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Letter Report

Damping Characteristics of Metal Matrix Composites

Contract No. N00014-85-C-0857

Prepared for:

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Quarterly Progress Report (#10)
(MCR-85-721)

1.0 Contract Number:
N00014-85-C-0857

2.0 Reporting Period:
8/11/88-12/10/88

3.0 ONR Scientific Officer:
Dr. Steven G. Fishman

4.0 Work Performed At:
Martin Marietta Astronautics Group, Denver, CO 80201

5.0 Principal Investigator:
Mohan S. Misra

6.0 Project Title:
Damping Characteristics of Metal Matrix Composites

7.0 Description of Research:

7.1 Objectives of Present Research

- Metal matrix composites (MMC) with enhanced material damping can be potential structural materials to improve significantly the stability, control and reliability of space structures. Objectives of this investigation are:
 - Identify the mechanisms and sources of damping in continuous fiber-reinforced MMC (Gr/Al and Gr/Mg) using in situ characterization techniques.
 - Determine the role of microstructural parameters (fiber volume, fiber orientation, interfiber spacing, grain size, precipitate morphology) in damping.
 - Define the role of the fiber-matrix interface in damping.
 - Develop high damping structural materials for space applications.

7.2 Summary of Work Accomplished During Previous Reporting Period

- Damping Measurements of Gr/Mg Composites
 - Damping data were obtained for Gr/Mg composites in the intermediate frequency range as a function of temperature at low strain amplitudes ($<10^{-7}$). A peak in damping was noted at 200 K (-73°C) which can be attributed to a phase transformation in graphite from rhombohedral to hcp structure. At temperatures above 373 K, the increase in damping could be attributed to the operative mechanisms in the matrix alloy.
 - Flexural and extensional damping capacity of as-cast and heat treated Gr/K1A were also measured at $<10^{-6}$ by using the test apparatus available at the University of Idaho, Moscow, Idaho. These results indicated that flexural damping capacity of 1.5% at 80 Hz is quite consistent with the values previously obtained at Martin Marietta.

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- Extensional damping capacity measurements were performed at ≈ 2 kHz. The enhanced extensional damping capacity ($\psi \approx 10\%$ @ 1977 Hz) for as-cast specimens could be attributed to a characteristic grain size or damage length plays. Results from flexural and extensional damping tests showed that flexural damping values were nearly identical to the values obtained for as-cast specimens, and at ≈ 2065 Hz is 5.6 %. Based on these results, it appeared that microstructural modifications induced by heat treatment at 800°F for 16 hours did not enhance composite damping.
- Preliminary investigations into high damping fibers resulted in the intercalation of P100 Gr fibers with bromide. However while intercalated fibers exhibit high damping at temperatures ranging from 100—300°C, the intercalants can escape the fibers at elevated temperatures. To seal intercalants within the graphite fibers at elevated temperatures experienced during composite fabrication ($>>300^\circ\text{C}$), an electroless nickel plating was applied to the fibers after intercalation and prior to final consolidation or metal infiltration.

7.3 Progress During the Reporting Period

- Damping Measurements of Gr/Mg Composites

- Preliminary estimates of the damping capacity of Gr/Mg composites, based on a -weighted rule of mixture calculation, that the damping can be enhanced significantly with intercalated fibers. Sparta/NASA LeRC have indicated that ψ_f can be increased from 0.2 — 3.0% by introducing bromide intercalants into the crystal structure of pitch graphite fibers.
- Martin Marietta obtained a preliminary 8 inch long Br intercalated P100 tow from NASA LeRC. Bromine intercalants were sealed in the fibers by utilizing a plating approach in which the fiber temperature never exceeds 212°F while electroless nickel is deposited uniformly on its surface.
- After the tow was plated in electroless nickel, 4 inch long precursor wires were prepared by dipping the coated fibers in molten magnesium, and the remaining length was used for damping measurements.
- Preliminary damping measurements conducted at NASA LeRC indicated the damping to be only $\psi \approx 0.2\text{—}0.3\%$, or nearly that of the untreated fibers.
- Because it is believed that no intercalants were lost in the fabrication of the precursor wires, the following issues were raised:
 - Uniformity of intercalant concentration along the length when a pound spool (4500') is treated.
 - Nature and duration of storage of the 8 inch long intercalated fiber received from NASA-LeRC.
 - Lack of reference specimen to obtain damping values.

- In Situ Characterization of Metal Matrix Composites

Acoustic Emission

- Preliminary attempts at acoustic emission (AE) of precursor wires at low load levels (i.e. 20% of failure load level) indicated an insufficient resolution in stress level measurement. Consequently, a small load cell has been designed to measure these levels.

- Centrifugal Casting of a Gr/Mg Tube

- We have demonstrated the feasibility of producing 4 inch diameter, 12 inch long Gr/Mg tubes by filament winding centrifugal casting (FWCC) process using the apparatus shown schematically in Figures 1 and 2. In this process, a tubular preform is prepared by filament winding air-stable coated P55 fibers on a perforated liner. The preform/liner assembly is placed inside a steel submold held inside the cen-

trifugal mold. The fugitive binder is burned off in the presence of a heated argon atmosphere, and molten Mg is introduced into the rotating mold.

- The FWCC process technology will be extended to produce 4 inch diameter, 8 foot long P55/AZ91C Mg tube.
- Air stable coatings have been applied on P55 fibers and perforated liner and submolds are being prepared.

7.4 Investigations in Progress

- Damping Behavior of Metal Matrix Composites

- A 2200 foot length of pitch 100 fiber has been shipped for intercalation. Damping of the tows will be measured before and after plating, as well as after precursor wire fabrication to ascertain if high damping characteristics have been retained.

- In Situ Characterization

Acoustic Emission

- Wire specimen geometry test are in progress with a modified load cell arrangement to determine the correlation to low and intermediate stress level acoustic emission and microstructural changes. P55Gr/Mg-1%Mn and P55Gr/Mg-1%Zr precursor wires have been fabricated. Tensile tests will be interrupted at 20%, 40%, 60%, 80%, and 100% of failure load. Where AE source location indicates a localized event source, microstructural investigations will be conducted, particularly at the fiber-matrix interface. These data will be correlated with AE analysis to provide an understanding of the fiber-matrix interfacial phenomenon in Gr/Mg composites.

- Centrifugal Casting of a Gr/Mg Tube

- Fabrication of 8 foot long Gr/Mg tube is in progress
- Damping measurements of tubes will be made after tube fabrication

7.5 Presentations

- S.P. Rawal, M.S. Misra, and J.H. Armstrong: "Microstructure and Damping Characteristics/Relationships in Gr/Al and Gr/Mg Composites", to be presented at TMS/ASM-MSD Annual Meeting, Las Vegas, NV, February 28, 1989.
- S.P. Rawal, J.H. Armstrong, M.S. Misra, and S.G. Fishman: "Damping in Metal Matrix Composites - An Overview", 1989 Damping Workshop, Palm Beach, Feb 7, 1989.
- J.H. Armstrong, S.P. Rawal, and M.S. Misra: "Damping Characteristics of Metal Matrix Composites", to be presented at 1989 Industry-University Advanced Materials Conference, Denver, CO, March 7, 1989.
- J.H. Armstrong, S.P. Rawal, and M.S. Misra: "In Situ Damage Characterization of Metal Matrix Composites", to be presented at 1989 Industry-University Advanced Materials Conference, Denver, CO, March 7, 1989.

7.6 Technical Reports

- None

7.7 Publications

- None

7.8 Participants

Name Task

Material Concepts, Inc, Columbus, OH.....	Flat cast composite panels
University of Illinois	TEM with deformation stage
University of Texas A&M, College Station, TX	Damping measurements
University of Denver, Denver, CO.....	Damping measurements
	In situ characterization

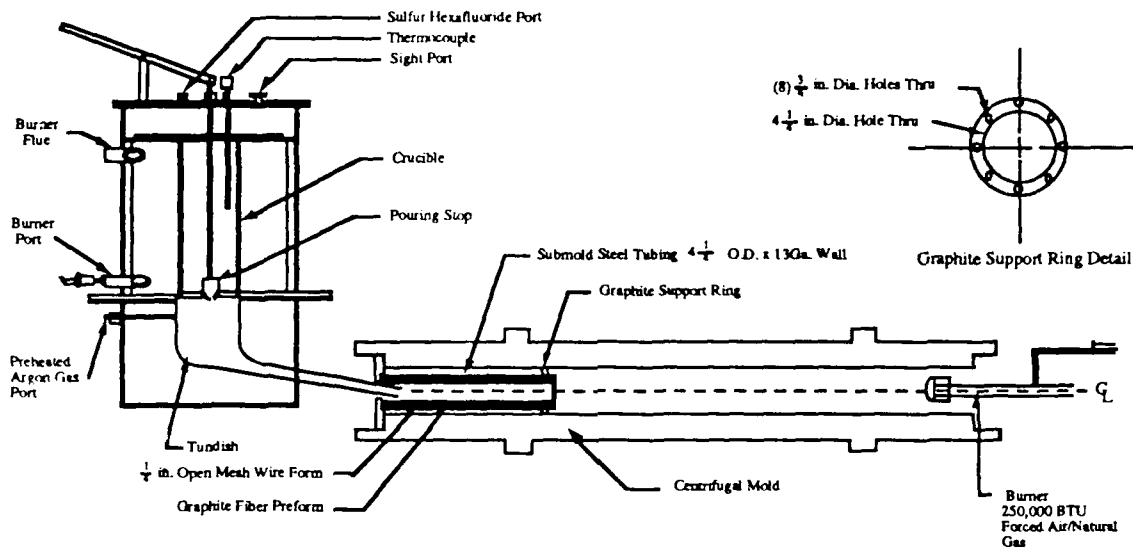


Figure 1
Schematic of the Centrifugal Casting Setup Which Uses the Submold-in-mold Design.

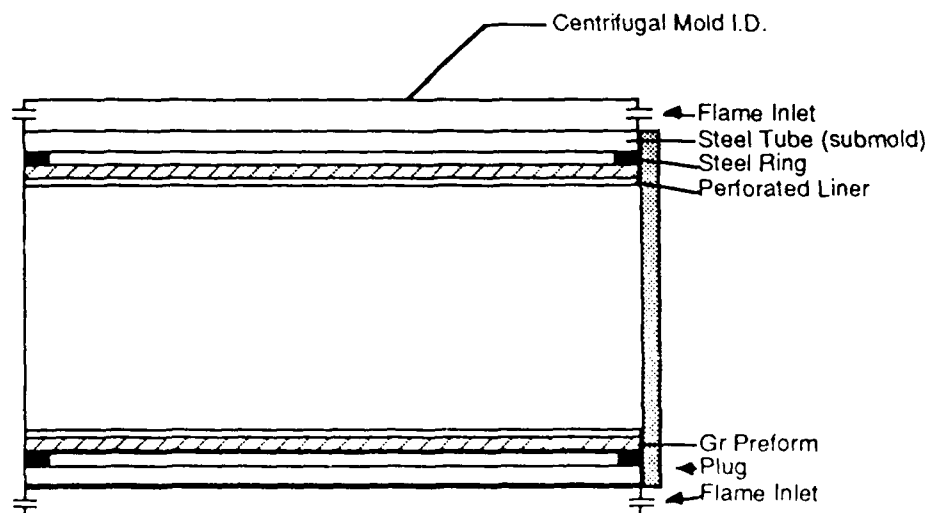


Figure 2
Schematic Illustration of the Submold-in-mold Design.