AFRL-SR-BL-TR-99-

0107

REPORT DOCUMENTATION PAGE

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1 Mar 99

3. REPORT TYPE AND DATES COVERED
Final Technical Report 15 Sep 95 to 14 Dec 98

4. TITLE AND SUBTITLE
Fracture and Fatigue Crack Growth Behavior of Advanced Ceramic Matrix Composites

5. FUNDING NUMBERS
F49620-95-1-0500
61103D
3484/WS

6. AUTHOR(S)
Dennis J. Buchanan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Structural Integrity Division
Advanced Materials Characterizaiton Group
University of Dayton Research Institute
300 College Park
Dayton, OH 45469-0128

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NA
801 N. Randolph Street, Rm 732
Arlington, VA 22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-95-1-0500

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Ultrasonic C-scans have successfully been used to investigate damage from notches and holes in Nextel610/Aluminosilicate (N610/AS) during tensile and fatigue loading conditions. Sectioned fatigue specimens verified that the region of distributed matrix damage and longitudinal fiber breakage correlated well with the C-scan damage zone at 23°C. At 950°C the C-scan data showed that the damage zone was confined to the notch plane where damage was primarily due to self similar crack growth. Sectioned samples verified that longitudinal fiber breaks were predominant in the vicinity of the matrix crack. The results from these tests are being employed to develop damage and failure criteria for N610/AS and other woven CMC.

19990412 079

14. SUBJECT TERMS

15. NUMBER OF PAGES
3

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

FRACTURE AND FATIGUE CRACK GROWTH BEHAVIOR OF ADVANCED CERAMIC MATRIX COMPOSITES

March 1999

D. Buchanan

PII Redacted

Fracture and Fatigue Crack Growth Behavior of Advanced Ceramic Matrix Composites

March 1999

Final Technical Progress Report

Grant No. F49620-95-1-0500

Prepared for:

AFOSR/NA
Dr. Ozden Ochoa
801 N. Randolph St.
Room 732
Arlington, VA 22203-1977

Prepared by:

Dennis J. Buchanan

STRUCTURAL INTEGRITY DIVISION
Advanced Materials Characterization Group
300 College Park
Dayton, OH 45469-0128

Fracture and Fatigue Crack Growth Behavior of Advanced Ceramic Matrix Composites

Abstract

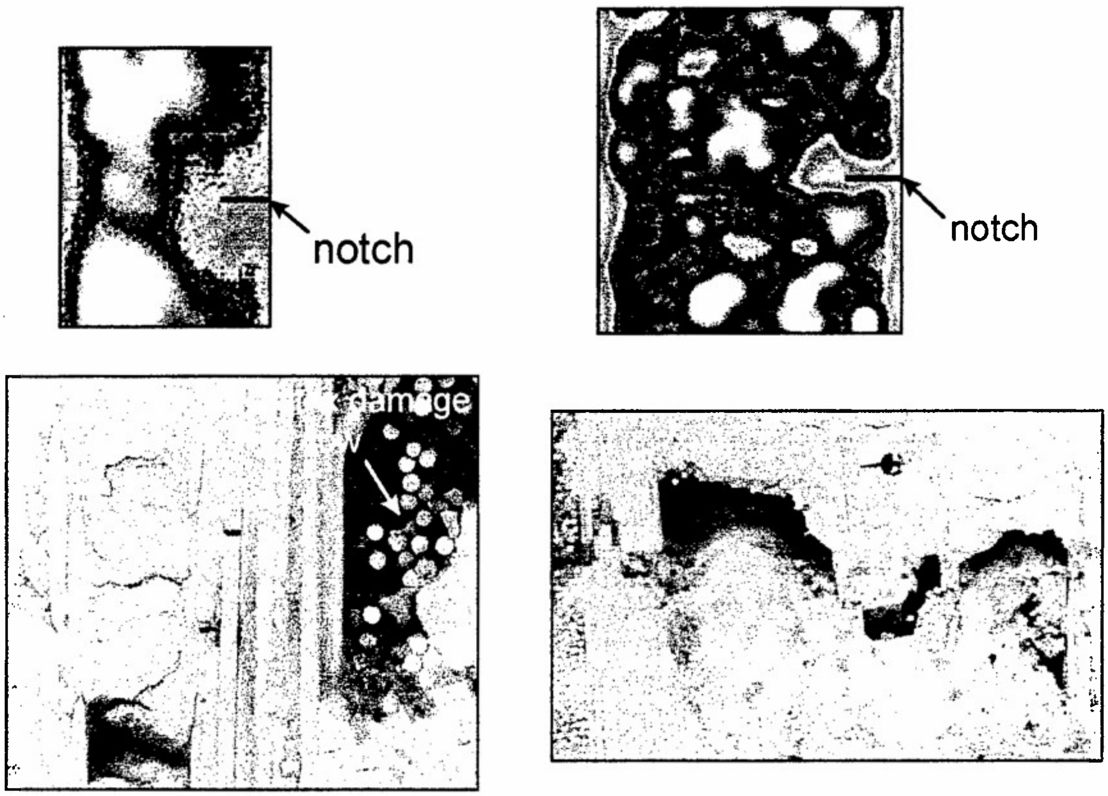
Ultrasonic C-scans have successfully been used to investigate damage from notches and holes in Nextel610/Aluminosilicate (N610/AS) during tensile and fatigue loading conditions. Sectioned fatigue specimens verified that the region of distributed matrix damage and longitudinal fiber breakage correlated well with the C-scan damage zone at 23°C. At 950°C the C-scan data showed that the damage zone was confined to the notch plane where damage was primarily due to self similar crack growth. Sectioned samples verified that longitudinal fiber breaks were predominant in the vicinity of the matrix crack. The results from these tests are being employed to develop damage and failure criteria for N610/AS and other woven CMC.

Objectives

The primary objective of this effort is to characterize the evolution of tensile, creep and fatigue damage in ceramic matrix composites (CMC) using nondestructive evaluation (NDE) techniques. The NDE measurements will also be correlated to results from conventional extensometry and damage/crack growth characterized using optical techniques.

Status of Effort

Ms. Victoria Kramb continued the investigation of damage progression from edge notches and center holes in a woven oxide/oxide, N610/AS, CMC system using ultrasonic C-scans. Specimens were C-scanned prior to testing and during interrupted fracture and fatigue crack growth (FCG) tests. Tests were conducted at 23 and 950°C. Interrupted FCG tests of edge notched specimens, showed that progressive damage, indicated by increasing crack mouth opening displacement (CMOD) and destructive evaluation, correlated with the ultrasonic C-scans. Fatigue cycling at an applied stress = 41 MPa at 23°C resulted in crack arrest. C-scans, taken during test interruption, showed no increase in the ultrasonic attenuation from the pretest condition. Cycling at applied stresses of 93 MPa at 23°C resulted in progressive damage as indicated in the C-scans that exhibited an increase in attenuation. At 23°C, damage was identified on sectioned specimens as distributed matrix cracking and longitudinal fiber breakage (Fig. 1a). The observed longitudinal fiber breaks were infrequent and widely distributed; however matrix degradation within transverse fiber tows was extensive. The size of the C-scan damage zone correlated well with the extent of matrix damage observed on the polished sections. At 950°C, progressive damage leading to eventual failure occurred for cycling at an applied stress = 41 MPa. A change in damage mode to self similar crack growth was observed at 950°C (Fig. 1b). The change in damage mode was reflected in the C-scans by a damage zone which was more confined to the notch plane than at 23°C. Sectioned specimens showed that longitudinal fiber breakage occurred along the entire matrix crack length. Extensive matrix cracking was observed only in the vicinity of broken longitudinal fibers. At 950°C, the C-scan damage zone was longer than the measured crack length. At both temperatures, the size of the C-scan damage zone was larger than that indicated by the exposed longitudinal fiber lengths on fracture surfaces.



(a) (b)

Figure 1. Ultrasonic C-scans of edge notched fatigue cycled specimens and corresponding damage near the notch tip (a) 23°C, 500,000 cycles at 93 MPa (b) 950°C, 1,347,668 cycles at 41 MPa.

Accomplishments/New Findings

Research highlights and their significance to the field

Ultrasonic C-scans were used effectively to monitor damage progression from notches and holes in N610/AS subjected to tensile and cyclic loading conditions. The observed change in damage mode with temperature was correlated to changes in ultrasonic attenuation at the notch tip. Under cyclic loading conditions, maximum applied loads that resulted in no progressive damage at room temperature resulted in fiber breakage and failure at 950°C. The C-scans reflected the change in damage mode. At 23°C, distributed matrix cracking resulted in a large damage zone, which was monitored using C-scans. Self similar crack growth at 950°C, resulted in failure at significantly lower stress levels than at 23°C. C-scans, of interrupted test specimens, were shown to be an effective method for monitoring crack growth under cyclic loading. The extent of damage above and below the crack plane was indicated during testing from C-scans and thus, measured stress redistribution around the notch tip. Comparison of the C-scan indicated damage zone with the damage zone size predicted using various failure models are being used in the development of a relevant failure criteria for N610/AS and other CMC systems.

Personnel Supported

PII Redacted

Ms. Victoria Kramb, [redacted], Materials Engineering Graduate Program, UD., [redacted], Graduate Research Assistant (PhD), 6/96-Present. (33%)

Inventions and Patents : None

Honors/Awards : None