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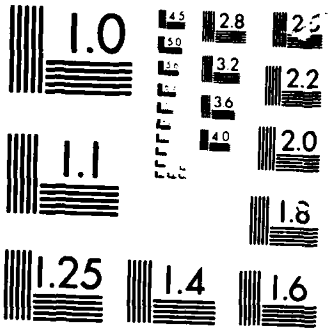

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Issue 3

PROGRESS REPORT

Metallurgical Characterization of the Interfaces and the Damping Mechanisms in Metal Matrix Composites

Contract No. N00014-84-C-0413

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Denver, Colorado 80201

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I. Contract Information

I.a. Title: Metallurgical Characterization of the Interfaces and the Damping Mechanisms in Metal Matrix Composites

I.b. ONR Contract Number: N00014-84-C-0413

I.c. ONR Work Unit Number: 039-269

I.d. Principal Investigator: Mohan S. Misra, Martin Marietta Aerospace, Denver, CO

I.e. ONR Scientific Officer: Dr. Steven G. Fishman

I.f. Period Covered: 2/4/84 - 4/15/86

II. Research Description

II.a. Description of Research

II.a.1 Introduction

Fiber reinforced metal matrix composites (MMC) are candidate structural materials for space applications because of their high specific modulus, low CTE, high electrical and thermal conductivity, and high environmental resistance. Furthermore, the need for dynamic dimensional precision and weight savings in space structures suggests inherent material damping as an additional property requirement. A preliminary investigation indicates that MMC exhibit improved damping with respect to conventional structural alloys of aluminum or titanium.

In the present investigation, a graphite-aluminum composite (P55/6061) has been selected to study the microstructural features and mechanisms responsible for damping in MMC.

II.a.2 Objectives

The objectives for this reporting period have been:

i) Establish a reliable test method and its limitations
ii) Develop reproducible damping test data at different frequencies and strain amplitudes
iii) Thorough metallurgical characterizations of interfaces
iv) Suggest an operative damping mechanism in MMC
v) Recommendations for further investigations

II.a.3 Technical Approach

i) Fabricate Specimens with Predefined Interfaces.
  - Fiber Matrix Interface Study
    - P55Gr/6061Al precursor wires
      - as received
      - shear deformed
  - Diffusion Bonded Interface Study
    - P55Gr/6061Al composite panels
      - standard, state-of-the-art bonding
      - imperfect bonding (reduced consolidation temperatures/pressures)

II.b. Significant Results in the Last Year

II.b.1 Establish Reliable Test Method and Its Limitations

i) Clamped-Free Flexure: The apparatus was improved to conduct damping measurements in vacuum. Any sources of extraneous losses were minimized.

- — Grip Losses: Energy dissipation due to the gripping arrangement was very low as specimen vibration within the grips was limited to less than 1% of the smallest specimen length, as shown in Figure 1.
- — Effects of Vacuum: The effects of air damping upon the total measured damping of thin beam specimens was investigated by varying the pressure within the apparatus chamber. These data, shown in Figure 2, indicate that measurements at a pressure of 30 millitorr should be sufficient to eliminate air damping.

ii) Uniaxial Tension-Tension Cycling: During damping measurements at 50 - 350 x 10^{-6} strain and 0.1 - 2.0 Hz frequency levels, the stress-strain hysteresis loop was very small and noise interference was significant. Strain signal enhancement was accomplished through the use of semiconductor strain gages which yielded high signal-to-noise ratio and eliminated the need for strain signal amplifiers (often sources of phase shifts.) Digital filtering techniques were employed to further minimize noise in the stress and strain signals.

II.b.2 Develop Reproducible Damping Test Data at Different Frequencies and Strain Amplitudes

Damping test methods include i) clamped-free flexure, ii) uniaxial tension-tension cycling and iii) free-free flexure. Test variables included strain amplitude, frequency and fiber orientation. Test specimens of a 6061 Aluminum alloy were used as a reference for calibration.

i) Clamped-Free Flexure: Data were taken at a vacuum better than 30 millitorr to minimize contributions from air damping. Reproducibility of the data was identified through three consecutive damping tests at the same strain amplitude and vibrational frequency. Both standard and imperfect bond specimens of Gr/Al and Al/Al panels were studied and their damping behavior is shown in Figures 3 and 4.

ii) Uniaxial Tension-Tension Cycling: Standard bond specimens were tested in both [0°] and [90°] fiber orientations. These data are shown in Figure 5. In addition, a series of specimens were tested at a number of frequencies (Fig. 6.)

iii) Free-Free Flexure: The test setup is currently being evaluated and preliminary data will be presented in the following report.

II.b.3 Summary

The following are a summary of the results of work conducted within this reporting period:

i) A vacuum level of 30 millitorr proved to be sufficient for reliable damping measurements in the clamped-free flexure test method.

ii) Strain amplitude dependent damping behavior of Gr/Al composites in flexural mode [0°] and extensional mode [90°] are equivalent to that of the matrix, suggesting dominant contributions from the matrix to the damping mechanisms in these modes and fiber orientations.

iii) Damping of Gr/Al composites in the extensional mode is greater than that of the matrix, which can be attributed to contributions from the matrix and the interfaces.

iv) Differences in the frequency and strain amplitude dependent damping behavior for the flexural and extensional vibratory modes indicate that operative damping mechanisms may be different.

II.b.3 Summary (continued)

v) Damping of imperfect bond specimens is greater than or equal to standard bond specimens due to frictional losses at the fiber-matrix interface.

II.c. Plans for the Remainder of the Contract

II.c.1 Finalize Test Data Matrix

— Data will be taken to complete the test matrix for both Gr/Al wires and composite panels.

II.c.2 Correlation of Metallurgical Characterization and Modeling with Damping Data to Determine Damping Mechanisms for Different Modes of Vibration.

II.c.3 Final Report

II.c.4 Recommendations for Further Research

II.d. Presentations

II.d.1 Invited Presentation at Topical or Scientific/Technical Society Conferences

i) A.K. Ray and V.K. Kinra, "Measurement of Damping in Continuous Fiber Metal Matrix Composites," presented at the symposium on The Role of Surfaces and Interfaces in Material Damping, sponsored by the American Society for Metals, Toronto, Canada, Oct. 16, 1985.

ii) S.P. Rawal and M.S. Misra, "Interfaces and Damping in Continuous Gr/Al Composites," presented at the symposium on The Role of Surfaces and Interfaces in Material Damping, sponsored by the American Society for Metals, Toronto, Canada, Oct. 17, 1985.

iii) S.P. Rawal, J.H. Armstrong, M.S. Misra, A.K. Ray and V.K. Kinra, "Damping Measurements of Gr/Al Composites", to be presented at the symposium on Dynamic Behavior of Composite Materials, Components and Structures, sponsored by the Society for Experimental Mechanics, New Orleans, June 8-12, 1986.

II.e. Technical Reports

— none

II.f. Publications

— none

II.g. Honors, Awards

— none

II.h. Participants

Mr. Asok Ray; Graduate Student working towards his Ph.D. Thesis.
Advisor: Dr. V.K. Kinra at Texas A&M University, College Station, Texas

II.i. Other Sponsored Research

II.i.1 Title: Damping in Metal Matrix Composites
Sponsor: Martin Marietta Denver Aerospace
Amount: $60k

II.i. Other Sponsored Research (continued)

II.i.2 Title: Novel Processing Techniques of Gr/Mg Composites
Sponsor: DARPA
Amount: $1.9M

II.i.3 Title: Role of Interfaces in the Damping Characteristics of Metal Matrix Composites
Sponsor: ONR
Amount: $199k

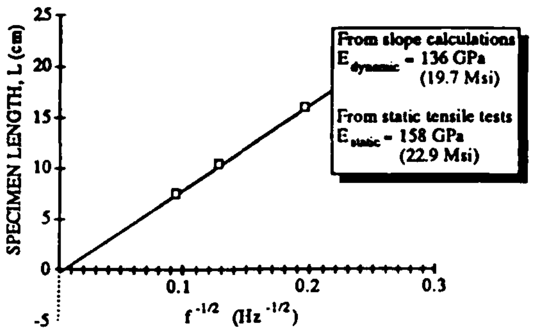

Figure 1
An Indication of Parasitic Losses at the Grips in a Clamped-Free Flexure Apparatus.

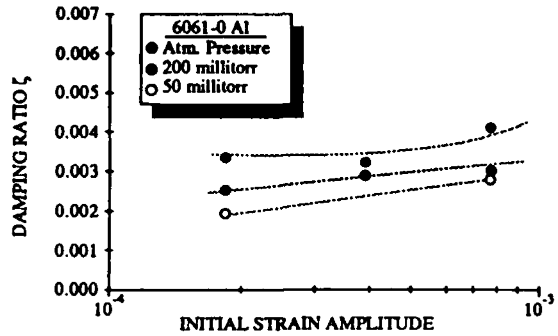

Figure 2
Effect of Vacuum in a Clamped-Free Flexure Apparatus.

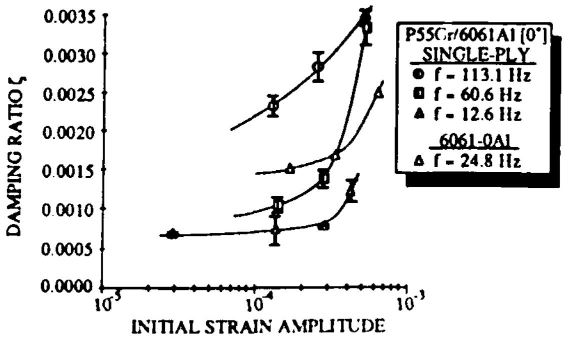

Figure 3
Flexural Damping Behavior of Single Ply P55Gr/6061Al Standard Bond Composites [0°] as a Function of Initial Strain Amplitude

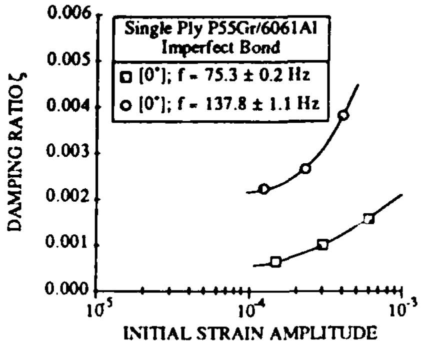

Figure 4
Flexural Damping Behavior of Single-Ply P55Gr/6061Al Imperfect Bond Composites [0°] as a Function of Initial Strain Amplitude

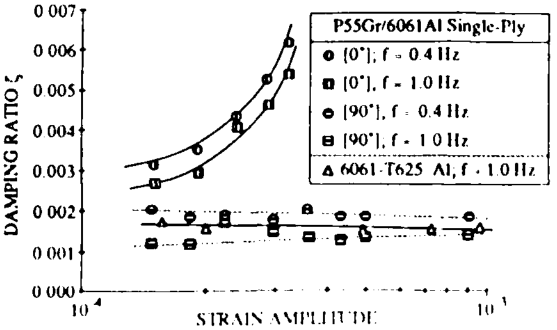

Figure 5
Extensional Mode Damping Behavior of Single Ply P55Gr/6061Al as a Function of Strain Amplitude

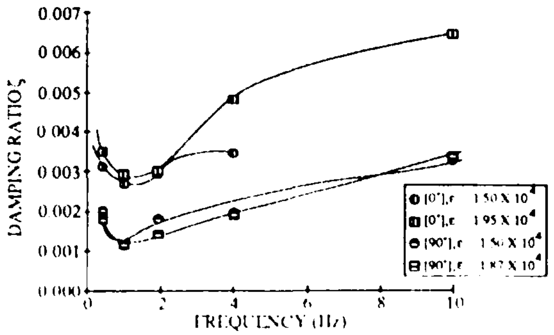

Figure 6
Extensional Mode Damping Behavior of Single Ply P55Gr/6061Al as a Function of Vibratory Frequency

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