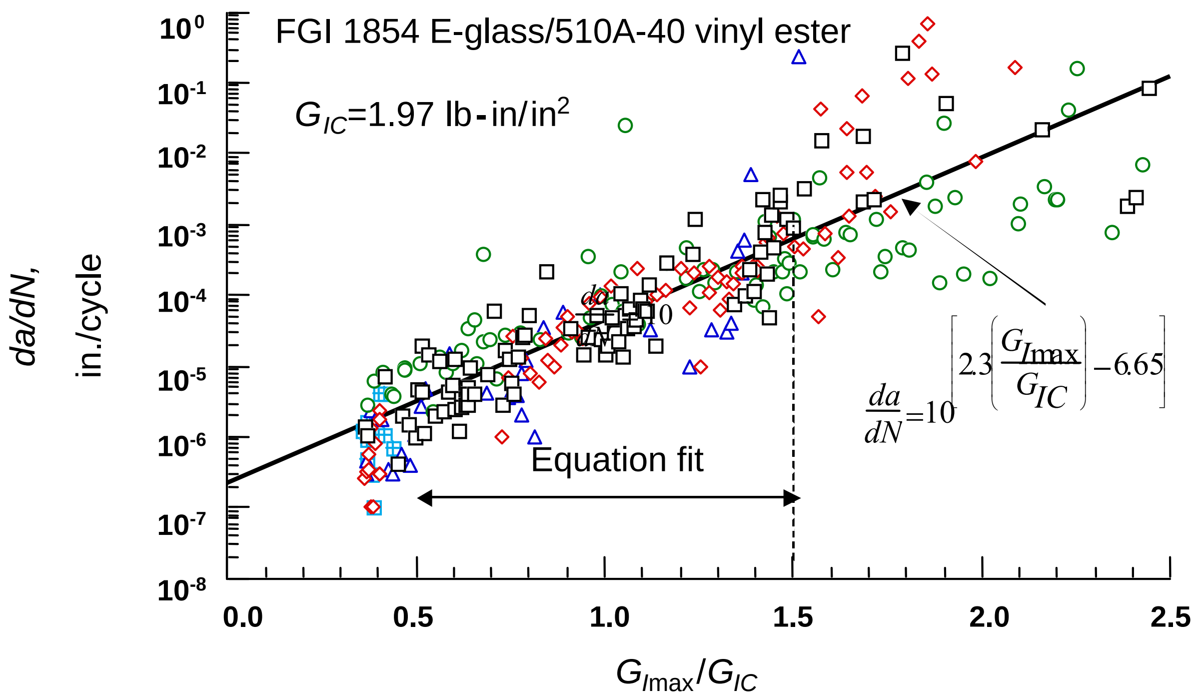


Figure 10-6. Log-Linear Equation Fit in the Domain 2

A least square log-log equation fit was also performed in the domain 2 for the same range of G_{Imax} ($0.5 \leq G_{Imax}/G_{IC} \leq 1.5$). The values of A_c and m_c in equation 3-6 were found to be 5.74×10^{-5} and 4.85. The da/dN equation in domain 2 was found to be

$$\frac{da}{dN} = 5.74\times10^{-5}\left(\frac{G_{Imax}}{G_{IC}}\right)^{4.85} \qquad (10\text{-}6)$$

Figure 10-7 compares the equation 10-6 with the test data for domain 2.

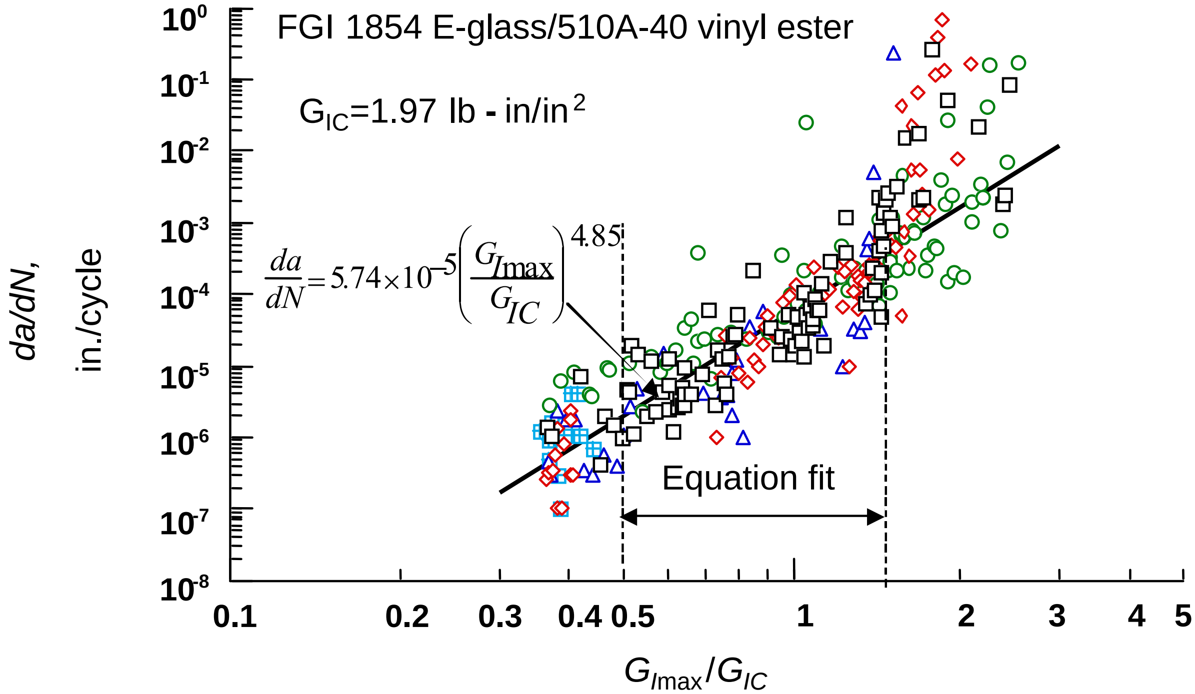


Figure 10-7. Log-Log Equation Fit in the Domain 2 of the Delamination Growth Rate

Considering domains 1 and 2, with G_{Ith} equal to 0.15 G_{IC}, the parameter D_1 was determined. Considering domains 2 and 3, the parameter D_2 was determined. For both log-linear (equation 3-5) and log-log (equation 3-6) equations, D_1 and D_2 were found to be 8 and 2. These values were identical to values determined for G_{IR} normalization equation (equation 3-3). The final equations are

$$\frac{da}{dN} = 10^{\left[2.3\left(\frac{G_{I\max}}{G_{IC}}\right)-6.65\right]} \frac{\left[1-\left(\frac{G_{Ith}}{G_{I\max}}\right)^{8}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{C}}\right)^{2}\right]} \tag{10-7}$$

and

$$\frac{da}{dN} = 5.74\times10^{-5}\left(\frac{G_{I\max}}{G_{IC}}\right)^{4.85} \frac{\left[1-\left(\frac{G_{Ith}}{G_{I\max}}\right)^{8}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{C}}\right)^{2}\right]} \tag{10-8}$$

Equations 10-7 and 10-8 are compared with the test data in figure 10-8. The agreement is fairly good except in the subcritical domain 1.

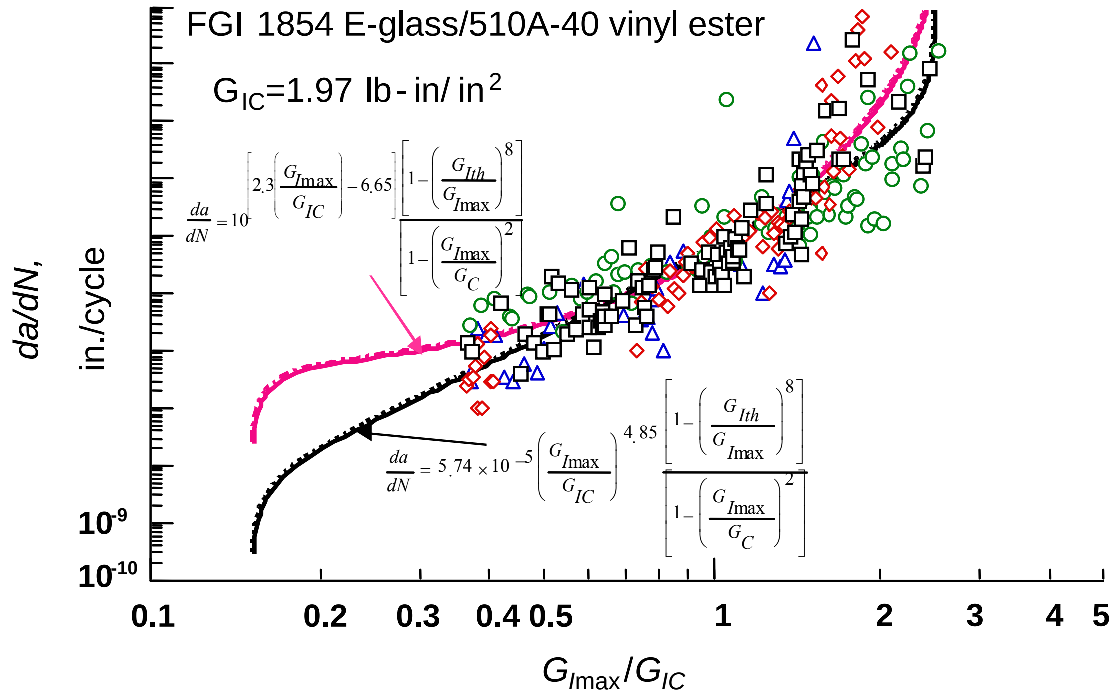


Figure 10-8. Comparison of Total Delamination Growth Rate Equations With the Test Data

10.2 T800H CARBON/3900-2 EPOXY COMPOSITE (G_{IR} NORMALIZED EQUATION).

Figure 10-9 shows the delamination growth rate data versus $G_{I\max}/G_{IR}$, and figure 10-10 shows $(G_{IR})_{Asym}$ normalization data. The equation fit procedure was same as that for glass/vinyl ester composite. Fatigue data was normalized by G_{IR} and $(G_{IR})_{Asym}$. Only log-log fit was performed. Because the test data was different from specimen to specimen, individual equations were fit. The parameters A, m, D_1, and D_2 calculated for different specimens are listed in figures 10-9 and 10-10. Comparisons for the da/dN equation with the test data are also shown in the same figures. The equation fit was not performed on the data generated by compliance method after eliminating or reducing the interlayer effect in the specimen because of insufficient of time.

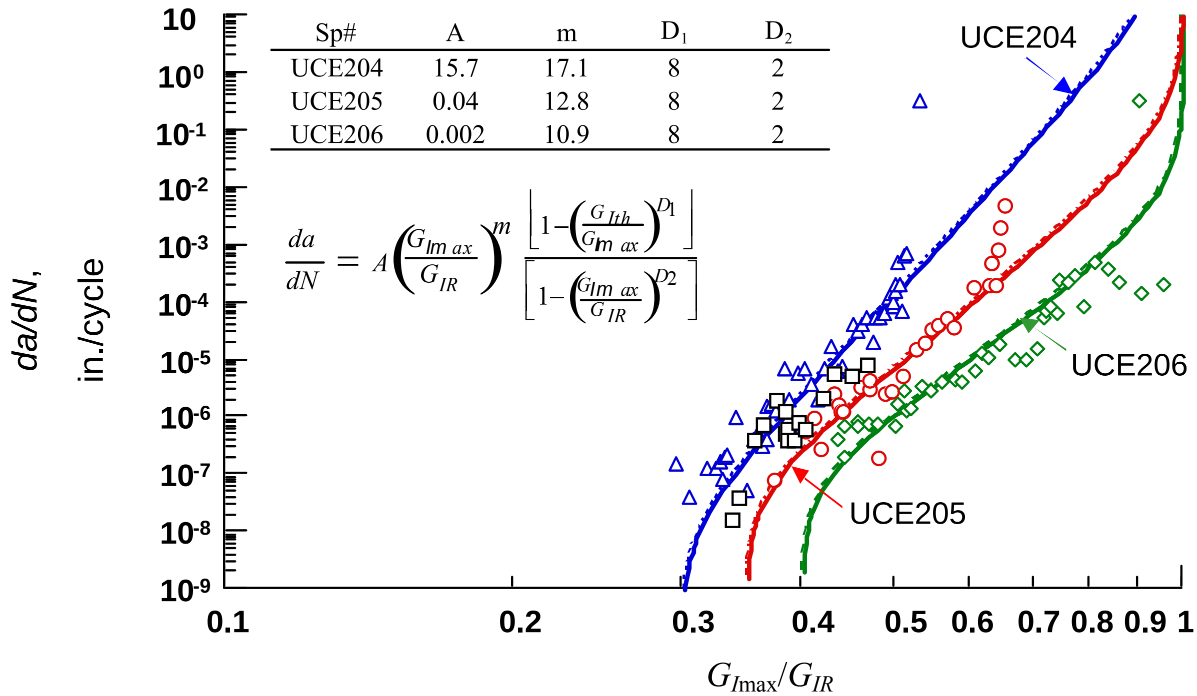


Figure 10-9. Delamination Growth Rate Equation (G_{IR} Normalization)

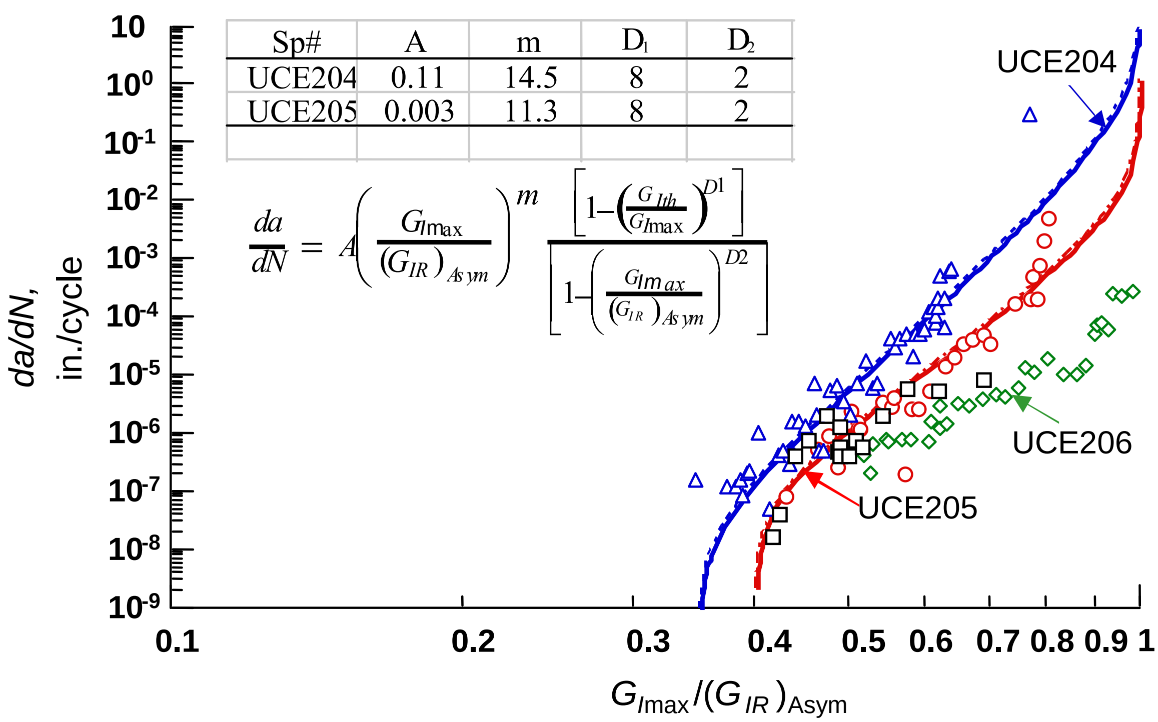


Figure 10-10. Delamination Growth Rate Equation ($(G_{IR})_{Asym}$ Normalization)

11. BLOCK LOADING FATIGUE TEST.

The purpose of this study was to verify the accuracy of the delamination growth rate equations (equations 10-4, 10-7, and 10-8) developed in section 10 for predicting the delamination propagation under an arbitrary fatigue loading. For simplicity, a simple block loading representing a rising, constant, and decreasing $G_{I\max}$ loading was considered. Two block-loading tests were conducted for FGI 1854 glass/Dow 510A-40 vinyl ester composite. One with $G_{I\max}$ ranged between 0.3 to 0.5 G_{IC} and another a more aggressive with $G_{I\max}$ varied between 0.2 to 2.0 G_{IC}. All tests were conducted by stroke (displacement)-controlled loading with $R = 0.1$. The loading was applied as stepped constant displacement to closely follow the $G_{I\max}$ versus N curve. For T800H carbon/3900-2 epoxy composite, only one block-loading test was conducted. $G_{I\max}$ varied from 0.5 to 0.7 and 0.6 $(G_{IR})_{Asym}$.

11.1 FIBER GLASS INDUSTRIES 1854/DOW 510A-40 GLASS/VINYL ESTER COMPOSITE.

11.1.1 Block Loading 1.

This is a typical in-service loading experienced by a structural component. The loading consists of increasing $G_{I\max}$ from 0.3 to 0.5 G_{IC}, constant $G_{I\max}$ = 0.5 G_{IC}, and a decreasing $G_{I\max}$ from 0.5 to 0.3 G_{IC}. Each of these segments was applied over 100,000 cycles so the total number of load cycles was 300,000. Each of the 100,000 cycles was divided into ten parts and each part was loaded by the constant-amplitude cyclic displacement. The specimen WF-5, with an initial delamination length of 1.463 in., was tested. The displacement corresponding to the $G_{I\max}$ was calculated from equation 9-1. Figure 11-1 compares intended and actual loading on the specimen. In figure 11-1, the broken line represents the intended loading, while the lines with the symbol represent the actual loading. The actual loading includes initial, average, and final G values for each 10,000 steps. The initial and final G values were determined by the initial and final loads measured at the beginning and the end of each 10,000 load cycles. The average G value is the average of the initial and final G values. The test data is presented table A-21 of appendix A. The final length of the delamination after 300,000 load cycles was 2.131 in.

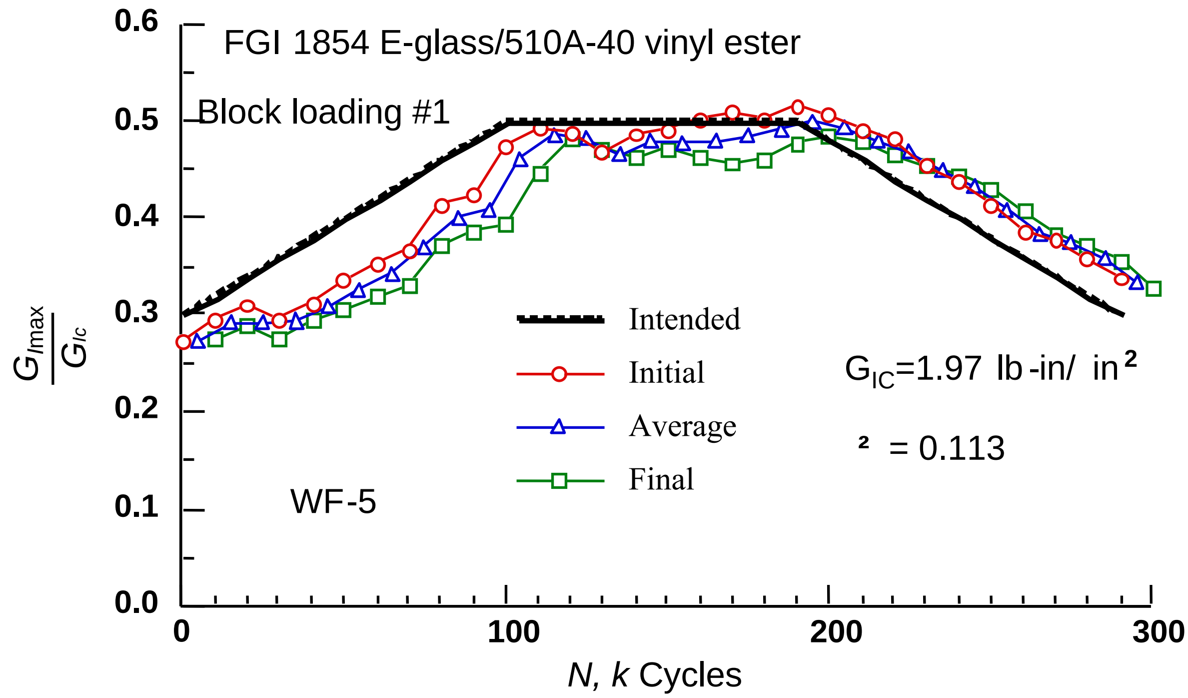


Figure 11-1. Constant-Displacement Amplitude Block Loading

The delamination lengths were predicted by integrating the growth rate equation

$$a = a_0 + \int_{N=0}^{300k} \frac{da}{dN} \qquad (11\text{-}1)$$

The numerical integration of equation 11-1 was performed by a summation equation. The 300,000 cycles were divided into 30 parts of 10,000 each, and each 10,000 cycles were further divided into ten parts of 1,000 cycles each. The summation is given by equation 27.

$$a = a_0 + \sum_{j=1}^{30} \left\{ \sum_{i=1}^{10} \left(\frac{da}{dN} \right)_i 10^3 \right\}_j \qquad (11\text{-}2)$$

Starting with initial delamination lengths, a_0 and $G_{I\max}$ values from the test were used to calculate a. The $(G_{I\max})_{Initial}$ and $(G_{I\max})_{Final}$ for each jth step was linearized to calculate average $G_{I\max}$ for 1000 load cycles. These averages were used in the prediction. A study of a different number of subdivision schemes showed that the subdivision of 10,000 segments after the first segment is not necessary. The difference between the results from subdividing and not subdividing the last 29 segments made only few percentiles. Therefore, the prediction presented in tables A-22 through A-24 of appendix A was detained by not subdividing the last 29 segments.

Figure 11-2 compares the predicted and the measured delamination lengths at the end of each load step from equations 10-4, 10-7, and 10-8. Agreement of the predicted results from equations 10-4 and 10-7 and the experiment is excellent, while equation 10-8 underpredicted the delamination propagation. Shapes of the curves for experimental data and equations 10-4 and 10-7 were similar. Final delamination length calculated from equations 10-4, 10-7, and 10-8 was 2.078 in., 2.113 in., and 1.764 in., while the measured length was 2.131 in. Equations 10-4 and 10-7 very accurately predicted the delamination length.

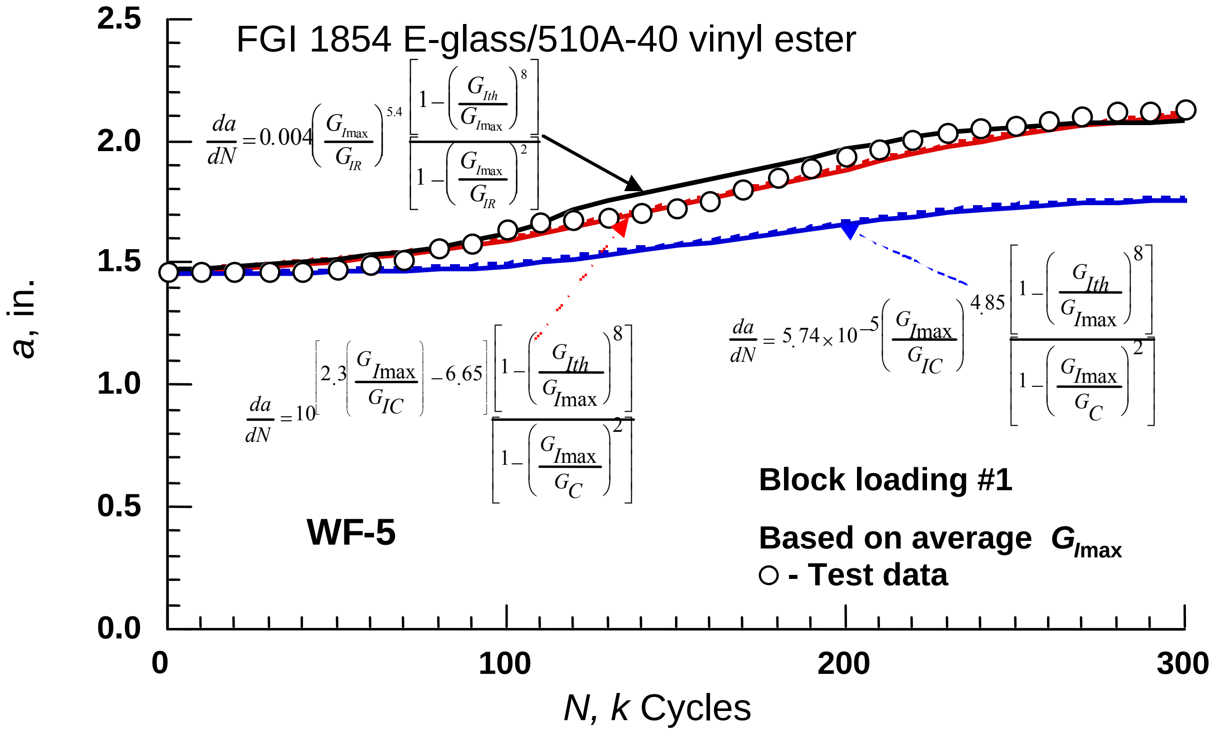


Figure 11-2. Comparison of Predicted Delamination Growth With Measured Values

11.1.2 Block Loading 2.

This was a more aggressive loading, as shown in figure 11-3. The loading $G_{I\max}$ was increased from 0.2 G_{IC} to 1.4 G_{IC} in 30,000 cycles, constant 1.4 G_{IC} for another 25,000 cycles, and decreased from 1.4 G_{IC} to 0.4 G_{IC} in the final 25,000 cycles. The total number of load cycles was 80,000. This test was again conducted by a constant-amplitude displacement loading (R = 0.1) with displacements incremented at every 5,000 cycles. Actual loading is represented by symbols and the intended loading was represented by the solid line. The test data is given in appendix table A-25, and the predictions from the three equations are given in tables A-26 through A-28.

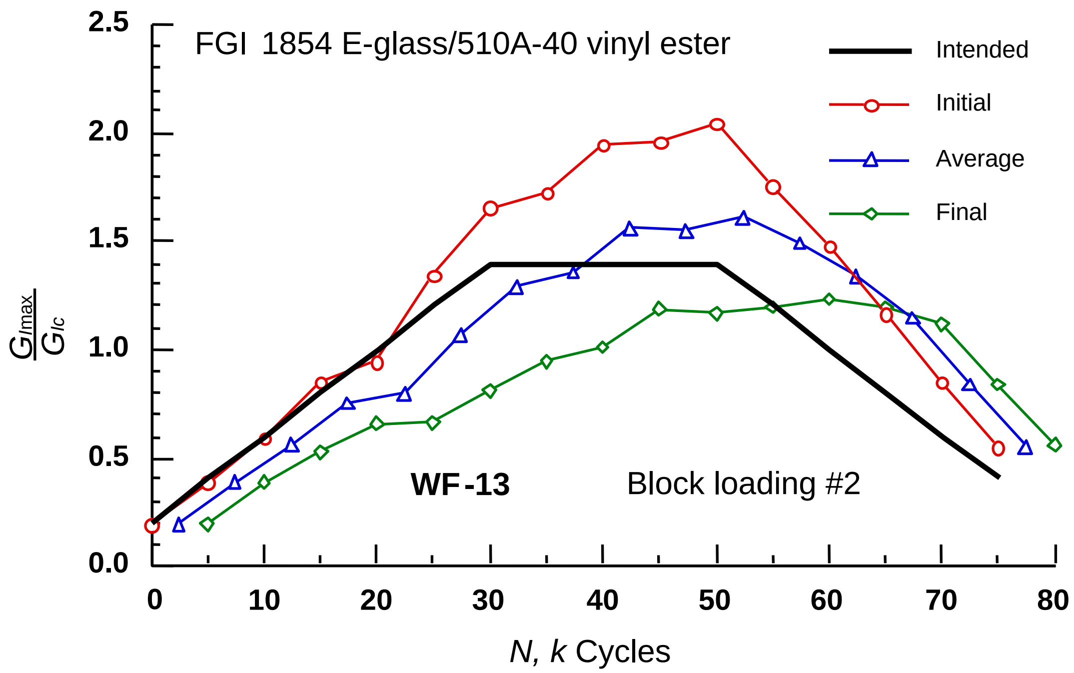


Figure 11-3. Constant-Displacement Amplitude Block Loading 2

Figure 11-4 shows a comparison of the predicted and the measured delamination lengths at the end of each load step. The final predicted delamination length from equation 10-4 was 9.485 in., while the experimental final was 4.98 in. This large difference is due to the more aggressive loading applied on the specimen. The delamination propagation rate in this loading range is in the unstable domain 3, wherein the growth rate is unstable large scatter is expected (see figure 49). Nevertheless, the prediction by equation 10-4 is reasonably good. Equations 10-7 and 10-8 excessively overpredicted the delamination lengths, indicating that these equations are unsuitable for predicting delamination propagation in domain 3.

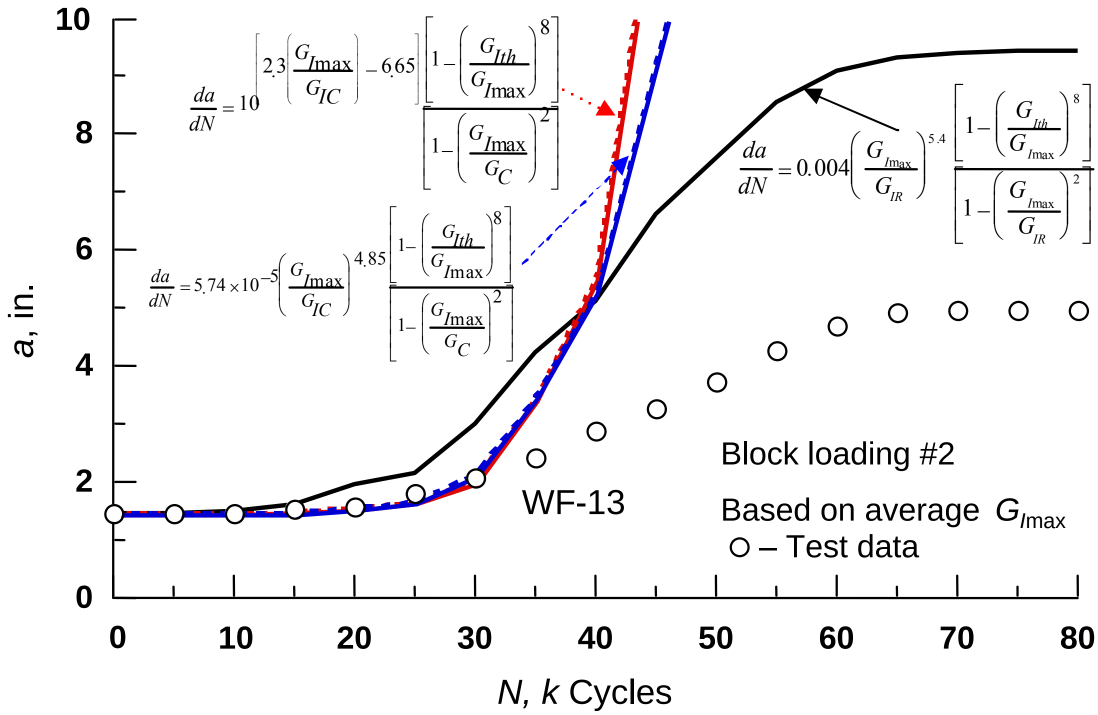


Figure 11-4. Comparison of Predicted Delamination Growth With Measured Values

11.2 T800H CARBON/3900-2 EPOXY COMPOSITE.

The block fatigue loading for T800H Carbon/3900-2 epoxy composite is shown in figure 11-5, and the results are shown in table A-29 of appendix A. This is also a constant-amplitude cyclic displacement loading test (R = 0.1) with increasing $G_{I\max}$ from 0.5 to 0.7 G_{IC}, constant $G_{I\max}$ = 0.7 G_{IC}, and decreasing $G_{I\max}$ from 0.7 to 0.6 G_{IC}. Each segment was applied over 100,000 cycles. The test was performed on specimen WF-13 with an initial delamination length of 1.447 in. The solid line represents the intended loading, while the lines with symbol represent the actual loading. The measured delamination length versus N is shown in figure 11-6. Attempts were made to compare the equations with experimental data but were found to be not realistic. The nonuniqueness of the equation was caused by the interleaving created by the thermoplastic powder in the prepreg. Further study is needed on these types of materials so that one can make reasonable conclusion from the data generated.

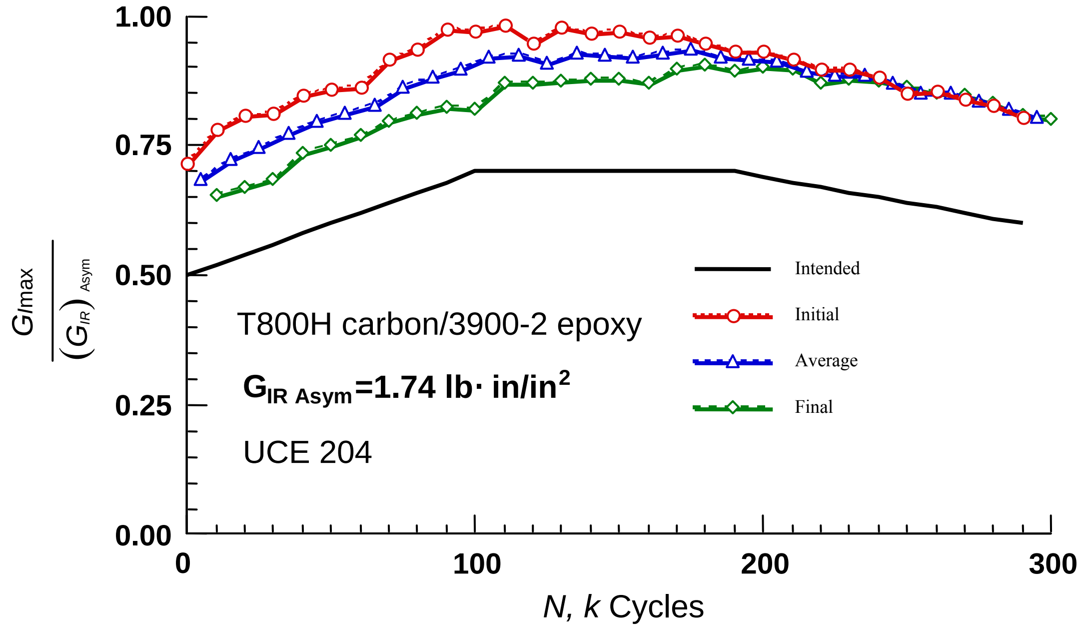


Figure 11-5. Block Loading Test for T800H/3900-2 Carbon/Epoxy Composite

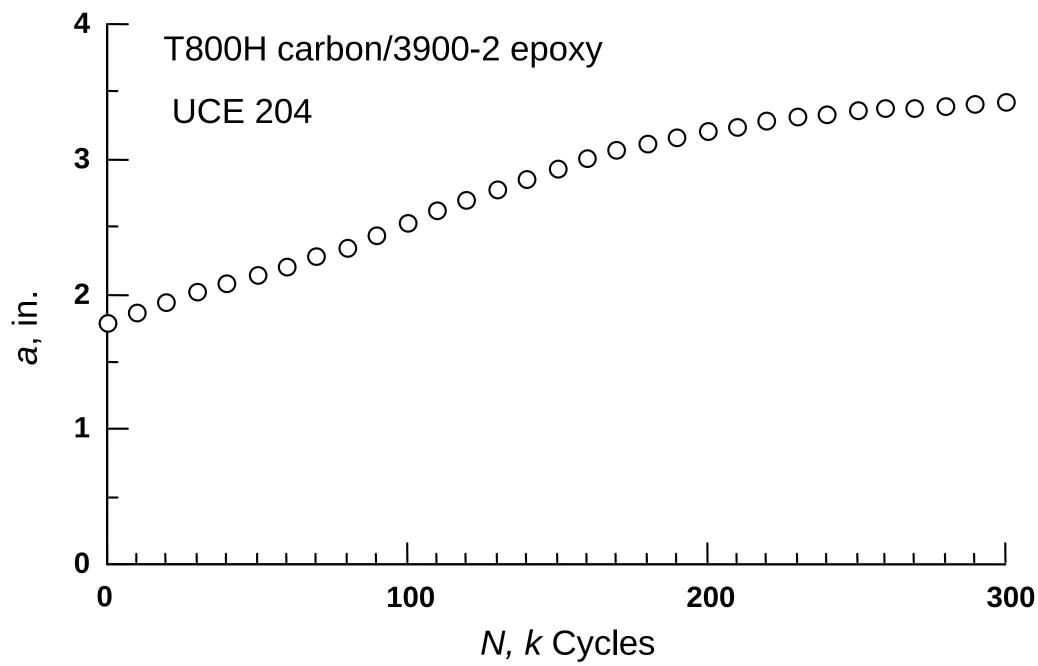


Figure 11-6. Experimental Delamination Growth of Block Loading Test for Carbon/Epoxy

12. CONCLUDING REMARKS.

This research was conducted as a part of the Federal Aviation Administration (FAA) damage tolerance technology development and database generation for composite materials for rotorcraft and general aviation industries. The objectives of the research were to review the status of the fracture and fatigue testing of composite laminates, develop a total fatigue life prediction model, generate the database of delamination growth rates for mode I loading, determine constants in the total fatigue life model, and verify the model.

A review of the state-of-the-art fracture and fatigue testing composite laminates found the following. Fracture testing under mode I, II, and mixed I-II conditions are very well established, and ASTM standards are available or under development. Fracture testing under mode III and its combination with mode I and II does not exist. The four point torsion-loaded split beam specimen shows a promise according to the theory, but the experimental data shows unsatisfactory results. Fatigue onset life test method for mode I loading is well established and is under development for mode II loading. There are no standards for delamination growth rate testing either for mode I, II, or mixed I-II. A number of papers have been published on the delamination growth rate (da/dN) versus energy release rate (G_{max} or ΔG_{max}) data for mode I double cantilever beam, mode II end-notched fixture loaded, and edge delaminated specimens. Finally, no method exists for predicting the total life of a composite structures based on interlaminar fracture mechanisms.

The present research proposed and developed three total life prediction models. They are log-log equation with resistance (G_R) normalization, log-linear equation with critical energy release rate (G_{IC}), and log-log equation with G_{IC} normalizations. All three total life equations were developed for the first time in the literature. The most promising total life prediction model is the G_R normalization, the equation for mode I loading is given by

$$\frac{da}{dN} = A\left(\frac{G_{I\max}}{G_{IR}}\right)^m \frac{\left[1-\left(\frac{G_{Ith}}{G_{I\max}}\right)^{D_1}\right]}{\left[1-\left(\frac{G_{I\max}}{G_{IR}}\right)^{D_2}\right]}$$

where $G_{I\max}$ is the maximum cyclic energy release rate loading, G_{Ith} is the threshold energy release rate, and G_{IR} is the material resistance at the current delamination length. The constants A, m, D_1, and D_2 are material constants to be determined from the fatigue test. In addition to the above equation, two other equations were also proposed and developed based on the critical energy release rate (G_{IC}) normalization. All the constants were established through fabrication of composite delaminated panels; specimen preparation; fracture, fatigue onset life, and fatigue delamination growth rate testing; and data analysis.

Two material systems were considered in this research: woven-roving Fiber Glass Industries, Inc. (FGI) 1854 E-glass/Dow 510A-40 vinyl ester and unidirectional Toray's T800H carbon/3900-2 epoxy composites. The glass/vinyl ester composite panel was fabricated by North Carolina A&T developed vacuum assisted resin transfer molding technique and the carbon/epoxy panel by no-bleed autoclave processing. Fracture resistance test data was generated by ASTM D 5528 test method. The G_{IC} and G_{IR} data were reduced by modified beam theory, compliance, and modified compliance methods. An automated data reduction program was developed using the Excel spreadsheet. The program is included in the report. The material resistance is expressed by an equation $G_{IR}(a) = G_{IC} + A_R \Delta a^{m_R}$. G_{IC} = 1.97 in.lb/in^2, A_R = 2.25, and m_R = 0.31 for glass/vinyl ester composite while G_{IC} = 1.74 in.lb/in^2, A_R = 0.29 and m_R = -0.78 for carbon/epoxy composite. Fracture modes for glass/vinyl ester were tow cracking and separation, multiple cracks, fiber bridging and breaking between the tow cross-over points, and matrix-fiber interfacial failure. Fracture modes for carbon/epoxy were matrix cracking and fiber bridging.

Fatigue onset life test was conducted as per the ASTM D 6115 standard. Constant-amplitude cyclic displacement loading was used with an R ratio of 0.1. One percent compliance change criteria was found to be invalid for woven textile composites because a number of microscope cracking within the tow occurs before any propagation in the delamination front. That damage alone causes more than 1% compliance increase. Either 2% or 5% compliance increase criteria was found to be appropriate for predicting the onset life. The asymptotic value of energy release rate from the data generated was about $0.22G_{IC}$ for glass/vinyl ester. The threshold G (G_{th}) will be less than the asymptotic value.

Fatigue delamination growth rate tests were also conducted to ASTM D 6115 test methods but started with the $G_{I\max}$ loading equivalent to 0.8 G_{IC}. Two types of data recording and reductions were used. One was the stepped number of load cycles approach and the other was the compliance approach. In the stepped approach, the test was conducted by incrementing the displacement at every specified number of load steps. Then, the load and the delamination length were recorded at the maximum cyclic displacement. From this data, all other required parameters were calculated. In the compliance approach, the compliance equation generated separately was used for calculation. The first method was used for both glass/vinyl ester and carbon/epoxy composites, while the second method was used for carbon/epoxy composite. The constants in the above delamination growth rate equation were found to be A = 0.004, m = 5.4, D_1 = 8, and D_2 = 2 for glass/vinyl ester composite. No unique equation was developed for carbon/epoxy composite because of thermoplastic interleaving between the plies. The interleaving effect was removed through fracturing the delaminated specimen and then separate da/dN was generated, but the development of the equation was not performed because of time limitation. All data are included in the report for future evaluation.

The delamination growth rate equation developed were verified for two types of block fatigue loading with R = 0.1. One was typical service loading while the other was aggressive loading with high value of $G_{I\max}$. The block loading consisted of $G_{I\max}$ rising, constant, and decreasing segments. The G_{IR} normalized delamination growth rate equation (given above) agreed very well with the experiment for block loading 1 and reasonably well for block loading 2. The log-linear equation agreed very well with the experiment for block loading 1 but was inaccurate for block loading 2. The verification was performed only for glass/vinyl ester composite but not for carbon/epoxy because of thermoplastic interlayer effect.

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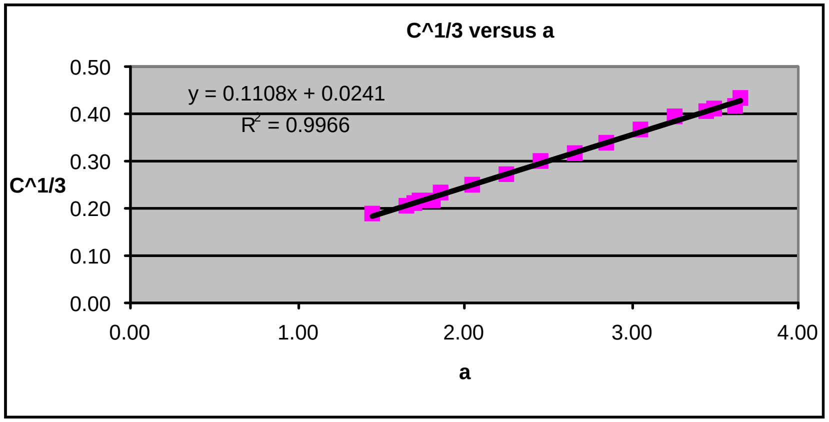
APPENDIX A—FRACTURE TEST DATA

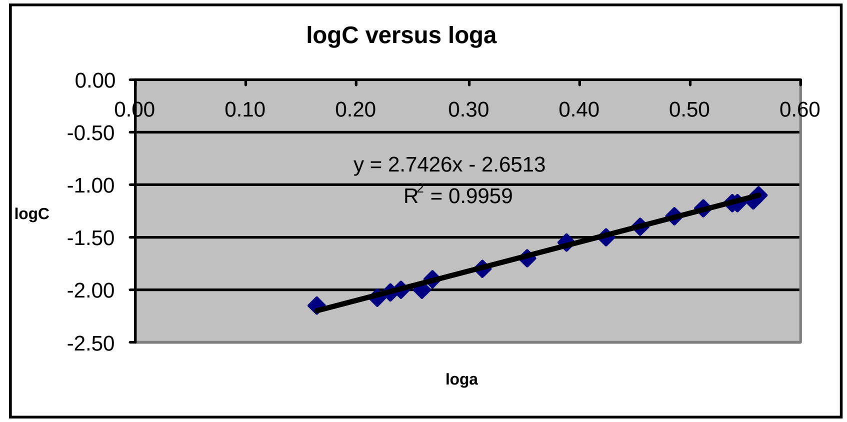
This appendix presents fracture test data in tables and is immediately followed by graphical representations of this data.

Table A-1. Fracture Data Reduction for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite Laminate (Specimen W-1)

$2h$ in.	b in.	Δ	n	A_1
0.195	1.497	0.2175	2.7426	46.223

a	P (lb)	Displacement (in.)	C = d/P	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	da
1.455	2.69E+01	1.87E-01	6.97E-03	0.19101	0.03648	3.02	3.17	2.94	0.0000
1.655	2.59E+01	2.21E-01	8.52E-03	0.20426	0.04172	3.07	3.17	3.13	0.2000
1.695	2.78E+01	2.68E-01	9.65E-03	0.21288	0.04532	3.90	4.02	3.89	0.2400
1.735	2.81E+01	2.77E-01	9.85E-03	0.21439	0.04596	3.99	4.11	4.04	0.2800
1.815	2.95E+01	3.00E-01	1.02E-02	0.21668	0.04695	4.35	4.46	4.54	0.3600
1.855	2.61E+01	3.34E-01	1.28E-02	0.23390	0.05471	4.21	4.30	4.14	0.4000
2.055	2.95E+01	4.72E-01	1.60E-02	0.25195	0.06348	6.13	6.20	6.15	0.6000
2.255	2.45E+01	4.84E-01	1.97E-02	0.27024	0.07303	4.82	4.83	4.90	0.8000
2.455	2.14E+01	5.85E-01	2.74E-02	0.30154	0.09093	4.69	4.66	4.61	1.0000
2.655	2.30E+01	7.13E-01	3.11E-02	0.31436	0.09882	5.71	5.65	5.80	1.2000
2.855	1.95E+01	7.62E-01	3.90E-02	0.33923	0.11508	4.85	4.77	4.88	1.4000
3.055	1.76E+01	8.85E-01	5.03E-02	0.36917	0.13629	4.76	4.67	4.69	1.6000
3.255	1.68E+01	1.02E+00	6.04E-02	0.39244	0.15401	4.94	4.82	4.85	1.8000
3.455	1.61E+01	1.07E+00	6.63E-02	0.40473	0.16381	4.67	4.54	4.71	2.0000
3.495	1.69E+01	1.16E+00	6.84E-02	0.40900	0.16728	5.30	5.14	5.34	2.0400
3.615	1.68E+01	1.21E+00	7.19E-02	0.41586	0.17294	5.33	5.17	5.46	2.1600
3.655	1.52E+01	1.23E+00	8.10E-02	0.43272	0.18725	4.84	4.69	4.81	2.2000


C^1/3 versus a
y = 0.1108x + 0.0241
R^2 = 0.9966
C^1/3
0.50
0.40
0.30
0.20
0.10
0.00
0.00
1.00
2.00
3.00
4.00
a


logC versus loga
y = 2.7426x - 2.6513
R^2 = 0.9959
logC
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
loga

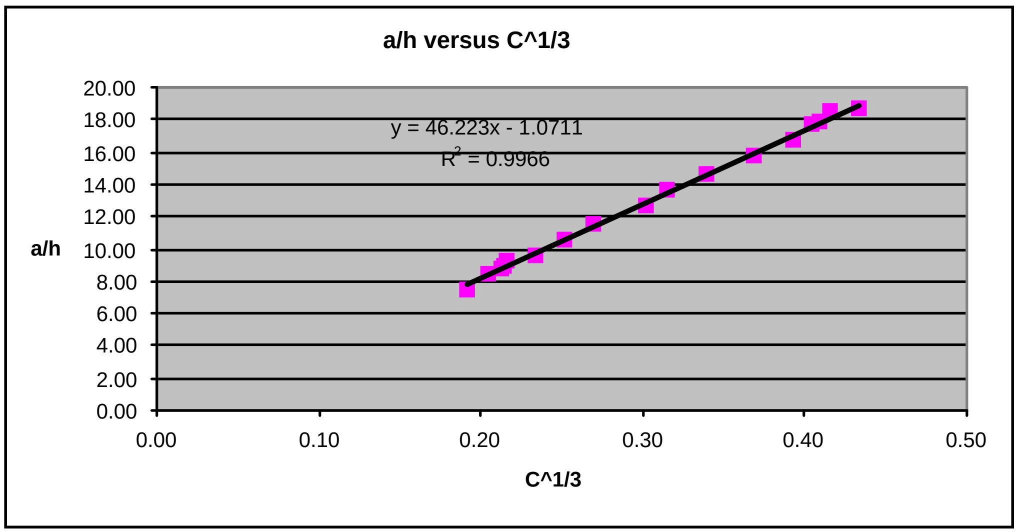
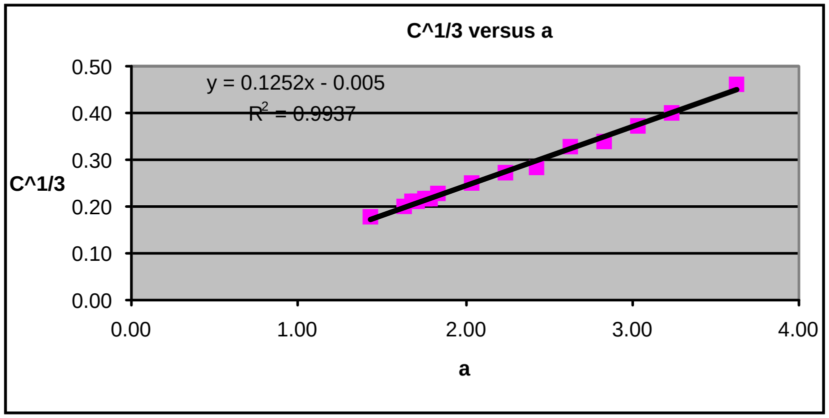
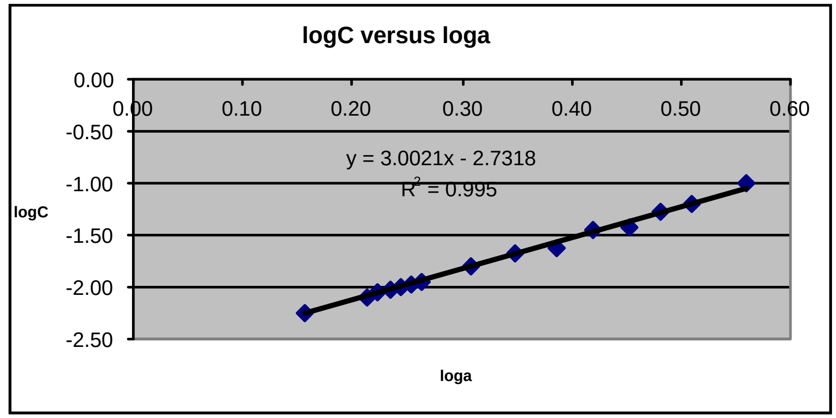

a/h versus C^1/3
y = 46.223x - 1.0711
R^2 = 0.9966
a/h
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
C^1/3

Table A-2. Fracture Data Reduction for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite Laminate (Specimen W-2)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.196	1.499	0.0399	3.0021	40.448				
a	P (lb)	Displacement (in.)	C = d/P	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	da
1.434	1.53E+01	8.79E-02	5.76E-03	0.17923	0.03212	0.91	0.94	0.94	0.0000
1.634	2.34E+01	1.84E-01	7.85E-03	0.19878	0.03952	2.58	2.65	2.74	0.2000
1.674	2.61E+01	2.36E-01	9.05E-03	0.20837	0.04342	3.60	3.69	3.73	0.2400
1.714	2.81E+01	2.70E-01	9.60E-03	0.21251	0.04516	4.32	4.42	4.49	0.2800
1.754	3.13E+01	3.19E-01	1.02E-02	0.21671	0.04696	5.57	5.70	5.81	0.3200
1.794	3.08E+01	3.24E-01	1.05E-02	0.21911	0.04801	5.44	5.57	5.74	0.3600
1.834	3.10E+01	3.54E-01	1.14E-02	0.22517	0.05070	5.86	5.99	6.15	0.4000
2.034	2.55E+01	4.01E-01	1.57E-02	0.25032	0.06266	4.94	5.04	5.16	0.6000
2.234	2.39E+01	4.93E-01	2.06E-02	0.27420	0.07519	5.18	5.28	5.42	0.8000
2.434	2.62E+01	6.06E-01	2.31E-02	0.28481	0.08111	6.44	6.55	7.05	1.0000
2.634	1.89E+01	6.71E-01	3.54E-02	0.32841	0.10786	4.75	4.83	4.88	1.2000
2.834	1.97E+01	7.55E-01	3.84E-02	0.33726	0.11374	5.18	5.25	5.56	1.4000
3.034	1.69E+01	8.86E-01	5.23E-02	0.37405	0.13992	4.88	4.95	5.05	1.6000
3.234	1.45E+01	9.17E-01	6.34E-02	0.39865	0.15892	4.05	4.11	4.20	1.8000
3.634	1.19E+01	1.18E+00	9.97E-02	0.46372	0.21503	3.83	3.87	3.82	2.2000


C^1/3 versus a
y = 0.1252x - 0.005
R^2 = 0.9937
C^1/3
0.00
0.10
0.20
0.30
0.40
0.50
0.00
1.00
2.00
3.00
4.00
a


logC versus loga
y = 3.0021x - 2.7318
R^2 = 0.995
logC
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
loga

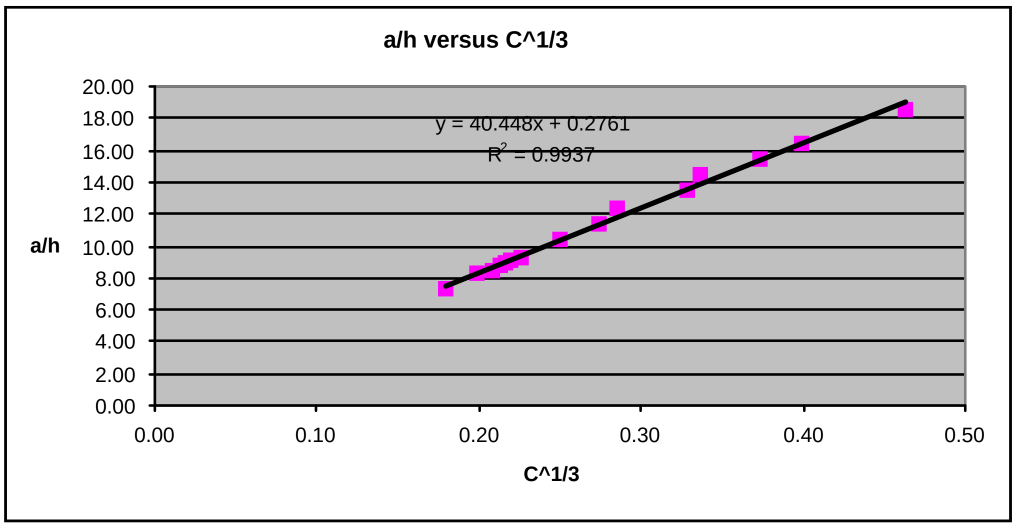
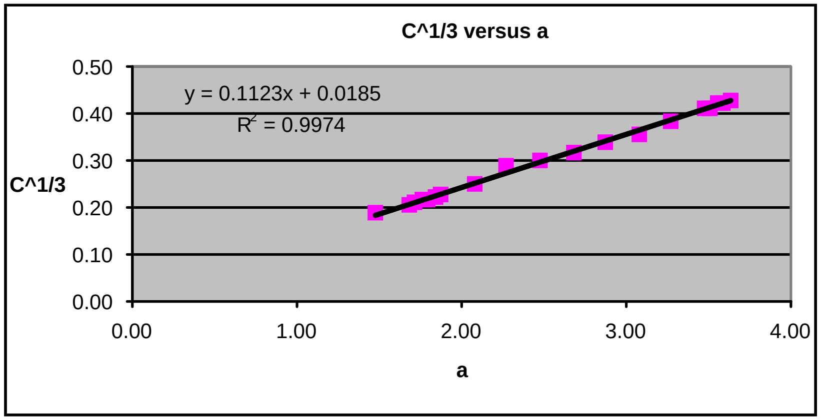
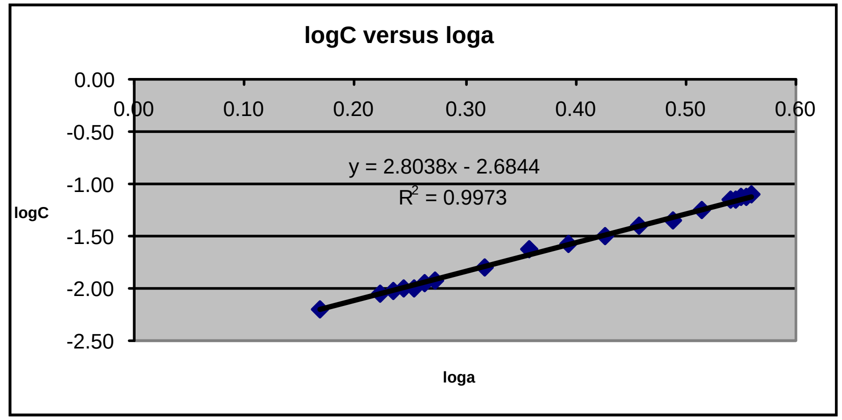

a/h versus C^1/3
y = 40.448x + 0.2761
R^2 = 0.9937
a/h
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
0.00
0.10
0.20
0.30
0.40
0.50
C^1/3

Table A-3. Fracture Data Reduction for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite Laminate (Specimen W-3)

2h in.	*b* in.	Δ	*n*	A_1
0.195	1.497	0.1647	2.8038	45.597

a	P (lb)	Displacement (in.)	C = d/P	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	da
1.475	2.06E+01	1.33E-01	6.47E-03	0.18636	0.03473	1.68	1.75	1.67	0.0000
1.675	2.68E+01	2.33E-01	8.69E-03	0.20556	0.04226	3.41	3.50	3.43	0.2000
1.715	2.58E+01	2.47E-01	9.59E-03	0.21244	0.04513	3.40	3.48	3.39	0.2400
1.755	2.52E+01	2.51E-01	9.95E-03	0.21506	0.04625	3.30	3.37	3.31	0.2800
1.795	2.56E+01	2.62E-01	1.02E-02	0.21708	0.04712	3.44	3.51	3.49	0.3200
1.835	2.48E+01	2.71E-01	1.09E-02	0.22184	0.04921	3.36	3.42	3.41	0.3600
1.875	2.40E+01	2.80E-01	1.17E-02	0.22677	0.05142	3.30	3.36	3.34	0.4000
2.075	2.42E+01	3.77E-01	1.56E-02	0.24961	0.06231	4.09	4.12	4.13	0.6000
2.275	2.10E+01	4.96E-01	2.36E-02	0.28677	0.08224	4.29	4.30	4.11	0.8000
2.475	1.94E+01	5.28E-01	2.73E-02	0.30107	0.09064	3.88	3.87	3.83	1.0000
2.675	1.87E+01	5.91E-01	3.16E-02	0.31631	0.10005	3.89	3.86	3.93	1.2000
2.875	1.85E+01	7.25E-01	3.92E-02	0.33963	0.11535	4.42	4.36	4.45	1.4000
3.075	1.82E+01	8.05E-01	4.43E-02	0.35385	0.12521	4.52	4.45	4.66	1.6000
3.275	1.52E+01	8.47E-01	5.57E-02	0.38193	0.14587	3.75	3.68	3.80	1.8000
3.475	1.53E+01	1.07E+00	6.99E-02	0.41190	0.16966	4.47	4.38	4.45	2.0000
3.515	1.52E+01	1.07E+00	7.05E-02	0.41314	0.17069	4.43	4.34	4.45	2.0400
3.555	1.47E+01	1.09E+00	7.40E-02	0.41984	0.17626	4.32	4.22	4.31	2.0800
3.595	1.45E+01	1.10E+00	7.55E-02	0.42257	0.17857	4.24	4.14	4.25	2.1200
3.635	1.46E+01	1.16E+00	7.92E-02	0.42943	0.18441	4.47	4.37	4.45	2.1600


C^1/3 versus a
y = 0.1123x + 0.0185
R^2 = 0.9974
C^1/3
0.00
0.10
0.20
0.30
0.40
0.50
0.00
1.00
2.00
3.00
4.00
a


logC versus loga
y = 2.8038x - 2.6844
R^2 = 0.9973
logC
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
loga

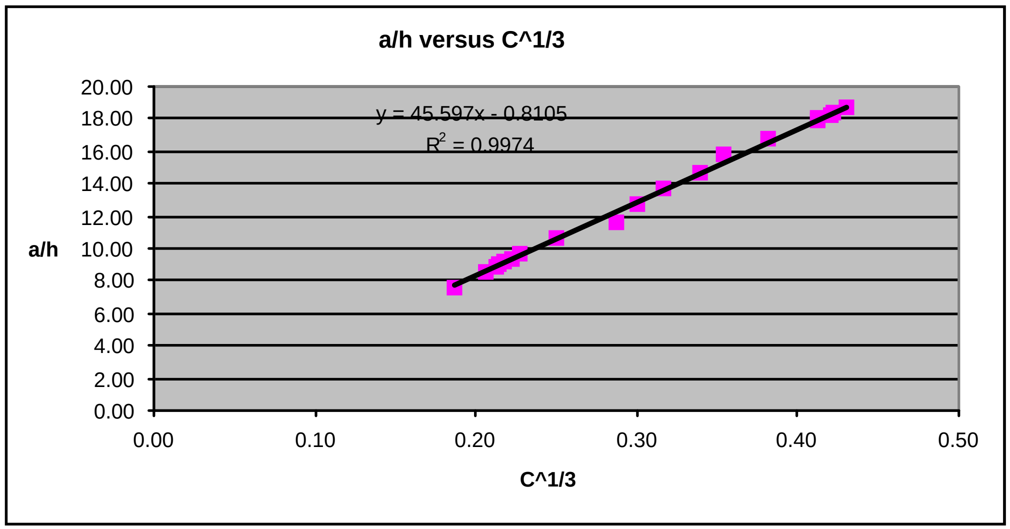
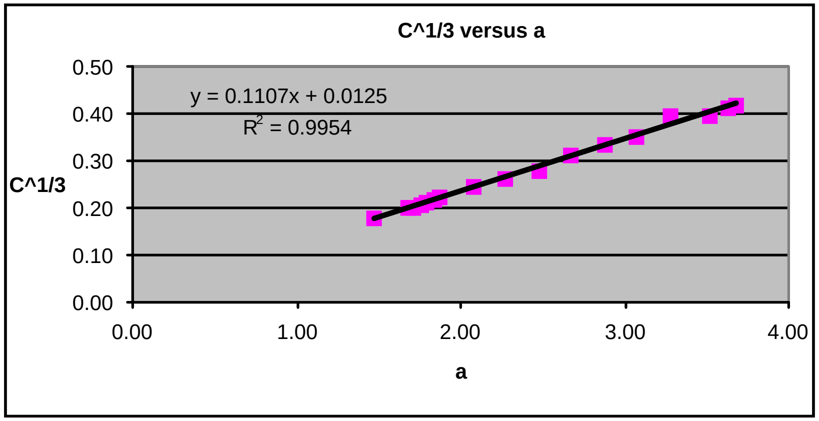
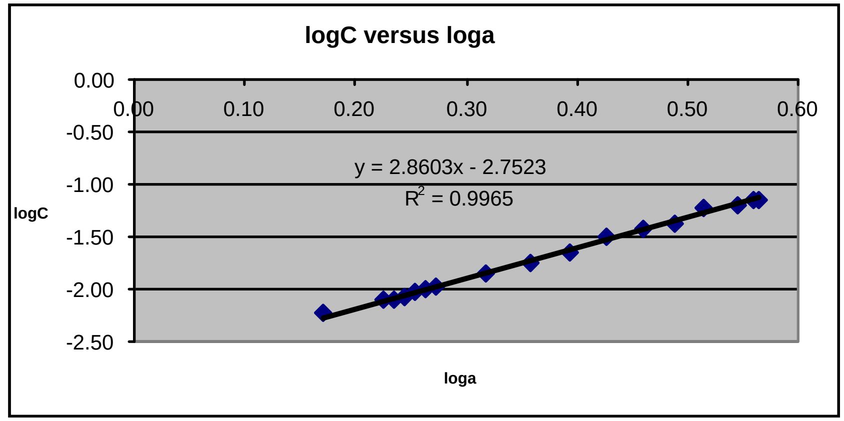

a/h versus C^1/3
y = 45.597x - 0.8105
R^2 = 0.9974
a/h
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
C^1/3

Table A-4. Fracture Data Reduction for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite Laminate (Specimen W-4)

2h in.	*b* in.	Δ	*n*	A_1
0.195	1.499	0.1129	2.8603	46.140

a	P (lb)	Displacement (in.)	C = d/P	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	da
1.478	1.93E+01	1.13E-01	5.87E-03	0.18043	0.03255	1.37	1.41	1.34	0.0000
1.678	2.60E+01	2.04E-01	7.82E-03	0.19850	0.03940	2.96	3.02	2.97	0.2000
1.718	2.62E+01	2.10E-01	8.02E-03	0.20019	0.04008	3.02	3.06	3.07	0.2400
1.758	2.64E+01	2.25E-01	8.55E-03	0.20449	0.04182	3.18	3.23	3.24	0.2800
1.798	2.59E+01	2.47E-01	9.53E-03	0.21205	0.04496	3.36	3.40	3.37	0.3200
1.838	2.57E+01	2.58E-01	1.00E-02	0.21569	0.04652	3.40	3.45	3.42	0.3600
1.878	2.58E+01	2.73E-01	1.06E-02	0.21969	0.04826	3.54	3.57	3.56	0.4000
2.078	2.69E+01	3.83E-01	1.42E-02	0.24238	0.05875	4.70	4.72	4.72	0.6000
2.278	2.24E+01	4.07E-01	1.82E-02	0.26299	0.06916	3.81	3.81	3.85	0.8000
2.478	2.07E+01	4.52E-01	2.18E-02	0.27938	0.07805	3.62	3.61	3.73	1.0000
2.678	2.23E+01	6.87E-01	3.09E-02	0.31364	0.09837	5.48	5.45	5.43	1.2000
2.878	1.85E+01	6.94E-01	3.76E-02	0.33502	0.11224	4.28	4.24	4.25	1.4000
3.078	1.73E+01	7.50E-01	4.32E-02	0.35092	0.12315	4.08	4.03	4.12	1.6000
3.278	1.63E+01	9.90E-01	6.08E-02	0.39314	0.15456	4.77	4.70	4.57	1.8000
3.518	1.62E+01	9.97E-01	6.17E-02	0.39509	0.15610	4.44	4.37	4.54	2.0400
3.638	1.45E+01	1.01E+00	6.94E-02	0.41085	0.16880	3.90	3.83	3.96	2.1600
3.678	1.46E+01	1.06E+00	7.25E-02	0.41704	0.17393	4.07	4.00	4.11	2.2000


C^1/3 versus a
y = 0.1107x + 0.0125
R2 = 0.9954
C^1/3
0.00
0.10
0.20
0.30
0.40
0.50
0.00
1.00
2.00
3.00
4.00
a


logC versus loga
y = 2.8603x - 2.7523
R2 = 0.9965
logC
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
loga

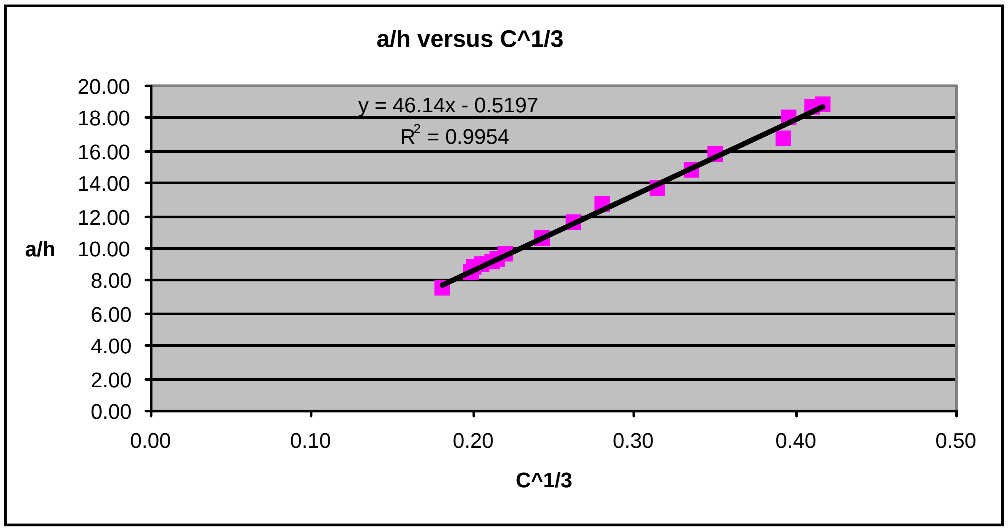
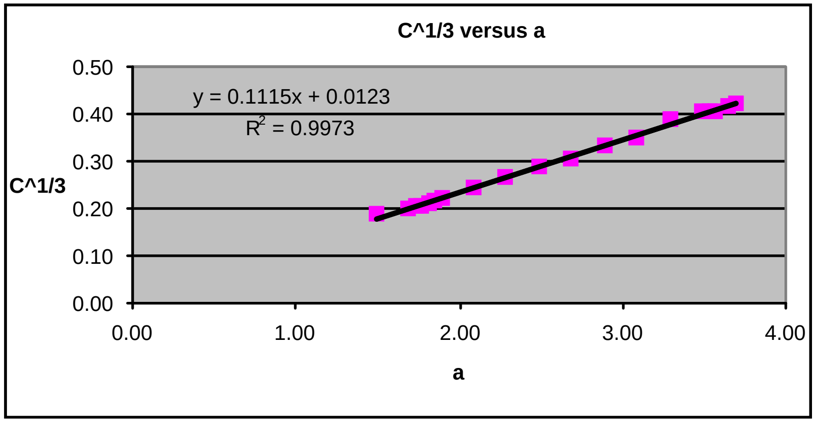
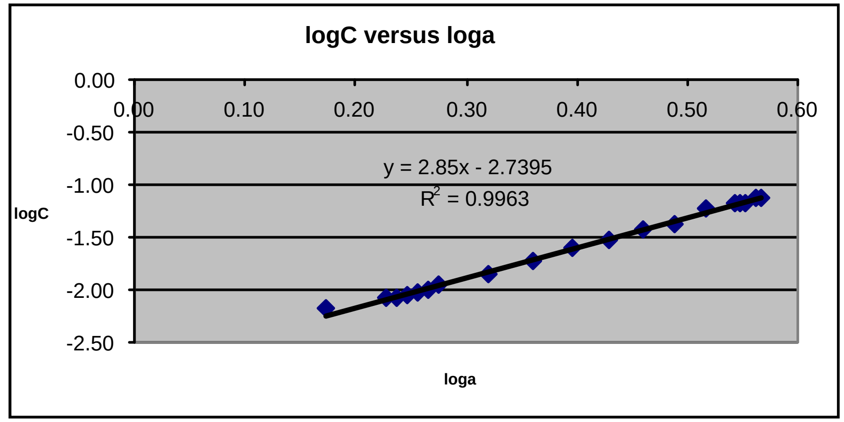

a/h versus C^1/3
y = 46.14x - 0.5197
R2 = 0.9954
a/h
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
C^1/3

Table A-5. Fracture Data Reduction for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite Laminate (Specimen W-5)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.199	1.498	0.1103	2.85	45.061				
a	P (lb)	Displacement (in.)	C = d/P	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	da
1.488	2.62E+01	1.75E-01	6.67E-03	0.18825	0.03544	2.87	2.93	2.72	0.0000
1.688	2.55E+01	2.11E-01	8.25E-03	0.20210	0.04084	3.00	3.03	2.98	0.2000
1.728	2.60E+01	2.20E-01	8.47E-03	0.20381	0.04154	3.11	3.15	3.14	0.2400
1.768	2.63E+01	2.29E-01	8.68E-03	0.20550	0.04223	3.21	3.24	3.28	0.2800
1.808	2.76E+01	2.64E-01	9.56E-03	0.21222	0.04504	3.79	3.82	3.83	0.3200
1.848	2.89E+01	2.85E-01	9.88E-03	0.21456	0.04604	4.22	4.24	4.30	0.3600
1.888	3.19E+01	3.49E-01	1.09E-02	0.22201	0.04929	5.57	5.60	5.60	0.4000
2.088	2.73E+01	3.92E-01	1.44E-02	0.24310	0.05910	4.88	4.88	4.93	0.6000
2.288	2.42E+01	4.68E-01	1.93E-02	0.26843	0.07205	4.72	4.70	4.71	0.8000
2.488	2.52E+01	6.24E-01	2.48E-02	0.29156	0.08501	6.05	6.00	6.03	1.0000
2.688	2.36E+01	6.89E-01	2.91E-02	0.30774	0.09470	5.83	5.77	5.93	1.2000
2.888	2.03E+01	7.50E-01	3.69E-02	0.33288	0.11081	5.10	5.03	5.13	1.4000
3.088	1.97E+01	8.49E-01	4.31E-02	0.35074	0.12302	5.23	5.14	5.33	1.6000
3.288	1.74E+01	1.05E+00	6.00E-02	0.39157	0.15332	5.38	5.28	5.22	1.8000
3.488	1.63E+01	1.07E+00	6.57E-02	0.40351	0.16282	4.88	4.79	4.87	2.0000
3.528	1.63E+01	1.09E+00	6.68E-02	0.40580	0.16467	4.89	4.79	4.90	2.0400
3.568	1.64E+01	1.11E+00	6.81E-02	0.40832	0.16673	4.97	4.87	5.00	2.0800
3.648	1.53E+01	1.12E+00	7.35E-02	0.41881	0.17540	4.58	4.48	4.60	2.1600
3.688	1.51E+01	1.13E+00	7.49E-02	0.42156	0.17771	4.51	4.41	4.54	2.2000


C^1/3 versus a
y = 0.1115x + 0.0123
R^2 = 0.9973
C^1/3
0.50
0.40
0.30
0.20
0.10
0.00
0.00
1.00
2.00
3.00
4.00
a


logC versus loga
y = 2.85x - 2.7395
R^2 = 0.9963
logC
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
loga

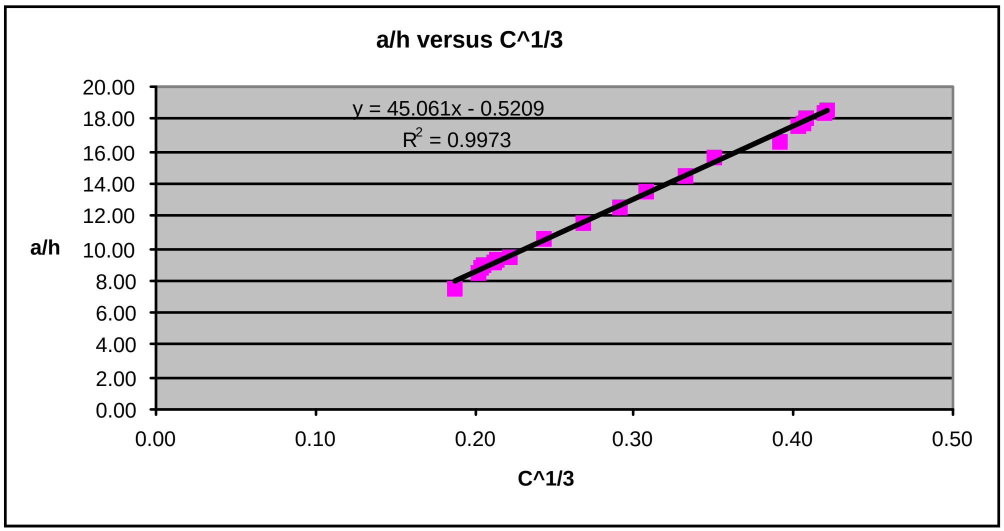

a/h versus C^1/3
y = 45.061x - 0.5209
R^2 = 0.9973
a/h
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
C^1/3

Table A-6. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S1)

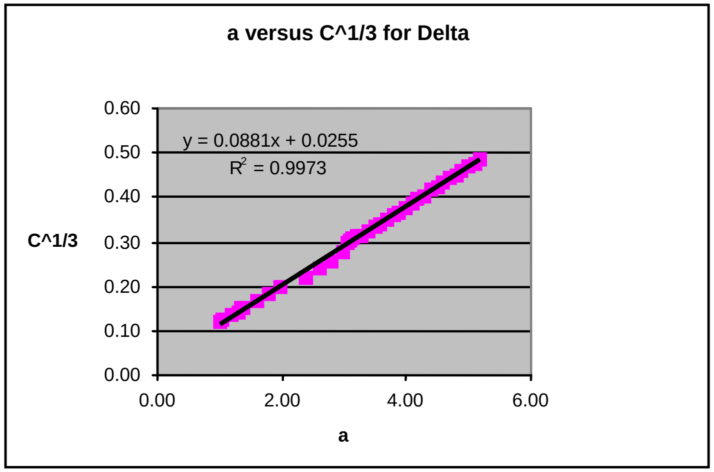
	2h in.	*b* in.	Δ	*n*	A_1				
	0.154	1.0994	0.289	2.593	76.684				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	Da
0.991	44.82	0.075	1.67E-03	0.11872	0.01409	3.58	4.00	3.27	*
0.991	45.18	0.076	1.69E-03	0.11908	0.01418	3.67	4.10	3.34	0.0000
1.058	39.70	0.081	2.03E-03	0.12662	0.01603	3.24	3.57	2.92	0.0670
1.191	34.79	0.085	2.45E-03	0.13477	0.01816	2.73	2.93	2.54	0.2000
1.291	29.86	0.086	2.89E-03	0.14240	0.02028	2.22	2.35	2.09	0.3000
1.341	28.99	0.099	3.41E-03	0.15057	0.02267	2.40	2.52	2.20	0.3500
1.391	29.05	0.105	3.62E-03	0.15357	0.02358	2.48	2.59	2.30	0.4000
1.591	29.28	0.135	4.60E-03	0.16631	0.02766	2.86	2.92	2.74	0.6000
1.791	24.44	0.147	6.03E-03	0.18197	0.03311	2.36	2.37	2.28	0.8000
1.991	21.59	0.170	7.89E-03	0.19908	0.03963	2.20	2.18	2.14	1.0000
2.191	18.69	0.197	1.05E-02	0.21916	0.04803	2.02	1.98	1.94	1.2000
2.391	16.89	0.228	1.35E-02	0.23800	0.05665	1.96	1.90	1.87	1.4000
2.591	15.43	0.263	1.71E-02	0.25739	0.06625	1.92	1.85	1.82	1.6000
2.791	14.28	0.304	2.13E-02	0.27710	0.07678	1.92	1.83	1.81	1.8000
2.991	13.27	0.347	2.61E-02	0.29679	0.08809	1.92	1.82	1.79	2.0000
3.041	12.88	0.351	2.72E-02	0.30090	0.09054	1.85	1.75	1.74	2.0500
3.091	12.48	0.356	2.85E-02	0.30551	0.09334	1.79	1.69	1.68	2.1000
3.141	12.49	0.377	3.02E-02	0.31142	0.09698	1.87	1.77	1.75	2.1500
3.191	12.41	0.386	3.11E-02	0.31460	0.09897	1.88	1.77	1.76	2.2000

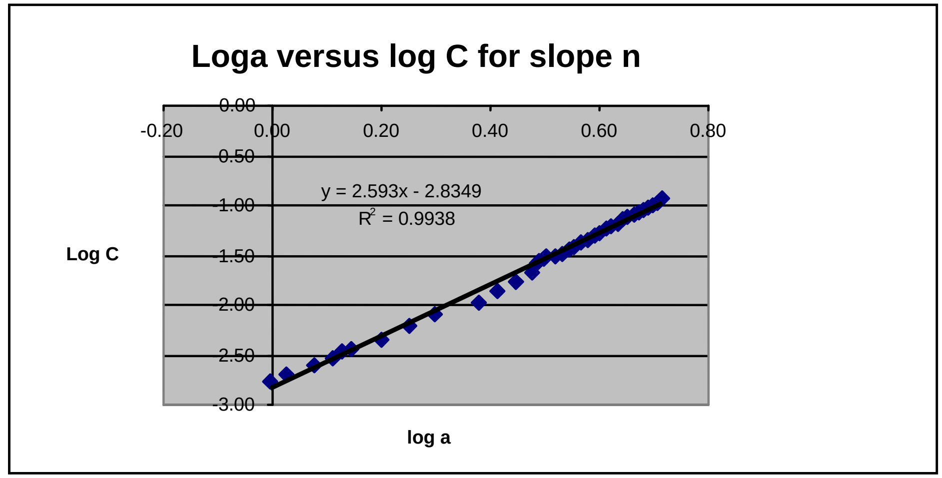
* NL point

Table A-6. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S1) (Continued)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.154	1.0994	0.289	2.593	76.684				
a	P	Displacement	C = d/P			Energy Release Rate			
(in.)	(lb)	(in.)	(in./lb)	$C^{1/3}$	$C^{2/3}$	G_MBT	G_CC	G_MCC	Da
3.291	11.92	0.395	3.31E-02	0.32113	0.10313	1.79	1.69	1.69	2.3000*
3.391	11.43	0.420	3.67E-02	0.33232	0.11044	1.78	1.67	1.67	2.4000**
3.491	11.35	0.439	3.87E-02	0.33835	0.11448	1.80	1.68	1.70	2.5000
3.591	11.15	0.469	4.20E-02	0.34769	0.12089	1.84	1.71	1.74	2.6000
3.691	10.95	0.501	4.57E-02	0.35762	0.12789	1.88	1.75	1.77	2.7000
3.791	10.57	0.523	4.94E-02	0.36705	0.13472	1.85	1.72	1.74	2.8000
3.891	10.28	0.551	5.36E-02	0.37702	0.14214	1.85	1.72	1.74	2.9000
3.991	9.94	0.580	5.84E-02	0.38801	0.15055	1.84	1.70	1.72	3.0000
4.091	9.79	0.605	6.18E-02	0.39538	0.15632	1.84	1.71	1.73	3.1000
4.191	9.68	0.637	6.59E-02	0.40385	0.16309	1.88	1.74	1.76	3.2000
4.291	9.27	0.669	7.22E-02	0.41637	0.17337	1.85	1.70	1.72	3.3000
4.391	9.13	0.694	7.60E-02	0.42349	0.17935	1.85	1.70	1.73	3.4000
4.491	8.97	0.722	8.05E-02	0.43183	0.18647	1.85	1.70	1.73	3.5000
4.591	8.78	0.758	8.64E-02	0.44209	0.19544	1.86	1.71	1.74	3.6000
4.691	8.63	0.793	9.19E-02	0.45128	0.20365	1.87	1.72	1.75	3.7000
4.791	8.57	0.825	9.63E-02	0.45836	0.21010	1.90	1.74	1.78	3.8000
4.891	8.45	0.863	1.02E-01	0.46731	0.21838	1.92	1.76	1.80	3.9000
4.991	8.28	0.891	1.08E-01	0.47552	0.22612	1.91	1.74	1.79	4.0000
5.091	8.15	0.935	1.15E-01	0.48605	0.23625	1.93	1.77	1.81	4.1000
5.191	7.91	0.955	1.21E-01	0.49438	0.24441	1.88	1.72	1.76	4.2000

*Added data
**Second Run


a versus C^1/3 for Delta
y = 0.0881x + 0.0255
R^2 = 0.9973
C^1/3
a
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.00
2.00
4.00
6.00


Loga versus log C for slope n
y = 2.593x - 2.8349
R^2 = 0.9938
Log C
log a
-0.20
0.00
0.20
0.40
0.60
0.80
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00

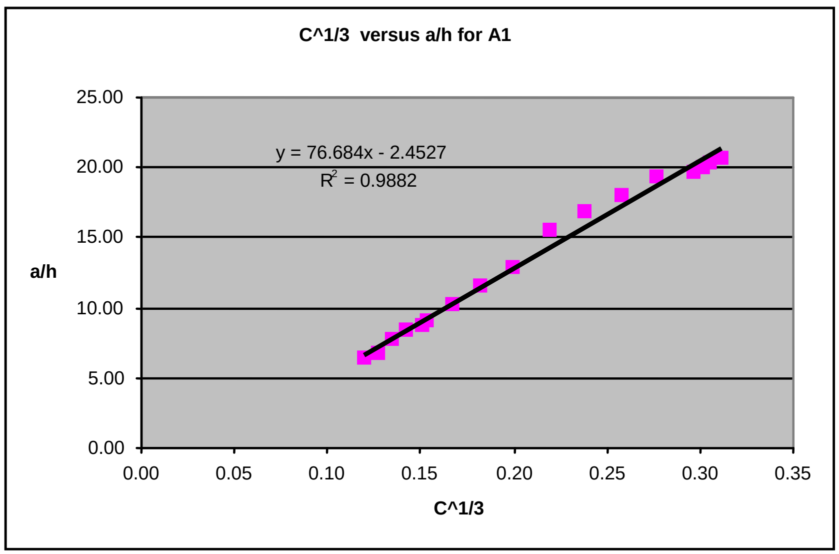

C^1/3 versus a/h for A1
y = 76.684x - 2.4527
R^2 = 0.9882
a/h
C^1/3
0.00
5.00
10.00
15.00
20.00
25.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

Table A-7. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S2)

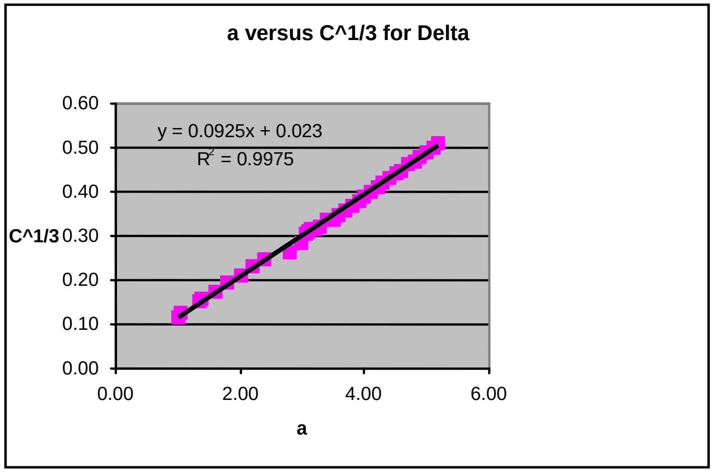
2h in.	*b* in.	Δ	*n*	A_1
0.152	1.090	0.2497	2.6510	71.072

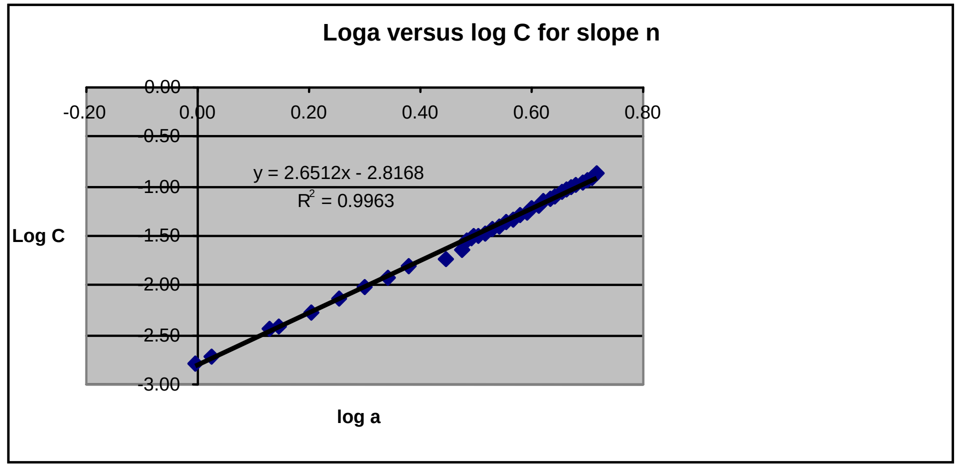
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
0.995	47.40	0.077	0.00163	0.11759	0.01383	4.04	4.46	3.97	*
0.995	47.65	0.077	1.61E-03	0.11727	0.01375	4.05	4.47	3.99	0.0000
1.062	41.91	0.080	1.91E-03	0.12399	0.01537	3.51	3.83	3.45	0.0670
1.345	25.31	0.092	3.64E-03	0.15381	0.02366	2.01	2.11	1.93	0.3500
1.395	25.89	0.101	3.92E-03	0.15766	0.02486	2.20	2.29	2.13	0.4000
1.595	23.09	0.123	5.31E-03	0.17443	0.03043	2.11	2.16	2.07	0.6000
1.795	21.20	0.153	7.22E-03	0.19332	0.03737	2.18	2.20	2.14	0.8000
1.995	18.85	0.181	9.58E-03	0.21236	0.04510	2.09	2.07	2.05	1.0000
2.195	17.19	0.208	1.21E-02	0.22968	0.05275	2.02	1.98	1.99	1.2000
2.395	15.72	0.242	1.54E-02	0.24872	0.06186	1.98	1.93	1.95	1.4000
2.595	14.17	0.264	1.86E-02	0.26515	0.07030	1.81	1.75	1.80	1.6000
2.795	12.96	0.298	2.30E-02	0.28433	0.08085	1.74	1.68	1.73	1.8000
2.995	11.86	0.333	2.81E-02	0.30407	0.09246	1.68	1.61	1.66	2.0000
3.045	11.68	0.342	2.93E-02	0.30818	0.09498	1.67	1.60	1.65	2.0500
3.095	11.37	0.353	3.11E-02	0.31433	0.09880	1.65	1.58	1.63	2.1000
3.145	11.36	0.355	3.13E-02	0.31513	0.09931	1.64	1.56	1.63	2.1500
3.195	11.23	0.373	3.32E-02	0.32152	0.10338	1.67	1.59	1.66	2.2000
3.295	10.71	0.401	3.74E-02	0.33457	0.11193	1.67	1.58	1.64	2.3000

* NL point

Table A-7. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S2) (Continued)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.152	1.090	0.2497	2.6510	71.072				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
3.395	10.59	0.413182	3.901E-02	0.33916	0.11503	1.65	1.57	1.65	2.4000
3.495	10.08	0.430503	4.273E-02	0.34960	0.12222	1.59	1.51	1.58	2.5000
3.595	9.82	0.455302	4.637E-02	0.35926	0.12907	1.60	1.51	1.59	2.6000
3.695	9.73	0.487044	5.007E-02	0.36858	0.13585	1.65	1.56	1.64	2.7000
3.795	9.39	0.512376	5.456E-02	0.37928	0.14385	1.64	1.54	1.62	2.8000
3.895	9.24	0.543661	5.883E-02	0.38891	0.15125	1.67	1.57	1.65	2.9000
3.995	8.92	0.571283	6.402E-02	0.40003	0.16003	1.65	1.55	1.63	3.0000
4.095	8.32	0.585322	7.038E-02	0.41287	0.17046	1.54	1.45	1.50	3.1000
4.195	8.23	0.621109	7.545E-02	0.42256	0.17856	1.58	1.48	1.54	3.2000
4.295	8.07	0.649646	8.050E-02	0.43179	0.18644	1.59	1.48	1.55	3.3000
4.395	7.84	0.678717	8.656E-02	0.44236	0.19568	1.58	1.47	1.54	3.4000
4.495	7.81	0.709391	9.080E-02	0.44946	0.20201	1.61	1.50	1.57	3.5000
4.595	7.48	0.739455	9.880E-02	0.46230	0.21372	1.57	1.46	1.53	3.6000
4.695	7.36	0.763567	1.038E-01	0.46990	0.22081	1.56	1.46	1.53	3.7000
4.795	7.17	0.796377	1.111E-01	0.48078	0.23115	1.56	1.45	1.52	3.8000
4.895	7.12	0.833079	1.169E-01	0.48901	0.23913	1.59	1.47	1.55	3.9000
4.995	6.96	0.870239	1.250E-01	0.50000	0.25000	1.59	1.47	1.55	4.0000
5.095	6.80	0.906788	1.334E-01	0.51090	0.26101	1.59	1.47	1.54	4.1000
5.195	6.73	0.929832	1.382E-01	0.51704	0.26733	1.58	1.46	1.54	4.2000


a versus C^1/3 for Delta
y = 0.0925x + 0.023
R² = 0.9975
C^1/3
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
2.00
4.00
6.00
a


Loga versus log C for slope n
y = 2.6512x - 2.8168
R² = 0.9963
Log C
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-0.20
0.00
0.20
0.40
0.60
0.80
log a

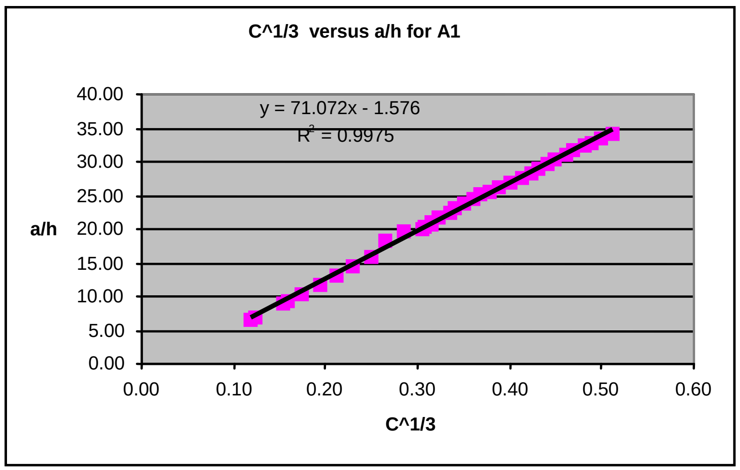

C^1/3 versus a/h for A1
y = 71.072x - 1.576
R² = 0.9975
a/h
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
C^1/3

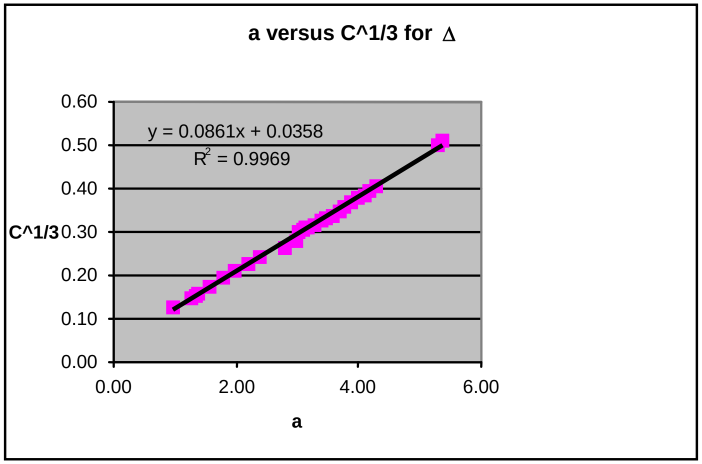
Table A-8. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S3)

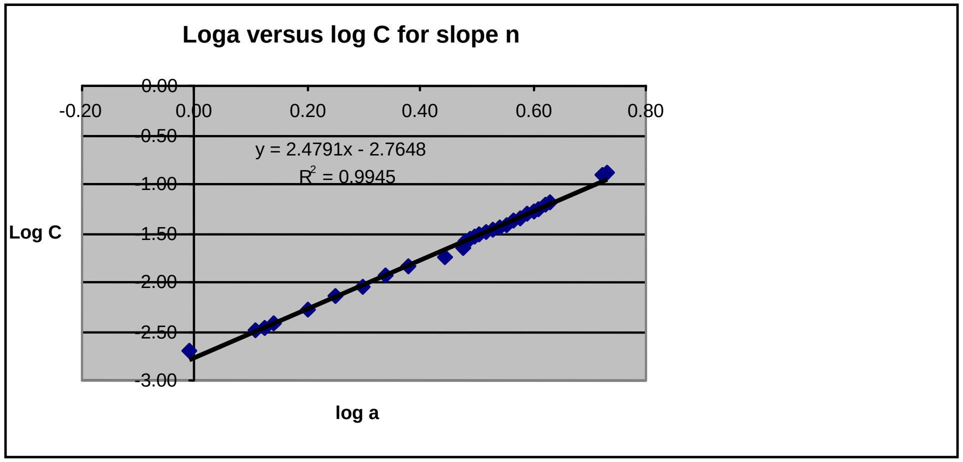
	2h in.	*b* in.	Δ	*n*	A_1				
	0.154	1.092	0.4158	2.4449	77.177				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
0.982	41.59	0.080	1.932E-03	0.12455	0.01551	3.28	3.81	3.10	*
0.982	46.76	0.095	2.033E-03	0.12669	0.01605	4.37	5.07	4.06	0.0000
1.282	31.70	0.101	3.187E-03	0.14716	0.02166	2.59	2.80	2.52	0.3000
1.332	29.91	0.104	3.485E-03	0.15161	0.02299	2.45	2.62	2.38	0.3500
1.382	29.17	0.113	3.867E-03	0.15696	0.02464	2.51	2.66	2.42	0.4000
1.582	23.94	0.129	5.382E-03	0.17525	0.03071	2.12	2.18	2.04	0.6000
1.782	21.59	0.155	7.162E-03	0.19276	0.03716	2.09	2.10	2.00	0.8000
1.982	19.56	0.177	9.064E-03	0.20850	0.04347	1.99	1.96	1.92	1.0000
2.182	17.42	0.201	1.152E-02	0.22585	0.05101	1.85	1.79	1.79	1.2000
2.382	16.39	0.233	1.419E-02	0.24211	0.05862	1.87	1.79	1.82	1.4000
2.582	14.59	0.261	1.786E-02	0.26138	0.06832	1.74	1.65	1.68	1.6000
2.782	13.36	0.296	2.212E-02	0.28070	0.07879	1.70	1.59	1.63	1.8000
2.982	12.49	0.336	2.686E-02	0.29950	0.08970	1.69	1.57	1.62	2.0000
3.032	12.37	0.347	2.802E-02	0.30374	0.09226	1.71	1.58	1.63	2.0500
3.082	12.01	0.351	2.921E-02	0.30798	0.09485	1.66	1.53	1.58	2.1000
3.132	11.78	0.360	3.056E-02	0.31266	0.09776	1.64	1.52	1.57	2.1500

* NL point

Table A-8. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S3) (Continued)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.154	1.092	0.4158	2.4449	77.177				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
3.182	11.77	0.378	3.210E-02	0.31780	0.10100	1.70	1.56	1.62	2.2000
3.282	11.60	0.397	3.426E-02	0.32480	0.10549	1.71	1.57	1.64	2.3000
3.382	11.19	0.403	3.598E-02	0.33012	0.10898	1.63	1.49	1.58	2.4000
3.482	10.80	0.420	3.890E-02	0.33883	0.11481	1.60	1.46	1.55	2.5000
3.582	10.42	0.435	4.177E-02	0.34696	0.12038	1.56	1.42	1.51	2.6000
3.682	10.01	0.457	4.570E-02	0.35752	0.12782	1.53	1.39	1.48	2.7000
3.782	9.68	0.477	4.926E-02	0.36658	0.13438	1.51	1.37	1.46	2.8000
3.882	9.57	0.512	5.354E-02	0.37689	0.14205	1.57	1.41	1.50	2.9000
3.982	9.55	0.538	5.639E-02	0.38346	0.14704	1.61	1.44	1.55	3.0000
4.082	9.26	0.564	6.087E-02	0.39337	0.15474	1.59	1.43	1.53	3.1000
4.182	8.93	0.590	6.612E-02	0.40438	0.16352	1.57	1.41	1.51	3.2000
4.282	8.71	0.634	7.280E-02	0.41755	0.17435	1.62	1.45	1.53	3.3000
5.182	7.11	0.902	1.268E-01	0.50245	0.25245	1.57	1.39	1.48	4.2000
5.282	6.92	0.918	1.327E-01	0.51010	0.26020	1.53	1.35	1.44	4.3000
5.382	6.87	0.959	1.396E-01	0.51875	0.26910	1.56	1.37	1.47	4.4000


a versus C^1/3 for Δ
y = 0.0861x + 0.0358
R^2 = 0.9969
C^1/3
a
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.00
2.00
4.00
6.00


Loga versus log C for slope n
y = 2.4791x - 2.7648
R^2 = 0.9945
Log C
log a
-0.20
0.00
0.20
0.40
0.60
0.80
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00

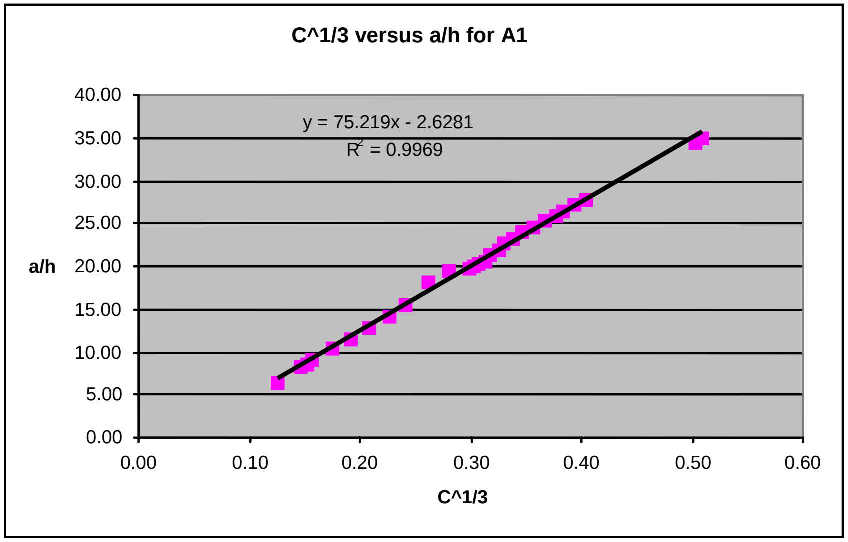

C^1/3 versus a/h for A1
y = 75.219x - 2.6281
R^2 = 0.9969
a/h
C^1/3
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60

Table A-9. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S4)

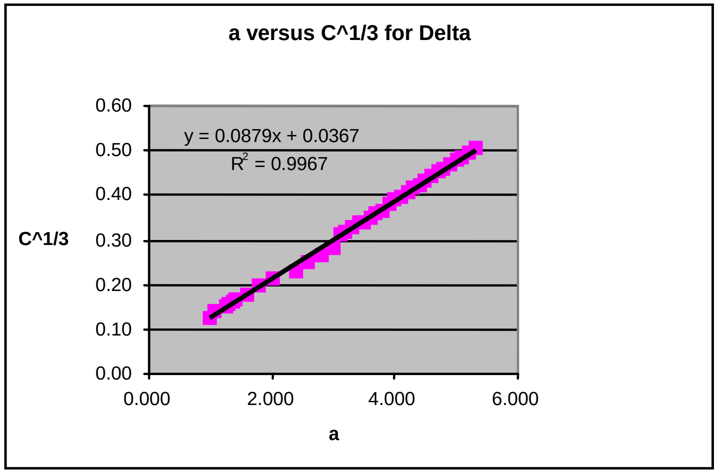
2h in.	*b* in.	Δ	*n*	A_1
0.155	1.095	0.4175	2.4805	73.186

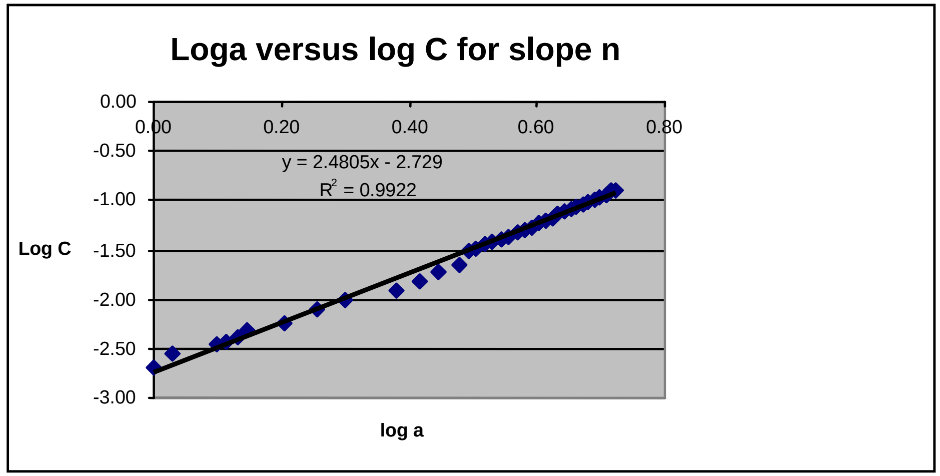
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
1.000	47.15	0.094	1.99E-03	0.12573	0.01581	4.269	5.004	4.243	*
1.000	47.70	0.096	2.01E-03	0.12612	0.01591	4.411	5.169	4.370	0.0000
1.067	34.56	0.097	2.80E-03	0.14102	0.01989	3.09	3.55	2.87	0.0670
1.250	29.47	0.102	3.45E-03	0.15113	0.02284	2.46	2.72	2.39	0.2500
1.300	28.72	0.108	3.77E-03	0.15560	0.02421	2.48	2.71	2.41	0.3000
1.350	27.17	0.112	4.11E-03	0.16013	0.02564	2.35	2.54	2.29	0.3500
1.400	25.60	0.122	4.75E-03	0.16808	0.02825	2.35	2.52	2.24	0.4000
1.600	25.24	0.145	5.73E-03	0.17898	0.03203	2.48	2.58	2.46	0.6000
1.800	22.71	0.177	7.80E-03	0.19832	0.03933	2.48	2.53	2.45	0.8000
2.000	21.57	0.209	9.68E-03	0.21311	0.04542	2.55	2.55	2.55	1.0000
2.200	19.05	0.235	1.24E-02	0.23122	0.05346	2.35	2.31	2.34	1.2000
2.400	17.75	0.271	1.53E-02	0.24814	0.06157	2.34	2.27	2.34	1.4000
2.600	16.40	0.305	1.86E-02	0.26508	0.07027	2.27	2.18	2.28	1.6000
2.800	15.12	0.339	2.24E-02	0.28187	0.07945	2.18	2.07	2.19	1.8000
3.000	13.88	0.375	2.70E-02	0.29994	0.08996	2.08	1.96	2.09	2.0000
3.050	12.99	0.408	3.14E-02	0.31543	0.09949	2.09	1.97	2.03	2.0500
3.100	11.77	0.378	3.21E-02	0.31780	0.10100	1.73	1.63	1.69	2.1000
3.200	12.172	0.435	3.58E-02	0.32945	0.10854	2.01	1.88	1.94	2.2000
3.300	11.442	0.438	3.83E-02	0.33698	0.11355	1.85	1.72	1.80	2.3000

* NL point

Table A-9. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S4) (Continued)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.155	1.095	0.4175	2.4805	73.186				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
3.400	11.44	0.453	3.96E-02	0.34079	0.11614	1.86	1.73	1.84	2.4000
3.500	11.08	0.479	4.33E-02	0.35103	0.12323	1.86	1.72	1.83	2.5000
3.600	10.87	0.511	4.70E-02	0.36087	0.13023	1.89	1.75	1.86	2.6000
3.700	10.55	0.523	4.96E-02	0.36732	0.13492	1.83	1.69	1.81	2.7000
3.800	10.27	0.558	5.43E-02	0.37877	0.14347	1.86	1.71	1.83	2.8000
3.900	9.80	0.577	5.89E-02	0.38906	0.15137	1.80	1.64	1.76	2.9000
4.000	9.46	0.593	6.27E-02	0.39725	0.15781	1.74	1.59	1.71	3.0000
4.100	9.34	0.626	6.70E-02	0.40615	0.16496	1.77	1.61	1.74	3.1000
4.200	8.97	0.643	7.16E-02	0.41530	0.17247	1.71	1.56	1.68	3.2000
4.300	8.99	0.683	7.60E-02	0.42358	0.17942	1.78	1.62	1.75	3.3000
4.400	8.75	0.716	8.18E-02	0.43410	0.18844	1.78	1.61	1.74	3.4000
4.500	8.54	0.750	8.78E-02	0.44450	0.19758	1.78	1.61	1.74	3.5000
4.600	8.34	0.771	9.24E-02	0.45217	0.20446	1.76	1.58	1.72	3.6000
4.700	8.09	0.793	9.80E-02	0.46109	0.21260	1.72	1.54	1.68	3.7000
4.800	8.09	0.836	1.03E-01	0.46939	0.22032	1.78	1.60	1.74	3.8000
4.900	7.88	0.862	1.09E-01	0.47812	0.22860	1.75	1.57	1.72	3.9000
5.000	7.91	0.918	1.16E-01	0.48778	0.23793	1.84	1.65	1.80	4.0000
5.100	7.71	0.950	1.23E-01	0.49758	0.24759	1.82	1.63	1.78	4.1000
5.200	7.68	0.994	1.29E-01	0.50578	0.25581	1.86	1.66	1.82	4.2000
5.300	7.55	1.028	1.36E-01	0.51456	0.26477	1.86	1.66	1.82	4.3000


a versus C^1/3 for Delta
y = 0.0879x + 0.0367
R² = 0.9967
C^1/3
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.000
2.000
4.000
6.000
a


Loga versus log C for slope n
y = 2.4805x - 2.729
R² = 0.9922
Log C
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
0.00
0.20
0.40
0.60
0.80
log a

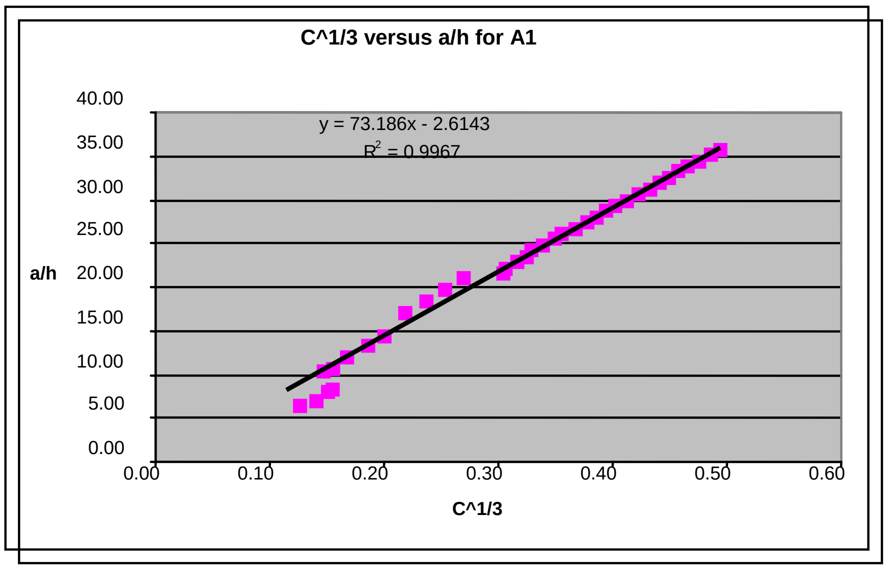
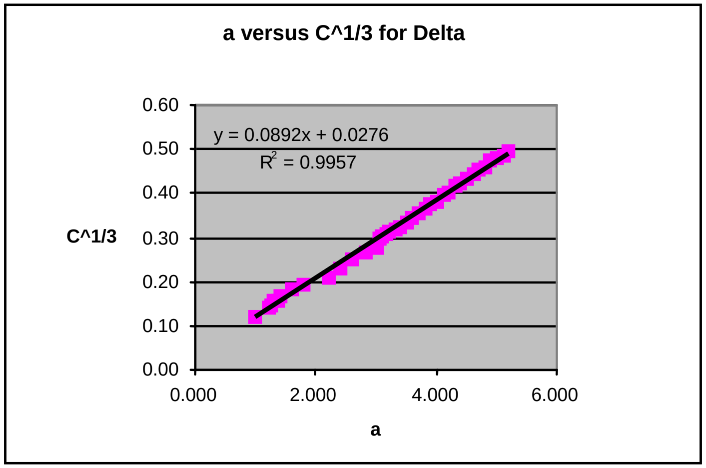

C^1/3 versus a/h for A1
y = 73.186x - 2.6143
R² = 0.9967
a/h
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
C^1/3

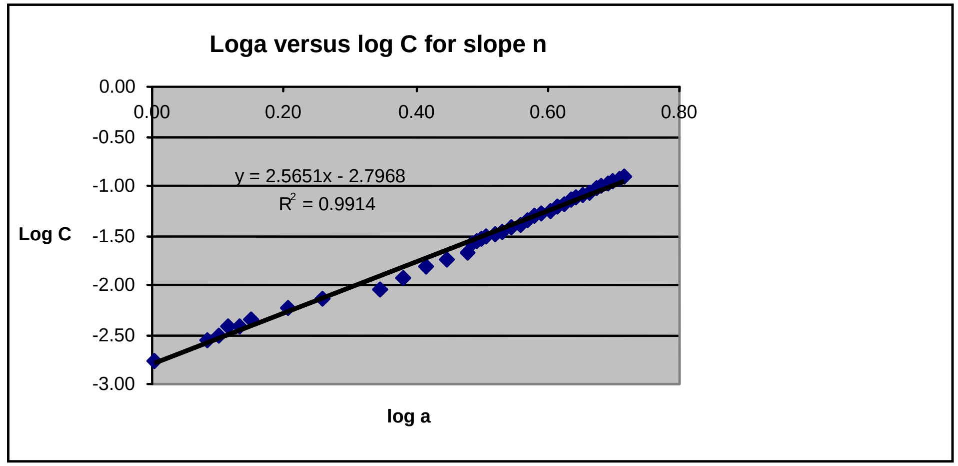
Table A-10. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S5)

	2h in.	*b* in.	Δ	*n*	A_1				
	0.153	1.089	0.3094	2.5650	72.970				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
1.009	50.47	0.086	1.71E-03	0.11958	0.01430	4.550	5.083	4.493	0.0000
1.209	31.11	0.088	2.83E-03	0.14146	0.02001	2.48	2.67	2.39	0.2000
1.259	30.19	0.092	3.04E-03	0.14479	0.02096	2.43	2.59	2.36	0.2500
1.309	25.95	0.097	3.73E-03	0.15502	0.02403	2.14	2.26	2.00	0.3000
1.359	25.78	0.099	3.85E-03	0.15673	0.02456	2.11	2.22	2.01	0.3500
1.409	24.29	0.111	4.56E-03	0.16588	0.02751	2.16	2.25	2.00	0.4000
1.609	23.30	0.137	5.87E-03	0.18035	0.03253	2.29	2.33	2.18	0.6000
1.809	22.11	0.164	7.44E-03	0.19520	0.03810	2.36	2.37	2.30	0.8000
2.009	20.92	0.192	9.19E-03	0.20946	0.04387	2.39	2.36	2.37	1.0000
2.209	18.74	0.219	1.17E-02	0.22704	0.05155	2.25	2.19	2.23	1.2000
2.409	16.94	0.258	1.52E-02	0.24793	0.06147	2.22	2.14	2.18	1.4000
2.609	15.89	0.292	1.84E-02	0.26378	0.06958	2.19	2.09	2.17	1.6000
2.809	14.90	0.323	2.17E-02	0.27889	0.07778	2.13	2.02	2.13	1.8000
3.009	13.82	0.363	2.63E-02	0.29721	0.08833	2.08	1.96	2.08	2.0000
3.059	13.64	0.382	2.80E-02	0.30369	0.09223	2.13	2.01	2.12	2.0500
3.109	13.24	0.388	2.93E-02	0.30836	0.09509	2.07	1.95	2.06	2.1000
3.159	12.93	0.395	3.05E-02	0.31256	0.09769	2.03	1.90	2.02	2.1500
3.209	12.78	0.411	3.22E-02	0.31811	0.10119	2.06	1.93	2.04	2.2000
3.309	12.30	0.423	3.44E-02	0.32530	0.10582	1.98	1.85	1.98	2.3000
3.409	12.10	0.459	3.79E-02	0.33595	0.11286	2.06	1.92	2.04	2.4000

Table A-10. Fracture Data Reduction for T800H Carbon/3900-2 Epoxy Composite Laminate (Specimen T800H-PN3S5) (Continued)

	2*h* in.	*b* in.	Δ	*n*	A_1				
	0.153	1.089	0.3094	2.5650	72.970				
a (in.)	P (lb)	Displacement (in.)	C = d/P (in./lb)	$C^{1/3}$	$C^{2/3}$	Energy Release Rate			
						G_MBT	G_CC	G_MCC	da
3.509	12.05	0.496	4.11E-02	0.34523	0.11919	2.16	2.01	2.14	2.5000
3.609	11.76	0.535	4.55E-02	0.35708	0.12750	2.21	2.05	2.18	2.6000
3.709	11.25	0.549	4.88E-02	0.36550	0.13359	2.12	1.96	2.08	2.7000
3.809	10.98	0.576	5.24E-02	0.37431	0.14011	2.11	1.95	2.08	2.8000
3.909	10.76	0.606	5.63E-02	0.38321	0.14685	2.13	1.96	2.10	2.9000
4.009	10.05	0.622	6.19E-02	0.39565	0.15654	1.99	1.84	1.95	3.0000
4.109	9.59	0.627	6.54E-02	0.40290	0.16233	1.88	1.72	1.84	3.1000
4.209	9.07	0.658	7.25E-02	0.41698	0.17387	1.82	1.67	1.77	3.2000
4.309	9.00	0.692	7.68E-02	0.42510	0.18071	1.86	1.70	1.81	3.3000
4.409	8.81	0.723	8.21E-02	0.43468	0.18895	1.86	1.70	1.81	3.4000
4.509	8.63	0.749	8.68E-02	0.44274	0.19602	1.85	1.69	1.80	3.5000
4.609	8.23	0.772	9.38E-02	0.45432	0.20641	1.78	1.62	1.73	3.6000
4.709	8.17	0.804	9.84E-02	0.46166	0.21313	1.80	1.64	1.75	3.7000
4.809	8.10	0.854	1.05E-01	0.47239	0.22315	1.86	1.69	1.80	3.8000
4.909	7.86	0.860	1.09E-01	0.47826	0.22873	1.78	1.62	1.74	3.9000
5.009	7.73	0.890	1.15E-01	0.48636	0.23655	1.78	1.62	1.75	4.0000
5.109	7.76	0.938	1.21E-01	0.49437	0.24440	1.85	1.68	1.82	4.1000
5.209	7.53	0.968	1.29E-01	0.50468	0.25470	1.82	1.65	1.78	4.2000


a versus C^1/3 for Delta
y = 0.0892x + 0.0276
R2 = 0.9957
C^1/3
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.000
2.000
4.000
6.000
a


Loga versus log C for slope n
y = 2.5651x - 2.7968
R2 = 0.9914
Log C
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
0.00
0.20
0.40
0.60
0.80
log a

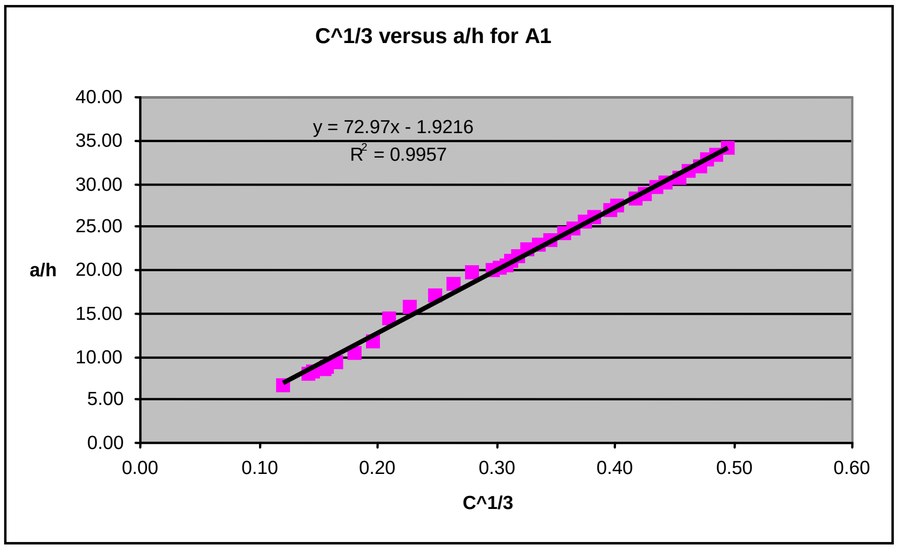

C^1/3 versus a/h for A1
y = 72.97x - 1.9216
R2 = 0.9957
a/h
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
C^1/3

Table A-11. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF6)

δ_{cr} = 0.14 Δ = 0.113

b = 1.495 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.464**

δ_{max}	f	a_i	a_f	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{ave}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
0.1500	0.799	1.609	1.735	0.126	0.271	17.68	15.06	1.232	2000	1.079	1.5454	1.3889	6.30E-05	0.705	3.475	0.400
0.1500	0.799	1.735	1.775	0.040	0.311	15.06	14.34	1.144	3000	1.079	1.2266	1.1852	1.33E-05	0.602	3.540	0.335
0.1500	0.799	1.775	1.787	0.012	0.323	14.34	13.89	1.100	5000	1.079	1.1433	1.1218	2.40E-06	0.569	3.559	0.315
0.1500	0.799	1.787	1.807	0.020	0.343	13.89	13.53	1.061	10000	1.079	1.1004	1.0806	2.00E-06	0.549	3.588	0.301
0.1500	0.799	1.807	1.83	0.023	0.366	13.53	12.73	0.986	20000	1.079	1.0607	1.0235	1.15E-06	0.520	3.621	0.283
0.1500	0.799	1.830	1.86	0.030	0.396	12.73	11.77	0.898	20000	1.079	0.9862	0.9422	1.50E-06	0.478	3.662	0.257
0.1500	0.799	1.860	2.003	0.143	0.539	11.77	10.37	0.741	20000	1.079	0.8979	0.8195	7.15E-06	0.416	3.830	0.214
0.1500	0.799	2.003	2.024	0.021	0.560	10.37	10.27	0.723	20000	1.079	0.7377	0.7306	1.05E-06	0.371	3.852	0.190
0.1500	0.799	2.024	2.052	0.028	0.588	10.27	10.14	0.705	20000	1.079	0.7234	0.7142	1.40E-06	0.363	3.881	0.184
0.2730	1.0	2.052	2.120	0.068	0.656	17.81	16.88	2.073	1000	1.964	2.2536	2.1632	6.80E-05	1.098	3.946	0.548
0.2730	1.0	2.120	2.143	0.023	0.679	16.88	16.5	2.004	1000	1.964	2.0709	2.0373	2.30E-05	1.034	3.967	0.514
0.2730	1.0	2.143	2.187	0.044	0.723	16.50	14.25	1.698	3000	1.964	2.0036	1.8508	1.47E-05	0.939	4.006	0.462
0.2730	1.0	2.187	2.332	0.145	0.868	14.25	12.36	1.390	5000	1.964	1.6973	1.5435	2.90E-05	0.784	4.124	0.374
0.2730	1.0	2.332	2.370	0.038	0.906	12.36	11.93	1.317	5000	1.964	1.3849	1.3507	7.60E-06	0.686	4.153	0.325
0.2730	1.0	2.370	2.390	0.020	0.926	11.93	11.53	1.262	5000	1.964	1.3162	1.2891	4.00E-06	0.654	4.167	0.309
0.2730	1.0	2.390	2.445	0.055	0.981	11.53	10.19	1.092	10000	1.964	1.2619	1.1769	5.50E-06	0.597	4.207	0.280
0.2730	1.0	2.445	2.647	0.202	1.183	10.19	9.26	0.924	10000	1.964	1.0913	1.0077	2.02E-05	0.512	4.340	0.232
0.2730	1.0	2.647	2.668	0.021	1.204	9.26	9.14	0.900	10000	1.964	0.9191	0.9098	2.10E-06	0.462	4.352	0.209
0.2730	1.0	2.668	2.668	0.000	1.204	9.14	9.12	0.898	10000	1.964	0.9004	0.8994	0.00E+00	0.457	4.352	0.207
0.2730	1.0	2.668	2.681	0.013	1.217	9.12	9.01	0.883	30000	1.964	0.8984	0.8909	4.33E-07	0.452	4.360	0.204
0.4792	0.5	3.233	3.233	0.000	1.769	8.74	8.76	1.259	100	3.448	1.2561	1.2575	0.00E+00	0.638	4.652	0.270
0.4792	0.5	3.233	3.237	0.004	1.773	8.76	8.79	1.262	400	3.448	1.2589	1.2603	1.00E-05	0.640	4.654	0.271
0.4792	0.5	3.237	3.239	0.002	1.775	8.79	8.73	1.252	500	3.448	1.2617	1.2571	4.00E-06	0.638	4.655	0.270
0.4792	0.5	3.239	3.242	0.003	1.778	8.73	8.75	1.254	1000	3.448	1.2524	1.2532	3.00E-06	0.636	4.656	0.269
0.4792	0.5	3.242	3.247	0.005	1.783	8.75	8.72	1.248	1000	3.448	1.2541	1.2510	5.00E-06	0.635	4.659	0.269
0.4792	0.5	3.247	3.253	0.006	1.789	8.72	8.69	1.241	2000	3.448	1.2480	1.2447	3.00E-06	0.632	4.661	0.267
0.4792	0.5	3.253	3.26	0.007	1.796	8.69	8.61	1.227	2000	3.448	1.2414	1.2345	3.50E-06	0.627	4.665	0.265
0.4792	0.5	3.26	3.268	0.008	1.804	8.61	8.55	1.216	3000	3.448	1.2275	1.2217	2.67E-06	0.620	4.668	0.262
0.4792	0.5	3.268	3.274	0.006	1.810	8.55	8.44	1.198	5000	3.448	1.2160	1.2071	1.20E-06	0.613	4.671	0.258

Table A-11. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF6) (Continued)

δ_{cr} = 0.14 Δ = 0.113

b = 1.495 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.464**

δ_{max}	f	ai	af	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{ave}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
0.4792	0.5	3.274	3.287	0.013	1.823	8.44	8.30	1.174	5000	3.448	1.1983	1.1861	2.60E-06	0.602	4.677	0.254
0.4792	0.5	3.287	3.309	0.022	1.845	8.30	8.02	1.127	5000	3.448	1.1739	1.1505	4.40E-06	0.584	4.687	0.245
0.4792	0.5	3.309	3.37	0.061	1.906	8.02	7.77	1.073	5000	3.448	1.1270	1.1000	1.22E-05	0.558	4.714	0.233
0.4792	0.5	3.37	3.446	0.076	1.982	7.77	7.48	1.011	5000	3.448	1.0727	1.0419	1.52E-05	0.529	4.748	0.219
0.4792	0.5	3.446	3.468	0.022	2.004	7.48	7.47	1.003	5000	3.448	1.0106	1.0069	4.40E-06	0.511	4.757	0.212
0.4792	0.5	3.468	3.491	0.023	2.027	7.47	7.37	0.983	5000	3.448	1.0031	0.9932	4.60E-06	0.504	4.767	0.208
0.4792	0.5	3.491	3.496	0.005	2.032	7.37	7.27	0.969	5000	3.448	0.9833	0.9760	1.00E-06	0.495	4.769	0.205
0.5100	1.2	2.681	2.686	0.005	1.222	16.77	16.57	3.030	20	3.670	3.0717	3.0507	2.50E-04	1.549	4.363	0.699
0.5100	1.2	2.686	2.691	0.005	1.227	16.57	16.39	2.991	20	3.670	3.0297	3.0105	2.50E-04	1.528	4.366	0.689
0.5100	1.2	2.691	2.693	0.002	1.229	16.39	16.25	2.964	20	3.670	2.9914	2.9776	1.00E-04	1.511	4.368	0.682
0.5100	1.2	2.693	2.696	0.003	1.232	16.25	16.05	2.924	40	3.670	2.9637	2.9439	7.50E-05	1.494	4.369	0.674
0.5100	1.2	2.696	2.701	0.005	1.237	16.05	15.86	2.884	50	3.670	2.9241	2.9043	1.00E-04	1.474	4.372	0.664
0.5100	1.2	2.701	2.709	0.008	1.245	15.86	15.65	2.838	50	3.670	2.8844	2.8613	1.60E-04	1.452	4.377	0.654
0.5100	1.2	2.709	2.716	0.007	1.252	15.65	15.30	2.768	50	3.670	2.8381	2.8030	1.40E-04	1.423	4.381	0.640
0.5100	1.2	2.716	2.718	0.002	1.254	15.30	14.87	2.688	50	3.670	2.7678	2.7280	4.00E-05	1.385	4.382	0.622
0.5100	1.2	2.718	2.728	0.010	1.264	14.87	14.08	2.536	100	3.670	2.6881	2.6122	1.00E-04	1.326	4.388	0.595
0.5100	1.2	2.728	2.851	0.123	1.387	14.08	13.48	2.332	100	3.670	2.5363	2.4339	1.23E-03	1.235	4.459	0.546
0.5100	1.2	2.851	2.881	0.030	1.417	13.48	13.14	2.246	100	3.670	2.3275	2.2869	3.00E-04	1.161	4.475	0.511
0.5100	1.2	2.881	2.883	0.002	1.419	13.14	12.99	2.219	100	3.670	2.2460	2.2325	2.00E-05	1.133	4.476	0.499
0.5100	1.2	2.883	2.897	0.014	1.433	12.99	12.85	2.185	100	3.670	2.2189	2.2019	1.40E-04	1.118	4.484	0.491
0.5100	1.2	2.897	2.903	0.006	1.439	12.85	12.76	2.165	100	3.670	2.1848	2.1750	6.00E-05	1.104	4.487	0.485
0.5100	1.2	2.903	2.912	0.009	1.448	12.76	12.65	2.140	100	3.670	2.1652	2.1527	9.00E-05	1.093	4.492	0.479
0.5100	1.2	2.912	2.921	0.009	1.457	12.65	12.53	2.114	200	3.670	2.1401	2.1268	4.50E-05	1.080	4.497	0.473
0.5100	1.2	2.921	2.934	0.013	1.470	12.53	12.42	2.086	200	3.670	2.1135	2.0998	6.50E-05	1.066	4.503	0.466
0.5100	1.2	2.934	2.945	0.011	1.481	12.42	12.34	2.065	200	3.670	2.0860	2.0756	5.50E-05	1.054	4.509	0.460
0.5100	1.2	2.945	2.966	0.021	1.502	12.34	12.2	2.028	200	3.670	2.0652	2.0465	1.05E-04	1.039	4.520	0.453
0.5100	1.2	2.966	2.972	0.006	1.508	12.2	12.11	2.009	200	3.670	2.0278	2.0184	3.00E-05	1.025	4.523	0.446
0.5100	1.2	2.972	2.982	0.010	1.518	12.11	12.07	1.996	200	3.670	2.0089	2.0024	5.00E-05	1.016	4.529	0.442
0.5100	1.2	2.982	2.986	0.004	1.522	12.07	11.96	1.975	200	3.670	1.9958	1.9855	2.00E-05	1.008	4.531	0.438

Table A-11. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF6) (Continued)

δ_{cr} = 0.14 Δ = 0.113

b = 1.495 G_{IC} = 1.97 Test Frequency = 5Hz a_o = 1.464

δ_{max}	f	ai	af	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{ave}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
0.5100	1.2	2.986	2.989	0.003	1.525	11.96	11.87	1.958	200	3.670	1.9751	1.9667	1.50E-05	0.998	4.532	0.434
0.5100	1.2	2.989	2.994	0.005	1.530	11.87	11.74	1.934	200	3.670	1.9583	1.9460	2.50E-05	0.988	4.535	0.429
0.5100	1.2	2.994	3.005	0.011	1.541	11.74	11.63	1.909	200	3.670	1.9338	1.9213	5.50E-05	0.975	4.541	0.423
0.5100	1.2	3.005	3.018	0.013	1.554	11.63	11.32	1.850	500	3.670	1.9089	1.8796	2.60E-05	0.954	4.547	0.413
0.5100	1.2	3.018	3.035	0.017	1.571	11.32	10.64	1.730	500	3.670	1.8503	1.7900	3.40E-05	0.909	4.556	0.393
0.5100	1.2	3.035	3.148	0.113	1.684	10.64	10.12	1.590	500	3.670	1.7297	1.6599	2.26E-04	0.843	4.612	0.360
0.5100	1.2	3.148	3.175	0.027	1.711	10.12	9.93	1.546	500	3.670	1.5882	1.5669	5.40E-05	0.795	4.625	0.339
0.5100	1.2	3.175	3.188	0.013	1.724	9.93	9.78	1.516	500	3.670	1.5456	1.5309	2.60E-05	0.777	4.631	0.331
0.5100	1.2	3.188	3.195	0.007	1.731	9.78	9.7	1.501	500	3.670	1.5162	1.5085	1.40E-05	0.766	4.634	0.326
0.5100	1.2	3.195	3.197	0.002	1.733	9.7	9.62	1.487	500	3.670	1.5007	1.4940	4.00E-06	0.758	4.635	0.322
0.5100	1.2	3.199	3.200	0.003	1.736	9.62	9.55	1.475	500	3.670	1.4874	1.4813	6.00E-06	0.752	4.637	0.319
0.5100	1.2	3.200	3.213	0.013	1.749	9.55	9.46	1.456	1000	3.670	1.4752	1.4654	1.30E-05	0.744	4.643	0.316
0.5100	1.2	3.213	3.230	0.017	1.766	9.46	9.39	1.438	1000	3.670	1.4556	1.4466	1.70E-05	0.734	4.651	0.311
0.5100	1.2	3.230	3.233	0.003	1.769	9.39	9.33	1.427	1000	3.670	1.4375	1.4323	3.00E-06	0.727	4.652	0.308
0.9706	1.5	3.496	3.550	0.054	2.086	13.98	13.98	3.718	1	6.984	3.7728	3.7454	5.40E-02	1.901	4.792	0.782
0.9706	1.5	3.550	3.550	0.000	2.086	13.98	13.49	3.587	4	6.984	3.7172	3.6521	0.00E+00	1.854	4.792	0.762
0.9706	1.5	3.550	3.715	0.165	2.251	13.49	11.94	3.044	9	6.984	3.5869	3.3153	1.83E-02	1.683	4.859	0.682
0.9706	1.5	3.715	3.747	0.032	2.283	11.94	11.76	2.968	10	6.984	3.0379	3.0027	3.20E-03	1.524	4.871	0.616
0.9706	1.5	3.747	3.756	0.009	2.292	11.76	11.63	2.928	10	6.984	2.9673	2.9475	9.00E-04	1.496	4.875	0.605
0.9706	1.5	3.756	3.768	0.012	2.304	11.63	11.54	2.896	10	6.984	2.9277	2.9119	1.20E-03	1.478	4.880	0.597
0.9706	1.5	3.768	3.789	0.021	2.325	11.54	11.45	2.858	10	6.984	2.8961	2.8771	2.10E-03	1.460	4.888	0.589
0.9706	1.5	3.789	3.794	0.005	2.330	11.45	11.39	2.839	10	6.984	2.8580	2.8487	5.00E-04	1.446	4.890	0.583
0.9706	1.5	3.794	3.794	0.000	2.330	11.39	11.35	2.829	10	6.984	2.8394	2.8344	0.00E+00	1.439	4.890	0.580
0.9706	1.5	3.794	3.795	0.001	2.331	11.35	11.31	2.819	20	6.984	2.8294	2.8241	5.00E-05	1.434	4.890	0.578
0.9706	1.5	3.795	3.797	0.002	2.333	11.31	11.29	2.812	10	6.984	2.8187	2.8155	2.00E-04	1.429	4.891	0.576
0.9706	1.5	3.797	3.805	0.008	2.341	11.29	11.26	2.799	10	6.984	2.8123	2.8057	8.00E-04	1.424	4.894	0.573
0.9706	1.5	3.805	3.826	0.021	2.362	11.26	11.17	2.762	50	6.984	2.7991	2.7806	4.20E-04	1.411	4.902	0.567
0.9706	1.5	3.826	3.832	0.006	2.368	11.17	11.08	2.736	50	6.984	2.7619	2.7487	1.20E-04	1.395	4.904	0.560
0.9706	1.5	3.832	3.844	0.012	2.380	11.08	11.01	2.710	50	6.984	2.7355	2.7228	2.40E-04	1.382	4.909	0.555

Table A-11. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF6) (Continued)

δ_{cr} = 0.14 Δ = 0.113

b = 1.495 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.464**

δ_{max}	f	ai	af	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{ave}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
0.9706	1.5	3.844	3.849	0.005	2.385	11.01	10.94	2.689	50	6.984	2.7100	2.6997	1.00E-04	1.370	4.911	0.550
0.9706	1.5	3.849	3.849	0.000	2.385	10.94	10.84	2.665	100	6.984	2.6894	2.6771	0.00E+00	1.359	4.911	0.545
0.9706	1.5	3.849	3.864	0.015	2.400	10.84	10.72	2.625	200	6.984	2.6648	2.6451	7.50E-05	1.343	4.916	0.538
0.9706	1.5	3.864	4.057	0.193	2.593	10.72	9.56	2.238	500	6.984	2.6253	2.4315	3.86E-04	1.234	4.987	0.488
0.9706	1.5	4.057	4.088	0.031	2.624	9.56	9.23	2.140	500	6.984	2.2329	2.1865	6.20E-05	1.110	4.998	0.437
0.9706	1.5	4.088	4.107	0.019	2.643	9.23	9.09	2.098	500	6.984	2.1399	2.1190	3.80E-05	1.076	5.005	0.423
0.9706	1.5	4.107	4.124	0.017	2.660	9.09	9	2.069	500	6.984	2.0980	2.0834	3.40E-05	1.058	5.011	0.416
0.9706	1.5	4.124	4.131	0.007	2.667	9.00	8.93	2.049	500	6.984	2.0689	2.0591	1.40E-05	1.045	5.014	0.411
1.4000	1.6	4.131	4.405	0.274	2.941	10.93	10.93	3.411	1	10.074	3.6181	3.5146	2.74E-01	1.784	5.107	0.688
1.4000	1.6	4.405	4.414	0.009	2.950	10.93	10.81	3.355	4	10.074	3.3987	3.3767	2.25E-03	1.714	5.110	0.661
1.4000	1.6	4.414	4.425	0.011	2.961	10.81	10.61	3.285	5	10.074	3.3547	3.3197	2.20E-03	1.685	5.113	0.649
1.4000	1.6	4.425	4.585	0.160	3.121	10.61	9.74	2.916	10	10.074	3.2846	3.1003	1.60E-02	1.574	5.165	0.600
1.4000	1.6	4.585	4.612	0.027	3.148	9.74	9.60	2.854	10	10.074	2.9126	2.8835	2.70E-03	1.464	5.173	0.557
1.4000	1.6	4.612	4.626	0.014	3.162	9.60	9.49	2.813	10	10.074	2.8543	2.8338	1.40E-03	1.438	5.178	0.547
1.4000	1.6	4.626	4.649	0.023	3.185	9.49	9.36	2.761	10	10.074	2.8133	2.7873	2.30E-03	1.415	5.185	0.538
1.8800	1.8	4.649	4.734	0.085	3.270	12.23	12.23	4.762	1	13.528	4.8451	4.8033	8.50E-02	2.438	5.211	0.922
1.8800	1.8	4.734	4.744	0.010	3.280	12.23	12.15	4.719	4	13.528	4.7601	4.7397	2.50E-03	2.406	5.214	0.909
1.8800	1.8	4.744	4.753	0.009	3.289	12.15	12.06	4.676	5	13.528	4.7192	4.6974	1.80E-03	2.384	5.217	0.900
1.8800	1.8	4.753	4.984	0.231	3.520	12.06	10.29	3.816	10	13.528	4.6756	4.2460	2.31E-02	2.155	5.285	0.803

Table A-12. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF7)

δcr = 0.13897 Δ = 0.11302

b = 1.49 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.441**

N	δ_{max}	f	a_i	a_f	da, in.	da,Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
1	0.2600	1.5	1.781	1.825	0.044	0.384	22.64	22.64	3.059	1	1.871	3.1287	3.0940	4.40E-02	1.571	3.646	0.849
20	0.2600	1.5	1.825	1.834	0.009	0.393	21.95	21.95	2.951	19	1.871	2.9645	2.9577	4.74E-04	1.501	3.658	0.809
40	0.2600	1.5	1.834	1.861	0.027	0.42	21.49	21.49	2.850	20	1.871	2.8890	2.8695	1.35E-03	1.457	3.692	0.777
60	0.2600	1.5	1.861	1.872	0.011	0.431	21.26	21.26	2.803	20	1.871	2.8190	2.8112	5.50E-04	1.427	3.706	0.759
80	0.2600	1.5	1.872	1.877	0.005	0.436	21.01	21.01	2.763	20	1.871	2.7704	2.7669	2.50E-04	1.405	3.712	0.745
100	0.2600	1.5	1.877	1.882	0.005	0.441	20.86	20.86	2.737	20	1.871	2.7437	2.7403	2.50E-04	1.391	3.719	0.737
150	0.2600	1.5	1.882	1.895	0.013	0.454	20.55	20.55	2.679	50	1.871	2.6961	2.6875	2.60E-04	1.364	3.734	0.720
200	0.2600	1.5	1.895	1.902	0.007	0.461	20.29	20.29	2.636	50	1.871	2.6448	2.6402	1.40E-04	1.340	3.743	0.705
250	0.2600	1.5	1.902	1.910	0.008	0.469	20.09	20.09	2.599	50	1.871	2.6096	2.6045	1.60E-04	1.322	3.752	0.694
300	0.2600	1.5	1.910	1.913	0.003	0.472	19.88	19.88	2.568	50	1.871	2.5721	2.5702	6.00E-05	1.305	3.755	0.684
400	0.2600	1.5	1.913	1.939	0.026	0.498	19.56	19.56	2.495	100	1.871	2.5270	2.5112	2.60E-04	1.275	3.785	0.663
500	0.2600	1.5	1.939	1.968	0.021	0.527	19.19	19.19	2.423	100	1.871	2.4478	2.4355	2.10E-04	1.236	3.817	0.638
600	0.2600	1.5	1.968	1.992	0.024	0.551	18.94	18.94	2.355	100	1.871	2.3822	2.3688	2.40E-04	1.202	3.843	0.616
700	0.2600	1.5	1.992	2.004	0.012	0.563	18.48	18.48	2.285	100	1.871	2.2979	2.2914	1.20E-04	1.163	3.855	0.594
800	0.2600	1.5	2.004	2.014	0.010	0.573	18.14	18.14	2.232	100	1.871	2.2428	2.2376	1.00E-04	1.136	3.865	0.579
900	0.2600	1.5	2.014	2.022	0.008	0.581	17.82	17.82	2.185	100	1.871	2.1929	2.1888	8.00E-05	1.111	3.873	0.565
1000	0.2600	1.5	2.022	2.045	0.023	0.604	17.52	17.52	2.125	100	1.871	2.1479	2.1366	2.30E-04	1.085	3.896	0.548
1200	0.2600	1.5	2.045	2.054	0.009	0.613	17.07	17.07	2.062	200	1.871	2.0704	2.0661	4.50E-05	1.049	3.905	0.529
1400	0.2600	1.5	2.054	2.08	0.026	0.639	16.68	16.68	1.991	200	1.871	2.0147	2.0029	1.30E-04	1.017	3.930	0.510
1600	0.2600	1.5	2.08	2.099	0.019	0.658	16.37	16.37	1.937	200	1.871	1.9538	1.9455	9.50E-05	0.988	3.948	0.493
1800	0.2600	1.5	2.099	2.114	0.015	0.673	16.06	16.06	1.888	200	1.871	1.9004	1.8940	7.50E-05	0.961	3.962	0.478
2000	0.2600	1.5	2.114	2.119	0.005	0.678	15.83	15.83	1.856	200	1.871	1.8605	1.8584	2.50E-05	0.943	3.966	0.469
2200	0.2600	1.5	2.119	2.125	0.006	0.684	15.61	15.61	1.826	200	1.871	1.8306	1.8281	3.00E-05	0.928	3.972	0.460
2400	0.2600	1.5	2.125	2.131	0.006	0.69	15.43	15.43	1.800	200	1.871	1.8046	1.8022	3.00E-05	0.915	3.977	0.453
2600	0.2600	1.5	2.131	2.141	0.010	0.7	15.29	15.29	1.776	200	1.871	1.7834	1.7795	5.00E-05	0.903	3.986	0.446
2800	0.2600	1.5	2.141	2.148	0.007	0.707	15.13	15.13	1.752	200	1.871	1.7570	1.7542	3.50E-05	0.890	3.992	0.439
3000	0.2600	1.5	2.148	2.152	0.004	0.711	15.02	15.02	1.736	200	1.871	1.7388	1.7372	2.00E-05	0.882	3.996	0.435
3500	0.2600	1.5	2.152	2.157	0.005	0.716	14.78	14.78	1.704	500	1.871	1.7080	1.7061	1.00E-05	0.866	4.000	0.427
4000	0.2600	1.5	2.157	2.163	0.006	0.722	14.58	14.58	1.677	500	1.871	1.6811	1.6789	1.20E-05	0.852	4.005	0.419
4500	0.2600	1.5	2.163	2.175	0.012	0.734	14.44	14.44	1.652	500	1.871	1.6606	1.6563	2.40E-05	0.841	4.016	0.412
5000	0.2600	1.5	2.175	2.178	0.003	0.737	14.25	14.25	1.628	500	1.871	1.6302	1.6291	6.00E-06	0.827	4.018	0.405
6000	0.2600	1.5	2.178	2.186	0.008	0.745	13.88	13.88	1.580	1000	1.871	1.5858	1.5830	8.00E-06	0.804	4.025	0.393
7000	0.2600	1.5	2.186	2.199	0.013	0.758	13.52	13.52	1.531	1000	1.871	1.5393	1.5350	1.30E-05	0.779	4.036	0.380
8000	0.2600	1.5	2.199	2.225	0.026	0.784	13.26	13.26	1.485	1000	1.871	1.5012	1.4929	2.60E-05	0.758	4.058	0.368

Table A-12. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF7) (Continued)

δcr = 0.13897 Δ = 0.11302

b = 1.49 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.441**

N	δ_{max}	f	a_i	a_f	da, in.	da,Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
9000	0.2600	1.5	2.225	2.232	0.007	0.791	13.09	13.09	1.461	1000	1.871	1.4654	1.4633	7.00E-06	0.743	4.063	0.360
10000	0.2600	1.5	2.232	2.233	0.001	0.792	12.89	12.89	1.438	1000	1.871	1.4387	1.4384	1.00E-06	0.730	4.064	0.354
5000	0.2600	0.7	2.635	2.647	0.012	1.206	8.36	8.36	0.793	5000	1.871	0.7963	0.7946	2.40E-06	0.403	4.354	0.183
10000	0.2600	0.7	2.647	2.647	0.000	1.206	8.40	8.41	0.798	5000	1.871	0.7966	0.7971	0.00E+00	0.405	4.354	0.183
15000	0.2600	0.7	2.647	2.650	0.003	1.209	8.41	8.41	0.797	10000	1.871	0.7976	0.7971	3.00E-07	0.405	4.355	0.183
20000	0.2600	0.7	2.650	2.659	0.009	1.218	8.41	8.40	0.793	5000	1.871	0.7967	0.7949	1.80E-06	0.404	4.361	0.182
30000	0.2600	0.7	2.659	2.662	0.003	1.221	8.40	8.41	0.793	10,000	1.871	0.7932	0.7932	3.00E-07	0.403	4.363	0.182
40000	0.2600	0.7	2.662	2.665	0.003	1.224	8.41	8.34	0.786	10,000	1.871	0.7932	0.7895	3.00E-07	0.401	4.365	0.181
60000	0.2600	0.7	2.665	2.681	0.016	1.24	8.34	8.16	0.764	20,000	1.871	0.7858	0.7751	8.00E-07	0.393	4.374	0.177
80000	0.2600	0.7	2.681	2.683	0.002	1.242	8.16	8.11	0.759	20,000	1.871	0.7644	0.7618	1.00E-07	0.387	4.375	0.174
1E+05	0.2600	0.7	2.683	2.710	0.027	1.269	8.11	8.03	0.745	20,000	1.871	0.7592	0.7519	1.35E-06	0.382	4.391	0.171
1E+05	0.2600	0.7	2.710	2.721	0.011	1.28	8.03	7.97	0.736	20,000	1.871	0.7445	0.7403	5.50E-07	0.376	4.398	0.168
1E+05	0.2600	0.7	2.721	2.728	0.007	1.287	7.97	8.00	0.737	20,000	1.871	0.7361	0.7366	3.50E-07	0.374	4.402	0.167
2E+05	0.2600	0.7	2.728	2.730	0.002	1.289	8.34	7.96	0.733	20,000	1.871	0.7684	0.7506	1.00E-07	0.381	4.403	0.170
2E+05	0.2600	0.7	2.730	2.743	0.013	1.302	7.96	7.86	0.720	40,000	1.871	0.7328	0.7266	3.25E-07	0.369	4.411	0.165
2E+05	0.2600	0.7	2.743	2.753	0.010	1.312	7.86	7.76	0.709	40,000	1.871	0.7203	0.7145	2.500E-07	0.363	4.416	0.162
1	0.4477	1.8	2.233	2.363	0.130	0.922	19.64	19.64	3.585	1	3.222	3.7731	3.6790	1.30E-01	1.868	4.164	0.883
20	0.4477	1.8	2.363	2.409	0.046	0.968	18.73	18.73	3.348	19	3.222	3.4094	3.3788	2.42E-03	1.715	4.198	0.805
40	0.4477	1.8	2.409	2.435	0.026	0.994	18.28	18.28	3.234	20	3.222	3.2668	3.2503	1.30E-03	1.650	4.216	0.771
60	0.4477	1.8	2.435	2.442	0.007	1.001	18.04	18.04	3.182	20	3.222	3.1910	3.1866	3.50E-04	1.618	4.221	0.755
80	0.4477	1.8	2.442	2.457	0.015	1.016	17.76	17.76	3.115	20	3.222	3.1329	3.1238	7.50E-04	1.586	4.231	0.738
100	0.4477	1.8	2.457	2.458	0.001	1.017	17.6	17.6	3.085	20	3.222	3.0865	3.0859	5.00E-05	1.566	4.232	0.729
150	0.4477	1.8	2.458	2.481	0.023	1.04	17.24	17.24	2.996	50	3.222	3.0222	3.0089	4.60E-04	1.527	4.247	0.708
200	0.4477	1.8	2.481	2.519	0.038	1.078	16.83	16.83	2.883	50	3.222	2.9242	2.9034	7.60E-04	1.474	4.273	0.680
250	0.4477	1.8	2.519	2.552	0.033	1.111	16.57	16.57	2.803	50	3.222	2.8374	2.8201	6.60E-04	1.432	4.294	0.657
300	0.4477	1.8	2.552	2.563	0.011	1.122	16.4	16.4	2.762	50	3.222	2.7735	2.7679	2.20E-04	1.405	4.301	0.644
400	0.4477	1.8	2.563	2.583	0.020	1.142	16.01	16.01	2.677	100	3.222	2.6965	2.6865	2.00E-04	1.364	4.314	0.623
500	0.4477	1.8	2.583	2.592	0.009	1.151	15.7	15.7	2.616	100	3.222	2.6246	2.6203	9.00E-05	1.330	4.320	0.607
600	0.4477	1.8	2.592	2.610	0.018	1.169	15.44	15.44	2.556	100	3.222	2.5726	2.5641	1.80E-04	1.302	4.331	0.592
700	0.4477	1.8	2.61	2.621	0.011	1.18	15.23	15.23	2.511	100	3.222	2.5208	2.5158	1.10E-04	1.277	4.338	0.580
800	0.4477	1.8	2.621	2.622	0.001	1.181	15.02	15.02	2.475	100	3.222	2.4761	2.4756	1.00E-05	1.257	4.338	0.571
900	0.4477	1.8	2.622	2.622	0.000	1.181	14.83	14.83	2.444	100	3.222	2.4438	2.4438	0.00E+00	1.241	4.338	0.563
1000	0.4477	1.8	2.622	2.635	0.013	1.194	14.66	14.66	2.404	200	3.222	2.4158	2.4101	6.50E-05	1.223	4.346	0.555

Table A-12. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF7) (Continued)

δcr = 0.13897 Δ = 0.11302

b = 1.49 **G_{IC} = 1.97** Test Frequency = 5Hz **a_o = 1.441**

N	δ_{max}	f	a_i	a_f	da, in.	da,Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
1	0.6002	1.4	2.753	2.816	0.063	1.375	15.87	15.87	3.275	1	4.319	3.3458	3.3106	6.30E-02	1.680	4.452	0.744
5	0.6002	1.4	2.816	2.838	0.022	1.397	15.72	15.72	3.219	4	4.319	3.2429	3.2309	5.50E-03	1.640	4.464	0.724
1	0.6818	1.6	2.838	2.953	0.115	1.512	15.54	15.54	3.484	1	4.906	3.6144	3.5491	1.15E-01	1.802	4.526	0.784
5	0.6818	1.6	2.953	2.959	0.006	1.518	15.50	15.50	3.463	4	4.906	3.4699	3.4665	1.50E-03	1.760	4.529	0.765
1	0.7862	1.8	2.959	3.129	0.170	1.688	16.36	16.36	4.005	1	5.657	4.2150	4.1100	1.70E-01	2.086	4.614	0.891
5	0.7862	1.8	3.129	3.161	0.032	1.72	16.09	16.09	3.890	4	5.657	3.9281	3.9091	8.00E-03	1.984	4.629	0.844
1	0.9457	2.0	3.161	3.547	0.386	2.106	13.03	13.03	3.427	1	6.805	3.7890	3.6082	3.86E-01	1.832	4.800	0.752
5	0.9457	2.0	3.547	3.568	0.021	2.127	12.85	12.85	3.324	4	6.805	3.3426	3.3331	5.25E-03	1.692	4.809	0.693
1	1.2637	2.0	3.568	4.247	0.679	2.806	11.34	11.34	3.391	1	9.093	3.9192	3.6551	6.79E-01	1.855	5.062	0.722
5	1.2637	2.0	4.247	4.337	0.090	2.896	11.19	11.19	3.200	4	9.093	3.2651	3.2327	2.25E-02	1.641	5.092	0.635

Table A-13. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF8)

δ_{max} = **δ_{cr} = 0.139** Δ =0.11

b = 1.491 **G_{IC} = 1.97** Test Frequency = 5Hz a_o = 1.468

N	δ_{max}	f	a_i	a_f	da, in.	da, Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
1	0.2270	0.8	1.984	2.009	0.025	0.541	19.16	19.16	2.062	1	1.633	2.0866	2.0744	2.50E-02	1.053	3.832	0.541
10	0.2270	0.8	2.009	2.011	0.002	0.543	19.16	18.87	2.029	9	1.633	2.0620	2.0454	2.22E-04	1.038	3.834	0.533
50	0.2270	0.8	2.011	2.014	0.003	0.546	18.87	18.4	1.976	40	1.633	2.0289	2.0022	7.50E-05	1.016	3.837	0.522
100	0.2270	0.8	2.014	2.019	0.005	0.551	18.4	17.98	1.926	50	1.633	1.9755	1.9507	1.00E-04	0.990	3.843	0.508
200	0.2270	0.8	2.019	2.055	0.036	0.587	17.98	17.3	1.823	100	1.633	1.9259	1.8744	3.60E-04	0.951	3.880	0.483
500	0.2270	0.8	2.055	2.064	0.009	0.596	17.30	16.58	1.739	300	1.633	1.8223	1.7808	3.00E-05	0.904	3.888	0.458
1000	0.2270	0.8	2.064	2.064	0	0.596	16.58	16.01	1.679	500	1.633	1.7392	1.7094	0.00E+00	0.868	3.888	0.440
2000	0.2270	0.8	2.064	2.100	0.036	0.632	16.01	15.22	1.571	1500	1.633	1.6795	1.6252	2.40E-05	0.825	3.923	0.414
3000	0.2270	0.8	2.100	2.131	0.031	0.663	15.22	14.52	1.478	1000	1.633	1.5706	1.5243	3.10E-05	0.774	3.952	0.386
4000	0.2270	0.8	2.131	2.159	0.028	0.691	14.52	14.07	1.414	1000	1.633	1.4777	1.4461	2.80E-05	0.734	3.978	0.364
5000	0.2270	0.8	2.159	2.166	0.007	0.698	14.07	13.77	1.380	1000	1.633	1.4142	1.3970	7.00E-06	0.709	3.984	0.351
6000	0.2270	0.8	2.166	2.191	0.025	0.723	13.77	13.58	1.346	1000	1.633	1.3798	1.3630	2.50E-05	0.692	4.006	0.340
7000	0.2270	0.8	2.191	2.213	0.022	0.745	13.58	13.39	1.315	1000	1.633	1.3460	1.3304	2.20E-05	0.675	4.025	0.331
8000	0.2270	0.8	2.213	2.224	0.011	0.756	13.39	13.2	1.290	1000	1.633	1.3146	1.3023	1.10E-05	0.661	4.034	0.323
100	0.1450	0.6	1.704	1.743	0.039	0.275	16.9	16.69	1.312	100	1.043	1.3568	1.3346	3.90E-04	0.677	3.482	0.383
200	0.1450	0.6	1.743	1.743	0.000	0.275	16.69	16.64	1.308	100	1.043	1.3118	1.3098	0.00E+00	0.665	3.482	0.376
500	0.1450	0.6	1.743	1.762	0.019	0.294	16.64	16.37	1.274	400	1.043	1.3078	1.2908	4.75E-05	0.655	3.513	0.367
1000	0.1450	0.6	1.762	1.779	0.017	0.311	16.37	16.01	1.234	500	1.043	1.2736	1.2540	3.40E-05	0.637	3.540	0.354
2000	0.1450	0.6	1.779	1.796	0.017	0.328	16.01	15.55	1.188	1000	1.043	1.2344	1.2114	1.70E-05	0.615	3.566	0.340
3000	0.1450	0.6	1.796	1.807	0.011	0.339	15.55	15.28	1.161	1000	1.043	1.1882	1.1746	1.10E-05	0.596	3.582	0.328
5000	0.1450	0.6	1.807	1.824	0.017	0.356	15.28	14.86	1.119	2000	1.043	1.1609	1.1400	8.50E-06	0.579	3.607	0.316
7000	0.1450	0.6	1.824	1.852	0.028	0.384	14.86	14.56	1.081	2000	1.043	1.1191	1.1001	1.40E-05	0.558	3.646	0.302
10000	0.1450	0.6	1.852	1.859	0.007	0.391	14.56	14.14	1.046	3000	1.043	1.0809	1.0634	2.33E-06	0.540	3.655	0.291
15000	0.1450	0.6	1.859	1.915	0.056	0.447	14.14	13.25	0.954	5000	1.043	1.0460	0.9999	1.12E-05	0.508	3.726	0.268
20000	0.1450	0.6	1.915	1.965	0.050	0.497	13.25	12.49	0.877	5000	1.043	0.9531	0.9152	1.00E-05	0.465	3.784	0.242
25000	0.1450	0.6	1.965	1.984	0.019	0.516	12.49	12.19	0.848	5000	1.043	0.8768	0.8624	3.80E-06	0.438	3.805	0.227
5000	0.1049	0.5	1.548	1.594	0.046	0.126	15.33	14.1	0.872	5000	0.755	0.9740	0.9232	9.20E-06	0.469	3.159	0.292
10000	0.1049	0.5	1.594	1.615	0.021	0.147	14.1	13.55	0.828	5000	0.755	0.8717	0.8497	4.20E-06	0.431	3.217	0.264
15000	0.1049	0.5	1.615	1.658	0.043	0.19	13.55	13.03	0.777	5000	0.755	0.8275	0.8022	8.60E-06	0.407	3.319	0.242
20000	0.1049	0.5	1.658	1.69	0.032	0.222	13.03	12.61	0.738	5000	0.755	0.7764	0.7574	6.40E-06	0.384	3.385	0.224
25000	0.1049	0.5	1.690	1.704	0.014	0.236	12.61	12.23	0.710	5000	0.755	0.7381	0.7242	2.80E-06	0.368	3.412	0.212
10	0.319	1.0	2.224	2.224	0.000	0.756	18.72	18.65	2.561	10	2.295	2.5707	2.5659	0.00E+00	1.302	4.034	0.636
50	0.319	1.0	2.224	2.234	0.010	0.766	18.65	18.32	2.505	50	2.295	2.5611	2.5331	2.00E-04	1.286	4.043	0.627
100	0.319	1.0	2.234	2.246	0.012	0.778	18.32	18.01	2.450	50	2.295	2.5050	2.4776	2.40E-04	1.258	4.053	0.611

Table A-13. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF8) (Continued)

δ_{max} = **δ_{cr} = 0.139** Δ = 0.11

b = 1.491 **G_{IC} = 1.97** Test Frequency = 5Hz a_o = 1.468

N	δ_{max}	f	a_i	a_f	da, in.	da, Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
200	0.319	1.0	2.246	2.296	0.050	0.828	18.01	17.47	2.328	100	2.295	2.4501	2.3892	5.00E-04	1.213	4.093	0.584
300	0.319	1.0	2.296	2.326	0.030	0.858	17.47	17.15	2.257	100	2.295	2.3273	2.2921	3.00E-04	1.164	4.116	0.557
400	0.319	1.0	2.326	2.326	0.000	0.858	17.15	16.91	2.225	100	2.295	2.2566	2.2408	0.00E+00	1.137	4.116	0.544
500	0.319	1.0	2.326	2.347	0.021	0.879	16.91	16.55	2.159	200	2.295	2.2250	2.1921	1.05E-04	1.113	4.132	0.530
600	0.319	1.0	2.347	2.351	0.004	0.883	16.55	16.3	2.123	100	2.295	2.1591	2.1410	4.00E-05	1.087	4.135	0.518
700	0.319	1.0	2.351	2.351	0.000	0.883	16.3	16.1	2.097	100	2.295	2.1230	2.1100	0.00E+00	1.071	4.135	0.510
1000	0.319	1.0	2.351	2.376	0.025	0.908	16.1	15.77	2.034	400	2.295	2.0969	2.0652	6.25E-05	1.048	4.154	0.497
1500	0.319	1.0	2.376	2.399	0.023	0.931	15.77	15.4	1.968	500	2.295	2.0333	2.0005	4.60E-05	1.015	4.171	0.480
2000	0.319	1.0	2.399	2.411	0.012	0.943	15.4	15.07	1.916	500	2.295	1.9674	1.9418	2.40E-05	0.986	4.180	0.465
2500	0.319	1.0	2.411	2.435	0.024	0.967	15.07	14.79	1.863	500	2.295	1.9161	1.8896	4.80E-05	0.959	4.197	0.450
3000	0.319	1.0	2.435	2.448	0.013	0.98	14.79	14.5	1.817	500	2.295	1.8628	1.8399	2.60E-05	0.934	4.206	0.437
1	0.5415	1.4	2.664	2.692	0.028	1.224	19.14	19.14	3.718	1	3.897	3.7547	3.7361	2.80E-02	1.897	4.365	0.856
10	0.5415	1.4	2.692	2.73	0.038	1.262	19.14	18.59	3.563	9	3.897	3.7172	3.6400	4.22E-03	1.848	4.387	0.830
20	0.5415	1.4	2.73	2.735	0.005	1.267	18.59	18.14	3.470	10	3.897	3.5621	3.5160	5.00E-04	1.785	4.390	0.801
50	0.5415	1.4	2.735	2.771	0.036	1.303	18.14	17.47	3.300	30	3.897	3.4698	3.3851	1.20E-03	1.718	4.411	0.767
100	0.5415	1.4	2.771	2.811	0.040	1.343	17.47	16.92	3.153	50	3.897	3.2999	3.2264	8.00E-04	1.638	4.434	0.728
200	0.5415	1.4	2.811	2.881	0.070	1.413	16.92	16.18	2.946	100	3.897	3.1523	3.0490	7.00E-04	1.548	4.473	0.682
300	0.5415	1.4	2.881	2.903	0.022	1.435	16.18	15.76	2.847	100	3.897	2.9440	2.8954	2.20E-04	1.470	4.485	0.646
400	0.5415	1.4	2.903	2.923	0.020	1.455	15.76	15.41	2.765	100	3.897	2.8466	2.8059	2.00E-04	1.424	4.495	0.624
500	0.5415	1.4	2.923	2.932	0.009	1.464	15.41	15.18	2.716	100	3.897	2.7651	2.7404	9.00E-05	1.391	4.500	0.609
10	0.4233	1.2	2.448	2.494	0.046	1.026	18.89	18.49	3.021	10	3.046	3.1411	3.0812	4.60E-03	1.564	4.238	0.727
50	0.4233	1.2	2.494	2.542	0.048	1.074	18.49	18.02	2.891	40	3.046	3.0203	2.9558	1.20E-03	1.500	4.270	0.692
100	0.4233	1.2	2.542	2.597	0.055	1.129	18.02	17.29	2.718	50	3.046	2.8903	2.8042	1.10E-03	1.423	4.306	0.651
200	0.4233	1.2	2.597	2.619	0.022	1.151	17.29	16.56	2.581	100	3.046	2.7170	2.6492	2.20E-04	1.345	4.320	0.613
300	0.4233	1.2	2.619	2.634	0.015	1.166	16.56	16.05	2.488	100	3.046	2.5813	2.5348	1.50E-04	1.287	4.329	0.586
400	0.4233	1.2	2.634	2.646	0.012	1.178	16.05	15.68	2.420	100	3.046	2.4881	2.4542	1.20E-04	1.246	4.336	0.566
500	0.4233	1.2	2.646	2.664	0.018	1.196	15.68	15.43	2.366	100	3.046	2.4202	2.3932	1.80E-04	1.215	4.348	0.550
1	0.7013	1.6	2.932	2.974	0.042	1.506	19.07	19.07	4.359	1	5.046	4.4185	4.3889	4.20E-02	2.228	4.522	0.970
10	0.7013	1.6	2.974	2.995	0.021	1.527	19.07	18.82	4.272	9	5.046	4.3584	4.3154	2.33E-03	2.191	4.533	0.952
50	0.7013	1.6	2.995	3.073	0.078	1.605	18.82	18.02	3.993	40	5.046	4.2722	4.1325	1.95E-03	2.098	4.573	0.904
100	0.7013	1.6	3.073	3.198	0.125	1.73	18.02	16.81	3.587	50	5.046	3.9905	3.7888	2.50E-03	1.923	4.634	0.818
200	0.7013	1.6	3.198	3.235	0.037	1.767	16.81	15.58	3.284	100	5.046	3.5820	3.4328	3.70E-04	1.743	4.651	0.738
300	0.7013	1.6	3.235	3.259	0.024	1.791	15.58	14.51	3.036	100	5.046	3.2832	3.1597	2.40E-04	1.604	4.662	0.678
400	0.7013	1.6	3.259	3.281	0.022	1.813	14.51	14.14	2.939	100	5.046	3.0360	2.9877	2.20E-04	1.517	4.673	0.639

Table A-13. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF8) (Continued)

δ_{max} = **δ_{cr} = 0.139** Δ = 0.11

b = 1.491 **G_{IC} = 1.97** Test Frequency = 5Hz a_o = 1.468

N	δ_{max}	f	a_i	a_f	da, in.	da, Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{ave}/G_{IR}
500	0.7013	1.6	3.281	3.292	0.011	1.824	14.14	13.91	2.882	100	5.046	2.9394	2.9108	1.10E-04	1.478	4.678	0.622
1	0.9376	1.8	3.292	3.454	0.162	1.986	16.34	16.34	4.330	1	6.747	4.5265	4.4282	1.62E-01	2.248	4.749	0.932
10	0.9376	1.8	3.454	3.485	0.031	2.017	16.34	16.03	4.203	9	6.747	4.3209	4.2618	3.44E-03	2.163	4.763	0.895
50	0.9376	1.8	3.485	3.526	0.041	2.058	16.03	15.63	4.052	40	6.747	4.2024	4.1272	1.03E-03	2.095	4.780	0.863
100	0.9376	1.8	3.526	3.535	0.009	2.067	15.63	15.1	3.904	50	6.747	4.0514	3.9779	1.80E-04	2.019	4.784	0.832
200	0.9376	1.8	3.535	3.556	0.021	2.088	15.1	14.72	3.784	100	6.747	3.9044	3.8444	2.10E-04	1.951	4.793	0.802
300	0.9376	1.8	3.556	3.572	0.016	2.104	14.72	14.25	3.648	100	6.747	3.7843	3.7160	1.60E-04	1.886	4.799	0.774
400	0.9376	1.8	3.572	3.617	0.045	2.149	14.25	13.72	3.470	100	6.747	3.6476	3.5588	4.50E-04	1.807	4.818	0.739
500	0.9376	1.8	3.617	3.639	0.022	2.171	13.72	13.32	3.349	100	6.747	3.4696	3.4092	2.20E-04	1.731	4.827	0.706
600	0.9376	1.8	3.639	3.713	0.074	2.245	13.32	12.74	3.142	100	6.747	3.3487	3.2454	7.40E-04	1.647	4.856	0.668
700	0.9376	1.8	3.713	3.786	0.073	2.318	12.74	12.27	2.969	100	6.747	3.1409	3.0552	7.30E-04	1.551	4.885	0.625
800	0.9376	1.8	3.786	3.815	0.029	2.347	12.27	11.98	2.877	100	6.747	2.9684	2.9227	2.90E-04	1.484	4.896	0.597
900	0.9376	1.8	3.815	3.837	0.022	2.369	11.98	11.8	2.818	100	6.747	2.8768	2.8474	2.20E-04	1.445	4.905	0.581
1000	0.9376	1.8	3.837	3.844	0.007	2.376	11.80	11.64	2.775	100	6.747	2.8178	2.7963	7.00E-05	1.419	4.907	0.570
1	1.3476	2.0	3.844	4.022	0.178	2.554	14.80	14.80	4.861	1	9.697	5.0707	4.9661	1.78E-01	2.521	4.973	0.999
10	1.3476	2.0	4.022	4.088	0.066	2.62	14.80	14.53	4.690	9	9.697	4.8524	4.7713	7.33E-03	2.422	4.997	0.955
50	1.3476	2.0	4.088	4.119	0.031	2.651	14.53	14.20	4.549	40	9.697	4.6891	4.6191	7.75E-04	2.345	5.008	0.922
100	1.3476	2.0	4.119	4.232	0.113	2.764	14.20	13.15	4.106	50	9.697	4.5490	4.3274	2.26E-03	2.197	5.047	0.857
200	1.3476	2.0	4.232	4.424	0.192	2.956	13.15	10.95	3.278	100	9.697	4.1031	3.6905	1.92E-03	1.873	5.112	0.722
300	1.3476	2.0	4.424	4.487	0.063	3.019	10.95	10.03	2.957	100	9.697	3.2720	3.1143	6.30E-04	1.581	5.132	0.607
400	1.3476	2.0	4.487	4.52	0.033	3.052	10.03	9.79	2.865	100	9.697	2.9561	2.9105	3.30E-04	1.477	5.143	0.566
500	1.3476	2.0	4.52	4.588	0.068	3.12	9.79	9.62	2.775	100	9.697	2.8648	2.8198	6.80E-04	1.431	5.164	0.546
600	1.3476	2.0	4.588	4.602	0.014	3.134	9.62	9.53	2.740	100	9.697	2.7743	2.7573	1.40E-04	1.400	5.169	0.533

Table A-14. Constant-Displacement Amplitude Fatigue Test Data for FGI 1854 Glass/Dow 510A-40 Vinyl Ester Composite (Specimen WF12)

				δ_{max} =			δ_{cr} =	**0.139**	Δ=	0.113							
				b=	**1.491**		**G_{IC} =**	**1.97**	Test Frequency		1H, 2H, 4Hz		a_0 =	1.44			
N	δ_{max}	f	a_i	a_f	da, in.	da,Tot	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	da/dN	G_{ave}/G_{IC}	G_{IR}	G_{av}/G_{IR}
1	0.2278	2.2	1.514	1.755	0.241	0.315	22.44	22.44	2.800	1	1.639	3.1608	2.9802	2.41E-01	1.513	3.546	0.840
5	0.2278	2.2	1.755	1.775	0.020	0.335	22.44	22.32	2.710	4	1.639	2.7530	2.7313	5.00E-03	1.386	3.577	0.764
10	0.2278	2.2	1.775	1.778	0.003	0.338	22.32	22.23	2.694	5	1.639	2.7093	2.7017	6.00E-04	1.371	3.581	0.754
20	0.2278	2.2	1.778	1.78	0.002	0.34	22.23	22.12	2.678	10	1.639	2.6941	2.6860	2.00E-04	1.363	3.584	0.749
50	0.2278	2.2	1.780	1.793	0.013	0.353	22.12	21.99	2.644	30	1.639	2.6779	2.6610	4.33E-04	1.351	3.603	0.739
100	0.2278	2.2	1.793	1.795	0.002	0.355	21.99	21.85	2.624	50	1.639	2.6440	2.6342	4.00E-05	1.337	3.606	0.731
200	0.2278	2.2	1.795	1.798	0.003	0.358	21.85	21.53	2.582	100	1.639	2.6244	2.6032	3.00E-05	1.321	3.610	0.721
500	0.2278	2.2	1.798	1.808	0.01	0.368	21.53	20.77	2.478	300	1.639	2.5819	2.5299	3.33E-05	1.284	3.624	0.698
1000	0.2278	2.2	1.808	1.813	0.005	0.373	20.77	19.79	2.355	500	1.639	2.4778	2.4163	1.00E-05	1.227	3.631	0.666
2000	0.2278	2.2	1.813	1.845	0.032	0.405	19.79	17.70	2.072	1000	1.639	2.3548	2.2135	3.20E-05	1.124	3.673	0.603
3000	0.2278	2.2	1.845	1.948	0.103	0.508	17.70	16.32	1.819	1000	1.639	2.0717	1.9455	1.03E-04	0.988	3.796	0.512
4000	0.2278	2.2	1.948	2.004	0.056	0.564	16.32	15.53	1.682	1000	1.639	1.8147	1.7485	5.60E-05	0.888	3.856	0.453
5000	0.2278	2.2	2.004	2.039	0.035	0.599	15.53	15.18	1.617	1000	1.639	1.6812	1.6491	3.50E-05	0.837	3.891	0.424
6000	0.2278	2.2	2.039	2.04	0.001	0.6	15.18	14.96	1.592	1000	1.639	1.6166	1.6045	1.00E-06	0.814	3.892	0.412
7000	0.2278	2.2	2.04	2.052	0.012	0.612	14.96	14.48	1.533	1000	1.639	1.5924	1.5626	1.20E-05	0.793	3.904	0.400
8000	0.2278	2.2	2.052	2.054	0.002	0.614	14.48	14.5	1.533	1000	1.639	1.5328	1.5331	2.00E-06	0.778	3.906	0.392
9000	0.2278	2.2	2.054	2.054	0.000	0.614	14.50	14.57	1.541	1000	1.639	1.5335	1.5372	0.00E+00	0.780	3.906	0.394
10000	0.2278	2.2	2.054	2.07	0.016	0.63	14.57	14.56	1.529	2000	1.639	1.5409	1.5347	8.00E-06	0.779	3.922	0.391
15000	0.2278	2.2	2.07	2.089	0.019	0.649	14.56	14.34	1.493	5000	1.639	1.5285	1.5105	3.80E-06	0.767	3.939	0.383
20000	0.2278	2.2	2.089	2.107	0.018	0.667	14.34	14.06	1.452	5000	1.639	1.4924	1.4720	3.60E-06	0.747	3.956	0.372
30000	0.2278	2.2	2.107	2.149	0.042	0.709	14.06	12.50	1.267	10000	1.639	1.4514	1.3591	4.20E-06	0.690	3.994	0.340
40000	0.2278	2.2	2.149	2.297	0.148	0.857	12.50	11.02	1.052	10000	1.639	1.2664	1.1592	1.48E-05	0.588	4.116	0.282
50000	0.2278	2.2	2.297	2.344	0.047	0.904	11.02	11.02	1.028	10000	1.639	1.0479	1.0381	4.70E-06	0.527	4.151	0.250
60000	0.2278	2.2	2.344	2.371	0.027	0.931	11.02	10.77	0.994	10000	1.639	1.0279	1.0108	2.70E-06	0.513	4.171	0.242
70000	0.2278	2.2	2.371	2.382	0.011	0.942	10.77	10.6	0.974	10000	1.639	0.9936	0.9836	1.10E-06	0.499	4.179	0.235
80000	0.2278	2.2	2.382	2.386	0.004	0.946	10.6	10.3	0.945	10000	1.639	0.9736	0.9591	4.00E-07	0.487	4.182	0.229
90000	0.2278	2.2	2.386	2.386	0.000	0.946	10.3	10.28	0.943	10000	1.639	0.9446	0.9437	0.00E+00	0.479	4.182	0.226
100000	0.2278	2.2	2.386	2.386	0.000	0.946	10.28	10.19	0.934	10000	1.639	0.9427	0.9386	0.00E+00	0.476	4.182	0.224
120000	0.2278	2.2	2.386	2.409	0.023	0.969	10.19	9.74	0.885	40000	1.639	0.9345	0.9098	5.75E-07	0.462	4.198	0.217
140000	0.2278	2.2	2.409	2.415	0.006	0.975	9.74	9.42	0.854	20000	1.639	0.8851	0.8695	3.00E-07	0.441	4.203	0.207
160000	0.2278	2.2	2.415	2.422	0.007	0.982	9.42	9.13	0.825	20000	1.639	0.8540	0.8397	3.50E-07	0.426	4.207	0.200
180000	0.2278	2.2	2.422	2.458	0.036	1.018	9.13	8.88	0.792	20000	1.639	0.8254	0.8085	1.80E-06	0.410	4.232	0.191
200000	0.2278	2.2	2.458	2.494	0.036	1.054	8.88	8.67	0.762	20000	1.639	0.7915	0.7769	1.80E-06	0.394	4.257	0.183
220000	0.2278	2.2	2.494	2.541	0.047	1.101	8.67	8.51	0.735	20000	1.639	0.7622	0.7486	2.35E-06	0.380	4.288	0.175
240000	0.2278	2.2	2.541	2.547	0.006	1.107	8.51	8.45	0.728	20000	1.639	0.7348	0.7314	3.00E-07	0.371	4.292	0.170
260000	0.2278	2.2	2.547	2.556	0.009	1.116	8.45	8.34	0.716	20000	1.639	0.7280	0.7221	4.50E-07	0.367	4.297	0.168
280000	0.2278	2.2	2.556	2.556	0.000	1.116	8.34	8.30	0.713	20000	1.639	0.7161	0.7144	0.00E+00	0.363	4.297	0.166
300000	0.2278	2.2	2.556	2.556	0.000	1.116	8.30	8.19	0.703	20000	1.639	0.7127	0.7080	0.00E+00	0.359	4.297	0.165

Table A-15. Constant-Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE203)

							δ_{cr} = 0.139			Δ = 0.401							
				b = 0.9903			**G_{IC} = 1.74**			Test Frequency = 5Hz		**a_o = 0.995**					
δ_{max}	f	a_i	a_f	da, in.	da	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.0687	0.3	1.118	1.120	0.002	0.123	0.125	29.00	29.00	1.984	1	0.494	1.9863	1.9850	2.6677	2.00E-03	1.1415	0.7446
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.90	28.90	1.977	4	0.494	1.9768	1.9768	2.6600	0.00E+00	1.1361	0.7432
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.67	28.67	1.961	5	0.494	1.9611	1.9611	2.6600	0.00E+00	1.1271	0.7373
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.69	28.69	1.962	10	0.494	1.9624	1.9624	2.6600	0.00E+00	1.1278	0.7378
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.69	28.69	1.962	10	0.494	1.9624	1.9624	2.6600	0.00E+00	1.1278	0.7378
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.75	28.75	1.967	20	0.494	1.9665	1.9665	2.6600	0.00E+00	1.1302	0.7393
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.80	28.80	1.970	50	0.494	1.9700	1.9700	2.6600	0.00E+00	1.1322	0.7406
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.82	28.82	1.971	100	0.494	1.9713	1.9713	2.6600	0.00E+00	1.1330	0.7411
0.0687	0.3	1.120	1.120	0.000	0.125	0.125	28.84	28.84	1.973	100	0.494	1.9727	1.9727	2.6600	0.00E+00	1.1337	0.7416
0.0687	0.3	1.120	1.125	0.005	0.125	0.130	28.74	28.74	1.959	499	0.494	1.9659	1.9626	2.6600	1.00E-05	1.1298	0.7391
0.0687	0.3	1.125	1.125	0.000	0.130	0.130	28.45	28.45	1.940	500	0.494	1.9397	1.9397	2.6414	0.00E+00	1.1147	0.7343
0.0687	0.3	1.125	1.125	0.000	0.130	0.130	28.19	28.19	1.922	500	0.494	1.9219	1.9219	2.6414	0.00E+00	1.1046	0.7276
0.0687	0.3	1.125	1.125	0.000	0.130	0.130	27.74	27.74	1.891	500	0.494	1.8912	1.8912	2.6414	0.00E+00	1.0869	0.7160
0.0687	0.3	1.125	1.127	0.002	0.130	0.132	27.12	27.12	1.847	2500	0.494	1.8490	1.8478	2.6414	8.00E-07	1.0626	0.7000
0.0687	0.3	1.127	1.127	0.000	0.132	0.132	25.99	25.99	1.770	2000	0.494	1.7696	1.7696	2.6342	0.00E+00	1.0170	0.6718
0.0687	0.3	1.127	1.130	0.003	0.132	0.135	22.92	22.92	1.558	7000	0.494	1.5606	1.5591	2.6342	4.29E-07	0.8969	0.5924
0.0687	0.3	1.130	1.153	0.023	0.135	0.158	19.39	19.39	1.298	10000	0.494	1.3176	1.3079	2.6236	2.30E-06	0.7573	0.5022
0.0687	0.3	1.153	1.237	0.084	0.158	0.242	17.90	17.90	1.137	10000	0.494	1.1984	1.1677	2.5517	8.40E-06	0.6887	0.4697
0.0687	0.3	1.237	1.289	0.052	0.242	0.294	16.92	16.92	1.042	10000	0.494	1.0747	1.0582	2.3747	5.20E-06	0.6176	0.4526
0.0687	0.3	1.289	1.348	0.059	0.294	0.353	16.21	16.21	0.964	10000	0.494	0.9979	0.9811	2.3036	5.90E-06	0.5735	0.4332
0.0687	0.3	1.348	1.369	0.021	0.353	0.374	15.86	15.86	0.932	10000	0.494	0.9435	0.9379	2.2425	2.10E-06	0.5422	0.4207
0.0687	0.3	1.369	1.375	0.006	0.374	0.380	15.28	15.28	0.895	10000	0.494	0.8982	0.8967	2.2243	6.00E-07	0.5162	0.4038
0.0687	0.3	1.375	1.383	0.008	0.380	0.388	15.07	15.07	0.879	10000	0.494	0.8828	0.8809	2.2194	8.00E-07	0.5074	0.3978
0.0687	0.3	1.383	1.387	0.004	0.388	0.392	14.91	14.91	0.868	10000	0.494	0.8695	0.8686	2.2130	4.00E-07	0.4997	0.3929
0.0687	0.3	1.387	1.400	0.013	0.392	0.405	14.64	14.64	0.846	10000	0.494	0.8519	0.8488	2.2099	1.30E-06	0.4896	0.3855
0.0687	0.3	1.400	1.404	0.004	0.405	0.409	14.76	14.76	0.851	10000	0.494	0.8527	0.8517	2.2002	4.00E-07	0.4900	0.3875
0.0687	0.3	1.404	1.410	0.006	0.409	0.415	14.73	14.73	0.846	10000	0.494	0.8491	0.8476	2.1973	6.00E-07	0.4880	0.3864
0.0687	0.3	1.410	1.415	0.005	0.415	0.420	14.70	14.70	0.842	10000	0.494	0.8445	0.8434	2.1930	5.00E-07	0.4854	0.3851
0.0687	0.3	1.415	1.455	0.040	0.420	0.460	14.39	14.39	0.807	20000	0.494	0.8244	0.8155	2.1895	2.00E-06	0.4738	0.3765
0.0687	0.3	1.455	1.493	0.038	0.460	0.498	14.09	14.09	0.774	50000	0.494	0.7898	0.7819	2.1636	7.60E-07	0.4539	0.3651
0.0687	0.3	1.493	1.509	0.016	0.498	0.514	13.95	13.95	0.760	40000	0.494	0.7663	0.7631	2.1421	4.00E-07	0.4404	0.3577
0.0687	0.3	1.509	1.510	0.001	0.514	0.515	13.30	13.30	0.724	60000	0.494	0.7245	0.7243	2.1338	1.67E-08	0.4164	0.3395
0.0687	0.3	1.510	1.512	0.002	0.515	0.517	13.52	13.52	0.735	50000	0.494	0.7361	0.7357	2.1333	4.00E-08	0.4230	0.3450

Table A-16. Constant-Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE204)

δ_{cr} = 0.139 Δ = 0.4013

b = 0.98 **G_{IC} = 1.74** Test Frequency = 5Hz **a_o = 0.989**

δ_{max}	f	a_i	a_f	da, in.	da	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.0835	0.4	1.158	1.466	0.308	0.169	0.477	16.39	16.39	1.119	1	0.601	1.3402	1.2297	2.5219	3.08E-01	0.7702	0.5314
0.0835	0.4	1.466	1.466	0.000	0.477	0.477	16.35	16.35	1.116	4	0.601	1.1164	1.1164	2.1537	0.00E+00	0.6416	0.5184
0.0835	0.4	1.466	1.472	0.006	0.477	0.483	16.3	16.3	1.109	9	0.601	1.1130	1.1112	2.1537	6.67E-04	0.6397	0.5168
0.0835	0.4	1.472	1.475	0.003	0.483	0.486	16.24	16.24	1.104	5	0.601	1.1053	1.1045	2.1503	6.00E-04	0.6353	0.5140
0.0835	0.4	1.475	1.475	0.000	0.486	0.486	16.2	16.2	1.101	5	0.601	1.1009	1.1009	2.1486	0.00E+00	0.6327	0.5124
0.0835	0.4	1.475	1.476	0.001	0.486	0.487	16.12	16.12	1.095	15	0.601	1.0954	1.0951	2.1486	6.67E-05	0.6296	0.5098
0.0835	0.4	1.476	1.478	0.002	0.487	0.489	16.08	16.08	1.091	10	0.601	1.0921	1.0915	2.1481	2.00E-04	0.6277	0.5084
0.0835	0.4	1.478	1.483	0.005	0.489	0.494	15.95	15.95	1.079	10	0.601	1.0821	1.0807	2.1470	5.00E-04	0.6219	0.5040
0.0835	0.4	1.483	1.485	0.002	0.494	0.496	15.93	15.93	1.077	10	0.601	1.0779	1.0773	2.1443	2.00E-04	0.6195	0.5027
0.0835	0.4	1.485	1.488	0.003	0.496	0.499	15.89	15.89	1.072	20	0.601	1.0741	1.0732	2.1432	1.50E-04	0.6173	0.5012
0.0835	0.4	1.488	1.490	0.002	0.499	0.501	15.84	15.84	1.068	20	0.601	1.0690	1.0684	2.1416	1.00E-04	0.6144	0.4992
0.0835	0.4	1.490	1.494	0.004	0.501	0.505	15.84	15.84	1.066	50	0.601	1.0679	1.0667	2.1405	8.00E-05	0.6137	0.4989
0.0835	0.4	1.494	1.501	0.007	0.505	0.512	15.79	15.79	1.058	50	0.601	1.0622	1.0603	2.1384	1.40E-04	0.6105	0.4967
0.0835	0.4	1.501	1.507	0.006	0.512	0.518	15.73	15.73	1.051	50	0.601	1.0543	1.0527	2.1348	1.20E-04	0.6059	0.4939
0.0835	0.4	1.507	1.510	0.003	0.518	0.521	15.59	15.59	1.040	50	0.601	1.0416	1.0408	2.1318	6.00E-05	0.5986	0.4886
0.0835	0.4	1.510	1.515	0.005	0.521	0.526	15.45	15.45	1.028	100	0.601	1.0307	1.0293	2.1303	5.00E-05	0.5923	0.4838
0.0835	0.4	1.515	1.520	0.005	0.526	0.531	15.32	15.32	1.017	100	0.601	1.0193	1.0180	2.1279	5.00E-05	0.5858	0.4790
0.0835	0.4	1.520	1.522	0.002	0.531	0.533	15.25	15.25	1.011	100	0.601	1.0120	1.0115	2.1254	2.00E-05	0.5816	0.4762
0.0835	0.4	1.522	1.532	0.010	0.533	0.543	15.06	15.06	0.993	200	0.601	0.9984	0.9958	2.1245	5.00E-05	0.5738	0.4699
0.0835	0.4	1.532	1.540	0.008	0.543	0.551	14.9	14.9	0.979	200	0.601	0.9827	0.9806	2.1198	4.00E-05	0.5648	0.4636
0.0835	0.4	1.540	1.546	0.006	0.551	0.557	14.81	14.81	0.970	200	0.601	0.9727	0.9712	2.1161	3.00E-05	0.5590	0.4597
0.0835	0.4	1.546	1.554	0.008	0.557	0.565	14.69	14.69	0.958	200	0.601	0.9619	0.9599	2.1134	4.00E-05	0.5528	0.4551
0.0835	0.4	1.554	1.554	0.000	0.565	0.565	14.62	14.62	0.953	200	0.601	0.9534	0.9534	2.1099	0.00E+00	0.5479	0.4519
0.0835	0.4	1.554	1.554	0.000	0.565	0.565	14.57	14.57	0.950	200	0.601	0.9501	0.9501	2.1099	0.00E+00	0.5460	0.4503
0.0835	0.4	1.554	1.554	0.000	0.565	0.565	14.47	14.47	0.944	200	0.601	0.9436	0.9436	2.1099	0.00E+00	0.5423	0.4472
0.0835	0.4	1.554	1.562	0.008	0.565	0.573	14.31	14.31	0.929	1100	0.601	0.9331	0.9312	2.1099	7.27E-06	0.5363	0.4423
0.0835	0.4	1.562	1.565	0.003	0.573	0.576	14.19	14.19	0.920	500	0.601	0.9215	0.9208	2.1064	6.00E-06	0.5296	0.4375
0.0835	0.4	1.565	1.582	0.017	0.576	0.593	13.96	13.96	0.897	1000	0.601	0.9052	0.9013	2.1051	1.70E-05	0.5202	0.4300
0.0835	0.4	1.582	1.589	0.007	0.593	0.600	13.8	13.8	0.884	1000	0.601	0.8872	0.8856	2.0981	7.00E-06	0.5099	0.4228

Table A-16. Constant-Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE204) (Continued)

δ_{cr} = 0.139 Δ = 0.4013

b = 0.98 **G_{IC} = 1.74** Test Frequency = 5Hz **a_o = 0.989**

δ_{max}	f	a_i	a_f	da, in.	da	da(Tot)	P_i	P_f	G_f	dN, cy	δ_{max}/δ_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.0835	0.4	1.589	1.591	0.002	0.600	0.602	13.64	13.64	0.873	1000	0.601	0.8738	0.8734	2.0953	2.00E-06	0.5022	0.4170
0.0835	0.4	1.591	1.598	0.007	0.602	0.609	13.4	13.4	0.855	2000	0.601	0.8576	0.8561	2.0945	3.50E-06	0.4929	0.4094
0.0835	0.4	1.598	1.611	0.013	0.609	0.622	13.26	13.26	0.840	2000	0.601	0.8456	0.8429	2.0918	6.50E-06	0.4860	0.4043
0.0835	0.4	1.611	1.622	0.011	0.622	0.633	13.12	13.12	0.827	2000	0.601	0.8313	0.8290	2.0868	5.50E-06	0.4778	0.3984
0.0835	0.4	1.622	1.623	0.001	0.633	0.634	12.99	12.99	0.818	2000	0.601	0.8186	0.8184	2.0828	5.00E-07	0.4705	0.3930
0.0835	0.4	1.623	1.624	0.001	0.634	0.635	12.9	12.9	0.812	2000	0.601	0.8125	0.8123	2.0824	5.00E-07	0.4670	0.3902
0.0835	0.4	1.624	1.628	0.004	0.635	0.639	12.84	12.84	0.807	2000	0.601	0.8083	0.8075	2.0821	2.00E-06	0.4646	0.3882
0.0835	0.4	1.628	1.642	0.014	0.639	0.653	12.77	12.77	0.797	2000	0.601	0.8024	0.7996	2.0806	7.00E-06	0.4611	0.3856
0.0835	0.4	1.642	1.642	0.000	0.653	0.653	12.62	12.62	0.787	5000	0.601	0.7875	0.7875	2.0757	0.00E+00	0.4526	0.3794
0.0835	0.4	1.642	1.655	0.013	0.653	0.666	12.56	12.56	0.779	10000	0.601	0.7838	0.7813	2.0757	1.30E-06	0.4504	0.3776
0.0835	0.4	1.655	1.663	0.008	0.666	0.674	12.46	12.46	0.770	5000	0.601	0.7726	0.7711	2.0713	1.60E-06	0.4440	0.3730
0.0835	0.4	1.663	1.665	0.002	0.674	0.676	12.36	12.36	0.763	5000	0.601	0.7634	0.7631	2.0686	4.00E-07	0.4387	0.3691
0.0835	0.4	1.665	1.668	0.003	0.676	0.679	12.26	12.26	0.755	10000	0.601	0.7565	0.7560	2.0679	3.00E-07	0.4348	0.3658
0.0835	0.4	1.668	1.683	0.015	0.679	0.694	12.35	12.35	0.755	10000	0.601	0.7610	0.7582	2.0670	1.50E-06	0.4373	0.3682
0.0835	0.4	1.683	1.693	0.010	0.694	0.704	12.18	12.18	0.742	20000	0.601	0.7451	0.7433	2.0622	5.00E-07	0.4282	0.3613
0.0835	0.4	1.693	1.701	0.008	0.704	0.712	12.1	12.1	0.734	20000	0.601	0.7367	0.7353	2.0591	4.00E-07	0.4234	0.3578
0.0835	0.4	1.701	1.702	0.001	0.712	0.713	11.91	11.91	0.722	20000	0.601	0.7223	0.7222	2.0566	5.00E-08	0.4151	0.3512
0.0835	0.4	1.702	1.731	0.029	0.713	0.742	11.59	11.59	0.693	30000	0.601	0.7026	0.6978	2.0563	9.67E-07	0.4038	0.3417
0.0835	0.4	1.731	1.742	0.011	0.742	0.753	11.49	11.49	0.684	50000	0.601	0.6871	0.6853	2.0479	2.20E-07	0.3949	0.3355
0.0835	0.4	1.742	1.746	0.004	0.753	0.757	11.39	11.39	0.676	50000	0.601	0.6776	0.6769	2.0448	8.00E-08	0.3894	0.3314
0.0835	0.4	1.746	1.756	0.010	0.757	0.767	11.5	11.5	0.680	50000	0.601	0.6829	0.6813	2.0437	2.00E-07	0.3924	0.3341
0.0835	0.4	1.756	1.762	0.006	0.767	0.773	11.29	11.29	0.665	50000	0.601	0.6673	0.6663	2.0410	1.20E-07	0.3835	0.3269
0.0835	0.4	1.762	1.770	0.008	0.773	0.781	11.42	11.42	0.671	50000	0.601	0.6731	0.6718	2.0394	1.60E-07	0.3868	0.3300
0.0835	0.4	1.770	1.782	0.012	0.781	0.793	11.1	11.1	0.648	100000	0.601	0.6518	0.6500	2.0373	1.20E-07	0.3746	0.3199
0.0835	0.4	1.782	1.797	0.015	0.793	0.808	10.35	10.35	0.600	100000	0.601	0.6044	0.6024	2.0343	1.50E-07	0.3474	0.2971
0.0835	0.4	1.797	1.801	0.004	0.808	0.812	10.72	10.72	0.621	100000	0.601	0.6218	0.6212	2.0305	4.00E-08	0.3573	0.3062

Table A-17. Constant-Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE205)

δ_{cr} = 0.139 Δ = 0.401

b = 0.929 **G_{IC} = 1.74** Test Frequency = 5Hz **a_o = 0.992**

δ_{max}	f	a_i	a_f	da, in.	da	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.1035	0.7	1.107	1.490	0.383	0.115	0.498	15.94	15.94	1.408	1	0.745	1.7661	1.5873	2.7001	3.83E-01	1.0150	0.6541
0.1035	0.7	1.490	1.500	0.010	0.498	0.508	15.80	15.80	1.389	2	0.745	1.3961	1.3924	2.1421	5.00E-03	0.8023	0.6517
0.1035	0.7	1.500	1.504	0.004	0.508	0.512	15.69	15.69	1.376	2	0.745	1.3791	1.3776	2.1369	2.00E-03	0.7926	0.6454
0.1035	0.7	1.504	1.508	0.004	0.512	0.516	15.62	15.62	1.367	5	0.745	1.3700	1.3686	2.1348	8.00E-04	0.7874	0.6418
0.1035	0.7	1.508	1.510	0.002	0.516	0.518	15.53	15.53	1.358	10	0.745	1.3593	1.3586	2.1328	2.00E-04	0.7812	0.6373
0.1035	0.7	1.510	1.515	0.005	0.518	0.523	15.42	15.42	1.345	10	0.745	1.3483	1.3465	2.1318	5.00E-04	0.7749	0.6324
0.1035	0.7	1.515	1.520	0.005	0.523	0.528	15.40	15.40	1.339	10	0.745	1.3430	1.3412	2.1293	5.00E-04	0.7718	0.6307
0.1035	0.7	1.520	1.522	0.002	0.528	0.530	15.35	15.35	1.334	10	0.745	1.3351	1.3345	2.1269	2.00E-04	0.7673	0.6277
0.1035	0.7	1.522	1.522	0.000	0.530	0.530	15.29	15.29	1.329	20	0.745	1.3285	1.3285	2.1259	0.00E+00	0.7635	0.6249
0.1035	0.7	1.522	1.522	0.000	0.530	0.530	15.22	15.22	1.322	30	0.745	1.3225	1.3225	2.1259	0.00E+00	0.7600	0.6221
0.1035	0.7	1.522	1.522	0.000	0.530	0.530	15.12	15.12	1.314	50	0.745	1.3138	1.3138	2.1259	0.00E+00	0.7550	0.6180
0.1035	0.7	1.522	1.522	0.000	0.530	0.530	15.00	15.00	1.303	50	0.745	1.3033	1.3033	2.1259	0.00E+00	0.7491	0.6131
0.1035	0.7	1.522	1.567	0.045	0.530	0.575	14.83	14.83	1.259	250	0.745	1.2886	1.2738	2.1259	1.80E-04	0.7406	0.6061
0.1035	0.7	1.567	1.567	0.000	0.575	0.575	14.72	14.72	1.250	100	0.745	1.2498	1.2498	2.1056	0.00E+00	0.7183	0.5936
0.1035	0.7	1.567	1.567	0.000	0.575	0.575	14.58	14.58	1.238	100	0.745	1.2379	1.2379	2.1056	0.00E+00	0.7114	0.5879
0.1035	0.7	1.567	1.581	0.014	0.575	0.589	14.35	14.35	1.210	400	0.745	1.2184	1.2141	2.1056	3.50E-05	0.7002	0.5786
0.1035	0.7	1.581	1.596	0.015	0.589	0.604	14.17	14.17	1.186	300	0.745	1.1946	1.1901	2.0997	5.00E-05	0.6865	0.5689
0.1035	0.7	1.596	1.616	0.020	0.604	0.624	13.91	13.91	1.152	500	0.745	1.1639	1.1581	2.0937	4.00E-05	0.6689	0.5559
0.1035	0.7	1.616	1.633	0.017	0.624	0.641	13.75	13.75	1.130	500	0.745	1.1391	1.1343	2.0861	3.40E-05	0.6546	0.5460
0.1035	0.7	1.633	1.643	0.010	0.641	0.651	13.62	13.62	1.113	500	0.745	1.1189	1.1161	2.0799	2.00E-05	0.6430	0.5379
0.1035	0.7	1.643	1.643	0.000	0.651	0.651	13.52	13.52	1.105	500	0.745	1.1052	1.1052	2.0764	0.00E+00	0.6352	0.5323
0.1035	0.7	1.643	1.665	0.022	0.651	0.673	13.37	13.37	1.081	1500	0.745	1.0930	1.0871	2.0764	1.47E-05	0.6281	0.5264
0.1035	0.7	1.665	1.665	0.000	0.673	0.673	13.25	13.25	1.072	1000	0.745	1.0716	1.0716	2.0689	0.00E+00	0.6159	0.5180
0.1035	0.7	1.665	1.681	0.016	0.673	0.689	13.05	13.05	1.047	3000	0.745	1.0554	1.0514	2.0689	5.33E-06	0.6066	0.5101
0.1035	0.7	1.681	1.689	0.008	0.689	0.697	12.77	12.77	1.021	3000	0.745	1.0249	1.0229	2.0637	2.67E-06	0.5890	0.4966
0.1035	0.7	1.689	1.702	0.013	0.697	0.710	12.61	12.61	1.002	5000	0.745	1.0081	1.0050	2.0612	2.60E-06	0.5794	0.4891
0.1035	0.7	1.702	1.703	0.001	0.710	0.711	12.49	12.49	0.992	5000	0.745	0.9924	0.9921	2.0572	2.00E-07	0.5703	0.4824
0.1035	0.7	1.703	1.746	0.043	0.711	0.754	12.20	12.20	0.949	10000	0.745	0.9689	0.9592	2.0569	4.30E-06	0.5568	0.4710
0.1035	0.7	1.746	1.776	0.030	0.754	0.784	12.36	12.36	0.949	10000	0.745	0.9619	0.9553	2.0446	3.00E-06	0.5528	0.4705
0.1035	0.7	1.776	1.810	0.034	0.784	0.818	12.24	12.24	0.925	10000	0.745	0.9395	0.9322	2.0366	3.40E-06	0.5399	0.4613
0.1035	0.7	1.810	1.822	0.012	0.818	0.830	11.84	11.84	0.890	10000	0.745	0.8948	0.8924	2.0281	1.20E-06	0.5142	0.4412

Table A-17. Constant-Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE205) (Continued)

δ_{cr} = 0.139 Δ = 0.401

b = 0.929 **G_{IC} = 1.74** Test Frequency = 5Hz **a_o = 0.992**

δ_{max}	f	a_i	a_f	da, in.	da	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.1035	0.7	1.822	1.834	0.012	0.830	0.842	11.83	11.83	0.884	10000	0.745	0.8892	0.8868	2.0252	1.20E-06	0.5110	0.4391
0.1035	0.7	1.834	1.850	0.016	0.842	0.858	11.85	11.85	0.880	10000	0.745	0.8859	0.8828	2.0225	1.60E-06	0.5092	0.4380
0.1035	0.7	1.850	1.875	0.025	0.858	0.883	11.77	11.77	0.864	10000	0.745	0.8737	0.8689	2.0188	2.50E-06	0.5021	0.4328
0.1035	0.7	1.875	1.875	0.000	0.883	0.883	11.14	11.14	0.818	10000	0.745	0.8178	0.8178	2.0134	0.00E+00	0.4700	0.4062
0.1035	0.7	1.875	1.875	0.000	0.883	0.883	11.26	11.26	0.827	20000	0.745	0.8267	0.8267	2.0134	0.00E+00	0.4751	0.4106
0.1035	0.7	1.875	1.891	0.016	0.883	0.899	11.51	11.51	0.839	60000	0.745	0.8450	0.8421	2.0134	2.67E-07	0.4856	0.4197
0.1035	0.7	1.891	1.937	0.046	0.899	0.945	11.38	11.38	0.813	50000	0.745	0.8296	0.8215	2.0101	9.20E-07	0.4768	0.4127
0.1035	0.7	1.937	1.965	0.028	0.945	0.973	11.31	11.31	0.799	50000	0.745	0.8083	0.8035	2.0009	5.60E-07	0.4645	0.4040
0.1035	0.7	1.965	1.969	0.004	0.973	0.977	10.60	10.60	0.747	50000	0.745	0.7486	0.7480	1.9957	8.00E-08	0.4302	0.3751
0.1035	0.7	1.969	1.969	0.000	0.977	0.977	10.73	10.73	0.757	50000	0.745	0.7565	0.7565	1.9950	0.00E+00	0.4348	0.3792

Table A-18. Constant Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE206)

δ_{cr} = 0.13897 Δ = 0.4013

b = 0.94 G_{IC} = 1.74 Test Frequency = 5Hz a_o = 0.974

δ_{max}	f	a_i	a_f	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.0908	0.7	1.009	1.310	0.301	0.035	28.9	28.9	2.457	1	0.653	2.9819	2.7196	3.2929	3.01E-01	1.7137	0.9055
0.0908	0.7	1.310	1.316	0.006	0.336	27.87	27.87	2.362	9	0.653	2.3698	2.3657	2.2584	6.67E-04	1.3620	1.0493
0.0908	0.7	1.316	1.316	0.000	0.342	27.49	27.49	2.329	10	0.653	2.3293	2.3293	2.2527	0.00E+00	1.3387	1.0340
0.0908	0.7	1.316	1.325	0.009	0.342	26.78	26.78	2.257	30	0.653	2.2692	2.2632	2.2527	3.00E-04	1.3041	1.0073
0.0908	0.7	1.325	1.335	0.010	0.351	25.45	25.45	2.133	50	0.653	2.1452	2.1390	2.2443	2.00E-04	1.2329	0.9559
0.0908	0.7	1.335	1.342	0.007	0.361	24.25	24.25	2.024	50	0.653	2.0323	2.0282	2.2354	1.40E-04	1.1680	0.9092
0.0908	0.7	1.342	1.353	0.011	0.368	22.99	22.99	1.907	50	0.653	1.9190	1.9130	2.2294	2.20E-04	1.1029	0.8608
0.0908	0.7	1.353	1.371	0.018	0.379	22.4	22.4	1.839	50	0.653	1.8580	1.8486	2.2202	3.60E-04	1.0678	0.8369
0.0908	0.7	1.371	1.395	0.024	0.397	21.79	21.79	1.765	50	0.653	1.7890	1.7771	2.2061	4.80E-04	1.0282	0.8109
0.0908	0.7	1.395	1.399	0.004	0.421	21.34	21.34	1.725	50	0.653	1.7287	1.7268	2.1888	8.00E-05	0.9935	0.7898
0.0908	0.7	1.399	1.413	0.014	0.425	20.95	20.95	1.680	50	0.653	1.6933	1.6868	2.1860	2.80E-04	0.9732	0.7746
0.0908	0.7	1.413	1.424	0.011	0.439	20.64	20.64	1.645	50	0.653	1.6554	1.6504	2.1767	2.20E-04	0.9514	0.7605
0.0908	0.7	1.424	1.436	0.012	0.450	20.33	20.33	1.610	50	0.653	1.6207	1.6154	2.1698	2.40E-04	0.9314	0.7470
0.0908	0.7	1.436	1.439	0.003	0.462	20.21	20.21	1.598	50	0.653	1.6006	1.5993	2.1624	6.00E-05	0.9199	0.7402
0.0908	0.7	1.439	1.443	0.004	0.465	19.91	19.91	1.571	50	0.653	1.5743	1.5726	2.1606	8.00E-05	0.9048	0.7286
0.0908	0.7	1.443	1.450	0.007	0.469	19.74	19.74	1.552	100	0.653	1.5575	1.5545	2.1583	7.00E-05	0.8951	0.7216
0.0908	0.7	1.450	1.455	0.005	0.476	19.71	19.71	1.545	100	0.653	1.5492	1.5471	2.1542	5.00E-05	0.8904	0.7191
0.0908	0.7	1.455	1.458	0.003	0.481	19.39	19.39	1.518	200	0.653	1.5200	1.5187	2.1514	1.50E-05	0.8735	0.7065
0.0908	0.7	1.458	1.463	0.005	0.484	18.95	18.95	1.479	500	0.653	1.4831	1.4811	2.1497	1.00E-05	0.8523	0.6899
0.0908	0.7	1.463	1.468	0.005	0.489	18.43	18.43	1.435	500	0.653	1.4385	1.4366	2.1470	1.00E-05	0.8267	0.6700
0.0908	0.7	1.468	1.486	0.018	0.494	17.78	17.78	1.371	1000	0.653	1.3841	1.3775	2.1443	1.80E-05	0.7954	0.6455
0.0908	0.7	1.486	1.497	0.011	0.512	17.37	17.37	1.331	1000	0.653	1.3392	1.3354	2.1348	1.10E-05	0.7697	0.6273
0.0908	0.7	1.497	1.510	0.013	0.523	17.18	17.18	1.308	1000	0.653	1.3169	1.3124	2.1293	1.30E-05	0.7569	0.6185
0.0908	0.7	1.510	1.516	0.006	0.536	16.97	16.97	1.288	1000	0.653	1.2920	1.2900	2.1230	6.00E-06	0.7425	0.6085
0.0908	0.7	1.516	1.524	0.008	0.542	16.49	16.49	1.246	2000	0.653	1.2515	1.2489	2.1202	4.00E-06	0.7193	0.5903
0.0908	0.7	1.524	1.533	0.009	0.550	16.24	16.24	1.222	2000	0.653	1.2274	1.2246	2.1165	4.50E-06	0.7054	0.5799
0.0908	0.7	1.533	1.552	0.019	0.559	15.78	15.78	1.176	5000	0.653	1.1871	1.1813	2.1125	3.80E-06	0.6822	0.5619
0.0908	0.7	1.552	1.566	0.014	0.578	15.44	15.44	1.142	5000	0.653	1.1502	1.1461	2.1043	2.80E-06	0.6610	0.5466
0.0908	0.7	1.566	1.582	0.016	0.592	15.16	15.16	1.112	5000	0.653	1.1213	1.1168	2.0985	3.20E-06	0.6444	0.5343
0.0908	0.7	1.582	1.589	0.007	0.608	14.89	14.89	1.089	5000	0.653	1.0925	1.0905	2.0922	1.40E-06	0.6279	0.5222
0.0908	0.7	1.589	1.603	0.014	0.615	14.65	14.65	1.064	5000	0.653	1.0711	1.0673	2.0895	2.80E-06	0.6156	0.5126
0.0908	0.7	1.603	1.611	0.008	0.629	14.47	14.47	1.046	5000	0.653	1.0505	1.0484	2.0842	1.60E-06	0.6038	0.5040
0.0908	0.7	1.611	1.623	0.012	0.637	14.82	14.82	1.065	10000	0.653	1.0717	1.0685	2.0813	1.20E-06	0.6159	0.5149
0.0908	0.7	1.623	1.630	0.007	0.649	14.52	14.52	1.040	10000	0.653	1.0437	1.0419	2.0771	7.00E-07	0.5999	0.5025
0.0908	0.7	1.630	1.645	0.015	0.656	13.98	13.98	0.994	20000	0.653	1.0015	0.9978	2.0746	7.50E-07	0.5756	0.4827

Table A-18. Constant Displacement Amplitude Fatigue Test Data for T800H Carbon/3900-2 Epoxy Composite (Specimen UCE206) (Continued)

δ_{cr} = 0.13897 Δ = 0.4013

b = 0.94 G_{IC} = 1.74 Test Frequency = 5Hz a_o = 0.974

δ_{max}	f	a_i	a_f	da, in.	da(Tot)	P_i	P_f	G_f	dN, cy	d_{max}/d_{cr}	G_{Imax}	G_{av}	G_{IR}	da/dN	$G_{Imax}/(G_{IR})_{Asym}$	G_{Imax}/G_{IR}
0.0908	0.7	1.645	1.660	0.015	0.671	13.75	13.75	0.971	20000	0.653	0.9778	0.9742	2.0696	7.50E-07	0.5619	0.4724
0.0908	0.7	1.660	1.674	0.014	0.686	13.43	13.43	0.942	20000	0.653	0.9481	0.9449	2.0647	7.00E-07	0.5449	0.4592
0.0908	0.7	1.674	1.690	0.016	0.700	13.47	13.47	0.937	20000	0.653	0.9445	0.9409	2.0603	8.00E-07	0.5428	0.4584
0.0908	0.7	1.690	1.703	0.013	0.716	13.14	13.14	0.909	20000	0.653	0.9143	0.9115	2.0554	6.50E-07	0.5254	0.4448
0.0908	0.7	1.703	1.707	0.004	0.729	13.18	13.18	0.910	20000	0.653	0.9114	0.9105	2.0516	2.00E-07	0.5238	0.4442
0.0908	0.7	1.707	1.715	0.008	0.733	12.99	12.99	0.893	20000	0.653	0.8966	0.8949	2.0505	4.00E-07	0.5153	0.4372

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
0	0	11.101	0.217	0.019573011	0.269496141	2.519787835	1.311073153	0.753490318	0.000178083
1	1.00244	11.082	0.217	0.019576791	0.269513487	2.519966352	1.306748778	0.751005045	0.000568844
2	2.00488	11.067	0.217	0.019588868	0.269568895	2.520536584	1.3037226	0.749265862	0.001118839
3	3.00732	11.049	0.217	0.019612635	0.269677872	2.521658153	1.300483114	0.747404089	0.000821634
4	4.00976	11.03	0.217	0.0196301	0.269757898	2.522481792	1.296744859	0.745255666	-0.001265263
5	4.9721024	11.018	0.216	0.019604284	0.269639592	2.521264176	1.292847233	0.743015651	0.000271296
6	5.9745424	11.027	0.216	0.019610048	0.269666016	2.521536134	1.295201252	0.744368535	0.000229808
7	6.9769824	11.037	0.216	0.019614932	0.2696884	2.521766503	1.29775603	0.745836799	-0.000614166
8	7.9794224	11.052	0.217	0.019601882	0.269628579	2.521150838	1.300737729	0.747550419	0.00101707
9	8.9818624	11.049	0.217	0.019623495	0.269727642	2.522170389	1.300939005	0.747666095	0.00055337
10	9.9843024	11.049	0.217	0.019635261	0.269781538	2.522725109	1.301432783	0.747949875	0.000181616
15	14.9965024	11.03	0.217	0.019654578	0.26986998	2.523635405	1.297768385	0.7458439	0.000224452
20	18.0038224	10.994	0.216	0.01966891	0.26993556	2.524310406	1.289905967	0.741325269	-9.76103E-06
25	21.9734848	11.027	0.217	0.019668087	0.269931795	2.524271658	1.297626877	0.745762573	0.000175659
30	26.9856848	11.015	0.217	0.019686791	0.270017332	2.525152098	1.295583564	0.744588255	1.93603E-05
35	31.9577872	10.991	0.216	0.019688836	0.270026684	2.52524836	1.290028814	0.74139587	8.22903E-05
40	36.9699872	11.012	0.217	0.019697603	0.270066754	2.525660815	1.295328124	0.744441451	0.000196576
45	41.9821872	10.979	0.216	0.019718554	0.27016247	2.526646091	1.288443134	0.74048456	0.000130534
50	46.9542896	10.985	0.217	0.019732362	0.270225519	2.52729512	1.290423576	0.741622745	1.36977E-06
55	51.9664896	10.991	0.217	0.019732508	0.270226186	2.527301985	1.291839674	0.742436594	-2.50965E-05
60	56.938592	10.957	0.216	0.019729853	0.270214065	2.527177203	1.283750197	0.737787469	0.000100992
65	61.950792	10.988	0.217	0.019740626	0.270263237	2.527683394	1.291470808	0.742224602	0.000266143
70	66.962992	10.954	0.217	0.019769034	0.270392817	2.529017353	1.284659875	0.738310273	5.22844E-05
75	71.9350944	10.957	0.217	0.019774573	0.270418069	2.529277316	1.285591641	0.738845771	5.29547E-05
80	76.9472944	10.966	0.217	0.01978023	0.270443851	2.529542736	1.28793765	0.740194052	0.000184184
85	80.9570544	10.93	0.216	0.019795974	0.270515587	2.53028127	1.280139948	0.735712614	-0.000254611
90	83.9242768	10.948	0.217	0.019779868	0.270442204	2.529525783	1.283698136	0.737757549	0.000138881
95	88.9364768	10.96	0.217	0.019794708	0.270509819	2.530221883	1.287124762	0.739726875	-3.51737E-05
100	93.9085792	10.908	0.216	0.019790979	0.270492831	2.530046995	1.274788082	0.732636829	0.000197567
110	102.9305392	10.936	0.217	0.019829005	0.270665961	2.53182944	1.282899177	0.737298378	5.57643E-05
120	112.9148416	10.936	0.217	0.019840892	0.270720037	2.532386208	1.28338604	0.737578184	6.72386E-05
130	122.899144	10.914	0.217	0.019855232	0.27078524	2.533057539	1.278812433	0.734949674	9.66834E-05
140	132.8834464	10.875	0.216	0.019875862	0.270878992	2.534022856	1.270524435	0.730186457	6.94795E-05
150	142.9078464	10.893	0.217	0.019890756	0.270946634	2.534719346	1.275338445	0.732953129	7.39897E-05
160	149.8848288	10.896	0.217	0.019901799	0.270996768	2.535235571	1.276489497	0.733614653	3.77311E-05
170	159.8691312	10.872	0.216	0.01990986	0.271033352	2.535612289	1.271198273	0.73057372	7.59986E-05
180	169.8534336	10.826	0.216	0.019926104	0.271107041	2.536371083	1.261114983	0.724778726	6.57183E-05
190	179.8778336	10.872	0.217	0.019940213	0.271171015	2.537029869	1.272424882	0.731278668	1.29741E-05
200	189.862136	10.875	0.217	0.019942989	0.271183595	2.537159406	1.273239373	0.731746766	0.000188827

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
210	199.8464384	10.847	0.217	0.019983406	0.271366667	2.539044711	1.26831602	0.728917253	8.09439E-05
220	208.8683984	10.811	0.216	0.019999075	0.271437577	2.539774984	1.260536562	0.7244463	-3.82479E-05
230	217.8502608	10.847	0.217	0.019991703	0.27140422	2.539431447	1.268649397	0.729108849	6.4549E-05
240	227.8345632	10.841	0.217	0.020005535	0.271466798	2.540075924	1.267801307	0.728621441	5.17648E-05
250	237.8188656	10.823	0.217	0.020016631	0.271516981	2.540592759	1.264038476	0.726458894	8.2358E-05
260	247.803168	10.789	0.216	0.020034294	0.271596821	2.541415047	1.256810731	0.722305018	9.43598E-05
270	257.827568	10.801	0.217	0.020054625	0.27168866	2.542360947	1.26041715	0.724377672	1.69244E-05
280	267.8118704	10.814	0.217	0.020058258	0.271705066	2.542529925	1.263597944	0.726205715	5.03194E-05
290	274.7888528	10.789	0.216	0.020065808	0.271739152	2.542881003	1.258061988	0.723024131	4.87549E-05
300	284.7731552	10.75	0.216	0.020076279	0.271786413	2.543367787	1.249395767	0.718043544	8.04743E-05
310	294.7975552	10.786	0.217	0.02009364	0.271864732	2.544174493	1.258466319	0.723256505	1.26911E-05
320	304.7818576	10.792	0.217	0.020096368	0.271877034	2.544301205	1.259975098	0.724123619	9.1251E-05
330	314.76616	10.777	0.217	0.020115988	0.271965483	2.545212282	1.257251499	0.722558333	1.00043E-05
340	324.7504624	10.75	0.216	0.02011814	0.271975179	2.545312168	1.251044434	0.718991054	9.47343E-05
350	334.7748624	10.75	0.216	0.020138605	0.27206737	2.546261822	1.25184999	0.719454018	-3.88376E-05
360	341.7518448	10.771	0.217	0.020132764	0.272041065	2.545990853	1.256514942	0.722135024	6.60325E-05
370	351.7361472	10.75	0.217	0.020146977	0.272105067	2.546650141	1.25217945	0.719643362	4.55049E-05
380	361.7204496	10.716	0.216	0.020156775	0.272149171	2.547104476	1.244654293	0.715318559	8.0177E-05
390	371.7448496	10.74	0.217	0.020174115	0.27222719	2.547908202	1.250916532	0.718917547	-9.38636E-06
400	381.729152	10.75	0.217	0.020172093	0.272218093	2.547814485	1.253167527	0.720211222	7.41903E-05
410	391.7134544	10.74	0.217	0.020188082	0.272289996	2.548555223	1.251464738	0.719232608	2.70679E-05
420	400.6953168	10.707	0.216	0.020193331	0.272313596	2.548798344	1.243990739	0.714937207	7.51909E-05
430	409.7172768	10.722	0.217	0.020207984	0.272379443	2.549476713	1.248051714	0.7172711	3.83488E-05
440	419.7015792	10.728	0.217	0.020216257	0.272416607	2.549859599	1.249772734	0.718260192	7.9257E-05
450	429.6858816	10.713	0.217	0.020233361	0.272493415	2.550650925	1.246947776	0.716636653	-3.74601E-05
460	439.670184	10.698	0.216	0.020225276	0.272457113	2.550276912	1.243143729	0.714450419	0.000143616
470	449.694584	10.686	0.216	0.02025641	0.272596847	2.551716576	1.24156492	0.713543058	2.4289E-05
480	459.6788864	10.701	0.217	0.020261658	0.272620384	2.551959085	1.245257142	0.715665024	-3.24736E-05
490	467.6583088	10.701	0.217	0.020256051	0.272595235	2.551699964	1.245038964	0.715539634	1.11109E-05
500	477.6426112	10.679	0.216	0.020258451	0.272606002	2.551810899	1.240017939	0.712653988	9.09911E-05
510	487.6670112	10.676	0.216	0.020278194	0.272694529	2.55272303	1.240085853	0.712693019	2.83569E-05
520	497.6513136	10.692	0.217	0.020284325	0.272722007	2.553006155	1.244043702	0.714967645	-3.92941E-05
530	507.635616	10.695	0.217	0.02027583	0.272683931	2.55261383	1.24441186	0.71517923	3.6564E-05
540	517.6199184	10.679	0.217	0.020283734	0.272719362	2.552978896	1.240997505	0.713216957	0.000143417
550	526.6418784	10.649	0.216	0.020311766	0.272844936	2.554272795	1.235114194	0.709835744	3.5032E-07
560	534.6213008	10.679	0.217	0.020311827	0.272845207	2.55427559	1.242085386	0.713842176	8.10058E-07
570	544.6056032	10.673	0.217	0.020312002	0.272845992	2.554283678	1.240696825	0.713044152	1.5856E-05

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
600	574.598608	10.658	0.217	0.020340589	0.272973933	2.555602023	1.238313998	0.711674711	-2.72985E-05
610	584.5829104	10.667	0.217	0.020334677	0.272947483	2.555329467	1.240177964	0.712745956	5.43336E-05
620	592.5623328	10.637	0.216	0.020344082	0.272989556	2.555763018	1.233573066	0.708950038	1.34089E-05
630	601.5842928	10.643	0.217	0.020346707	0.273001296	2.555883993	1.235065972	0.70980803	5.06408E-05
640	611.5685952	10.652	0.217	0.020357679	0.273050362	2.556389606	1.237578014	0.711251732	5.2934E-05
650	621.5528976	10.646	0.217	0.020369153	0.273101648	2.556918115	1.236625257	0.710704171	5.12778E-05
660	631.5372	10.624	0.217	0.020380271	0.27315133	2.557430088	1.231945099	0.708014425	6.74344E-05
670	641.5215024	10.585	0.216	0.020394898	0.273216663	2.558103373	1.223472538	0.703145137	2.35905E-05
680	651.5459024	10.624	0.217	0.020400038	0.27323961	2.558339854	1.232701433	0.708449099	-2.86411E-05
690	659.5253248	10.631	0.217	0.020395071	0.273217433	2.558111315	1.234136122	0.709273633	-2.8159E-05
700	669.5096272	10.618	0.216	0.020388962	0.273190152	2.557830167	1.230886194	0.707405859	0.000107875
710	679.4939296	10.573	0.216	0.020412371	0.273294664	2.558907226	1.221362057	0.701932216	2.27686E-05
720	689.5183296	10.615	0.217	0.020417334	0.273316811	2.559135467	1.231274252	0.707628881	-3.70257E-05
730	699.502632	10.628	0.217	0.020409296	0.27328094	2.558765791	1.233984283	0.70918637	0.000142845
740	709.4869344	10.606	0.217	0.020440317	0.273419325	2.560191996	1.230063061	0.706932794	-8.61622E-05
750	718.4687968	10.579	0.216	0.02042348	0.273344235	2.559418098	1.223169931	0.702971225	7.88749E-05
760	726.4883168	10.612	0.217	0.020437241	0.27340561	2.560050637	1.231337864	0.707665439	5.32097E-05
770	736.4726192	10.606	0.217	0.020448803	0.273457157	2.560581899	1.230386339	0.707118586	4.26175E-05
780	746.4569216	10.588	0.217	0.020458066	0.273498442	2.561007405	1.226565217	0.704922539	-4.29231E-05
790	756.441224	10.563	0.216	0.020448736	0.273456861	2.560578848	1.220427321	0.701395012	6.87126E-05
800	766.465624	10.588	0.217	0.020463733	0.273523692	2.561267651	1.226780307	0.705046153	1.49405E-05
810	776.4499264	10.6	0.217	0.020466981	0.273538165	2.561416821	1.229686221	0.706716219	9.30679E-05
820	783.4670064	10.536	0.216	0.020481207	0.273601527	2.562069886	1.21541656	0.698515264	1.58254E-06
830	793.4513088	10.57	0.216	0.020481552	0.27360306	2.562085687	1.223286609	0.703038281	-3.7632E-06
840	803.4356112	10.588	0.217	0.020480733	0.273599415	2.562048114	1.227425445	0.705416922	3.97063E-05
850	813.4199136	10.585	0.217	0.020489372	0.273637878	2.562444554	1.227057556	0.705205492	4.16659E-05
860	823.404216	10.573	0.217	0.020498439	0.273678239	2.562860559	1.224619949	0.703804568	2.41646E-05
870	833.3885184	10.542	0.216	0.020503699	0.273701646	2.563101826	1.217647092	0.699797179	3.93926E-05
880	843.4129184	10.56	0.217	0.020512311	0.273739957	2.563496713	1.222133644	0.702375657	-1.53209E-05
890	851.3923408	10.576	0.217	0.020509644	0.273728097	2.563374462	1.225739008	0.704447706	2.52904E-05
900	861.3766432	10.56	0.217	0.020515152	0.273752594	2.563626968	1.222240802	0.702437243	1.7042E-06
910	871.3609456	10.533	0.216	0.020515523	0.273754245	2.563643984	1.216012625	0.69885783	5.16349E-05
920	881.3853456	10.554	0.217	0.020526814	0.273804461	2.564161593	1.221291657	0.701891757	-2.53767E-05
930	891.369648	10.57	0.217	0.020521287	0.27377988	2.563908224	1.224788586	0.703901486	2.33162E-05
940	901.3539504	10.563	0.217	0.020526366	0.273802465	2.564141021	1.223358539	0.70307962	0.000137791
950	909.3734704	10.518	0.216	0.020550485	0.273909666	2.565246041	1.213859508	0.697620407	-3.29455E-05
960	918.3553328	10.551	0.217	0.020544024	0.273880959	2.564950129	1.22124524	0.701865081	-1.41855E-06
970	928.3396352	10.557	0.217	0.020543715	0.273879585	2.564935966	1.222622948	0.702656866	2.82233E-05
980	938.3239376	10.548	0.217	0.020549867	0.273906922	2.565217756	1.220770625	0.701592313	5.58918E-05

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
990	948.30824	10.515	0.216	0.020562054	0.273961057	2.565775797	1.213599514	0.697470985	5.34632E-05
1000	958.33264	10.527	0.217	0.020573763	0.274013047	2.566311733	1.216809543	0.699315829	1.70794E-05
1100	1052.241219	10.512	0.217	0.020608828	0.274168632	2.567915632	1.214653183	0.698076542	2.19273E-05
1200	1150.199656	10.475	0.216	0.020655847	0.27437698	2.570063599	1.20785903	0.694171856	1.66016E-05
1300	1244.108235	10.478	0.217	0.020690017	0.274528192	2.571622632	1.209816336	0.695296745	2.53082E-05
1400	1342.026574	10.411	0.216	0.020744405	0.274768532	2.574100765	1.196380636	0.687575078	1.32047E-05
1500	1436.977691	10.441	0.217	0.020771957	0.274890123	2.575354568	1.204297028	0.692124729	2.03067E-05
1600	1534.89603	10.396	0.216	0.020815698	0.275082943	2.577342965	1.195529667	0.687086016	1.49874E-05
1700	1628.844707	10.405	0.217	0.020846708	0.275219476	2.578751008	1.198729774	0.688925157	1.97166E-05
1800	1726.763046	10.368	0.217	0.020889275	0.27540667	2.580681624	1.191757662	0.684918196	1.10368E-05
1900	1820.711723	10.371	0.217	0.020912159	0.275507202	2.581718518	1.193274316	0.685789837	2.42509E-05
2000	1917.627622	10.331	0.217	0.020964089	0.275735063	2.584068818	1.185948089	0.681579362	5.47353E-06
2100	2013.581179	10.331	0.217	0.020975704	0.275785979	2.584594022	1.18636406	0.681818425	8.39427E-06
2200	2110.497078	10.325	0.217	0.020993705	0.275864846	2.585407561	1.185630143	0.681396634	1.75794E-05
2300	2205.448195	10.304	0.217	0.021030668	0.276026654	2.587076745	1.18212797	0.679383891	5.28125E-06
2400	2302.364094	10.307	0.217	0.02104201	0.276076268	2.587588583	1.183220263	0.680011646	2.03403E-05
2500	2398.277554	10.237	0.216	0.021085279	0.27626537	2.589539488	1.168722116	0.671679377	4.07047E-06
2600	2495.23355	10.283	0.217	0.021094039	0.276303623	2.589934145	1.179559175	0.677907572	1.14493E-05
2700	2590.14457	10.231	0.216	0.02111817	0.276408947	2.591020808	1.168505067	0.671554636	1.56847E-05
2800	2687.100566	10.252	0.217	0.02115197	0.276556334	2.592541532	1.174495469	0.674997396	1.1383E-06
2900	2782.011586	10.222	0.216	0.021154373	0.276566805	2.592649569	1.167715738	0.671100999	1.34147E-05
3000	2878.967582	10.234	0.217	0.021183311	0.276692855	2.593950207	1.171472416	0.673260009	1.06414E-05
3100	2973.878602	10.209	0.216	0.021205799	0.276790733	2.594960194	1.166539337	0.670424906	8.40837E-06
3200	3071.837038	10.203	0.217	0.02122415	0.276870552	2.595783865	1.165806816	0.670003918	2.80968E-06
3300	3165.745618	10.203	0.217	0.02123003	0.276896121	2.596047717	1.166011308	0.670121441	1.36406E-05
3400	3263.704054	10.176	0.216	0.021259827	0.277025603	2.597383927	1.160878637	0.66717163	6.07448E-06
3500	3358.615074	10.191	0.217	0.021272692	0.277081469	2.597960462	1.164749557	0.669396297	5.32819E-06
3600	3455.57107	10.154	0.216	0.021284223	0.277131526	2.598477062	1.156704099	0.664772471	1.13817E-07
3700	3551.48453	10.191	0.217	0.021284467	0.277132584	2.598487979	1.165157696	0.66963086	1.96327E-05
3800	3647.438086	10.124	0.216	0.021326551	0.277315114	2.600371811	1.151326467	0.661681878	1.22332E-06
3900	3744.353986	10.164	0.217	0.021329201	0.277326602	2.60049037	1.160533539	0.666973298	1.26093E-05
4000	3839.265005	10.133	0.216	0.021355966	0.277442552	2.601687127	1.154381279	0.663437517	2.33384E-06
4100	3937.223442	10.139	0.217	0.021361081	0.277464702	2.601915747	1.155924016	0.664324147	-7.71732E-06
4200	4032.134461	10.151	0.217	0.021344695	0.277393737	2.601183289	1.158099036	0.665574159	1.8711E-05
4300	4130.0528	10.096	0.216	0.021385697	0.277571244	2.603015444	1.14697618	0.659181713	-6.37277E-07
4400	4225.003917	10.142	0.217	0.021384342	0.277565382	2.602954933	1.157405405	0.66517552	1.30748E-05
4500	4322.922256	10.106	0.216	0.021413022	0.277689412	2.604235192	1.150178886	0.661022348	-3.1947E-06
4600	4416.870933	10.133	0.217	0.021406296	0.277660335	2.603935054	1.15610296	0.664426988	1.27254E-05
4700	4514.789272	10.103	0.217	0.021434227	0.277781048	2.605181108	1.15021669	0.661044075	3.93914E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
4800	4609.740389	10.118	0.217	0.021435066	0.277784671	2.60521851	1.153663277	0.663024872	7.61879E-06
4900	4706.656288	10.099	0.217	0.021451629	0.2778562	2.605956892	1.149896722	0.660860185	2.80878E-06
5000	4800.604965	10.106	0.217	0.02145755	0.277881762	2.606220774	1.151692563	0.661892278	2.71272E-06
5100	4898.523304	10.099	0.217	0.021463511	0.277907493	2.606486399	1.150299936	0.661091917	1.53917E-05
5200	4993.474421	10.078	0.217	0.021496329	0.27804906	2.607947858	1.14662958	0.658982517	9.5673E-06
5300	5090.39032	10.078	0.217	0.021517166	0.278138873	2.608875081	1.147333145	0.659386865	1.3365E-06
5400	5186.303779	10.026	0.216	0.021520048	0.27815129	2.609003269	1.135620058	0.652655206	5.92379E-06
5500	5283.259776	10.072	0.217	0.021532963	0.278206921	2.609577616	1.146499969	0.658908028	1.02238E-05
5600	5379.173235	10.032	0.216	0.021555024	0.278301899	2.61055822	1.138149252	0.654108765	-3.80628E-06
5700	5476.129232	10.06	0.217	0.02154672	0.278266155	2.610189178	1.144232246	0.657604739	1.09715E-05
5800	5572.042691	10.042	0.217	0.021570404	0.278368076	2.611241489	1.140934535	0.655709503	7.44402E-06
5900	5670.001128	10.02	0.216	0.021586826	0.278438701	2.611970693	1.136488343	0.65315422	4.80969E-07
6000	5764.912147	10.045	0.217	0.021587855	0.278443122	2.612016343	1.142200963	0.656437335	5.83123E-06
6100	5862.830486	10.008	0.216	0.021600719	0.278498422	2.612587327	1.134229758	0.651856183	1.4499E-05
6200	5957.781603	10.026	0.217	0.021631757	0.278631749	2.613964019	1.139348654	0.654798077	4.04275E-06
6300	6055.699942	10.008	0.217	0.021640687	0.278670086	2.614359879	1.135557997	0.652619539	2.1078E-06
6400	6150.651059	10.017	0.217	0.021645203	0.278689467	2.614560017	1.137751568	0.653880211	4.29015E-06
6500	6248.569398	10.014	0.217	0.021654683	0.278730149	2.614980101	1.137385453	0.6536698	3.95771E-06
6600	6343.520515	9.999	0.217	0.021663166	0.27876654	2.61535589	1.134261837	0.651874619	6.32951E-06
6700	6441.438854	10.005	0.217	0.021677161	0.278826558	2.615975665	1.13608792	0.652924092	1.27169E-06
6800	6536.349874	9.959	0.216	0.021679888	0.278838246	2.616096362	1.125754773	0.646985502	3.51919E-06
6900	6634.30831	9.996	0.217	0.021687675	0.278871628	2.616441096	1.134393097	0.651950056	1.1804E-05
7000	6729.21933	9.965	0.216	0.021712995	0.278980114	2.617561427	1.128201077	0.648391424	6.15426E-06
7100	6826.175326	9.974	0.217	0.021726489	0.279037892	2.618158119	1.130684524	0.649818692	7.65563E-06
7200	6922.088786	9.965	0.217	0.021743101	0.279108991	2.618892398	1.129191176	0.648960446	5.31947E-06
7300	7019.044782	9.95	0.216	0.021754774	0.27915893	2.619408152	1.126176872	0.647228087	-2.8459E-06
7400	7114.958242	9.968	0.217	0.021748596	0.2791325	2.619135192	1.130051934	0.649455134	2.39215E-05
7500	7210.911798	9.919	0.216	0.021800585	0.279354742	2.621430546	1.120661911	0.644058569	-3.01146E-06
7600	7307.827698	9.95	0.217	0.02179397	0.279326484	2.621138688	1.127461059	0.647966126	1.18876E-05
7700	7402.778814	9.898	0.216	0.02181956	0.279435766	2.62226743	1.116536542	0.641687668	3.7907E-06
7800	7500.697154	9.929	0.217	0.021827979	0.279471702	2.622638609	1.123815805	0.645871152	6.5229E-06
7900	7595.608173	9.913	0.217	0.021842026	0.279531639	2.623257704	1.120653139	0.644053528	3.22577E-06
8000	7693.56661	9.907	0.216	0.021849198	0.279562231	2.623573696	1.119529633	0.643407835	-2.57849E-06
8100	7788.477629	9.926	0.217	0.021843643	0.279538538	2.623328969	1.123647009	0.645774143	7.9065E-06
8200	7886.395968	9.886	0.216	0.021861218	0.279613488	2.62410316	1.115176746	0.640906176	-1.26237E-06
8300	7981.347085	9.922	0.217	0.021858496	0.279601884	2.623983297	1.123224856	0.645531526	9.09685E-06
8400	8079.265424	9.895	0.216	0.021878727	0.279688116	2.624874045	1.117774543	0.642399163	4.82471E-06
8500	8174.216541	9.904	0.217	0.021889136	0.279732464	2.625332156	1.120146079	0.643762115	-4.34022E-06
8600	8272.13488	9.907	0.217	0.021879479	0.279691323	2.624907169	1.120511713	0.643972249	4.08925E-06

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
8700	8368.088437	9.892	0.217	0.021888395	0.279729308	2.625299547	1.117409364	0.64218929	1.04863E-05
8800	8465.004336	9.898	0.217	0.021911497	0.279827689	2.62631584	1.119512753	0.643398134	9.01291E-06
8900	8560.917795	9.849	0.216	0.021931161	0.279911369	2.6271803	1.109085568	0.637405499	-1.19276E-05
9000	8657.873792	9.901	0.217	0.021904858	0.279799423	2.626023849	1.119976585	0.643664704	8.00739E-06
9100	8752.784811	9.864	0.216	0.021922141	0.279872991	2.626783839	1.112176732	0.63918203	5.85649E-06
9200	8849.740808	9.886	0.217	0.02193506	0.279927956	2.627351661	1.117560058	0.642275895	1.20698E-07
9300	8944.651827	9.864	0.216	0.02193532	0.279929065	2.627363116	1.112599996	0.639425285	1.60758E-05
9400	9042.610264	9.852	0.216	0.021971173	0.280081496	2.628937879	1.11104277	0.638530327	2.97568E-07
9500	9137.521283	9.864	0.217	0.021971817	0.280084229	2.628966121	1.113771625	0.640098635	1.04401E-05
9600	9235.439622	9.819	0.216	0.021995112	0.280183177	2.629988402	1.104373302	0.6346973	-6.54856E-06
9700	9330.390739	9.864	0.217	0.021980941	0.280122994	2.629366609	1.11406442	0.640266908	1.52825E-05
9800	9428.309078	9.831	0.216	0.022015054	0.280267832	2.630863042	1.107709702	0.636614771	8.28815E-07
9900	9523.260195	9.852	0.217	0.022016849	0.280275449	2.630941739	1.112504537	0.639370423	-2.17834E-06
10000	9621.178534	9.846	0.217	0.022011985	0.280254804	2.63072844	1.110994443	0.638502554	4.89368E-06
11000	10584.48328	9.761	0.216	0.02211966	0.280711032	2.635442548	1.095273452	0.629467501	4.06337E-06
12000	11545.82324	9.764	0.217	0.022209136	0.281089023	2.639348825	1.098751421	0.631466334	4.80542E-06
13000	12509.12798	9.7	0.216	0.022315464	0.281536889	2.643977908	1.087678666	0.625102682	2.92218E-06
14000	13471.47038	9.684	0.217	0.022380215	0.281808929	2.646790048	1.086083868	0.624186131	2.43204E-06
15000	14435.77756	9.666	0.217	0.022434306	0.282035783	2.649135283	1.083705118	0.622819033	6.0901E-07
16000	15398.07986	9.633	0.216	0.022447836	0.282092468	2.649721335	1.07672906	0.618809805	2.94678E-06
17000	16362.42714	9.62	0.217	0.022513514	0.282367316	2.652563056	1.075812903	0.618283278	2.59819E-06
18000	17323.72701	9.602	0.217	0.022571339	0.282608862	2.655060692	1.073532814	0.616972881	5.87019E-06
19000	18286.06941	9.532	0.216	0.022702476	0.283155113	2.660709826	1.061824693	0.610244076	5.09626E-06
20000	19248.37171	9.504	0.217	0.022816709	0.283629239	2.665613967	1.058955336	0.608595021	2.20729E-06
21000	20211.67645	9.465	0.216	0.02286635	0.283834782	2.667740261	1.051728345	0.604441578	2.47971E-06
22000	21173.01641	9.459	0.217	0.022922085	0.284065204	2.670124108	1.052015556	0.604606641	2.3144E-06
23000	22135.31871	9.431	0.217	0.022974234	0.284280462	2.67235126	1.047302235	0.601897836	2.84264E-06
24000	23095.65623	9.41	0.217	0.023038257	0.284544289	2.675081152	1.04448198	0.600277	9.18242E-07
25000	24055.95366	9.379	0.216	0.023058962	0.284629503	2.675962937	1.038201773	0.596667686	2.3681E-06
26000	25016.29118	9.385	0.217	0.023112413	0.284849262	2.678237108	1.041055475	0.598307744	2.55087E-07
27000	25978.59348	9.358	0.216	0.023118188	0.284872982	2.67848258	1.035237712	0.594964202	9.99111E-07
28000	26940.93588	9.367	0.217	0.023140813	0.284965887	2.679444066	1.037872515	0.596478457	2.30014E-06
29000	27900.23086	9.321	0.216	0.02319279	0.285179083	2.681650579	1.029164687	0.591473958	1.6669E-06
30000	28859.56594	9.336	0.217	0.023230506	0.285333581	2.683249691	1.033542414	0.593989893	2.01859E-06
31000	29820.9059	9.297	0.216	0.023276326	0.285521056	2.685190245	1.026204869	0.589772913	1.00053E-07
32000	30783.2082	9.318	0.217	0.023278601	0.285530358	2.685286526	1.030909857	0.592476929	1.9001E-06
33000	31745.51051	9.272	0.216	0.023321829	0.285706993	2.687114995	1.021956117	0.587331101	-1.52538E-06
34000	32706.85047	9.312	0.217	0.023287156	0.285565335	2.685648586	1.029822207	0.591851843	-1.94172E-06
35000	33668.15033	9.306	0.216	0.023243069	0.28538501	2.683782012	1.027262357	0.590380665	1.69705E-06

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
36000	34632.49761	9.3	0.217	0.02328172	0.285543113	2.685418561	1.027017928	0.590240188	8.52229E-07
37000	35591.79259	9.291	0.216	0.023301044	0.28562209	2.6862361	1.025569658	0.589407849	9.57668E-07
38000	36556.09977	9.251	0.216	0.023322884	0.2857113	2.687159586	1.017361267	0.584690384	6.0197E-07
39000	37516.43729	9.291	0.217	0.023336562	0.285767143	2.687737681	1.026559117	0.589976504	1.52449E-06
40000	38482.74936	9.272	0.217	0.023371441	0.285909441	2.689210814	1.02333194	0.588121805	9.96368E-07
41000	39442.08444	9.272	0.217	0.02339409	0.286001768	2.690166664	1.023959677	0.588482573	5.33572E-07
42000	40402.38186	9.236	0.216	0.023406236	0.286051258	2.690679052	1.016357703	0.584113623	1.79782E-06
43000	41362.71938	9.251	0.217	0.023447195	0.286218014	2.69240557	1.020790969	0.586661476	1.5971E-06
44000	42326.02412	9.22	0.217	0.023483731	0.286366602	2.693944064	1.014961128	0.583310993	1.29291E-06
45000	43290.3714	9.202	0.216	0.023513367	0.286487013	2.695190874	1.011809588	0.581499763	5.09809E-07
46000	44255.68102	9.214	0.217	0.023525071	0.286534538	2.695682998	1.014769896	0.583201089	1.21114E-06
47000	45215.0161	9.162	0.216	0.023552718	0.286646741	2.696844889	1.004094708	0.577065924	8.18132E-08
48000	46176.31596	9.205	0.217	0.02355459	0.286654336	2.696923536	1.013592862	0.582524634	2.43301E-07
49000	47139.62071	9.199	0.217	0.02356017	0.286676969	2.69715791	1.01242374	0.581852724	1.73168E-06
50000	48100.96067	9.181	0.217	0.023599826	0.286837722	2.698822644	1.009539856	0.58019532	5.14097E-08
51000	49061.25809	9.178	0.217	0.023601002	0.286842489	2.698872013	1.008912052	0.579834513	8.15492E-07
52000	50023.60049	9.172	0.217	0.023619712	0.286918268	2.699656795	1.008098993	0.579367237	1.3002E-07
53000	50986.90523	9.181	0.217	0.023622699	0.286930362	2.699782044	1.010159219	0.580551275	1.32501E-06
54000	51948.20509	9.132	0.216	0.023653088	0.287053348	2.701055772	1.000219107	0.574838567	5.31088E-07
55000	52915.5196	9.126	0.216	0.023665352	0.28710295	2.7015695	0.999233055	0.574271871	6.30518E-07
56000	53873.85224	9.15	0.217	0.023679781	0.287161291	2.702173747	1.004883352	0.577519168	8.85659E-07
57000	54837.15698	9.105	0.216	0.023700165	0.287243662	2.703026906	0.995565735	0.572164215	4.64299E-07
58000	55802.5067	9.138	0.217	0.023710878	0.287286935	2.703475117	1.003082387	0.57648413	6.5958E-07
59000	56765.81144	9.141	0.217	0.023726069	0.287348278	2.704110493	1.004148224	0.57709668	1.38555E-06
60000	57728.11374	9.098	0.216	0.023757969	0.287476999	2.705443814	0.995569762	0.57216653	-3.09627E-08
61000	58688.45126	9.129	0.217	0.023757257	0.287474128	2.705414079	1.002346804	0.576061382	8.37308E-07
62000	59653.76089	9.114	0.217	0.023776607	0.287552157	2.70622234	0.999570671	0.574465903	1.91483E-06
63000	60617.10573	9.074	0.216	0.023820807	0.287730227	2.708066979	0.991981693	0.570104421	-2.37522E-07
64000	61579.40803	9.108	0.217	0.023815327	0.287708163	2.707838411	0.999283913	0.574301099	1.178E-06
65000	62541.71033	9.08	0.216	0.023842511	0.287817589	2.708972006	0.993866875	0.571187859	2.64368E-07
66000	63503.05029	9.089	0.217	0.023848608	0.287842121	2.709226153	0.995999294	0.572413387	8.49001E-07
67000	64464.35015	9.074	0.217	0.023868195	0.2879209	2.710042298	0.993230619	0.570822195	4.84795E-07
68000	65426.69255	9.071	0.217	0.023879396	0.287965932	2.710508837	0.992868851	0.570614282	1.19184E-07
69000	66392.00218	9.08	0.217	0.023882159	0.287977037	2.710623886	0.994912891	0.571789018	8.75952E-07
70000	67353.30204	9.056	0.216	0.023902385	0.288058313	2.711465939	0.990190964	0.569075267	1.74104E-06
71000	68318.61166	9.019	0.216	0.023942787	0.288220524	2.713146579	0.98316695	0.565038477	-8.45562E-08
72000	69279.95162	9.059	0.217	0.023940832	0.288212679	2.713065291	0.991855859	0.570032103	9.76283E-07
73000	70242.25392	9.025	0.216	0.023963435	0.288303351	2.714004771	0.985012923	0.566099381	6.23434E-07
74000	71204.59632	9.04	0.217	0.023977876	0.288361253	2.714604727	0.988666949	0.568199396	-9.11478E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
75000	72169.90595	9.053	0.217	0.023956699	0.288276337	2.713724869	0.990958015	0.5695161	2.76308E-06
76000	73131.20581	9.001	0.216	0.024020664	0.288532677	2.716381015	0.981261809	0.563943568	-2.97564E-07
77000	74095.55309	9.019	0.217	0.024013749	0.288504984	2.71609406	0.98501076	0.566098138	1.20632E-06
78000	75056.85295	9.016	0.217	0.024041704	0.288616893	2.717253692	0.985080908	0.566138453	1.21119E-06
79000	76018.19291	8.998	0.217	0.024069793	0.288729253	2.718418056	0.981877111	0.56429719	-4.90563E-07
80000	76977.48789	9.001	0.217	0.024058438	0.288683841	2.717947462	0.982238463	0.564504864	8.5295E-07
81000	77941.79508	8.967	0.216	0.024078287	0.288763211	2.718769968	0.97534106	0.560540839	-1.69159E-07
82000	78903.13504	9.01	0.217	0.024074362	0.288747519	2.718607348	0.984616078	0.565871309	8.70296E-07
83000	79866.43978	8.985	0.216	0.024094602	0.288828417	2.719445709	0.979680747	0.563034912	7.15863E-07
84000	80824.77242	8.995	0.217	0.024111173	0.288894614	2.720131744	0.982290124	0.564534554	4.44371E-07
85000	81788.07716	8.97	0.216	0.024121516	0.288935919	2.720559808	0.977102792	0.561553329	1.94074E-07
86000	82750.41956	8.982	0.217	0.02412603	0.28895394	2.720746574	0.979834925	0.56312352	7.1788E-07
87000	83712.72186	8.982	0.217	0.02414273	0.289020596	2.721437391	0.980264272	0.563370271	7.05558E-07
88000	84674.06182	8.961	0.216	0.024159134	0.289086041	2.722115672	0.976105559	0.560980206	1.37312E-06
89000	85631.39202	8.924	0.216	0.024190946	0.28921287	2.723430199	0.968868344	0.556820887	-6.23407E-07
90000	86593.69432	8.967	0.217	0.024176425	0.28915499	2.722830293	0.977855957	0.561986182	5.88795E-07
91000	87554.99419	8.952	0.217	0.024190125	0.2892096	2.723396301	0.974936797	0.560308504	-6.0252E-08
92000	88517.33659	8.955	0.217	0.024188721	0.289204006	2.723338318	0.975554508	0.56066351	1.20925E-07
93000	89476.63157	8.949	0.216	0.02419153	0.289215198	2.723454321	0.974319281	0.55995361	1.23634E-06
94000	90436.96909	8.952	0.217	0.024220286	0.289329748	2.724641627	0.975706213	0.560750697	7.47748E-07
95000	91398.26895	8.927	0.216	0.024237706	0.289399096	2.725360437	0.970705917	0.557876964	1.54329E-07
96000	92360.61135	8.943	0.217	0.024241306	0.289413424	2.725508955	0.974280268	0.559931189	-3.93489E-07
97000	93320.90877	8.934	0.216	0.024232147	0.289376969	2.725131088	0.97208767	0.558671075	7.42079E-07
98000	94282.24873	8.94	0.217	0.024249441	0.289445793	2.725844478	0.973833555	0.559674457	9.30981E-07
99000	95241.58381	8.897	0.216	0.024271103	0.289531955	2.726737601	0.965033489	0.554616948	-1.19524E-06
100000	96202.88368	8.946	0.217	0.024243237	0.289421109	2.725588614	0.974983209	0.560335177	1.33576E-07
105000	101008.4607	8.918	0.216	0.024258802	0.289483036	2.726230524	0.96928337	0.557059408	1.14152E-07
110000	105805.096	8.909	0.216	0.024272084	0.289535858	2.726778068	0.967663241	0.556128299	8.09214E-07
115000	110593.6717	8.891	0.217	0.024366213	0.289909655	2.730653052	0.966121569	0.555242281	6.8513E-07
120000	115381.2851	8.873	0.217	0.024446072	0.290226032	2.733933189	0.964209048	0.554143131	8.18959E-07
125000	120163.8862	8.836	0.217	0.024541648	0.290603767	2.737849944	0.958549481	0.550890506	5.06225E-07
130000	124942.5177	8.805	0.217	0.024600795	0.290837039	2.740269006	0.953287083	0.547866139	1.83393E-07
135000	129716.0969	8.775	0.216	0.024622222	0.290921454	2.741144449	0.947324172	0.544439179	3.90053E-07
140000	134486.7489	8.775	0.216	0.024667806	0.291100874	2.743005255	0.948434151	0.545077099	7.58249E-08
145000	139263.3354	8.784	0.217	0.024676685	0.291135795	2.743367439	0.950597207	0.546320234	5.182E-07
150000	144041.9669	8.76	0.217	0.024737443	0.291374541	2.745843724	0.946882838	0.544185539	1.66928E-07
155000	148826.5729	8.747	0.217	0.02475706	0.29145154	2.746642408	0.944548445	0.542843934	2.77111E-07
160000	153621.1633	8.75	0.217	0.024789714	0.291579625	2.747971043	0.945985587	0.543669878	3.59174E-07
165000	158412.7463	8.723	0.217	0.024832053	0.29174553	2.749692053	0.941172785	0.540903899	3.92442E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
170000	163203.3669	8.714	0.217	0.024878357	0.291926753	2.751572092	0.940340084	0.540425336	2.31563E-07
175000	167993.9475	8.696	0.217	0.024905704	0.292033679	2.752681413	0.937110867	0.538569464	3.18927E-07
180000	172788.5378	8.662	0.216	0.024943431	0.292181063	2.754210537	0.930688741	0.534878587	1.86287E-07
185000	177578.156	8.686	0.217	0.024965462	0.292267057	2.75510278	0.936376467	0.538147395	2.6735E-07
190000	182368.7366	8.641	0.216	0.024997107	0.292390494	2.756383544	0.927442838	0.533013125	-9.24691E-08
195000	187156.35	8.674	0.217	0.024986166	0.292347828	2.755940838	0.934281184	0.536943209	2.9081E-08
200000	191948.9755	8.662	0.216	0.02498961	0.29236126	2.756080213	0.931779228	0.535505303	1.60782E-07
205000	196739.5561	8.671	0.217	0.02500865	0.292435492	2.756850453	0.934166843	0.536877496	5.0817E-07
210000	201534.1464	8.631	0.216	0.025068938	0.292670293	2.759286922	0.926979956	0.532747101	1.65059E-07
215000	206326.7719	8.641	0.217	0.025088531	0.292746524	2.760077986	0.929588926	0.534246509	1.48866E-08
220000	211118.3549	8.638	0.217	0.025090299	0.292753397	2.760149316	0.928984992	0.533899421	7.28689E-08
225000	215907.9732	8.641	0.217	0.025098947	0.292787029	2.76049833	0.929833235	0.534386917	3.33219E-07
230000	220701.561	8.625	0.217	0.025138551	0.292940945	2.762095645	0.927318182	0.532941484	1.03924E-07
235000	225484.1622	8.616	0.217	0.025150882	0.292988837	2.762592671	0.925671282	0.53199499	2.6063E-07
240000	230265.7609	8.58	0.216	0.025181818	0.293108915	2.763838901	0.918666709	0.527969373	2.10687E-07
245000	235054.3767	8.604	0.217	0.025206881	0.293206122	2.764847802	0.924395284	0.531261657	3.19642E-07
250000	239839.9851	8.595	0.217	0.02524491	0.2933535	2.766377484	0.923343272	0.530657053	1.92984E-07
255000	244623.5887	8.586	0.217	0.025267878	0.293442439	2.767300641	0.921941234	0.529851284	2.07264E-07
260000	249402.1801	8.546	0.216	0.025292535	0.293537856	2.768291072	0.913935234	0.525250134	1.20642E-07
265000	254177.8043	8.57	0.217	0.025306884	0.293593359	2.768867214	0.919405805	0.528394141	6.14817E-07
270000	258954.4309	8.537	0.217	0.02538011	0.293876258	2.771803965	0.914009263	0.52529268	1.95162E-07
275000	263730.0149	8.528	0.217	0.025403377	0.293966033	2.772735977	0.9126124	0.524489885	5.6098E-07
280000	268506.6415	8.515	0.217	0.025470346	0.294224128	2.77541557	0.911349964	0.523764347	1.0477E-07
285000	273276.251	8.512	0.217	0.025482848	0.294272257	2.775915281	0.910990873	0.523557973	3.40645E-07
290000	278046.863	8.5	0.217	0.025523529	0.294428769	2.777540364	0.90934199	0.522610339	1.90087E-07
295000	282819.4798	8.485	0.217	0.025546258	0.294516139	2.778447577	0.906646159	0.521061011	3.31528E-07
300000	287593.059	8.448	0.216	0.025585938	0.294668545	2.780030153	0.899639847	0.517034395	4.99975E-08
305000	292361.7062	8.464	0.217	0.025591919	0.294691504	2.780268573	0.903184447	0.519071521	-1.99981E-10
310000	297133.2805	8.439	0.216	0.025591895	0.294691413	2.780267619	0.897856348	0.516009396	2.41213E-07
315000	301903.8925	8.433	0.216	0.025620776	0.294802225	2.781418354	0.897220525	0.51564398	-2.24541E-07
320000	306672.5396	8.461	0.217	0.025593901	0.294699115	2.7803476	0.902588576	0.518729067	-1.34957E-07
325000	311446.1188	8.464	0.216	0.025577741	0.294637076	2.779703371	0.902867636	0.518889446	5.08177E-07
330000	316214.7259	8.433	0.216	0.025638563	0.294870432	2.782126668	0.897614836	0.515870595	4.87059E-08
335000	320983.3731	8.442	0.216	0.025644397	0.294892797	2.782358929	0.899661381	0.517046771	3.30141E-07
340000	325752.9826	8.436	0.217	0.025683973	0.295044419	2.783933574	0.899260526	0.516816394	-4.64909E-08
345000	330522.5921	8.439	0.217	0.025678398	0.295023068	2.783711831	0.899776543	0.517112956	1.08113E-07
350000	335296.1713	8.418	0.216	0.025691376	0.29507276	2.784227918	0.895590467	0.514707165	2.97012E-08
355000	340066.7833	8.418	0.216	0.025694939	0.295086404	2.784369611	0.895669117	0.514752366	4.51372E-07
360000	344837.3952	8.403	0.216	0.025749137	0.295293731	2.786522933	0.893671342	0.513604219	1.74227E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
365000	349613.0194	8.421	0.217	0.025770099	0.295373838	2.787354975	0.897966589	0.516072752	9.28261E-08
370000	354387.6411	8.403	0.217	0.025781269	0.295416509	2.787798184	0.894377209	0.51400989	1.48448E-07
375000	359157.2506	8.403	0.217	0.025799119	0.295484674	2.788506222	0.894769218	0.514235183	2.40975E-07
380000	363916.8357	8.363	0.216	0.025828052	0.295595092	2.789653162	0.886900054	0.509712675	9.67559E-08
385000	368684.4805	8.384	0.217	0.025839695	0.2956395	2.79011446	0.891614127	0.512421912	1.01625E-07
390000	373447.0729	8.387	0.217	0.025851914	0.295686093	2.790598458	0.892519426	0.512942199	4.57007E-07
395000	378200.6835	8.348	0.216	0.025906804	0.295895218	2.792770894	0.885426376	0.508865733	3.49566E-07
400000	382952.3293	8.363	0.217	0.025948822	0.296055102	2.794431909	0.889523357	0.51122032	5.27976E-07
405000	387698.9228	8.293	0.216	0.0260123	0.296296314	2.796937998	0.876048766	0.503476302	1.30257E-07
410000	392445.5965	8.293	0.216	0.026027975	0.296355821	2.797556286	0.876382969	0.503668373	-1.32832E-07
415000	397194.1949	8.345	0.217	0.026011983	0.296295113	2.79692552	0.887062642	0.509806116	3.0351E-07
420000	401942.7932	8.283	0.216	0.026048533	0.296433825	2.798366767	0.87470781	0.502705638	-4.12034E-08
425000	406688.4244	8.308	0.216	0.026043572	0.296415006	2.798171231	0.879889813	0.505683801	-2.50205E-07
430000	411431.0482	8.308	0.216	0.026013481	0.2963008	2.796984605	0.879246028	0.505313809	-1.9814E-07
435000	416166.6951	8.351	0.217	0.025989702	0.296210488	2.796046284	0.887856856	0.510262561	-2.80454E-07
440000	420912.3262	8.363	0.217	0.025955997	0.296082385	2.794715351	0.889679055	0.511309802	-2.14785E-07
445000	425654.9501	8.369	0.217	0.025930219	0.295984335	2.793696705	0.890395801	0.511721725	1.74397E-07
450000	430392.5617	8.348	0.217	0.025951126	0.296063864	2.794522932	0.886385114	0.509416732	2.31655E-07
455000	435121.1915	8.326	0.216	0.025978861	0.296169299	2.795618342	0.882315866	0.507078084	1.56285E-07
460000	439854.8334	8.345	0.217	0.025997603	0.296240504	2.796358137	0.886752145	0.50962767	4.40768E-07
465000	444582.5009	8.287	0.216	0.02605044	0.29644106	2.798441942	0.875593424	0.503214611	-2.32285E-07
470000	449314.0979	8.332	0.217	0.026022564	0.29633528	2.797342861	0.884528735	0.508349848	-2.93818E-07
475000	454050.7472	8.341	0.217	0.025987292	0.296201332	2.79595115	0.885679777	0.509011366	1.38067E-07
480000	458780.3794	8.338	0.217	0.026003838	0.296264183	2.796604154	0.885399509	0.508850292	1.2247E-07
485000	463512.9788	8.311	0.216	0.02601853	0.296319967	2.797183755	0.87998924	0.505740942	1.56727E-07
490000	468242.611	8.305	0.216	0.026037327	0.296391309	2.797925016	0.879120976	0.50524194	-2.42692E-07
495000	472982.2676	8.332	0.217	0.026008161	0.296280601	2.796774739	0.884218767	0.508171705	3.57555E-07
500000	477722.8866	8.329	0.217	0.026051147	0.296443738	2.798469773	0.884506423	0.508337024	1.49724E-07
505000	482462.5031	8.329	0.217	0.026069156	0.296512034	2.799179408	0.884893498	0.508559482	9.92407E-08
510000	487202.1196	8.311	0.217	0.026081097	0.296557301	2.799649771	0.881328396	0.506510572	2.31258E-07
515000	491947.7508	8.314	0.217	0.026108973	0.296662917	2.800747237	0.882561451	0.507219225	5.15844E-08
520000	496694.3844	8.299	0.217	0.026115195	0.29668648	2.80099209	0.879512381	0.505466886	1.49748E-07
525000	501442.9828	8.299	0.217	0.026133269	0.29675491	2.801703183	0.879897715	0.505688342	3.98193E-07
530000	506183.6418	8.241	0.216	0.026181289	0.29693656	2.803590881	0.868650858	0.499224631	-2.87746E-09
535000	510932.2402	8.29	0.217	0.026180941	0.296935245	2.803577217	0.879003964	0.505174692	1.16335E-07
540000	515668.8494	8.268	0.217	0.026194969	0.296988268	2.804128249	0.874641317	0.502667423	1.35249E-07
545000	520408.4659	8.235	0.216	0.026211293	0.29704995	2.804769278	0.868015657	0.498859573	2.46721E-07
550000	525147.1201	8.271	0.217	0.026241083	0.297162443	2.805938404	0.876251375	0.503592744	-1.77243E-08
555000	529883.7293	8.253	0.217	0.026238943	0.297154365	2.805854451	0.872396548	0.501377326	3.33581E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
560000	534617.3712	8.259	0.217	0.026279211	0.297306295	2.807433504	0.874514093	0.502594306	4.6921E-08
565000	539351.9756	8.207	0.216	0.026284879	0.297327669	2.807655656	0.863654512	0.496353168	5.11278E-08
570000	544078.6405	8.253	0.217	0.026291046	0.29735092	2.80789732	0.873492885	0.502007405	0
575000	548816.2522	8.253	0.217	0.026291046	0.29735092	2.80789732	0.873492885	0.502007405	8.91238E-09
580000	553544.8819	8.25	0.217	0.026292121	0.297354975	2.807939464	0.87288057	0.5016555	1.11508E-07
585000	558275.5166	8.253	0.217	0.026305586	0.297405726	2.808466966	0.873798697	0.502183159	1.23034E-07
590000	563009.1586	8.232	0.217	0.026320457	0.297461758	2.809049363	0.869668657	0.499809573	-1.2861E-07
595000	567737.7883	8.238	0.217	0.026304928	0.297403248	2.808441212	0.870611512	0.500351444	-1.83195E-07
600000	572461.4059	8.259	0.217	0.026282843	0.297319993	2.807575871	0.87459062	0.502638287	2.51463E-07
605000	577186.0259	8.232	0.217	0.026313168	0.297434298	2.80876394	0.869516179	0.499721942	-7.39009E-08
610000	581916.6606	8.25	0.217	0.026304242	0.297400663	2.808414342	0.873135322	0.501801909	-5.13959E-08
615000	586638.3134	8.247	0.217	0.026298048	0.297377316	2.808171669	0.872370337	0.501362262	8.15286E-08
620000	591361.9309	8.25	0.217	0.026307879	0.297414367	2.808556779	0.873211739	0.501845827	7.92613E-08
625000	596090.5607	8.247	0.217	0.026317449	0.297450426	2.808931576	0.872777736	0.5015964	-1.03767E-07
630000	600816.1832	8.238	0.217	0.026304928	0.297403248	2.808441212	0.870611512	0.500351444	6.96587E-07
635000	605530.859	8.183	0.216	0.026388855	0.297719204	2.811725396	0.860759429	0.494689327	-3.12818E-07
640000	610246.457	8.219	0.217	0.026351138	0.297577294	2.810250274	0.867563706	0.498599831	2.28151E-07
645000	614965.1025	8.229	0.217	0.026378661	0.297680862	2.811326837	0.870251087	0.500144303	-5.38153E-08
650000	619675.7285	8.195	0.216	0.026372178	0.297656475	2.811073333	0.862940368	0.49594274	-5.53408E-07
655000	624385.3921	8.253	0.217	0.026305586	0.297405726	2.808466966	0.873798697	0.502183159	6.48758E-07
660000	629096.018	8.21	0.217	0.026383678	0.297699735	2.811523022	0.866341382	0.497897346	1.33993E-07
665000	633800.6694	8.219	0.217	0.026399805	0.297760379	2.812153415	0.86857779	0.499182638	1.90342E-07
670000	638509.3306	8.213	0.217	0.026422744	0.297846596	2.813049673	0.867787146	0.498728245	4.87864E-07
675000	643226.9335	8.146	0.216	0.026481709	0.298067987	2.815351224	0.854892052	0.491317271	-4.00404E-08
680000	647942.5717	8.149	0.216	0.026476868	0.298049825	2.815162408	0.855422838	0.491622321	-2.4487E-07
685000	652659.2123	8.174	0.216	0.026447272	0.297938728	2.814007443	0.860070295	0.494293273	4.17029E-07
690000	657373.848	8.146	0.216	0.026497668	0.298127851	2.815973582	0.855218185	0.491504704	3.54537E-07
695000	662091.5311	8.143	0.216	0.026540587	0.298288727	2.817646175	0.85546448	0.491646253	4.86244E-07
700000	666808.1316	8.14	0.217	0.026599509	0.298509304	2.819939594	0.856035277	0.491974297	2.02946E-07
705000	671527.7795	8.152	0.217	0.026624141	0.298601421	2.820897425	0.859064359	0.493715149	1.30376E-07
710000	676252.3995	8.122	0.216	0.02663999	0.29866066	2.821513403	0.853074493	0.490272697	4.84276E-07
715000	680969.0802	8.088	0.216	0.026698813	0.298880319	2.823797577	0.847129338	0.486855941	-1.5979E-07
720000	685691.6953	8.134	0.217	0.026679371	0.298807752	2.82304295	0.856397663	0.492182565	2.33114E-07
725000	690414.3105	8.116	0.217	0.026707738	0.298913618	2.824143858	0.853185389	0.49033643	5.00646E-08
730000	695133.9584	8.128	0.217	0.026713829	0.29893634	2.824380146	0.855833775	0.491858491	-3.03757E-08
735000	699847.5917	8.128	0.217	0.026710138	0.298922571	2.824236966	0.85575891	0.491815465	5.07646E-08
740000	704562.2274	8.125	0.217	0.026716308	0.298945586	2.824476303	0.855252367	0.491524349	-2.22975E-07
745000	709276.8631	8.131	0.217	0.026689214	0.298844496	2.823425055	0.855965948	0.491934453	-2.02358E-07
750000	713995.5085	8.143	0.217	0.02666462	0.298752673	2.822470199	0.857993398	0.493099654	3.21316E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
755000	718717.1613	8.1	0.216	0.026703704	0.298898567	2.823987344	0.849743471	0.488358317	1.51933E-07
760000	723434.7643	8.106	0.217	0.026722181	0.298967492	2.824704106	0.851375571	0.489296305	3.06639E-07
765000	728155.4146	8.113	0.217	0.026759522	0.299106682	2.82615164	0.853600937	0.490575251	-1.92829E-07
770000	732873.0576	8.119	0.217	0.026736051	0.299019209	2.82524194	0.854389195	0.491028273	0
775000	737585.6885	8.119	0.217	0.026736051	0.299019209	2.82524194	0.854389195	0.491028273	3.27466E-07
780000	742298.3594	8.058	0.216	0.026775875	0.2991676	2.826785178	0.842392391	0.484133558	-2.45811E-07
785000	747017.9672	8.116	0.217	0.026745934	0.299056048	2.825625048	0.853957696	0.490780285	8.12487E-08
790000	751735.6102	8.113	0.217	0.026755824	0.299092904	2.826008351	0.853526256	0.490532331	2.50609E-07
795000	756451.2484	8.106	0.217	0.026786331	0.299206537	2.827190133	0.852668972	0.490039639	1.32554E-07
800000	761164.8817	8.1	0.217	0.026802469	0.299266613	2.827814942	0.851731877	0.489501079	2.26691E-07
805000	765873.5428	8.079	0.217	0.026830053	0.299369242	2.828882352	0.8478732	0.487283448	2.08525E-08
810000	770580.159	8.076	0.217	0.02683259	0.299378678	2.828980497	0.847294354	0.486950778	-1.14695E-07
815000	775288.8202	8.094	0.217	0.026818631	0.299326754	2.828440439	0.850795164	0.488962738	3.29864E-07
820000	779999.4461	8.067	0.217	0.026858807	0.299476151	2.829994304	0.845929797	0.48616655	-1.33318E-07
825000	784711.1146	8.073	0.217	0.026842562	0.299415758	2.829366156	0.84686416	0.48670354	1.51385E-07
830000	789419.7357	8.079	0.217	0.026860998	0.29948429	2.830078969	0.848492182	0.487639185	3.27872E-07
835000	794128.3969	8.067	0.217	0.026900955	0.299632715	2.831622805	0.846769968	0.486649407	-1.39747E-07
840000	798836.0155	8.055	0.217	0.026883923	0.299569468	2.830964928	0.843914187	0.485008154	1.56806E-08
845000	803545.6791	8.076	0.217	0.026885835	0.299576568	2.831038778	0.848358408	0.487562304	0
850000	808260.3148	8.076	0.217	0.026885835	0.299576568	2.831038778	0.848358408	0.487562304	2.76214E-07
855000	812973.9481	8.067	0.217	0.026919549	0.299701736	2.832340748	0.847140478	0.486862344	1.33475E-07
860000	817691.5911	8.061	0.217	0.026935864	0.299762271	2.832970437	0.846205327	0.486324901	-7.01237E-08
865000	822417.2136	8.058	0.217	0.026927277	0.299730414	2.832639059	0.845404924	0.485864899	2.72971E-07
870000	827140.8311	8.015	0.216	0.026960699	0.299854369	2.83392847	0.837063406	0.481070923	3.92232E-07
875000	831859.4766	8.03	0.217	0.027008717	0.300032283	2.835779275	0.841146554	0.48341756	2.65572E-07
880000	836584.0966	7.99	0.216	0.027041302	0.300152891	2.837034002	0.833423332	0.478978926	-1.52782E-07
885000	841309.7592	8.027	0.217	0.027022549	0.300083491	2.836312006	0.840790659	0.483213022	8.03483E-08
890000	846020.3851	8.03	0.217	0.027032379	0.300119873	2.836690496	0.841613013	0.48368564	7.34655E-08
895000	850735.0208	8.024	0.217	0.027041376	0.300153166	2.83703686	0.840532849	0.483064856	3.21748E-07
900000	855458.6384	7.975	0.216	0.027080878	0.300299249	2.838556676	0.831066151	0.477624225	1.98994E-07
905000	860176.2814	7.987	0.216	0.027105296	0.30038948	2.839495459	0.834044822	0.479336105	2.88454E-07
910000	864892.922	7.981	0.217	0.027140709	0.300520242	2.840855992	0.833480874	0.479011996	5.24866E-08
915000	869608.5602	7.978	0.217	0.027147155	0.30054403	2.8411035	0.832979609	0.478723913	-2.62441E-08
920000	874328.2081	7.997	0.217	0.027143929	0.300532126	2.840979637	0.836888934	0.480970652	5.23652E-08
925000	879045.8511	7.994	0.217	0.027150363	0.300555869	2.841226677	0.836386636	0.480681975	1.56377E-07
930000	883767.5039	7.96	0.216	0.027169598	0.30062683	2.841965037	0.829659062	0.476815553	-1.78459E-07
935000	888481.1372	7.99	0.217	0.027147685	0.300545986	2.841123848	0.835497649	0.480171063	1.09311E-07
940000	893202.7499	7.975	0.217	0.027161129	0.300595589	2.84163997	0.832624499	0.478519827	-2.9231E-07
945000	897928.4124	7.99	0.217	0.027125156	0.300462828	2.840258611	0.835058631	0.479918754	-1.04331E-07

Table A-19. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE203) (Continued)

N	N	P	δ	C	$C^{1/3}$	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
950000	902651.0276	8.003	0.217	0.027112333	0.300415472	2.839765894	0.837527406	0.48133759	3.22442E-07
955000	907374.6852	7.981	0.217	0.027151986	0.300561858	2.841288998	0.833700106	0.479137992	-6.54785E-08
960000	912099.3052	7.997	0.217	0.027143929	0.300532126	2.840979637	0.836888934	0.480970652	2.09487E-07
965000	916824.9277	7.978	0.217	0.027169717	0.300627268	2.841969593	0.833417838	0.478975769	6.49225E-08
970000	921551.5526	7.951	0.216	0.027177713	0.300656759	2.842276458	0.827940542	0.475827898	-1.08672E-07
975000	926278.2176	7.984	0.217	0.027164329	0.300607394	2.841762802	0.834567084	0.479636255	4.42552E-07
980000	930998.8679	7.939	0.216	0.027218793	0.300808166	2.843851934	0.826232996	0.474846549	-7.44599E-08
985000	935720.4806	7.981	0.217	0.027209623	0.30077438	2.843500364	0.834820105	0.47978167	1.68805E-07
990000	940443.0958	7.929	0.216	0.02723042	0.300850991	2.844297563	0.824375716	0.473779147	-6.36746E-08
995000	945167.7559	7.975	0.217	0.027222571	0.300822081	2.843996722	0.833816467	0.479204866	2.27812E-07
1000000	949892.3759	7.951	0.217	0.02725066	0.300925513	2.845073049	0.829346773	0.476636077	2.99515E-06

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205)

N	N	d	P	C	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
0	0	0.217	12.035	0.018056502	2.471165067	1.513818326	0.870010532	0.005356746
1	0.9623424	0.216	11.891	0.01815743	2.476320091	1.482975798	0.852284941	0.003617955
2	1.9647824	0.216	11.861	0.018228649	2.479946874	1.479123419	0.850070931	0.003961683
3	2.9672224	0.216	11.824	0.018306834	2.483918223	1.473854085	0.847042578	0.003096549
4	3.9696624	0.217	11.796	0.018368091	2.487022328	1.469953413	0.844800812	0.00360791
5	4.9721024	0.217	11.760	0.018439626	2.490639041	1.464554929	0.841698235	0.004091128
6	5.9745424	0.217	11.717	0.018520952	2.494740151	1.457875938	0.837859735	0.003570063
7	6.9769824	0.217	11.677	0.018592104	2.498318924	1.451419434	0.8341491	0.004244796
8	7.9794224	0.217	11.632	0.018676926	2.502574077	1.444364963	0.830094806	0.002975328
9	8.9818624	0.217	11.595	0.018736524	2.505556665	1.438056723	0.826469381	0.003458816
10	9.9843024	0.217	11.549	0.018805957	2.509023921	1.429977199	0.821825977	0.002167328
15	14.9564048	0.216	11.369	0.019022781	2.519800099	1.395732419	0.802145068	0.00158619
20	19.9686048	0.217	11.320	0.019183746	2.527750401	1.391046923	0.799452254	0.00141959
25	24.9808048	0.217	11.229	0.019328524	2.534865669	1.375230897	0.790362585	0.00087205
30	29.9529072	0.217	11.168	0.019417085	2.539201591	1.364229254	0.784039801	0.001080841
35	34.9651072	0.217	11.125	0.01952809	2.544618982	1.358584796	0.78079586	0.000723252
40	39.9372096	0.216	11.030	0.019601995	2.548215066	1.338643452	0.769335318	0.001119466
45	44.9494096	0.217	11.015	0.019717658	2.553826052	1.339931885	0.770075796	0.000771444
50	49.9616096	0.217	10.969	0.019797611	2.557692684	1.33213493	0.765594788	0.000792364
55	52.9689296	0.217	10.914	0.019846986	2.560075576	1.320867862	0.759119461	0.00034376
60	55.936152	0.217	10.921	0.019868144	2.561095588	1.32344541	0.76060081	0.000581912
65	59.945912	0.217	10.911	0.019916598	2.563428914	1.323039154	0.76036733	0.000449144
70	64.9180144	0.216	10.823	0.019963042	2.565662102	1.303683831	0.749243581	0.000548235
75	69.9302144	0.217	10.847	0.020020282	2.568409964	1.311821774	0.75392056	0.000451194
80	74.9424144	0.217	10.820	0.020067468	2.570671438	1.307224651	0.751278535	0.00035989
85	79.9145168	0.217	10.777	0.020104853	2.572460849	1.298367393	0.746188157	0.000299505
90	84.9267168	0.217	10.789	0.02013625	2.573962026	1.302532447	0.748581866	0.00038729
95	89.8988192	0.216	10.704	0.02017657	2.575887673	1.283696378	0.737756539	0.000277422
100	94.9110192	0.217	10.743	0.020205715	2.577278166	1.294236953	0.743814341	0.000282094
110	104.8953216	0.217	10.686	0.020264832	2.580094679	1.282884101	0.737289713	0.000263357
120	114.879624	0.216	10.621	0.020320121	2.58272411	1.26948855	0.729591121	0.000145068
130	119.891824	0.217	10.673	0.020335426	2.583451221	1.282554215	0.737100123	0.000336044
140	129.8761264	0.217	10.612	0.020406144	2.58680639	1.270694682	0.7302843	0.000164161
150	139.9005264	0.217	10.615	0.020440886	2.58845201	1.272768135	0.73147594	0.000202825
160	149.8848288	0.217	10.606	0.020483688	2.590477071	1.272276083	0.731193151	0.000123917
170	159.8691312	0.217	10.591	0.020509867	2.591714299	1.269694858	0.729709688	0.000174242
180	169.8534336	0.217	10.554	0.020546712	2.593453984	1.26225668	0.725434873	0.000214133
190	178.8753936	0.217	10.533	0.020587677	2.595385879	1.258807382	0.723452519	0.00020824

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
200	184.849936	0.217	10.536	0.020614085	2.596630016	1.26053591	0.724445925	0.000107289
210	194.8342384	0.217	10.505	0.02063684	2.597701222	1.253995019	0.720686793	0.000117405
220	204.8185408	0.216	10.457	0.020661758	2.598873431	1.24350077	0.714655615	0.000131429
230	214.8429408	0.217	10.496	0.020689787	2.600190925	1.253857335	0.720607664	0.000122932
240	224.8272432	0.217	10.490	0.02071592	2.60141831	1.253414502	0.720353162	3.07782E-05
250	234.8115456	0.217	10.478	0.020722466	2.601725609	1.250795882	0.718848208	0.000222272
260	242.8310656	0.217	10.441	0.020760464	2.603508127	1.243403279	0.714599586	-2.00874E-05
270	249.808048	0.217	10.469	0.020757474	2.603367978	1.249968478	0.718372689	0.000154462
280	259.7923504	0.217	10.438	0.020790381	2.604910177	1.243809859	0.714833252	8.94827E-05
290	269.7766528	0.216	10.402	0.02080946	2.605803599	1.235954639	0.710318758	0.000170776
300	279.7609552	0.216	10.344	0.020845901	2.607508682	1.22354977	0.703189523	2.55703E-06
310	289.7853552	0.217	10.420	0.020846449	2.607534314	1.241615724	0.713572255	0.000112533
320	299.7696576	0.217	10.408	0.020870484	2.608657874	1.239651688	0.712443499	0.000113025
330	307.74908	0.216	10.362	0.02088979	2.609559747	1.229429714	0.706568801	7.02496E-05
340	314.76616	0.217	10.396	0.020900346	2.610052694	1.237902546	0.711438245	0.000166604
350	324.7504624	0.217	10.374	0.020935994	2.611716116	1.233984794	0.709186663	5.97719E-05
360	334.7347648	0.217	10.350	0.020948792	2.612312897	1.228751903	0.706179254	9.09406E-05
370	344.7190672	0.216	10.307	0.020968274	2.613220876	1.219272627	0.700731395	4.99751E-05
380	354.7434672	0.217	10.347	0.020979028	2.613721846	1.229149179	0.706407574	3.92377E-05
390	364.7277696	0.217	10.350	0.02098744	2.614113607	1.230170787	0.706994705	0.000253532
400	371.7448496	0.216	10.286	0.021025666	2.61589266	1.216389293	0.699074307	3.77675E-05
410	379.724272	0.217	10.328	0.021032146	2.616194023	1.22657977	0.704930902	-3.93154E-05
420	389.7085744	0.217	10.335	0.021023706	2.615801487	1.227934381	0.705709414	5.84517E-05
430	399.6928768	0.217	10.316	0.021036254	2.616385087	1.223880805	0.703379773	0.000122495
440	409.6771792	0.216	10.277	0.021062567	2.61760811	1.215595521	0.698618115	7.6795E-05
450	419.6614816	0.216	10.231	0.021079073	2.618374854	1.205328906	0.692717762	9.4892E-05
460	429.6858816	0.217	10.295	0.021099563	2.61932609	1.221198605	0.701838279	0.000115886
470	435.7005216	0.216	10.237	0.021114584	2.620023101	1.208015566	0.69426182	7.7478E-06
480	444.682384	0.217	10.277	0.021116084	2.620092691	1.217528556	0.699729055	-6.04794E-06
490	454.6666864	0.217	10.289	0.021114783	2.620032306	1.22032642	0.701337023	5.87611E-05
500	464.6509888	0.217	10.280	0.021127432	2.620618995	1.218649356	0.700373193	0.000115495
510	474.6352912	0.217	10.249	0.021152308	2.62177213	1.212203417	0.696668631	9.36649E-05
520	484.6195936	0.216	10.209	0.021172495	2.622707309	1.20347847	0.691654293	1.78361E-05
530	494.6439936	0.217	10.252	0.021176356	2.622886105	1.213776421	0.697572656	-4.76164E-05
540	500.618536	0.217	10.246	0.021170213	2.622601619	1.212135886	0.696629819	0.000158988
550	509.6003984	0.216	10.191	0.02120106	2.624029627	1.200251195	0.689799538	5.46012E-05
560	519.6247984	0.217	10.240	0.021212891	2.624576971	1.212244326	0.696692142	0
570	529.6091008	0.217	10.240	0.021212891	2.624576971	1.212244326	0.696692142	7.61887E-05
580	539.5934032	0.217	10.225	0.02122934	2.625337662	1.209282205	0.694989773	9.16668E-05

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
590	549.5777056	0.217	10.191	0.021249141	2.626252891	1.20195485	0.690778649	8.26657E-05
600	559.562008	0.216	10.142	0.021267008	2.62707825	1.191050884	0.684512002	-6.41853E-05
610	564.574208	0.217	10.206	0.021260043	2.626756541	1.205882949	0.693036178	0.000111578
620	574.5585104	0.216	10.170	0.021284169	2.627870568	1.198241465	0.68864452	6.18555E-05
630	584.5829104	0.217	10.188	0.021297605	2.628490632	1.202962019	0.691357482	5.08628E-05
640	594.5672128	0.217	10.194	0.021308613	2.628998462	1.204769084	0.692396026	4.43654E-05
650	604.5515152	0.217	10.188	0.021318218	2.629441419	1.20369088	0.691776368	7.79727E-05
660	614.5358176	0.217	10.164	0.021335104	2.630219923	1.198620574	0.688862399	0.000154613
670	623.5577776	0.217	10.151	0.021365383	2.631614834	1.196618505	0.687711784	-9.54652E-05
680	629.53232	0.217	10.170	0.021352999	2.631044473	1.200666255	0.690038078	4.44007E-06
690	639.5166224	0.217	10.148	0.021353961	2.631088804	1.195510986	0.687075279	1.76757E-05
700	649.5009248	0.216	10.112	0.021357793	2.631265283	1.187177239	0.68228577	0.000161529
710	659.5253248	0.217	10.151	0.021392966	2.632884513	1.197585582	0.688267576	-1.89661E-06
720	669.5096272	0.217	10.154	0.021392555	2.632865577	1.198279115	0.688666158	1.93199E-05
730	679.4939296	0.217	10.145	0.021396747	2.633058472	1.196302643	0.687530254	0.000126
740	688.475792	0.216	10.096	0.021421355	2.63419019	1.185627331	0.681395018	-5.24795E-05
750	694.490432	0.217	10.145	0.02141449	2.633874545	1.19692368	0.687887173	-3.77404E-05
760	704.4747344	0.217	10.133	0.021406296	2.633497733	1.193807701	0.68609638	0.000142311
770	714.4590368	0.216	10.096	0.021437203	2.634918606	1.186176471	0.681710616	5.10635E-05
780	724.4834368	0.217	10.115	0.021448344	2.635430486	1.191032697	0.68450155	-2.34949E-05
790	734.4677392	0.217	10.130	0.021443238	2.635195906	1.194389717	0.686430872	8.77207E-05
800	744.4520416	0.217	10.121	0.021462306	2.636071736	1.19293208	0.685593149	-1.47779E-05
810	752.431464	0.216	10.084	0.021459738	2.635953817	1.184137144	0.680538589	3.62006E-05
820	759.448544	0.217	10.121	0.02146527	2.636207839	1.193035236	0.685652435	1.76353E-05
830	769.4328464	0.217	10.115	0.021469105	2.636383915	1.191754429	0.684916339	9.16611E-05
840	779.4171488	0.217	10.087	0.021489045	2.637299087	1.185854721	0.681525701	6.31357E-05
850	789.4014512	0.216	10.048	0.021502787	2.637929453	1.177173642	0.676536576	3.56477E-06
860	799.4258512	0.217	10.096	0.021503566	2.637965187	1.188474351	0.683031236	4.09436E-05
870	809.4101536	0.217	10.096	0.02151248	2.638373981	1.188782819	0.683208517	0.000134702
880	816.4272336	0.216	10.045	0.021533101	2.639319197	1.177509045	0.676729336	-9.87945E-05
890	824.406656	0.217	10.093	0.021515902	2.638530874	1.188194763	0.682870554	7.24085E-05
900	834.3909584	0.217	10.087	0.021531674	2.639253822	1.18732714	0.682371919	-7.38491E-06
910	844.3752608	0.217	10.078	0.021530065	2.639180089	1.185153875	0.681122917	1.42986E-05
920	854.3595632	0.216	10.051	0.021533181	2.63932285	1.17891888	0.677539586	1.47099E-05
930	864.3839632	0.217	10.069	0.021536399	2.639470308	1.183255943	0.680032151	5.07788E-05
940	874.3682656	0.217	10.081	0.021547466	2.639977299	1.186459559	0.68187331	0.000329604
950	880.3829056	0.216	10.014	0.021590773	2.641959746	1.172213923	0.673686163	-0.000178564
960	889.364768	0.217	10.066	0.021555732	2.640355907	1.183215547	0.680008935	5.15686E-06
970	899.3490704	0.217	10.078	0.021556857	2.640407394	1.186077062	0.681653484	7.68393E-05

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
980	909.3333728	0.217	10.066	0.021573614	2.641174581	1.183830045	0.680362095	4.00608E-05
990	919.3176752	0.217	10.042	0.021582354	2.64157456	1.178490491	0.677293385	7.49865E-05
1000	928.2995376	0.216	9.987	0.021597076	2.642248079	1.166114452	0.670180719	3.09454E-05
1100	1019.240894	0.216	9.990	0.021658659	2.645062292	1.16889725	0.671780029	2.23393E-05
1200	1114.192011	0.217	10.005	0.021705147	2.647183433	1.173985135	0.6747041	3.05146E-05
1300	1205.133368	0.217	9.977	0.021766062	2.649958475	1.16947366	0.672111299	2.53271E-05
1400	1300.044387	0.217	9.929	0.021818914	2.652362298	1.160008095	0.666671319	3.76095E-05
1500	1390.023402	0.216	9.855	0.021893455	2.655746362	1.145224617	0.658175067	1.44588E-05
1600	1485.936861	0.217	9.901	0.021924048	2.657133159	1.156951772	0.664914812	1.49706E-05
1700	1578.843	0.216	9.858	0.021954758	2.658524019	1.147929966	0.659729865	2.51765E-05
1800	1671.789237	0.217	9.868	0.022006486	2.660864077	1.151956266	0.662043831	4.18684E-05
1900	1766.740354	0.217	9.816	0.02209454	2.664839526	1.142701246	0.656724854	2.58359E-05
2000	1857.641613	0.216	9.764	0.022146661	2.667188037	1.132295749	0.650744683	1.54267E-05
2100	1953.59517	0.217	9.791	0.022179553	2.668668288	1.139625076	0.65495694	1.70129E-05
2200	2043.534086	0.217	9.776	0.022213584	2.670198406	1.137227103	0.653578795	2.47332E-05
2300	2138.445106	0.217	9.727	0.022265858	2.672545857	1.127513648	0.647996349	1.26587E-05
2400	2228.384022	0.217	9.724	0.022291238	2.673684363	1.127622322	0.648058806	1.29181E-05
2500	2323.335139	0.217	9.730	0.022318602	2.674910951	1.129881902	0.649357415	1.76863E-05
2600	2414.276496	0.217	9.709	0.022354516	2.676519367	1.12614315	0.647208707	1.51956E-05
2700	2509.187515	0.217	9.691	0.022386751	2.677961596	1.122984111	0.645393167	1.82432E-05
2800	2600.128872	0.217	9.687	0.022423867	2.67962066	1.123221737	0.645529734	1.48927E-05
2900	2695.039891	0.216	9.611	0.02245552	2.681034141	1.106643224	0.636001853	1.11396E-05
3000	2786.983688	0.217	9.639	0.022478473	2.682058357	1.113812913	0.640122364	1.57961E-05
3100	2879.929925	0.217	9.648	0.022511401	2.683526547	1.11691708	0.641906368	1.63389E-05
3200	2974.840944	0.216	9.575	0.022546214	2.685077293	1.101143978	0.632841367	6.95968E-06
3300	3064.779861	0.216	9.581	0.022560276	2.685703239	1.102954927	0.633882142	1.44015E-05
3400	3159.730978	0.217	9.614	0.022591013	2.687070673	1.11151304	0.638800598	3.84434E-06
3500	3250.672334	0.217	9.608	0.022598876	2.687420283	1.110368017	0.638142539	7.26365E-06
3600	3346.585794	0.217	9.581	0.02261455	2.688116965	1.104615593	0.634836548	1.08267E-05
3700	3436.52471	0.217	9.581	0.022636468	2.689090711	1.105285825	0.635221738	1.73729E-05
3800	3531.475827	0.217	9.575	0.022673629	2.690740288	1.10503627	0.635078316	1.22144E-05
3900	3622.377086	0.216	9.501	0.022698663	2.691850588	1.088773837	0.62573209	9.35833E-06
4000	3717.328203	0.217	9.556	0.022718711	2.692739173	1.102024841	0.63334761	9.59442E-06
4100	3808.26956	0.217	9.553	0.022738407	2.693611702	1.101930756	0.633293538	1.74609E-05
4200	3903.180579	0.216	9.489	0.022775846	2.695268934	1.088336032	0.625480478	3.14846E-06
4300	3995.124376	0.217	9.517	0.022782389	2.695558415	1.094965333	0.629290421	1.49124E-05
4400	4089.073053	0.217	9.520	0.022814076	2.69695942	1.096609666	0.63023544	5.36033E-06
4500	4182.981632	0.216	9.471	0.022825467	2.697462801	1.085689388	0.623959418	2.31391E-05
4600	4273.922989	0.217	9.474	0.022873126	2.699567102	1.08779704	0.625170713	7.19276E-06

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
4700	4368.874106	0.217	9.489	0.022888608	2.700250063	1.091706749	0.627417672	1.69297E-05
4800	4459.815462	0.217	9.468	0.022923532	2.701789672	1.087918096	0.625240285	4.25698E-07
4900	4555.728922	0.217	9.465	0.022924459	2.701830502	1.087256295	0.62485994	1.96399E-05
5000	4645.667838	0.217	9.455	0.022964569	2.703596897	1.086148319	0.624223172	1.17608E-05
5100	4741.581298	0.216	9.394	0.022990207	2.704724916	1.072928028	0.616625303	7.35547E-06
5200	4832.522654	0.217	9.413	0.023005418	2.705393832	1.077718801	0.619378621	9.24745E-07
5300	4927.473771	0.217	9.440	0.023007415	2.705481637	1.083969187	0.622970797	9.64545E-06
5400	5017.412688	0.217	9.428	0.023027153	2.706349138	1.081795778	0.621721712	1.97673E-05
5500	5112.323707	0.217	9.388	0.023069876	2.708225276	1.073881476	0.617173262	-5.51599E-06
5600	5203.265064	0.217	9.410	0.023058448	2.707723644	1.078585802	0.619876897	8.63771E-06
5700	5299.218621	0.217	9.401	0.023077332	2.708552463	1.077075539	0.619008931	1.03868E-05
5800	5391.162418	0.216	9.364	0.023099103	2.709507468	1.069245128	0.614508694	6.88381E-06
5900	5484.068557	0.217	9.394	0.02311369	2.710147016	1.076532748	0.618696982	8.1741E-06
6000	5579.019674	0.217	9.376	0.023131399	2.710923156	1.072925591	0.616623903	1.0078E-05
6100	5669.920933	0.216	9.336	0.023152314	2.71183926	1.064392601	0.611719886	7.10552E-07
6200	5764.87205	0.217	9.379	0.023153854	2.711906727	1.074264757	0.617393539	8.77237E-06
6300	5854.810966	0.217	9.373	0.023171877	2.712695705	1.073413543	0.616904335	4.6247E-06
6400	5950.724426	0.217	9.340	0.023182013	2.713139277	1.066160318	0.612735815	1.42063E-05
6500	6040.663342	0.217	9.336	0.023211225	2.714416972	1.06608762	0.612694035	3.32619E-06
6600	6136.616899	0.217	9.349	0.023218526	2.714736132	1.069269184	0.61452252	2.47545E-05
6700	6227.518158	0.216	9.269	0.02327004	2.716986349	1.052507367	0.604889291	1.66444E-08
6800	6322.469275	0.217	9.327	0.023270076	2.716987929	1.065721572	0.612483662	2.5819E-06
6900	6413.410632	0.217	9.330	0.023275456	2.717222731	1.066561606	0.61296644	5.46719E-06
7000	6508.321651	0.216	9.278	0.023287346	2.717741627	1.055043294	0.606346721	3.97468E-06
7100	6600.265448	0.217	9.306	0.023295723	2.718107075	1.061659965	0.610149405	1.8256E-05
7200	6695.216565	0.217	9.306	0.023335482	2.719840503	1.062794143	0.610801232	9.7799E-06
7300	6788.162802	0.216	9.269	0.023356349	2.720749508	1.054949988	0.606293096	1.34608E-06
7400	6880.066501	0.217	9.282	0.02335919	2.720873217	1.057991812	0.608041271	1.9629E-06
7500	6975.017618	0.217	9.291	0.02336347	2.721059596	1.060166118	0.609290873	5.86785E-06
7600	7065.958974	0.217	9.278	0.023375728	2.721593226	1.057548675	0.607786595	1.05819E-05
7700	7161.872434	0.217	9.282	0.023399052	2.722608169	1.059121914	0.608690755	6.44201E-06
7800	7251.81135	0.217	9.278	0.023412373	2.723187556	1.058586452	0.608383019	3.10797E-06
7900	7347.72481	0.216	9.236	0.023419229	2.723485652	1.049216375	0.602997917	1.30801E-05
8000	7437.663726	0.217	9.236	0.023446297	2.724662066	1.049975523	0.603434209	-3.13046E-06
8100	7532.614843	0.217	9.266	0.023439456	2.724364826	1.056614496	0.60724971	1.10069E-05
8200	7622.55376	0.217	9.257	0.023462245	2.725354778	1.055204785	0.606439531	7.62842E-06
8300	7717.464779	0.217	9.227	0.023478921	2.726078799	1.048842967	0.602783314	1.45958E-06
8400	7808.406136	0.217	9.239	0.023481979	2.726211536	1.051658602	0.604401495	-1.03304E-06
8500	7903.357253	0.217	9.245	0.023479719	2.726113447	1.05296153	0.605150305	8.02821E-06

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
8600	7996.263392	0.216	9.211	0.023496906	2.726859317	1.045709894	0.600982698	6.82693E-06
8700	8088.207189	0.217	9.230	0.023511376	2.727487011	1.050433261	0.603697277	4.97603E-06
8800	8183.158306	0.217	9.227	0.023522272	2.727959491	1.050055109	0.603479948	6.40143E-06
8900	8274.059565	0.216	9.175	0.023535695	2.728541389	1.038623948	0.596910315	7.96379E-06
9000	8369.010682	0.217	9.220	0.023553145	2.729297559	1.049323925	0.603059727	3.13434E-06
9100	8458.949598	0.217	9.220	0.023559653	2.729579458	1.049505448	0.60316405	2.46994E-06
9200	8554.863058	0.216	9.175	0.023565123	2.729816359	1.039436889	0.597377523	-3.8504E-06
9300	8644.801974	0.216	9.190	0.023557127	2.729470058	1.042616816	0.599205067	9.6339E-06
9400	8739.753091	0.217	9.214	0.02357825	2.730384807	1.048657923	0.602676967	6.87617E-06
9500	8830.694448	0.217	9.202	0.023592697	2.731010135	1.046329449	0.601338764	-1.33411E-06
9600	8925.605467	0.217	9.190	0.023589771	2.730883513	1.04352123	0.599724845	2.57684E-06
9700	9015.544384	0.217	9.193	0.023595127	2.731115272	1.04435106	0.600201758	8.46749E-06
9800	9110.495501	0.217	9.190	0.023613711	2.731919269	1.04418417	0.600105845	8.27924E-06
9900	9203.40164	0.216	9.156	0.023631498	2.732688461	1.036960979	0.595954586	1.38838E-06
10000	9296.347877	0.217	9.187	0.023634484	2.732817506	1.044077233	0.600044387	3.69689E-06
11000	10222.68263	0.217	9.147	0.023713786	2.736242061	1.03717836	0.596079517	4.14494E-06
12000	11156.03447	0.217	9.123	0.023803573	2.74011075	1.03418706	0.594360379	3.87712E-06
13000	12084.3741	0.217	9.086	0.023887299	2.743710034	1.028073133	0.590846628	4.38339E-06
14000	13015.72106	0.216	9.022	0.023982487	2.747792491	1.016168302	0.584004771	2.01903E-06
15000	13946.02548	0.217	9.028	0.024026362	2.749670807	1.018685513	0.585451444	3.57795E-06
16000	14872.36023	0.217	8.989	0.024103905	2.752985185	1.011942876	0.581576366	2.98012E-06
17000	15806.71451	0.217	8.985	0.024169171	2.75576967	1.012755724	0.58204352	2.78973E-06
18000	16736.05658	0.217	8.955	0.024230039	2.758362288	1.007589647	0.57907451	2.29609E-06
19000	17666.361	0.216	8.906	0.02428026	2.760498347	0.997886024	0.573497715	2.68496E-06
20000	18598.71039	0.217	8.921	0.0243392	2.76300167	1.002771385	0.576305394	2.77743E-06
21000	19527.05003	0.217	8.900	0.0244	2.76558007	0.999616258	0.574492102	1.12583E-06
22000	20456.3921	0.217	8.891	0.024424699	2.766626353	0.998227757	0.573694113	1.94687E-06
23000	21390.70628	0.216	8.848	0.024467676	2.768445337	0.989684366	0.568784118	1.47325E-06
24000	22320.04836	0.217	8.851	0.024500056	2.769814488	0.991176034	0.569641399	2.12188E-06
25000	23250.39287	0.217	8.848	0.02454679	2.771788563	0.991686837	0.569934964	9.6448E-07
26000	24182.74227	0.217	8.833	0.024568097	2.772687795	0.988864337	0.568312838	1.6091E-06
27000	25111.0819	0.217	8.815	0.024603517	2.774181582	0.985726983	0.566509761	3.05216E-06
28000	26042.42886	0.216	8.754	0.024671008	2.777024199	0.973800547	0.559655487	5.62592E-07
29000	26975.7406	0.217	8.799	0.024683487	2.777549273	0.984149507	0.565603165	2.44873E-06
30000	27903.07779	0.217	8.781	0.024737501	2.77982007	0.981469501	0.564062931	2.41864E-06
31000	28835.42719	0.217	8.741	0.024791214	2.782075083	0.973869788	0.55969528	8.42264E-07
32000	29765.7316	0.217	8.732	0.024809895	2.782858645	0.972323842	0.558806806	1.16103E-06
33000	30694.07124	0.217	8.729	0.024835605	2.783936474	0.972286209	0.558785178	1.3812E-06
34000	31629.42795	0.217	8.723	0.024866445	2.785228386	0.971704787	0.558451027	1.98953E-06

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
35000	32558.72993	0.216	8.671	0.024910622	2.787077257	0.961221858	0.552426355	1.55477E-06
36000	33486.06713	0.216	8.653	0.024945106	2.788519054	0.958064721	0.550611908	9.64828E-07
37000	34418.41652	0.217	8.692	0.024966636	2.789418611	0.967242739	0.555886632	2.59098E-07
38000	35347.7586	0.217	8.696	0.024972401	2.789659402	0.968273152	0.556478823	5.17488E-07
39000	36275.09579	0.217	8.692	0.024983893	2.790139287	0.967661304	0.556127186	2.08865E-06
40000	37207.44519	0.217	8.671	0.025030562	2.792086635	0.964117099	0.554090287	7.01415E-07
41000	38135.78482	0.217	8.662	0.025046179	2.792737786	0.962492559	0.553156643	4.18522E-07
42000	39067.09168	0.217	8.644	0.02505553	2.793127559	0.95872057	0.550988834	1.28852E-06
43000	39998.43864	0.217	8.656	0.025084335	2.794327619	0.962076186	0.552917348	7.79563E-07
44000	40927.78071	0.217	8.650	0.025101734	2.7950521	0.961160114	0.55239087	1.87804E-06
45000	41860.13011	0.217	8.622	0.025143818	2.796803093	0.955949787	0.549396429	5.1189E-07
46000	42793.44184	0.217	8.628	0.025155308	2.797280846	0.957554615	0.550318744	9.33016E-07
47000	43722.78392	0.217	8.628	0.025176171	2.798147937	0.95805178	0.550604471	1.2908E-06
48000	44655.09322	0.216	8.555	0.025205143	2.799351366	0.942587099	0.541716724	1.68512E-06
49000	45584.43529	0.216	8.564	0.025242877	2.800917418	0.94545655	0.543365833	1.30398E-06
50000	46512.77493	0.216	8.564	0.025272069	2.80212795	0.946141003	0.543759197	1.88937E-07
51000	47446.12676	0.217	8.595	0.025276323	2.802304295	0.953103538	0.547760654	4.03767E-07
52000	48372.46152	0.217	8.586	0.025285348	2.802678318	0.951321171	0.546736305	1.39407E-06
53000	49303.80847	0.217	8.573	0.025316692	2.803976677	0.949178551	0.545504914	1.62704E-06
54000	50237.12021	0.217	8.546	0.025353382	2.80549521	0.944064894	0.542566031	6.65519E-07
55000	51166.46228	0.217	8.552	0.025368335	2.806113705	0.94574007	0.543528776	7.94089E-07
56000	52093.79948	0.217	8.546	0.025386146	2.806850093	0.944828603	0.543004944	5.97891E-08
57000	53025.14644	0.217	8.555	0.025387493	2.806905777	0.946851154	0.54416733	7.09551E-07
58000	53952.48363	0.217	8.552	0.025403414	2.80756377	0.946558709	0.543999258	1.94329E-06
59000	54884.83303	0.217	8.518	0.025447288	2.809375593	0.940062397	0.540265745	1.06805E-06
60000	55814.135	0.216	8.497	0.025471343	2.810368135	0.935986475	0.537923261	1.26778E-06
61000	56740.46976	0.216	8.473	0.025499823	2.811542519	0.931357959	0.535263195	-3.53702E-07
62000	57671.81671	0.217	8.509	0.025491832	2.811213101	0.939104752	0.539715375	2.08987E-07
63000	58599.15391	0.217	8.509	0.025496533	2.811406902	0.939213182	0.539777691	1.75494E-06
64000	59525.52876	0.216	8.461	0.025535989	2.813032636	0.929546252	0.534221984	-9.92964E-08
65000	60457.83806	0.217	8.506	0.025533741	2.812940061	0.939408388	0.539889878	1.27032E-06
66000	61385.17525	0.217	8.500	0.025562353	2.814118077	0.938741614	0.539506675	5.04258E-07
67000	62318.52709	0.217	8.470	0.02557379	2.814588727	0.932388003	0.535855174	1.02731E-06
68000	63248.83151	0.217	8.467	0.025597024	2.815544439	0.932257557	0.535780205	-5.424E-07
69000	64178.17358	0.217	8.482	0.025584768	2.815040364	0.935283121	0.537519035	2.15967E-06
70000	65113.4902	0.216	8.424	0.025633903	2.817060336	0.923644853	0.530830375	-6.60689E-07
71000	66038.86261	0.217	8.473	0.025619025	2.816448953	0.934081641	0.53682853	1.20697E-06
72000	66966.19981	0.217	8.464	0.025646267	2.817568218	0.932718797	0.536045286	1.58509E-06
73000	67897.50667	0.216	8.421	0.025682223	2.819044419	0.924076097	0.531078217	5.03022E-07

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
74000	68825.8463	0.217	8.427	0.025693604	2.819511394	0.92565013	0.531982833	5.39454E-07
75000	69754.18594	0.217	8.430	0.025705813	2.820012191	0.926584878	0.532520045	8.80782E-07
76000	70684.53045	0.217	8.439	0.025725797	2.820831621	0.929016345	0.53391744	8.08948E-07
77000	71611.86765	0.217	8.433	0.025744101	2.821581789	0.928109009	0.533395982	3.12663E-07
78000	72544.21704	0.217	8.433	0.025751215	2.8218733	0.928269606	0.53348828	8.10699E-07
79000	73470.5518	0.217	8.427	0.02576955	2.822624279	0.927362355	0.53296687	8.78724E-07
80000	74395.88411	0.217	8.424	0.025789411	2.82343739	0.927149332	0.532844443	1.01282E-06
81000	75330.19829	0.216	8.375	0.025812537	2.824383684	0.916909225	0.526959325	1.15716E-06
82000	76258.53792	0.216	8.375	0.025838806	2.825457924	0.917493373	0.527295042	3.16247E-07
83000	77186.91766	0.216	8.363	0.025845988	2.825751521	0.915025242	0.525876576	6.92695E-07
84000	78116.21964	0.217	8.390	0.02586174	2.826395244	0.921294503	0.5294796	-2.75376E-07
85000	79043.55683	0.217	8.387	0.025855491	2.826139878	0.920496464	0.529020956	3.12366E-07
86000	79973.90135	0.217	8.399	0.025862603	2.826430486	0.923291399	0.530627241	1.72256E-06
87000	80901.23854	0.217	8.384	0.025901718	2.828027876	0.920867455	0.52923417	8.60591E-07
88000	81825.60851	0.216	8.326	0.025921211	2.82882338	0.908598405	0.522182991	-1.3417E-07
89000	82756.91537	0.217	8.381	0.025918148	2.828698427	0.920574009	0.529065522	2.80517E-07
90000	83682.24769	0.217	8.372	0.02592451	2.828957999	0.918739119	0.528010988	4.70836E-07
91000	84613.59464	0.217	8.372	0.02593526	2.829396511	0.918977644	0.528148071	5.65856E-07
92000	85541.93428	0.217	8.369	0.025948142	2.829921817	0.918604718	0.527933746	5.67311E-07
93000	86468.26903	0.217	8.366	0.025961033	2.830447337	0.918231769	0.527719408	9.41038E-07
94000	87398.61355	0.217	8.351	0.025982517	2.831322826	0.915416015	0.526101158	1.52586E-06
95000	88325.95074	0.217	8.341	0.026017264	2.832737816	0.913989478	0.525281309	-4.50315E-07
96000	89256.25516	0.216	8.317	0.026006974	2.832318886	0.908512236	0.522133469	2.02262E-08
97000	90186.59968	0.217	8.338	0.026007436	2.832337703	0.913116082	0.524779357	1.26757E-06
98000	91112.93443	0.217	8.323	0.026036285	2.833511893	0.910465459	0.523256011	-9.9824E-07
99000	92045.28383	0.217	8.348	0.026013416	2.832581184	0.915439432	0.526114616	5.68876E-07
100000	92971.61858	0.217	8.345	0.026026363	2.833108154	0.915066635	0.525900365	7.33293E-07
105000	97618.28886	0.217	8.296	0.026110174	2.836515525	0.9061744	0.520789885	8.11424E-07
110000	102265.9616	0.216	8.241	0.026203131	2.840286757	0.896190901	0.515052242	5.64637E-07
115000	106915.6392	0.216	8.210	0.026267966	2.842912139	0.890838603	0.511976208	1.19964E-07
120000	111555.3726	0.216	8.235	0.026281724	2.84346874	0.896566098	0.515267872	4.06098E-07
125000	116198.0331	0.217	8.247	0.026328362	2.845354113	0.900179693	0.517344651	3.96306E-07
130000	120849.7156	0.217	8.235	0.026374013	2.847197604	0.898536094	0.516400054	4.22384E-07
135000	125503.4029	0.217	8.213	0.026422744	2.849163248	0.894775212	0.514238627	5.32624E-07
140000	130169.0394	0.216	8.158	0.026484432	2.851648279	0.884121235	0.508115653	1.47237E-07
145000	134824.7316	0.217	8.192	0.026501465	2.852333771	0.891865021	0.512566104	5.70189E-07
150000	139483.3911	0.216	8.137	0.026567531	2.854990087	0.881302357	0.506495608	2.45857E-07
155000	144139.0833	0.217	8.164	0.026596031	2.85613472	0.887756473	0.51020487	3.74731E-07
160000	148796.7403	0.216	8.106	0.026639526	2.857880087	0.8760833	0.50349615	2.68928E-07

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
165000	153453.435	0.217	8.140	0.026670762	2.859132403	0.884096495	0.508101434	1.58574E-07
170000	158116.1042	0.217	8.131	0.026689214	2.859871782	0.882524668	0.507198085	5.30157E-07
175000	162768.7891	0.217	8.119	0.026750831	2.862338437	0.881193109	0.506432821	2.42111E-07
180000	167423.4789	0.217	8.100	0.026779012	2.863465387	0.877652033	0.50439772	2.48335E-07
185000	172077.1262	0.216	8.070	0.026807931	2.864621051	0.871751873	0.501006823	6.14162E-07
190000	176732.8184	0.217	8.079	0.026879564	2.867480399	0.875158452	0.502964627	1.93265E-07
195000	181383.4985	0.217	8.070	0.026902107	2.868379214	0.873668142	0.502108127	3.18916E-07
200000	186041.1555	0.216	8.018	0.026939386	2.869864618	0.86319338	0.49608815	5.5615E-08
205000	190699.8551	0.217	8.058	0.026945892	2.870123711	0.871959245	0.501126003	2.44871E-07
210000	195353.5424	0.217	8.045	0.026974518	2.871263263	0.869726072	0.49984257	5.42496E-08
215000	199998.2078	0.217	8.042	0.026980851	2.871515234	0.869205282	0.499543266	3.54231E-07
220000	204649.8903	0.217	8.033	0.027022283	2.873163006	0.868094521	0.498904897	7.37454E-07
225000	209308.5498	0.216	7.969	0.027108797	2.876598554	0.856028734	0.491970537	-6.98428E-08
230000	213965.2444	0.217	8.012	0.027100599	2.876273317	0.865127921	0.497199955	4.65009E-07
235000	218619.9342	0.217	7.997	0.027155183	2.878437792	0.862978129	0.495964442	0
240000	223267.607	0.217	7.997	0.027155183	2.878437792	0.862978129	0.495964442	3.622E-07
245000	227916.2821	0.217	7.972	0.027197692	2.880121544	0.858431256	0.493351297	1.10252E-07
250000	232566.9621	0.217	7.966	0.027210645	2.880634292	0.857395157	0.492755837	-7.26396E-08
255000	237220.6495	0.217	7.981	0.027202105	2.88029625	0.860458013	0.494516099	4.04677E-07
260000	241866.3574	0.217	7.948	0.027249623	2.882176259	0.854290111	0.490971328	7.23504E-08
265000	246513.0277	0.217	7.969	0.027258125	2.882512447	0.858978221	0.493665645	2.53328E-07
270000	251161.7029	0.217	7.957	0.027287923	2.883690088	0.856979264	0.492516819	4.9563E-07
275000	255807.3707	0.216	7.902	0.027346241	2.88599262	0.846303597	0.486381378	2.16886E-07
280000	260459.0532	0.216	7.899	0.027371819	2.887001505	0.846156292	0.48629672	8.89313E-08
285000	265107.7685	0.217	7.923	0.027382305	2.887414921	0.851510136	0.489373641	2.92378E-07
290000	269760.4534	0.217	7.905	0.027416825	2.888775265	0.848314434	0.487537031	1.72392E-07
295000	274406.1212	0.217	7.917	0.027437161	2.88957614	0.851287036	0.489245423	1.76058E-07
300000	279058.8061	0.217	7.911	0.02745797	2.890395283	0.850400804	0.488736094	4.79193E-08
305000	283707.4813	0.217	7.905	0.027463631	2.890618044	0.849220944	0.488058014	1.68382E-07
310000	288358.1613	0.217	7.896	0.027483536	2.891401136	0.847672799	0.487168275	4.12987E-07
315000	293007.8389	0.217	7.874	0.027532385	2.893321393	0.843893585	0.484996313	3.71939E-08
320000	297653.5469	0.217	7.884	0.027536783	2.893494185	0.846123063	0.486277623	1.8504E-07
325000	302302.222	0.217	7.881	0.027558685	2.894354378	0.845900257	0.486149573	2.87466E-07
330000	306947.8899	0.217	7.847	0.027592711	2.895689847	0.839265432	0.482336455	-2.87525E-07
335000	311592.5954	0.217	7.881	0.027558685	2.894354378	0.845900257	0.486149573	2.06699E-07
340000	316245.2803	0.217	7.874	0.027583185	2.895316083	0.844868194	0.485556433	-1.18221E-07
345000	320894.9579	0.217	7.878	0.02756918	2.894766393	0.845457902	0.485895346	-3.21375E-08
350000	325546.6403	0.217	7.878	0.027565372	2.8946169	0.845384779	0.485853321	4.08555E-07
355000	330201.3301	0.217	7.862	0.027613839	2.896518597	0.842880972	0.484414352	-2.44267E-08

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
360000	334863.9994	0.217	7.865	0.027610935	2.896404704	0.843468802	0.484752185	7.3473E-07
365000	339527.671	0.217	7.838	0.027698392	2.899831244	0.839348011	0.482383915	8.73583E-07
370000	344181.3584	0.217	7.813	0.027802381	2.903896624	0.835961333	0.480437548	2.62017E-07
375000	348834.0433	0.217	7.801	0.027833611	2.905115707	0.833981436	0.479299676	1.80309E-07
380000	353488.7331	0.217	7.786	0.027855125	2.905954991	0.831179319	0.477689264	1.14384E-07
385000	358147.3926	0.217	7.789	0.027868789	2.906487868	0.832075441	0.478204276	2.36363E-07
390000	362796.1078	0.216	7.746	0.027896979	2.907586654	0.823434774	0.473238376	-2.03756E-07
395000	367451.76	0.217	7.789	0.027872641	2.906638036	0.832147443	0.478245657	7.21206E-07
400000	372101.4376	0.217	7.755	0.027958736	2.90999141	0.826492931	0.474995937	-1.73851E-07
405000	376744.1382	0.217	7.774	0.027937998	2.909184273	0.830161978	0.477104585	5.79633E-08
410000	381394.8182	0.217	7.771	0.027944923	2.909453842	0.829650116	0.476810412	1.54874E-07
415000	386047.5031	0.217	7.768	0.02796344	2.910174421	0.829353564	0.476639979	1.99975E-07
420000	390693.2111	0.216	7.731	0.027987324	2.911103448	0.82191099	0.472362638	-1.16087E-07
425000	395337.8765	0.217	7.762	0.02797346	2.910564261	0.828258662	0.476010725	9.03242E-08
430000	399986.5516	0.217	7.749	0.027984256	2.910984149	0.825686064	0.474532221	3.33876E-07
435000	404644.2487	0.217	7.749	0.028024261	2.912539242	0.826424943	0.474956864	-5.82938E-08
440000	409293.9263	0.217	7.752	0.028017286	2.912268195	0.826936059	0.475250609	4.84259E-07
445000	413940.5966	0.216	7.710	0.028075227	2.914518389	0.819058535	0.470723296	-6.60554E-08
450000	418590.3143	0.217	7.725	0.028067314	2.91421125	0.822103516	0.472473285	2.82652E-07
455000	423230.97	0.216	7.694	0.028101118	2.91552294	0.816133498	0.46904224	2.64109E-08
460000	427871.7058	0.216	7.691	0.028104278	2.915645506	0.815554596	0.468709538	6.20545E-08
465000	432520.3809	0.217	7.716	0.028111716	2.915933976	0.821001244	0.471839795	8.78304E-08
470000	437170.0585	0.217	7.722	0.028122248	2.916342359	0.822471452	0.472684742	7.62514E-08
475000	441828.718	0.217	7.701	0.028131412	2.916697589	0.818170989	0.470213212	1.42646E-07
480000	446467.4089	0.216	7.691	0.028148485	2.917359279	0.816357605	0.469171038	3.38674E-07
485000	451106.0997	0.216	7.670	0.028189048	2.918930285	0.812637999	0.467033333	8.46791E-08
490000	455743.8282	0.217	7.691	0.028199194	2.919323003	0.817278124	0.469700071	-9.9529E-09
495000	460389.4961	0.217	7.697	0.028197999	2.919276766	0.818532079	0.470420735	3.06941E-07
500000	465042.181	0.217	7.688	0.028234912	2.920704868	0.817288173	0.469705847	6.48644E-08
505000	469694.8659	0.217	7.688	0.028242716	2.921006661	0.817429615	0.469787135	2.96325E-07
510000	474346.5484	0.217	7.673	0.028278379	2.922385072	0.814886589	0.468325626	-1.7214E-07
515000	479001.2382	0.217	7.685	0.028257645	2.921583812	0.817062095	0.469575917	-3.24955E-08
520000	483644.9412	0.217	7.685	0.028253741	2.921432912	0.816991418	0.469535298	8.61248E-08
525000	488292.614	0.217	7.679	0.028264097	2.921833192	0.815903391	0.468909995	7.55991E-07
530000	492943.294	0.217	7.636	0.02835516	2.925349063	0.808417956	0.464608021	-2.91841E-07
535000	497584.9922	0.217	7.655	0.028320052	2.923994426	0.811816003	0.466560921	2.1703E-07
540000	502228.6952	0.217	7.661	0.028346169	2.925002247	0.813558523	0.46756237	-2.81792E-07
545000	506874.4032	0.217	7.667	0.028312247	2.923693126	0.814222671	0.467944064	4.34401E-07
550000	511517.1038	0.217	7.643	0.028364517	2.92570992	0.810068134	0.465556399	5.26216E-07

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	$G_{I\max}$	$G_{I\max}/(G_{IR})_{Asym}$	da/dN
555000	516151.7849	0.217	7.639	0.028427805	2.928148763	0.810350518	0.465718688	7.54265E-07
560000	520788.4708	0.216	7.588	0.028518714	2.931646051	0.801166445	0.460440486	2.30327E-07
565000	525429.1666	0.216	7.575	0.028546535	2.932714931	0.798911233	0.459144387	1.59429E-07
570000	530066.8951	0.217	7.600	0.028565789	2.93345432	0.804532873	0.462375214	2.01734E-08
575000	534699.5713	0.216	7.578	0.028568224	2.933547777	0.799924473	0.459726708	5.68208E-07
580000	539328.2779	0.217	7.563	0.028636784	2.936177844	0.797957573	0.458596306	2.77358E-07
585000	543968.9736	0.216	7.551	0.028670375	2.937464976	0.796011463	0.457477852	4.75033E-07
590000	548598.6826	0.217	7.554	0.028727826	2.93966424	0.797643272	0.458415673	1.94392E-07
595000	553222.417	0.217	7.536	0.028751327	2.940563059	0.794253037	0.456467263	9.71635E-08
600000	557846.1114	0.217	7.551	0.028763078	2.941012313	0.797622067	0.458403487	-3.48875E-07
605000	562469.8058	0.217	7.560	0.028720899	2.939399224	0.79879026	0.459074862	2.72324E-07
610000	567093.5001	0.216	7.527	0.02875382	2.940658366	0.79240008	0.455402345	-2.47812E-07
615000	571718.237	0.217	7.554	0.028723855	2.939512302	0.797574226	0.458375992	1.72485E-07
620000	576342.9338	0.217	7.560	0.028744709	2.940309991	0.799204822	0.459313116	2.13316E-07
625000	580971.6403	0.217	7.548	0.028770535	2.941297368	0.797117783	0.458113669	-3.28207E-08
630000	585600.3469	0.217	7.548	0.028766561	2.94114545	0.797048831	0.458074041	-9.86073E-08
635000	590223.0388	0.217	7.548	0.028754637	2.940689619	0.796841954	0.457955146	2.91139E-07
640000	594855.7551	0.217	7.545	0.028789927	2.942038384	0.796820368	0.45794274	-1.27301E-07
645000	599483.4592	0.217	7.548	0.02877451	2.941449272	0.797186732	0.458153294	1.92988E-07
650000	604110.1609	0.217	7.545	0.028797879	2.942342172	0.796958172	0.458021938	1.89317E-07
655000	608730.848	0.216	7.505	0.028820786	2.943216948	0.788923056	0.453404055	-1.21029E-07
660000	613361.5594	0.217	7.530	0.028806109	2.942656495	0.793934528	0.456284212	-2.278E-07
665000	617994.2757	0.217	7.548	0.028778484	2.941601164	0.797255677	0.458192918	2.88407E-08
670000	622618.9725	0.217	7.545	0.028781975	2.941734543	0.79668255	0.457863535	-3.16071E-07
675000	627246.6766	0.217	7.554	0.028743712	2.940271861	0.797919416	0.458574377	6.29522E-08
680000	631872.3758	0.217	7.536	0.028751327	2.940563059	0.794253037	0.456467263	2.30078E-07
685000	636502.0848	0.217	7.536	0.028779193	2.941628251	0.794734954	0.456744226	-1.08192E-07
690000	641137.8085	0.217	7.545	0.02876607	2.941126704	0.796406871	0.457705099	1.69911E-07
695000	645771.4871	0.217	7.533	0.028786672	2.941914018	0.794231534	0.456454905	-2.23356E-07
700000	650404.2034	0.217	7.554	0.028759598	2.940879272	0.798195504	0.458733048	2.63795E-07
705000	655038.8845	0.216	7.514	0.028791589	2.942101876	0.790314622	0.454203806	9.88453E-08
710000	659667.5911	0.216	7.514	0.028803567	2.942559402	0.790520469	0.454322108	-1.78397E-07
715000	664291.3255	0.217	7.545	0.028781975	2.941734543	0.79668255	0.457863535	1.43303E-07
720000	668926.0467	0.216	7.496	0.02879936	2.942398715	0.786665625	0.452106681	7.81258E-08
725000	673570.7121	0.217	7.539	0.028808861	2.942761583	0.795881113	0.457402939	-5.93887E-08
730000	678209.403	0.217	7.527	0.028801647	2.942486097	0.793225103	0.455876496	3.00032E-07
735000	682849.0963	0.216	7.505	0.028838108	2.943878153	0.789219911	0.453574662	-1.90859E-08
740000	687485.8224	0.217	7.533	0.028835789	2.943789657	0.795079782	0.456942403	-1.1478E-08
745000	692116.5338	0.217	7.524	0.028834397	2.943736505	0.793157099	0.455837413	1.25595E-07

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
750000	696748.2076	0.216	7.502	0.02884964	2.944318219	0.788786521	0.453325587	-2.62045E-08
755000	701375.9117	0.216	7.490	0.028846462	2.944196953	0.78621086	0.451845322	-4.37767E-07
760000	706001.651	0.217	7.542	0.028793423	2.942171957	0.796247382	0.457613438	3.63531E-07
765000	710633.3248	0.216	7.484	0.02883752	2.943855716	0.784799386	0.45103413	-4.28871E-07
770000	715268.046	0.217	7.542	0.028785468	2.941868019	0.796109625	0.457534267	4.07593E-07
775000	719895.7501	0.217	7.527	0.028834861	2.943754237	0.793797735	0.456205595	-5.42865E-08
780000	724515.4748	0.217	7.536	0.028828291	2.943503448	0.795583622	0.457231967	5.02729E-07
785000	729136.2019	0.217	7.499	0.028889185	2.945826422	0.788832064	0.453351761	-9.48362E-08
790000	733769.8806	0.217	7.520	0.02887766	2.945386982	0.793058125	0.455780531	-2.83034E-07
795000	738401.5944	0.217	7.530	0.028843293	2.944076047	0.794576078	0.456652918	1.91913E-07
800000	743023.2839	0.217	7.508	0.028866542	2.944963009	0.790338537	0.45421755	-9.50182E-08
805000	747651.9905	0.217	7.511	0.028855013	2.944523198	0.790772433	0.454466915	1.89914E-07
810000	752279.7347	0.216	7.487	0.028878055	2.945402071	0.786119791	0.451792983	1.65331E-09
815000	756914.4158	0.217	7.524	0.028878256	2.945409734	0.793912299	0.456271436	2.50745E-07
820000	761543.1223	0.217	7.514	0.028908704	2.946570359	0.792325973	0.455359754	-5.47032E-08
825000	766167.8191	0.217	7.505	0.028902065	2.946317373	0.790315414	0.454204261	4.7476E-08
830000	770796.5257	0.217	7.508	0.028907832	2.946537126	0.791046176	0.454624239	-2.14566E-08
835000	775423.2674	0.216	7.481	0.028905227	2.946437851	0.785322627	0.451334843	-6.631E-08
840000	780055.9437	0.217	7.517	0.028897166	2.946130659	0.792760612	0.455609547	1.76597E-07
845000	784679.638	0.216	7.481	0.028918594	2.94694719	0.785550003	0.451465519	1.47397E-07
850000	789295.353	0.216	7.475	0.028936455	2.947627533	0.784593706	0.450915923	-3.52998E-07
855000	793919.0874	0.217	7.520	0.028893617	2.945995365	0.793332492	0.455938214	0
860000	798535.8048	0.217	7.520	0.028893617	2.945995365	0.793332492	0.455938214	-1.42982E-07
865000	803157.4942	0.216	7.493	0.028876285	2.945334548	0.78735004	0.452500023	1.90848E-07
870000	807785.1984	0.216	7.469	0.028899451	2.946217737	0.782707293	0.449831778	-2.96197E-07
875000	812418.9171	0.217	7.514	0.028863455	2.944845246	0.791549222	0.454913346	1.42484E-07
880000	817049.6285	0.217	7.514	0.028880756	2.945505047	0.791846268	0.455084062	3.48276E-07
885000	821676.3302	0.216	7.484	0.028923036	2.947116416	0.786255777	0.451871136	5.86621E-07
890000	826304.0343	0.216	7.438	0.028994353	2.949831125	0.777818609	0.447022189	-3.19077E-07
895000	830934.7859	0.217	7.487	0.028955523	2.94835356	0.787439551	0.452551466	2.11139E-07
900000	835564.4548	0.216	7.450	0.028981208	2.949331063	0.780108865	0.448338428	-6.29705E-07
905000	840190.1941	0.217	7.514	0.028904711	2.946418211	0.792257454	0.455320376	4.97982E-07
910000	844822.9104	0.217	7.490	0.028965287	2.948725219	0.788237107	0.453009832	7.7603E-08
915000	849456.5891	0.217	7.481	0.028974736	2.949084807	0.786504557	0.452014113	-4.40735E-07
920000	854082.3284	0.217	7.499	0.028921189	2.94704608	0.789379129	0.453666166	1.75564E-07
925000	858711.0349	0.217	7.499	0.028942526	2.947858715	0.789743713	0.453875697	-9.53496E-08
930000	863333.7269	0.217	7.502	0.028930952	2.947417943	0.790177803	0.454125174	-9.52758E-08
935000	867957.4613	0.217	7.505	0.028919387	2.946977414	0.790611957	0.454374688	4.15822E-07
940000	872588.1326	0.216	7.456	0.028969957	2.94890295	0.781175976	0.44895171	-3.56366E-07

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
945000	877218.8441	0.216	7.481	0.028926614	2.947252723	0.785686411	0.451543914	1.34485E-07
950000	881844.5834	0.217	7.502	0.028942949	2.947874818	0.79038295	0.454243075	-6.22973E-08
955000	886473.29	0.217	7.505	0.028935376	2.947586462	0.790885629	0.454531971	-1.31524E-07
960000	891104.0014	0.217	7.505	0.028919387	2.946977414	0.790611957	0.454374688	3.87896E-07
965000	895731.7055	0.217	7.499	0.028966529	2.948772482	0.790153751	0.454111351	2.77794E-07
970000	900352.3925	0.216	7.462	0.029000268	2.950056081	0.78294623	0.449969097	-4.97343E-07
975000	904970.1124	0.217	7.490	0.02893992	2.947759489	0.787804799	0.452761379	2.86509E-07
980000	909595.8517	0.217	7.481	0.028974736	2.949084807	0.786504557	0.452014113	-1.94857E-07
985000	914213.5314	0.217	7.484	0.028951096	2.948185017	0.786733305	0.452145577	-3.07842E-08
990000	918823.2718	0.217	7.505	0.028947368	2.94804311	0.791090847	0.454649912	-3.64528E-08
995000	923439.9892	0.217	7.502	0.028942949	2.947874818	0.79038295	0.454243075	6.25124E-08
1000000	928055.7041	0.217	7.499	0.028950527	2.948163357	0.789880407	0.453954257	1.85932E-07
1005000	932674.4263	0.216	7.469	0.028973089	2.949022125	0.783955467	0.450549119	-2.44001E-07
1010000	937290.1012	0.217	7.487	0.028943502	2.947895895	0.787234847	0.45243382	-1.26156E-07
1015000	941897.8367	0.217	7.511	0.028928239	2.947314601	0.79202835	0.455188707	0
1020000	946512.5492	0.217	7.511	0.028928239	2.947314601	0.79202835	0.455188707	2.11584E-07
1025000	951121.247	0.216	7.475	0.028953846	2.948289729	0.784888932	0.451085593	-2.4396E-07
1030000	955741.9742	0.217	7.511	0.028924244	2.947162457	0.791959876	0.455149354	-9.89683E-08
1035000	960354.6818	0.217	7.511	0.028912262	2.946705946	0.791754433	0.455031283	2.58921E-07
1040000	964968.4319	0.216	7.450	0.028943624	2.947900544	0.779475262	0.447974288	-4.12494E-07
1045000	969587.1141	0.217	7.520	0.028893617	2.945995365	0.793332492	0.455938214	-1.92762E-07
1050000	974202.829	0.217	7.524	0.028870282	2.945105629	0.793775022	0.456192541	2.21999E-07
1055000	978823.516	0.217	7.499	0.028897186	2.946131416	0.788968852	0.453430375	4.07559E-07
1060000	983448.2128	0.216	7.462	0.028946663	2.948016255	0.782039753	0.449448134	-1.02764E-07
1065000	988063.9278	0.216	7.478	0.028934207	2.947541925	0.785185413	0.451255984	-4.00614E-07
1070000	992683.6525	0.217	7.520	0.028885638	2.9456912	0.793195316	0.455859377	1.35398E-07
1075000	997308.3492	0.217	7.505	0.028902065	2.946317373	0.790315414	0.454204261	-2.67491E-07
1080000	1001924.064	0.217	7.520	0.028869681	2.945082711	0.792920919	0.455701678	-1.85038E-07
1085000	1006542.786	0.217	7.530	0.028847278	2.944228074	0.794644797	0.456692412	3.38364E-07
1090000	1011166.481	0.217	7.511	0.028888297	2.945792567	0.791343451	0.454795087	1.54157E-07
1095000	1015791.178	0.216	7.484	0.028907002	2.946505495	0.785982826	0.451714268	-1.43281E-07
1100000	1020412.907	0.217	7.520	0.028889628	2.945843289	0.793263906	0.455898796	5.14131E-08
1105000	1025034.637	0.216	7.490	0.028895861	2.946080906	0.787053611	0.452329661	3.59155E-07
1110000	1029663.303	0.217	7.487	0.028939495	2.947743313	0.787166606	0.452394601	1.91352E-07
1115000	1034289.002	0.216	7.462	0.028962745	2.948628451	0.782311762	0.449604461	-1.66403E-07
1120000	1038914.742	0.217	7.499	0.028942526	2.947858715	0.789743713	0.453875697	2.6348E-07
1125000	1043538.436	0.217	7.499	0.02897453	2.949076966	0.790290401	0.454189886	1.87511E-07
1130000	1048164.135	0.217	7.490	0.02899733	2.949944333	0.788782979	0.453323551	2.50896E-07
1135000	1052783.86	0.217	7.478	0.029027815	2.951103404	0.786774993	0.452169536	-1.74343E-08

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
1140000	1057403.545	0.217	7.472	0.029025696	2.951022863	0.785477052	0.451423593	2.44459E-07
1145000	1062026.237	0.216	7.432	0.029055436	2.95215292	0.77758819	0.446889764	-7.74246E-07
1150000	1066639.947	0.216	7.453	0.028961492	2.948580776	0.780404657	0.448508424	1.07663E-07
1155000	1071248.685	0.217	7.499	0.02897453	2.949076966	0.790290401	0.454189886	3.79756E-07
1160000	1075860.39	0.217	7.484	0.029020577	2.95082829	0.78791501	0.452824718	-3.57261E-07
1165000	1080467.123	0.217	7.490	0.028977303	2.949182486	0.788441836	0.453127492	4.23231E-07
1170000	1085075.821	0.217	7.484	0.029028594	2.951133028	0.788051292	0.452903041	-3.62622E-08
1175000	1089687.526	0.217	7.481	0.029024195	2.950965797	0.787344901	0.45249707	1.32018E-07
1180000	1094305.246	0.217	7.481	0.029040235	2.951575417	0.78761733	0.452653638	-2.87687E-07
1185000	1098915.948	0.217	7.490	0.02900534	2.95024898	0.788919411	0.453401961	-3.7801E-07
1190000	1103526.651	0.217	7.487	0.02895953	2.948506089	0.787507779	0.452590677	2.96295E-08
1195000	1108140.361	0.217	7.484	0.028963121	2.948642791	0.786937906	0.452263164	2.13343E-08
1200000	1112743.084	0.217	7.493	0.028965701	2.948740986	0.78887573	0.453376856	1.05999E-07
1205000	1117348.815	0.217	7.499	0.02897853	2.949229188	0.790358722	0.45422915	5.11204E-07
1210000	1121954.506	0.216	7.441	0.029040452	2.951583636	0.779220892	0.447828099	-1.0913E-07
1215000	1126556.226	0.216	7.453	0.029027237	2.951081451	0.781513453	0.449145662	-5.82211E-08
1220000	1131160.955	0.217	7.481	0.029020184	2.950813359	0.787276785	0.452457922	3.20798E-07
1225000	1135769.652	0.216	7.429	0.029059093	2.952291821	0.77702178	0.446564241	-3.44375E-07
1230000	1140384.405	0.217	7.469	0.029017271	2.950702616	0.784703802	0.450979196	6.35688E-08
1235000	1144992.1	0.217	7.487	0.029024977	2.950995522	0.788621663	0.453230841	1.24391E-07
1240000	1149601.841	0.216	7.438	0.029040065	2.95156893	0.778586202	0.447463335	5.69852E-08
1245000	1154211.501	0.216	7.429	0.029046978	2.951831612	0.776818933	0.446447663	-1.84678E-07
1250000	1158819.237	0.217	7.484	0.029024586	2.950980665	0.787983152	0.452863881	8.95479E-08
1255000	1163430.942	0.217	7.475	0.029035452	2.951393634	0.786273339	0.451881229	3.6334E-07
1260000	1168042.647	0.217	7.453	0.029079565	2.953069251	0.782395292	0.449652467	-6.13499E-07
1265000	1172664.376	0.217	7.487	0.029004942	2.950233824	0.788280778	0.45303493	4.52021E-07
1270000	1177281.054	0.216	7.435	0.029059852	2.952320661	0.778290137	0.447293182	-1.32745E-07
1275000	1181896.769	0.217	7.456	0.029043723	2.951707946	0.782420843	0.449667151	3.41279E-08
1280000	1186517.496	0.217	7.478	0.029047874	2.951865642	0.787115368	0.452365154	7.65467E-07
1285000	1191135.176	0.216	7.404	0.029141005	2.955400323	0.773162417	0.444346217	7.3179E-08
1290000	1195749.888	0.216	7.411	0.029149912	2.955738024	0.774773305	0.445272014	-2.39024E-07
1295000	1200367.608	0.217	7.450	0.029120805	2.954634277	0.782459564	0.449689405	7.47679E-08
1300000	1204986.33	0.217	7.459	0.02912991	2.954979609	0.784504753	0.450864801	-1.32209E-07
1305000	1209602.045	0.217	7.459	0.029113822	2.95436937	0.784233439	0.450708873	9.61465E-08
1310000	1214223.735	0.217	7.456	0.029125536	2.954813729	0.783800132	0.450459846	0
1315000	1218842.457	0.217	7.456	0.029125536	2.954813729	0.783800132	0.450459846	4.82888E-07
1320000	1223451.155	0.217	7.441	0.029184249	2.957039215	0.781634574	0.449215273	2.9006E-07
1325000	1228064.865	0.217	7.432	0.029219591	2.958377468	0.780336023	0.448468979	2.29857E-07
1330000	1232666.586	0.217	7.429	0.029247543	2.959435206	0.78017312	0.448375356	-9.93667E-08

Table A-20. Compliance Method Constant Displacement Amplitude Fatigue Test Data (Specimen UCE205) (Continued)

N	N	d	P	C	a	G_{Imax}	$G_{Imax}/(G_{IR})_{Asym}$	da/dN
1335000	1237279.293	0.217	7.429	0.029235429	2.958976856	0.779970763	0.448259059	-9.44128E-08
1340000	1241884.021	0.217	7.435	0.029223941	2.958542111	0.781038924	0.448872945	-6.36538E-08
1345000	1246494.724	0.217	7.438	0.029216187	2.958248622	0.781539482	0.449160622	-3.87318E-07
1350000	1251096.445	0.217	7.450	0.029169128	2.956466295	0.783272286	0.450156486	-3.59147E-08
1355000	1255700.171	0.217	7.447	0.029164764	2.956300953	0.782568286	0.449751888	4.52366E-07
1360000	1260304.859	0.216	7.408	0.029219762	2.958383958	0.775307164	0.44557883	1.00874E-07
1365000	1264903.572	0.216	7.383	0.02923202	2.95884785	0.770285338	0.442692723	-2.92908E-07
1370000	1269514.315	0.217	7.441	0.029196345	2.957497328	0.781837391	0.449331834	1.9657E-07
1375000	1274113.029	0.217	7.438	0.02922022	2.958401297	0.781607037	0.449199446	-3.31777E-08
1380000	1278714.75	0.217	7.438	0.029216187	2.958248622	0.781539482	0.449160622	-1.30085E-07
1385000	1283316.47	0.217	7.441	0.029200376	2.957650006	0.78190499	0.449370684	1.30142E-07
1390000	1287916.186	0.217	7.438	0.029216187	2.958248622	0.781539482	0.449160622	3.30442E-07
1395000	1292520.875	0.216	7.383	0.0292564	2.959770206	0.770687533	0.442923869	3.16485E-07
1400000	1297115.618	0.217	7.417	0.029294863	2.961224372	0.778442295	0.447380629	3.58551E-07
1405000	1301718.342	0.217	7.408	0.029338553	2.962874682	0.777279228	0.4467122	3.45454E-07
1410000	1306312.083	0.216	7.362	0.029380603	2.964461607	0.768344896	0.441577526	-2.83848E-07
1415000	1310907.789	0.217	7.401	0.029346034	2.963157125	0.775934847	0.445939567	-2.25526E-07
1420000	1315504.498	0.217	7.411	0.02931858	2.962120447	0.777577275	0.446883492	1.54631E-07
1425000	1320098.239	0.217	7.395	0.02933739	2.962830779	0.774534368	0.445134694	0
1430000	1324689.936	0.217	7.395	0.02933739	2.962830779	0.774534368	0.445134694	1.78011E-08
1435000	1329289.652	0.217	7.389	0.029339559	2.962912659	0.773313818	0.444433229	1.97867E-07
1440000	1333887.403	0.217	7.386	0.029363661	2.963822402	0.773083385	0.444300796	-4.34684E-07
1445000	1338482.107	0.217	7.414	0.029310763	2.961825157	0.778077011	0.447170696	-1.95397E-08
1450000	1343088.8	0.216	7.374	0.029308381	2.961735143	0.769664723	0.442336048	-7.03358E-08
1455000	1347692.526	0.217	7.398	0.029299811	2.961411337	0.774541055	0.445138537	-2.74882E-07
1460000	1352307.238	0.217	7.414	0.029266253	2.960142836	0.777336977	0.446745389	7.30718E-09
1465000	1356910.964	0.217	7.423	0.029267143	2.960176476	0.779240203	0.447839197	-3.31178E-08
1470000	1361525.676	0.217	7.423	0.029263101	2.960023647	0.779172825	0.447800474	3.03298E-07
1475000	1366136.379	0.217	7.401	0.029300095	2.961422062	0.77517406	0.445502333	-1.16289E-07
1480000	1370747.122	0.217	7.408	0.029285907	2.960885882	0.776405614	0.446210123	-2.55613E-07
1485000	1375360.832	0.217	7.420	0.029254717	2.959706556	0.778403473	0.447358318	6.2697E-07
1490000	1379968.568	0.216	7.356	0.029331158	2.962595468	0.766284442	0.440393357	2.14686E-06

Table A-21. Delamination Propagation Under Fatigue Block Loading 1 (Specimen WF-5)

Experimental Data									b = 1.4965 Δ = 0.113				
		Displacement, in.		Crack Length, in.		Load, P, lb			Applied G				
G_{max}/G_{IC}	N	δ_{maxi}, in.	δ_{maxf}, in.	a_i,in.	a_f,in.	P_i	P_f	da/dN, 10^{-6}	G_{mi}	G_{mf}	G_{max}	G_{mi}/G_{IC}	G_{mf}/G_{IC}
0.30	10000	0.0761	0.0761	1.463	1.463	11.10	11.17	0.0000	0.537	0.541	0.539	0.273	0.274
0.32	20000	0.0786	0.0786	1.463	1.463	11.61	11.39	0.0000	0.580	0.569	0.575	0.295	0.289
0.34	30000	0.0810	0.0810	1.463	1.463	11.80	10.51	0.0000	0.608	0.541	0.575	0.309	0.275
0.36	40000	0.0834	0.0834	1.463	1.463	10.95	10.93	0.0000	0.581	0.580	0.580	0.295	0.294
0.38	50000	0.0857	0.0857	1.463	1.477	11.30	11.09	1.4000	0.616	0.599	0.608	0.313	0.304
0.40	60000	0.0896	0.0896	1.477	1.492	11.65	11.24	1.5000	0.658	0.629	0.643	0.334	0.319
0.42	70000	0.0937	0.0937	1.492	1.513	11.87	11.29	2.1000	0.695	0.652	0.673	0.353	0.331
0.44	80000	0.0986	0.0986	1.513	1.565	11.92	12.49	5.2000	0.725	0.736	0.730	0.368	0.373
0.46	90000	0.1078	0.1078	1.565	1.583	12.68	11.97	1.8000	0.817	0.763	0.790	0.414	0.387
0.48	100000	0.1127	0.1127	1.583	1.636	12.55	12.01	5.3000	0.836	0.776	0.806	0.424	0.394
0.50	110000	0.1229	0.1229	1.636	1.668	13.23	12.69	3.2000	0.932	0.878	0.905	0.473	0.446
0.50	120000	0.1277	0.1277	1.668	1.676	13.49	13.21	0.8000	0.970	0.945	0.957	0.492	0.480
0.50	130000	0.1290	0.1290	1.676	1.686	13.33	12.91	1.0000	0.963	0.928	0.946	0.489	0.471
0.50	140000	0.1305	0.1305	1.686	1.709	12.68	12.68	2.3000	0.922	0.910	0.916	0.468	0.462
0.50	150000	0.1341	0.1341	1.709	1.726	12.98	12.73	1.7000	0.958	0.930	0.944	0.486	0.472
0.50	160000	0.1368	0.1368	1.726	1.759	12.95	12.46	3.3000	0.966	0.913	0.939	0.490	0.463
0.50	170000	0.1421	0.1421	1.759	1.807	12.96	12.09	4.8000	0.986	0.897	0.941	0.501	0.455
0.50	180000	0.1499	0.1499	1.807	1.855	12.78	11.86	4.8000	1.000	0.905	0.953	0.508	0.460
0.50	190000	0.1580	0.1580	1.855	1.891	12.29	11.88	3.6000	0.989	0.939	0.964	0.502	0.477
0.50	200000	0.1642	0.1642	1.891	1.933	12.37	11.85	4.2000	1.016	0.953	0.985	0.516	0.484
0.48	210000	0.1681	0.1681	1.933	1.967	12.11	11.65	3.4000	0.997	0.944	0.971	0.506	0.479
0.46	220000	0.1704	0.1704	1.967	2.009	11.77	11.37	4.2000	0.966	0.915	0.941	0.491	0.465
0.44	230000	0.1738	0.1738	2.009	2.036	11.56	11.03	2.7000	0.949	0.894	0.922	0.482	0.454
0.42	240000	0.1744	0.1744	2.036	2.055	11.00	10.85	1.9000	0.895	0.875	0.885	0.454	0.444
0.40	250000	0.1734	0.1734	2.055	2.065	10.71	10.62	1.0000	0.859	0.847	0.853	0.436	0.430
0.38	260000	0.1707	0.1707	2.065	2.082	10.35	10.29	1.7000	0.813	0.802	0.808	0.413	0.407
0.36	270000	0.1689	0.1689	2.082	2.105	9.86	9.89	2.3000	0.760	0.755	0.758	0.386	0.383
0.34	280000	0.1678	0.1678	2.105	2.118	9.77	9.75	1.3000	0.741	0.735	0.738	0.376	0.373
0.32	290000	0.1648	0.1648	2.118	2.125	9.53	9.54	0.7000	0.706	0.704	0.705	0.358	0.357
0.30	300000	0.1606	0.1606	2.125	2.131	9.22	9.04	0.6000	0.663	0.648	0.656	0.337	0.329

Table A-22. Delamination Propagation Prediction for Fatigue Block Loading 1 Based on Equation 10-4

WF-5		Predition Based on Equation 10-4									
		Initial Crack Length = 1.463		G_{IC} = 1.97		D_1 = 8		D_2 = 4			
Loading		Predicted Crack Length									
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f	
0.5389	1000	1.463	0.000	0.000	1.970	0.274	0.274	3.9123915E-06	3.9123915E-03	1.467	
0.5389	2000	1.467	0.001	0.004	2.378	0.227	0.274	1.3409259E-06	1.3409259E-03	1.468	
0.5389	3000	1.468	0.001	0.005	2.417	0.223	0.274	1.2202082E-06	1.2202082E-03	1.469	
0.5389	4000	1.469	0.001	0.006	2.446	0.220	0.274	1.1358026E-06	1.1358026E-03	1.471	
0.5389	5000	1.471	0.001	0.008	2.471	0.218	0.274	1.0713516E-06	1.0713516E-03	1.472	
0.5389	6000	1.472	0.001	0.009	2.492	0.216	0.274	1.0195067E-06	1.0195067E-03	1.473	
0.5389	7000	1.473	0.001	0.010	2.510	0.215	0.274	9.7632984E-07	9.7632984E-04	1.474	
0.5389	8000	1.474	0.001	0.011	2.526	0.213	0.274	9.3946601E-07	9.3946601E-04	1.475	
0.5389	9000	1.475	0.001	0.012	2.540	0.212	0.274	9.0739623E-07	9.0739623E-04	1.476	
0.5389	10000	1.476	0.001	0.013	2.554	0.211	0.274	8.7908462E-07	8.7908462E-04	1.476	
0.5749	20000	1.476	0.0125	0.013	2.566	0.224	0.292	1.2534746E-06	0.013	1.489	
0.5747	30000	1.489	0.009	0.026	2.701	0.213	0.292	9.2432033E-07	0.009	1.498	
0.5803	40000	1.498	0.008	0.035	2.772	0.209	0.295	8.3627480E-07	0.008	1.507	
0.6075	50000	1.507	0.010	0.044	2.827	0.215	0.308	9.8066817E-07	0.010	1.516	
0.6435	60000	1.516	0.012	0.053	2.882	0.223	0.327	1.2285322E-06	0.012	1.529	
0.6734	70000	1.529	0.014	0.066	2.942	0.229	0.342	1.4186298E-06	0.014	1.543	
0.7301	80000	1.543	0.020	0.080	3.003	0.243	0.371	2.0082242E-06	0.020	1.563	
0.7896	90000	1.563	0.027	0.100	3.077	0.257	0.401	2.7280680E-06	0.027	1.590	
0.8058	100000	1.590	0.026	0.127	3.162	0.255	0.409	2.6217959E-06	0.026	1.616	
0.9048	110000	1.616	0.044	0.153	3.233	0.280	0.459	4.4457723E-06	0.044	1.661	
0.9573	120000	1.661	0.051	0.198	3.336	0.287	0.486	5.1196623E-06	0.051	1.712	
0.9457	130000	1.712	0.040	0.249	3.436	0.275	0.480	4.0449712E-06	0.040	1.753	
0.9161	140000	1.753	0.030	0.290	3.506	0.261	0.465	3.0219436E-06	0.030	1.783	
0.9440	150000	1.783	0.033	0.320	3.554	0.266	0.479	3.3156038E-06	0.033	1.816	
0.9391	160000	1.816	0.030	0.353	3.602	0.261	0.477	2.9813961E-06	0.030	1.846	
0.9415	170000	1.846	0.028	0.383	3.644	0.258	0.478	2.8353235E-06	0.028	1.874	
0.9528	180000	1.874	0.029	0.411	3.681	0.259	0.484	2.8638824E-06	0.029	1.903	
0.9639	190000	1.903	0.029	0.440	3.717	0.259	0.489	2.8950856E-06	0.029	1.932	
0.9846	200000	1.932	0.031	0.469	3.752	0.262	0.500	3.0966027E-06	0.031	1.963	
0.9705	210000	1.963	0.027	0.500	3.787	0.256	0.493	2.7072081E-06	0.027	1.990	
0.9408	220000	1.990	0.022	0.527	3.817	0.246	0.478	2.1718040E-06	0.022	2.011	
0.9216	230000	2.011	0.019	0.548	3.840	0.240	0.468	1.8652176E-06	0.019	2.030	
0.8848	240000	2.030	0.014	0.567	3.859	0.229	0.449	1.4339839E-06	0.014	2.044	
0.8530	250000	2.044	0.011	0.581	3.874	0.220	0.433	1.1331630E-06	0.011	2.056	
0.8076	260000	2.056	0.008	0.593	3.885	0.208	0.410	8.0175938E-07	0.008	2.064	
0.7577	270000	2.064	0.005	0.601	3.893	0.195	0.385	5.2802824E-07	0.005	2.069	
0.7380	280000	2.069	0.004	0.606	3.898	0.189	0.375	4.3765834E-07	0.004	2.073	
0.7049	290000	2.073	0.003	0.610	3.903	0.181	0.358	3.1010518E-07	0.003	2.076	
0.6558	300000	2.076	0.002	0.613	3.906	0.168	0.333	1.6004126E-07	0.002	2.078	

Table A-23. Delamination Propagation Prediction for Fatigue Block Loading 1 Based on Equation 10-7

WF-5	Predition Based on Equation 10-7									
		Initial Crack Length = 1.463		G_{IC} = 1.97			D$_1$ = 8		D$_2$ = 2	
Loading		Predicted Crack length								
G_{mav}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.5389	1000	1.463	0.000	0.000	1.970	0.274	0.274	9.5692546E-07	9.5692546E-04	1.464
0.5389	2000	1.464	0.001	0.001	2.234	0.241	0.274	9.5692546E-07	9.5692546E-04	1.465
0.5389	3000	1.465	0.001	0.002	2.297	0.235	0.274	9.5692546E-07	9.5692546E-04	1.466
0.5389	4000	1.466	0.001	0.003	2.341	0.230	0.274	9.5692546E-07	9.5692546E-04	1.467
0.5389	5000	1.467	0.001	0.004	2.375	0.227	0.274	9.5692546E-07	9.5692546E-04	1.468
0.5389	6000	1.468	0.001	0.005	2.404	0.224	0.274	9.5692546E-07	9.5692546E-04	1.469
0.5389	7000	1.469	0.001	0.006	2.429	0.222	0.274	9.5692546E-07	9.5692546E-04	1.470
0.5389	8000	1.470	0.001	0.007	2.451	0.220	0.274	9.5692546E-07	9.5692546E-04	1.471
0.5389	9000	1.471	0.001	0.008	2.472	0.218	0.274	9.5692546E-07	9.5692546E-04	1.472
0.5389	10000	1.472	0.001	0.009	2.490	0.216	0.274	9.5692546E-07	9.5692546E-04	1.473
0.5749	20000	1.473	0.011	0.010	2.507	0.229	0.292	1.0592987E-06	0.011	1.483
0.5747	30000	1.483	0.011	0.020	2.646	0.217	0.292	1.0586470E-06	0.011	1.494
0.5803	40000	1.494	0.011	0.031	2.740	0.212	0.295	1.0754587E-06	0.011	1.505
0.6075	50000	1.505	0.012	0.042	2.814	0.216	0.308	1.1603558E-06	0.012	1.516
0.6435	60000	1.516	0.013	0.053	2.881	0.223	0.327	1.2820479E-06	0.013	1.529
0.6734	70000	1.529	0.014	0.066	2.944	0.229	0.342	1.3923517E-06	0.014	1.543
0.7301	80000	1.543	0.016	0.080	3.003	0.243	0.371	1.6282014E-06	0.016	1.559
0.7896	90000	1.559	0.019	0.096	3.064	0.258	0.401	1.9184925E-06	0.019	1.578
0.8058	100000	1.578	0.020	0.115	3.127	0.258	0.409	2.0064300E-06	0.020	1.598
0.9048	110000	1.598	0.026	0.135	3.185	0.284	0.459	2.6375455E-06	0.026	1.625
0.9573	120000	1.625	0.031	0.162	3.254	0.294	0.486	3.0505950E-06	0.031	1.655
0.9457	130000	1.655	0.030	0.192	3.324	0.284	0.480	2.9536151E-06	0.030	1.685
0.9161	140000	1.685	0.027	0.222	3.385	0.271	0.465	2.7217726E-06	0.027	1.712
0.9440	150000	1.712	0.029	0.249	3.436	0.275	0.479	2.9400521E-06	0.029	1.741
0.9391	160000	1.741	0.029	0.278	3.488	0.269	0.477	2.9005714E-06	0.029	1.770
0.9415	170000	1.770	0.029	0.307	3.535	0.266	0.478	2.9195104E-06	0.029	1.800
0.9528	180000	1.800	0.030	0.337	3.579	0.266	0.484	3.0124708E-06	0.030	1.830
0.9639	190000	1.830	0.031	0.367	3.622	0.266	0.489	3.1068441E-06	0.031	1.861
0.9846	200000	1.861	0.033	0.398	3.664	0.269	0.500	3.2899718E-06	0.033	1.894
0.9705	210000	1.894	0.032	0.431	3.706	0.262	0.493	3.1640729E-06	0.032	1.925
0.9408	220000	1.925	0.029	0.462	3.744	0.251	0.478	2.9142820E-06	0.029	1.954
0.9216	230000	1.954	0.028	0.491	3.778	0.244	0.468	2.7630354E-06	0.028	1.982
0.8848	240000	1.982	0.025	0.519	3.809	0.232	0.449	2.4958193E-06	0.025	2.007
0.8530	250000	2.007	0.023	0.544	3.835	0.222	0.433	2.2860084E-06	0.023	2.030
0.8076	260000	2.030	0.020	0.567	3.859	0.209	0.410	2.0163542E-06	0.020	2.050
0.7577	270000	2.050	0.018	0.587	3.880	0.195	0.385	1.7569957E-06	0.018	2.068
0.7380	280000	2.068	0.017	0.605	3.897	0.189	0.375	1.6639658E-06	0.017	2.084
0.7049	290000	2.084	0.015	0.621	3.913	0.180	0.358	1.5188879E-06	0.015	2.100
0.6558	300000	2.100	0.013	0.637	3.928	0.167	0.333	1.3265675E-06	0.013	2.113

Table A-24. Delamination Propagation Prediction for Fatigue Block Loading 1 Based on Equation 10-8

WF-5	Predition Based on Equation 10-8									
		Initial Crack Length = 1.463		G_{IC} = 1.97		D_1 = 8		D_2 = 2		
Loading		Predicted Crack Length								
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.5389	1000	1.463	0.000	0.000	1.97	0.274	0.274	1.0723980E-07	1.0723980E-04	1.463
0.5389	2000	1.463	0.000	0.000	2.1048	0.256	0.274	1.0723980E-07	1.0723980E-04	1.463
0.5389	3000	1.463	0.000	0.000	2.1368	0.252	0.274	1.0723980E-07	1.0723980E-04	1.463
0.5389	4000	1.463	0.000	0.000	2.1590	0.250	0.274	1.0723980E-07	1.0723980E-04	1.463
0.5389	5000	1.463	0.000	0.000	2.1765	0.248	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5389	6000	1.464	0.000	0.001	2.1912	0.246	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5389	7000	1.464	0.000	0.001	2.2040	0.245	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5389	8000	1.464	0.000	0.001	2.2154	0.243	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5389	9000	1.464	0.000	0.001	2.2257	0.242	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5389	10000	1.464	0.000	0.001	2.2351	0.241	0.274	1.0723980E-07	1.0723980E-04	1.464
0.5749	20000	1.464	0.001	0.001	2.2439	0.256	0.292	1.4741574E-07	0.001	1.466
0.5747	30000	1.466	0.001	0.003	2.3275	0.247	0.292	1.4713929E-07	0.001	1.467
0.5803	40000	1.467	0.002	0.004	2.3814	0.244	0.295	1.5435333E-07	0.002	1.469
0.6075	50000	1.469	0.002	0.006	2.4247	0.251	0.308	1.9334713E-07	0.002	1.470
0.6435	60000	1.470	0.003	0.007	2.4684	0.261	0.327	2.5633356E-07	0.003	1.473
0.6734	70000	1.473	0.003	0.010	2.5157	0.268	0.342	3.2013635E-07	0.003	1.476
0.7301	80000	1.476	0.005	0.013	2.5642	0.285	0.371	4.7579326E-07	0.005	1.481
0.7896	90000	1.481	0.007	0.018	2.6230	0.301	0.401	6.9856195E-07	0.007	1.488
0.8058	100000	1.488	0.008	0.025	2.6924	0.299	0.409	7.7196080E-07	0.008	1.496
0.9048	110000	1.496	0.014	0.033	2.7548	0.328	0.459	1.3640977E-06	0.014	1.509
0.9573	120000	1.509	0.018	0.046	2.8437	0.337	0.486	1.8013064E-06	0.018	1.527
0.9457	130000	1.527	0.017	0.064	2.9367	0.322	0.480	1.6957318E-06	0.017	1.544
0.9161	140000	1.544	0.015	0.081	3.0088	0.304	0.465	1.4504938E-06	0.015	1.559
0.9440	150000	1.559	0.017	0.096	3.0627	0.308	0.479	1.6811019E-06	0.017	1.576
0.9391	160000	1.576	0.016	0.113	3.1185	0.301	0.477	1.6387090E-06	0.016	1.592
0.9415	170000	1.592	0.017	0.129	3.1675	0.297	0.478	1.6590087E-06	0.017	1.609
0.9528	180000	1.609	0.018	0.146	3.2130	0.297	0.484	1.7596041E-06	0.018	1.626

Table A-24. Delamination Propagation Prediction for Fatigue Block Loading 1 Based on Equation 10-8 (Continued)

WF-5		Predition Based on Equation 10-8								
		Initial Crack Length = 1.463		G_{IC} = 1.97		D_1 = 8		D_2 = 2		
Loading		Predicted Crack Length								
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.9639	190000	1.626	0.019	0.163	3.2574	0.296	0.489	1.8632933E-06	0.019	1.645
0.9846	200000	1.645	0.021	0.182	3.3010	0.298	0.500	2.0687063E-06	0.021	1.666
0.9705	210000	1.666	0.019	0.203	3.3459	0.290	0.493	1.9269060E-06	0.019	1.685
0.9408	220000	1.685	0.017	0.222	3.3850	0.278	0.478	1.6533980E-06	0.017	1.701
0.9216	230000	1.701	0.015	0.238	3.4166	0.270	0.468	1.4933628E-06	0.015	1.716
0.8848	240000	1.716	0.012	0.253	3.4440	0.257	0.449	1.2222620E-06	0.012	1.729
0.8530	250000	1.729	0.010	0.266	3.4655	0.246	0.433	1.0211743E-06	0.010	1.739
0.8076	260000	1.739	0.008	0.276	3.4830	0.232	0.410	7.8040276E-07	0.008	1.747
0.7577	270000	1.747	0.006	0.284	3.4961	0.217	0.385	5.7072424E-07	0.006	1.752
0.7380	280000	1.752	0.005	0.289	3.5055	0.211	0.375	5.0149362E-07	0.005	1.757
0.7049	290000	1.757	0.004	0.294	3.5136	0.201	0.358	4.0056375E-07	0.004	1.761
0.6558	300000	1.761	0.003	0.298	3.5201	0.186	0.333	2.8134614E-07	0.003	1.764

Table A-25. Delamination Propagation Under Fatigue Block Loading 2 (Specimen WF-13)

WF-13			Experimental Data						b = 1.4965 Δ = 0.113					
		Displacement, in.		Crack Length, in.		Load, P, lb			Applied G					
G_{max}/G_{IC}	N	δ_{maxi}	δ_{maxf}	a_i	a_f	P_i	P_f	da/dN, 10^{-5}	G_{mi}	G_{mf}	G_{max}	G_{mi}/G_{IC}	G_{mf}/G_{IC}	G_{max}/G_{IC}
0.20	5000	0.0621	0.0621	1.447	1.447	9.35	9.38	0.0000	0.373	0.374	0.374	0.189	0.190	0.190
0.40	10000	0.0879	0.0879	1.447	1.455	13.56	13.30	0.1600	0.766	0.747	0.757	0.389	0.379	0.384
0.60	15000	0.1088	0.1088	1.455	1.515	16.75	15.47	1.2000	1.165	1.036	1.101	0.591	0.526	0.559
0.80	20000	0.1363	0.1363	1.515	1.568	19.81	15.83	1.0600	1.662	1.287	1.474	0.844	0.653	0.748
1.00	25000	0.1632	0.1632	1.568	1.795	19.11	14.99	4.5400	1.860	1.285	1.572	0.944	0.652	0.798
1.20	30000	0.2343	0.2343	1.795	2.083	21.41	14.56	5.7600	2.635	1.557	2.096	1.338	0.790	1.064
1.40	35000	0.3407	0.3407	2.083	2.44	20.93	13.61	7.1400	3.255	1.821	2.538	1.652	0.924	1.288
1.40	40000	0.4675	0.4675	2.44	2.893	18.54	12.50	9.0600	3.403	1.949	2.676	1.727	0.989	1.358
1.40	45000	0.6573	0.6573	2.893	3.258	17.46	11.77	7.3000	3.827	2.300	3.064	1.943	1.168	1.555
1.40	50000	0.8336	0.8336	3.258	3.744	15.54	10.44	9.7200	3.852	2.262	3.057	1.955	1.148	1.552
1.40	55000	1.1008	1.1008	3.744	4.285	14.05	9.26	10.8200	4.019	2.323	3.171	2.040	1.179	1.610
1.20	60000	1.3344	1.3344	4.285	4.69	11.37	8.67	8.1000	3.458	2.414	2.936	1.755	1.226	1.490
1.00	65000	1.4599	1.4599	4.69	4.937	9.52	8.12	4.9400	2.900	2.353	2.627	1.472	1.194	1.333
0.80	70000	1.4469	1.4469	4.937	4.978	8.01	7.73	0.8200	2.300	2.202	2.251	1.168	1.118	1.143
0.60	75000	1.2740	1.2740	4.978	4.982	6.62	6.60	0.0800	1.660	1.654	1.657	0.843	0.840	0.841
0.40	80000	1.0420	1.0420	4.982	4.982	5.24	5.32	0.0000	1.074	1.091	1.082	0.545	0.554	0.549

Table A-26. Delamination Propagation Prediction for Fatigue Block Loading 2 Based on Equation 10-4

WF-13		Predition Based on Equation 10-4								
		Initial Crack 1.447		G_{IC} = 1.97		D_1 = 8		D_2 = 2		
Loading		Predicted Crack Length								
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.3737	500	1.447	0.000E+00	0.000E+00	1.97	0.190	0.190	4.4382106E-07	2.2191053E-04	1.447
0.3737	1000	1.447	1.179E-04	2.219E-04	2.1386	0.175	0.190	2.3576588E-07	1.1788294E-04	1.447
0.3737	1500	1.447	1.067E-04	3.398E-04	2.1622	0.173	0.190	2.1348488E-07	1.0674244E-04	1.447
0.3737	2000	1.447	9.919E-05	4.465E-04	2.1791	0.171	0.190	1.9837366E-07	9.9186829E-05	1.448
0.3737	2500	1.448	9.344E-05	5.457E-04	2.1924	0.170	0.190	1.8687672E-07	9.3438360E-05	1.448
0.3737	3000	1.448	8.879E-05	6.392E-04	2.2035	0.170	0.190	1.7758457E-07	8.8792287E-05	1.448
0.3737	3500	1.448	8.489E-05	7.280E-04	2.2131	0.169	0.190	1.6978544E-07	8.4892718E-05	1.448
0.3737	4000	1.448	8.153E-05	8.128E-04	2.2215	0.168	0.190	1.6306722E-07	8.1533611E-05	1.448
0.3737	4500	1.448	7.858E-05	8.944E-04	2.2290	0.168	0.190	1.5716906E-07	7.8584528E-05	1.448
0.3737	5000	1.448	7.596E-05	9.730E-04	2.2358	0.167	0.190	1.5191496E-07	7.5957479E-05	1.448
0.7566	10000	1.448	0.064	0.001	2.2420	0.337	0.384	1.2773037E-05	0.064	1.512
1.1006	15000	1.512	0.116	0.065	2.9391	0.374	0.559	2.3113060E-05	0.116	1.627
1.4745	20000	1.627	0.324	0.180	3.2979	0.447	0.748	6.4716997E-05	0.324	1.951
1.5724	25000	1.951	0.208	0.504	3.7920	0.415	0.798	4.1631581E-05	0.208	2.159
2.0962	30000	2.159	0.846	0.712	3.9967	0.524	1.064	1.6915455E-04	0.846	3.005
2.5377	35000	3.005	1.242	1.558	4.5492	0.558	1.288	2.4830911E-04	1.242	4.247
2.6758	40000	4.247	0.890	2.800	5.0595	0.529	1.358	1.7806093E-04	0.890	5.137
3.0636	45000	5.137	1.495	3.690	5.3337	0.574	1.555	2.9893685E-04	1.495	6.632
3.0567	50000	6.632	0.965	5.185	5.7052	0.536	1.552	1.9298026E-04	0.965	7.596
3.1712	55000	7.596	0.977	6.149	5.9068	0.537	1.610	1.9544799E-04	0.977	8.574
2.9361	60000	8.574	0.507	7.127	6.0898	0.482	1.490	1.0140451E-04	0.507	9.081
2.6267	65000	9.081	0.241	7.634	6.1779	0.425	1.333	4.8171799E-05	0.241	9.322
2.2512	70000	9.322	0.095	7.875	6.2183	0.362	1.143	1.9049872E-05	0.095	9.417
1.6573	75000	9.417	0.017	7.970	6.2341	0.266	0.841	3.3300634E-06	0.017	9.433
1.0824	80000	9.433	0.001	7.986	6.2369	0.174	0.549	2.2183575E-07	0.001	9.435

Table A-27. Delamination Propagation Prediction for Fatigue Block Loading 2 Based on Equation 10-7

WF-13		Predition Based on Equation 10-7								
		Initial Crack Length = 1.447		G_{IC} = 1.97		D_1 = 8			D_2=2	
Loading		Predicted Crack Length								
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.3737	500	1.447	0.0000	0.0000	1.97	0.190	0.190	5.2081399E-07	2.6040700E-04	1.447
0.3737	1000	1.447	0.0003	0.0003	2.1471	0.174	0.190	5.2081399E-07	2.6040700E-04	1.448
0.3737	1500	1.448	0.0003	0.0005	2.1892	0.171	0.190	5.2081399E-07	2.6040700E-04	1.448
0.3737	2000	1.448	0.0003	0.0008	2.2184	0.168	0.190	5.2081399E-07	2.6040700E-04	1.448
0.3737	2500	1.448	0.0003	0.0010	2.2414	0.167	0.190	5.2081399E-07	2.6040700E-04	1.448
0.3737	3000	1.448	0.0003	0.0013	2.2607	0.165	0.190	5.2081399E-07	2.6040700E-04	1.449
0.3737	3500	1.449	0.0003	0.0016	2.2775	0.164	0.190	5.2081399E-07	2.6040700E-04	1.449
0.3737	4000	1.449	0.0003	0.0018	2.2925	0.163	0.190	5.2081399E-07	2.6040700E-04	1.449
0.3737	4500	1.449	0.0003	0.0021	2.3060	0.162	0.190	5.2081399E-07	2.6040700E-04	1.449
0.3737	5000	1.449	0.0003	0.0023	2.3184	0.161	0.190	5.2081399E-07	2.6040700E-04	1.450
0.7566	10000	1.450	0.009	0.003	2.3299	0.325	0.384	1.7516863E-06	0.009	1.458
1.1006	15000	1.458	0.023	0.011	2.5366	0.434	0.559	4.5418303E-06	0.023	1.481
1.4745	20000	1.481	0.065	0.034	2.7646	0.533	0.748	1.2949592E-05	0.065	1.546
1.5724	25000	1.546	0.085	0.099	3.0730	0.512	0.798	1.7079910E-05	0.085	1.631
2.0962	30000	1.631	0.383	0.184	3.3063	0.634	1.064	7.6580572E-05	0.383	2.014
2.5377	35000	2.014	1.399	0.567	3.8594	0.658	1.288	2.7973525E-04	1.399	3.413
2.6758	40000	3.413	2.113	1.966	4.7407	0.564	1.358	4.2257548E-04	2.113	5.526
3.0636	45000	5.526	6.890	4.079	5.4391	0.563	1.555	1.3780135E-03	6.890	12.416
3.0567	50000	12.416	6.745	10.969	6.6749	0.458	1.552	1.3490770E-03	6.745	19.161
3.1712	55000	19.161	9.638	17.714	7.4234	0.427	1.610	1.9275333E-03	9.638	28.799
2.9361	60000	28.799	4.652	27.352	8.2041	0.358	1.490	9.3040869E-04	4.652	33.451
2.6267	65000	33.451	1.824	32.004	8.5131	0.309	1.333	3.6476685E-04	1.824	35.275
2.2512	70000	35.275	0.601	33.828	8.6258	0.261	1.143	1.2025463E-04	0.601	35.876
1.6573	75000	35.876	0.109	34.429	8.6620	0.191	0.841	2.1735143E-05	0.109	35.985
1.0824	80000	35.985	0.022	34.538	8.6685	0.125	0.549	4.3167363E-06	0.022	36.006

Table A-28. Delamination Propagation Prediction for Fatigue Block Loading 2 Based on Equation 10-8

WF-13		Predition Based on Equation 10-8								
		Initial Crack 1.447		G_{IC} = 1.97		D_1 = 8		D_2 = 2		
Loading		Predicted Crack Length								
G_{max}, lb/in.	N	a_i	da	Cum da	G_{IR}	G_{max}/G_{IR}	G_{max}/G_{IC}	da/dN	da	a_f
0.3737	500	1.447	0.000E+00	0.000E+00	1.97	0.190	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	1000	1.447	7.704E-06	7.704E-06	2.0299	0.184	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	1500	1.447	7.704E-06	1.541E-05	2.0441	0.183	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	2000	1.447	7.704E-06	2.311E-05	2.0540	0.182	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	2500	1.447	7.704E-06	3.082E-05	2.0618	0.181	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	3000	1.447	7.704E-06	3.852E-05	2.0683	0.181	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	3500	1.447	7.704E-06	4.622E-05	2.0740	0.180	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	4000	1.447	7.704E-06	5.393E-05	2.0790	0.180	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	4500	1.447	7.704E-06	6.163E-05	2.0836	0.179	0.190	1.5407813E-08	7.7039063E-06	1.447
0.3737	5000	1.447	7.704E-06	6.934E-05	2.0878	0.179	0.190	1.5407813E-08	7.7039063E-06	1.447
0.7566	10000	1.447	0.003	0.000	2.0917	0.362	0.384	5.6668315E-07	2.8334158E-03	1.450
1.1006	15000	1.450	0.018	0.003	2.3425	0.470	0.559	3.5887097E-06	1.7943549E-02	1.468
1.4745	20000	1.468	0.077	0.021	2.6531	0.556	0.748	1.5467896E-05	7.7339481E-02	1.545
1.5724	25000	1.545	0.107	0.098	3.0709	0.512	0.798	2.1417550E-05	1.0708775E-01	1.652
2.0962	30000	1.652	0.474	0.205	3.3516	0.625	1.064	9.4728465E-05	4.7364232E-01	2.126
2.5377	35000	2.126	1.334	0.679	3.9670	0.640	1.288	2.6684052E-04	1.3342026E+00	3.460
2.6758	40000	3.460	1.798	2.013	4.7611	0.562	1.358	3.5957516E-04	1.7978758E+00	5.258
3.0636	45000	5.258	3.985	3.811	5.3674	0.571	1.555	7.9698878E-04	3.9849439E+00	9.243
3.0567	50000	9.243	3.931	7.796	6.2052	0.493	1.552	7.8617060E-04	3.9308530E+00	13.174
3.1712	55000	13.174	4.934	11.727	6.7727	0.468	1.610	9.8686608E-04	4.9343304E+00	18.108
2.9361	60000	18.108	3.084	16.661	7.3214	0.401	1.490	6.1683792E-04	3.0841896E+00	21.192
2.6267	65000	21.192	1.619	19.745	7.6088	0.345	1.333	3.2375441E-04	1.6187720E+00	22.811
2.2512	70000	22.811	0.693	21.364	7.7473	0.291	1.143	1.3859728E-04	6.9298639E-01	23.504
1.6573	75000	23.504	0.140	22.057	7.8044	0.212	0.841	2.7995887E-05	1.3997943E-01	23.644
1.0824	80000	23.644	0.017	22.197	7.8158	0.138	0.549	3.3032435E-06	1.6516217E-02	23.661

Table A-29. Delamination Propagation Under Fatigue Block Loading for T800H carbon/3900-2 Epoxy Composite (Specimen UCE204)

UCE204		Experimental Data							b = 0.991	Δ= 0.4013		G_{Asym}=1.74		
		Displacement, in.		Crack Length, in.		Load, P, lb			**Applied G**					
G_{max}/G_{Ic}	N	δ_{maxi}	δ_{maxf}	a_i	$a_{i,f}$	P_i	P_f	da/dN, 10^-6	$G_{Initial}$	G_{Final}	$G_{Average}$	G_{mi}/G_{IC}	G_{mf}/G_{IC}	G_{mave}/G_{IC}
0.50	10000	0.1189	0.1189	1.801	1.870	15.29	14.41	6.9000	1.249	1.142	1.196	0.718	0.656	0.687
0.52	20000	0.1289	0.1289	1.870	1.954	15.82	14.05	8.4000	1.359	1.164	1.261	0.781	0.669	0.725
0.54	30000	0.1411	0.1411	1.954	2.032	15.52	13.56	7.8000	1.407	1.190	1.299	0.809	0.684	0.746
0.56	40000	0.1532	0.1532	2.032	2.093	14.87	13.80	6.1000	1.417	1.283	1.350	0.814	0.737	0.776
0.58	50000	0.1637	0.1637	2.093	2.153	14.84	13.48	6.0000	1.474	1.308	1.391	0.847	0.752	0.799
0.60	60000	0.1745	0.1745	2.153	2.217	14.48	13.27	6.4000	1.497	1.339	1.418	0.861	0.769	0.815
0.62	70000	0.1863	0.1863	2.217	2.285	13.96	13.19	6.8000	1.503	1.385	1.444	0.864	0.796	0.830
0.64	80000	0.1991	0.1991	2.285	2.355	14.20	12.95	7.0000	1.593	1.416	1.504	0.916	0.814	0.865
0.66	90000	0.2128	0.2128	2.355	2.445	13.97	12.70	9.0000	1.633	1.437	1.535	0.938	0.826	0.882
0.68	100000	0.2302	0.2302	2.445	2.540	13.86	12.08	9.5000	1.697	1.431	1.564	0.975	0.822	0.899
0.70	110000	0.2492	0.2492	2.540	2.625	13.20	12.18	8.5000	1.693	1.518	1.605	0.973	0.872	0.923
0.70	120000	0.2637	0.2637	2.625	2.698	12.96	11.77	7.3000	1.709	1.516	1.613	0.982	0.871	0.927
0.70	130000	0.2764	0.2764	2.698	2.783	12.21	11.56	8.5000	1.648	1.519	1.583	0.947	0.873	0.910
0.70	140000	0.2916	0.2916	2.783	2.859	12.28	11.30	7.6000	1.702	1.530	1.616	0.978	0.879	0.929
0.70	150000	0.3056	0.3056	2.859	2.938	11.88	11.06	7.9000	1.686	1.532	1.609	0.969	0.880	0.925
0.70	160000	0.3204	0.3204	2.938	3.017	11.64	10.68	7.9000	1.690	1.515	1.603	0.972	0.871	0.921
0.70	170000	0.3356	0.3356	3.017	3.075	11.25	10.71	5.8000	1.672	1.565	1.618	0.961	0.899	0.930
0.70	180000	0.3470	0.3470	3.075	3.115	11.10	10.55	4.0000	1.677	1.576	1.626	0.964	0.906	0.935
0.70	190000	0.3550	0.3550	3.115	3.170	10.81	10.34	5.5000	1.652	1.556	1.604	0.949	0.894	0.922
0.70	200000	0.3661	0.3661	3.170	3.213	10.44	10.23	4.3000	1.620	1.568	1.594	0.931	0.901	0.916
0.69	210000	0.3722	0.3722	3.213	3.242	10.39	10.12	2.9000	1.620	1.565	1.592	0.931	0.899	0.915
0.68	220000	0.3754	0.3754	3.242	3.285	10.22	9.83	4.3000	1.594	1.515	1.555	0.916	0.871	0.893
0.67	230000	0.3813	0.3813	3.285	3.319	9.99	9.84	3.4000	1.564	1.527	1.545	0.899	0.877	0.888
0.66	240000	0.3854	0.3854	3.319	3.343	9.96	9.75	2.4000	1.562	1.519	1.540	0.898	0.873	0.885
0.65	250000	0.3874	0.3874	3.343	3.361	9.80	9.63	1.8000	1.535	1.501	1.518	0.882	0.863	0.872
0.64	260000	0.3881	0.3881	3.361	3.380	9.47	9.55	1.9000	1.479	1.484	1.481	0.850	0.853	0.851
0.63	270000	0.3889	0.3889	3.380	3.391	9.57	9.51	1.1000	1.490	1.476	1.483	0.856	0.848	0.852
0.62	280000	0.3880	0.3880	3.391	3.405	9.46	9.39	1.4000	1.465	1.449	1.457	0.842	0.833	0.837
0.61	290000	0.3877	0.3877	3.405	3.417	9.37	9.18	1.2000	1.445	1.411	1.428	0.830	0.811	0.821
0.60	300000	0.3869	0.3869	3.417	3.428	9.14	9.14	1.1000	1.402	1.398	1.400	0.806	0.803	0.804