WL-TR-91-3078 Volume II



Proceedings of Damping '91

13-15 February 1991 San Diego, California

(EAA-1 through GBC-16)

August 1991

Final Report for Period February 1989 to February 1991

Approved for public release; distribution is unlimited

Sponsored by:

Wright Laboratory

Flight Dynamics Directorate

AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, CHIOTES 45435-6553

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188		
1a. REPORT SECURITY CLASSIFICATION Unclassified	1a. REPORT SECURITY CLASSIFICATION Unclassified 1b. RESTRICTIVE MARKINGS				
2a. SECURITY CLASSIFICATION AUTHORITY	<u> </u>		AVAILABILITY OF		
2b. DECLASSIFICATION / DOWNGRADING SCHEDU	LE		or public re on unlimited		
4. PERFORMING ORGANIZATION REPORT NUMBE	R(S)	5. MONITORING	ORGANIZATION RE	PORT NÜ	MBER(S)
WL-TR-91-3078, Volume II					
6a. NAME OF PERFORMING ORGANIZATION Flight Dynamics Directorate					
Wright Laboratory	WL/FIBG				
6c. ADDRESS (City, State, and ZIP Code)		7b. ADDRESS (City	y, State, and ZIP Co	ode)	
Wright-Patterson AFB, OH 45433	5-6553				
8a. NAME OF FUNDING/SPONSORING ORGANIZATION	8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF F	UNDING NUMBERS		
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
		62201F	2401	04	23
11. TITLE (Include Security Classification) Proceedings of Damping '91					
12. PERSONAL AUTHOR(S)			·		
13a. TYPE OF REPORT 13b. TIME CONTROL FROM FE	E 89 TO FEB 91	14. DATE OF REPORT		Day) 15.	PAGE COUNT 566
16. SUPPLEMENTARY NOTATION		1144450 15.	∠ ±		300
Pages EAA-1 through G	BC-16				
17. COSATI CODES 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number		by block number)			
FIELD GROUP SUB-GROUP	}				
	Vibration Damping, controls/structure interaction.			raction.	
19. ABSTRACT (Continue on reverse if necessary	and identify by block n	umber)			
Individual papers of Damping '91 held 13-15 February 1991 in San Diego CA are presented. The subjects included: Viscoelastic Material Testing and Characterization, Passive Damping Concepts, Passive Damping Analysis and Design Techniques, Optimization, Damped Control/Structure Interaction, Viscous Dampers, Friction Damping, Other Vibration Suppression Techniques, Damping Identification and Dynamic Testing, Applications to Aircraft, Space Structures, Marine Structures, Commercial Products, Defense Applications, and Payoffs of Vibration Suppression. 20. DISTRIBUTION/AVAILABILITY OF ABSTRACT 21. ABSTRACT SECURITY CLASSIFICATION					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT 21. ABSTRACT SECURITY CLASSIFICATION 21. ABSTRACT SECURITY CLASSIFICATION DICUSERS Unclassified					
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE (I	Include Area Code)	1	FICE SYMBOL
Dr. Lynn Rogers		(513) 255	<u>)-6622</u>	WL/F	TBG

Part of ADA241312 Digitized 4/28/2021

Workshop Administration

Director

Dr. Lynn C. Rogers Wright Laboratory Flight Dynamics Directorate

Technical Chairman

Dr. Conor D. Johnson CSA Engineering, Inc.

Administrative Chairman

Mrs. Beryl D. Deremigio CSA Engineering, Inc.

Assistant Administrative Chairman

Ms. Bonnie L. Portis CSA Engineering, Inc.

Session Chairmen

Mr. Bradley Allen, CSA Engineering, Inc.

Capt. Walter Andress, Space Systems Division

Dr. Mohan Aswani, Aerospace Corporation

Capt. Mark Arnold, Wright Laboratory, Flight Dynamics Directorate

Mr. Eric Austin, CSA Engineering, Inc.

Lt. Col. Ronald L. Bagley, Air Force Institute of Technology

Dr. Andrew S. Bicos, McDonnell Douglas Space Systems Company

Mr. Daniel Cyphers, W. J. Schafer Associates. Inc.

Mr. Eric Dalton, Teledyne Brown

Mr. Ralph Dornsife, US Army / CERL

Mr. William Driscoll, 3M / Industrial Specialties Division

Mr. Robert Dunning, TRW

Mr. Rod Eddleman, US Army Strategic Defense

Mr. Richard Ely, LTV Aircraft Group

Dr. James Fanson, Jet Propulsion Laboratory

Mr. Bryce Fowler, CSA Engineering, Inc.

Dr. Joseph Garibotti, Ketema, Inc.

Mr. Russell Gehling, Martin Marietta Astronautics Group

Dr. Steven Ginter, Honeywell Satellite Systems

Dr. John Gubser, McDonnel Douglas Missile System Company

Dr. John Henderson, Consultant

Mr. Dennis Hill, GE Astro Space Division

- Dr. Philip Hipol, The Aerospace Corporation
- Dr. Robert Holman, Hughes Aircraft Company
- Mr. J. Warren Hoskins, Lockheed Missiles and Space Company
- Dr. Roy Ikegami, Boeing Aerospace
- Dr. Conor Johnson, CSA Engineering, Inc.
- Mr. Derrick Johnson, Boeing Aerospace
- Dr. David I. G. Jones, Wright Laboratory, Flight Dynamics Directorate
- Dr. Edward Kerwin, Bolt, Beranek and Newman, Inc.
- Mr. John Lassiter, Warner Robins ALC
- Mr. Paul Lindquist, Wright Laboratory, Flight Dynamics Directorate
- Lt. John Mackaman, Wright Laboratory, Flight Dynamics Directorate
- Dr. Ray Manning, TRW, Space and Technology Group
- Mr. Daniel Morgenthaler, Martin Marietta Space Systems
- Mr. Ahid Nashif, Anatrol Corporation
- Mr. Rory Ninneman, Phillips Laboratory
- Mr. Earl Pinson, Lockheed Missiles and Space Company
- Mr. Ken Qassim, Phillips Laboratory
- Mr. Keith Quinn, Nichols Research Corporation
- Dr. Dantam Rao, Mechanical Technology, Inc.
- Dr. Wayne Reader, Vector Research Company, Inc.
- Dr. Kenneth Richards, Martin Marietta
- Mr. Stanley Sattinger, Westinghouse Science and Technology Center
- Dr. Daniel Segalman, Sandia National Laboratories
- Mr. Leonard Shaw, Wright Laboratory, Flight Dynamics Directorate
- Professor Young Shin, Naval Postgraduate School
- Dr. Stepan Simonian, TRW, Space and Technology Group
- Mr. Kevin Slimak, Phillips Laboratory, Astronautics Directorate
- Dr. Jaak Soovere, Lockheed Missiles and Space Company
- Mr. Clyde Stahle, GE Astro Space
- Mr. Ralph Tate, LTV Aircraft Products Group
- Mr. Roger Thaller, Aeronautical Systems Division
- Capt. Steven G. Webb, US Air Force Academy
- Mr. Kenneth R. Wentz, Wright Laboratory, Flight Dynamics Directorate
- Maj. Stephen Whitehouse, Wright Laboratory, Flight Dynamics Directorate
- Dr. William Witt, The CORE Group
- Dr. Y. C. Yiu, Lockheed Missiles and Space Company
- Mr. Wayne Yuen, Wright Laboratory, Flight Dynamics Directorate
- Mr. Michael L. Zeigler, Wright Laboratory, Flight Dynamics Directorate

FOREWORD

This publication includes individual papers of **Damping '91** held February 13-15, 1991, San Diego, California. The Conference was sponsored by the Wright Laboratory Flight Dynamics Directorate, Wright-Patterson Air Force Base, Ohio.

It is desired to transfer vibration damping technology in a timely manner within the aerospace community, thereby, stimulating research, development and applications.



TABLE OF CONTENTS

	Paper No.
The F-117 Stealth Aircraft (Keynote Address) Mr. Paul Martin	AAA*
Use of Passive Damping for Aircraft Cabin Noise Control (Invited Speaker) Dr. Leo Butzel	AAB*
The Society of Damping Technology in Japan and its Activities (Invited Speaker) Dr. Yasuo Tokita and Hiroshi Okamura	AAC
SESSION BA - Aircraft Applications	
Integral Damping Treatment for Primary Aircraft Structures Sal Liguore, Marty Ferman, and Rudy Yurkovich	BAA
An Investigation of Add-on Damping Treatment for Life Extension of the F-15 Upper Outer Wing Skin Michael Parin, V. Levraea, Jr., Dr. Lynn Rogers, and A. Pacia	BAB
Damping Treatments for Aircraft Hardmounted Antennae Ralph E. Tate and Carl L. Rupert	BAC*
SESSION BB - Plates and Beams	
Examination of Boundary Conditions for Sixth-Order Damped Beam Theory Ralph E. Tate	BBA
The Effect of Compliant Layering on Damped Beams David John Barrett	ввв
The Damping Property of Laminated Steel Sheet after Deep Drawing Hiroshi Okamura	ввс

^{*}Not available for publication

	Paper No.
SESSION BC - Analysis and Design 1	
Practical Design and Analysis of Systems with Fractional Derivative Materials and Active Controls Daniel R. Morgenthaler	ВСА
An Implicit Fourier Transform Method for Nonlinear Dynamic Analysis with Frequency Dependent Damping Prof. F. Venancio-Filho and A. M. Claret	ВСВ
On a Linear Property of Lightly Damped Systems Z. Liang, M. Tong, and G. C. Lee	ВСС
SESSION CA - Control Structure	
Active Vibration Suppression via LQG/LTR: Analytic and Experimental Results for the PACOSS Dynamic Test Article Russell N. Gehling	CAA
H∞ Control for the PACOSS DTA Christopher T. Voth and R. Michael Stoughton	CAB
Active Damping of a Cantilever Beam Dr. Hung V. Vu, Stein Husher, and D. E. Zimmerman	CAC
The Investigation of Large Space Structure Passive Electrodynamic Dampers Dr. Roger Stettner and Dr. Paul Mlakar	CAD
SESSION CB - Damping Material and Measurements	
A Method for the Measurement of the Complex Compressional Modulus of Thin Layers Dr. Jonathan D. Rogers and Dr. Daniel J. Segalman	CBA*

	Paper No.
The Evaluation of Young's Complex Modulus of Viscoelastic Materials	СВВ
Marc Tardif and Prof. Germain Ostiguy	
Role of Morphology in Damping Efficiency Dr. L. H. Sperling, J. J. Fay, and Dr. D. A. Thomas	CBC*
The Thermorheologically Complex Material Lt. Col. Ronald L. Bagley	CBD*
SESSION CC - Analysis and Design 2	
Methods of Reduction of Wind Induced Dynamic Response in Solar Concentrators and Other Small Lightweight Structures Monte A. McGlaun	CCA
Analysis of a Five-Layer, Viscoelastic, Constrained-Layer Beam Michael A. Falugi	CCB
Dynamics of a Class of Viscously Damped Struts Dr. Y. C. Yiu and Dr. Steven Ginter	CCC
A Study of a Vibration Absorber to Control the Vibration of a Rectangular Plate	CCD
Akio Sugimoto, Hideo Utsuno, and Toshimitsu Tanaka	
SESSION DA - Analysis and Testing	
Impedance Matched Mass-Dampers: A New Approach for Improving Structural Damping Craig Gardner and Prof. Richard H. Lyon	DAA
Analytical and Experimental Modal Analysis of a Two-Tiered Structure Dr. Hung V. Vu, William C. Flynn, and T. K. Vuong	DAB

	Paper No.
Development of a Magnetic Suspension System for Reliable Vibration Damping Measurement Dr. Dantam K. Rao	DAC*
SESSION DB - Viscoelastic Material	
VEM Characterization Program Bryce L. Fowler	DBA
Data Base of the Dynamic Properties of Materials Ahid D. Nashif and Thomas M. Lewis	DBB
Establishing the Validity of the Master Curve Technique for Complex Modulus Data Reduction Dr. S. O. Oyadiji and Prof. G. R. Tomlinson	DBC
SESSION DC - Optimization	
Integrated Optimization of Composite Structures for Advanced Damped Dynamic Characteristics Dr. Dimitris A. Saravanos and Christos C. Chamis	DCA
An Optimum Design Methodology for Passively Damped Truss Structures Dr. Ray Manning	DCB
On An Application of Complex Damping Coefficients Z. Liang, M. Tong and G. C. Lee	DCC
SESSION EA - DAMMPS 1	
Statistcal and Worst Case Evaluation of Orbital Jitter Reduction Using Passive Damping J. Molnar, Dennis Hill, and Clyde Stahle	EAA

	Paper No.
LMSC DAMMPS Program Status J. Warren Hoskins and Dr. Y. C. Yiu	EAB
Damping of Precision Metal Matrix Trusses Dr. Stepan S. Simonian	EAC
Development of Low Modulus Damping Material for Precision Mounting Platforms Steven Kirshenbaum, Dennis Hill, and Clyde Stahle	EAD
Complex Stiffness Test Data for Three Viscoelastic Materials by the Direct Complex Stiffness Method Bradley R. Allen and Earl Pinson	EAE
SESSION EB - Viscoelastic Material Measurements	
Direct Measurement of the Dynamic Material Properties of Polymers for Low Frequencies Ahid D. Nashif, Thomas M. Lewis, and Paul J. Macioce	EBA
Correlation of Complex Modulus Data by Direct Stiffness and Indirect Resonant Beam Test Techniques T. Lewis, Mona P. Khoury, and Dr. David I. G. Jones	ЕВВ
Constitutive Modeling of Nonlinear Damping Materials Dr. Jerome Sackman, Prof. J. M. Kelly, and A. E. Javid	EBC
Results of a Round Robin Test Series to Evaluate Complex Moduli of a Selected Damping Material Dr. David I. G. Jones	EBD
SESSION EC- Analysis and Design 3	
A Mathematical Framework for the Study of Indirect Damping Mechanisms David L. Russell	ECA*

^{*}Not available for publication

	Paper No.
Techniques of Design and Using Viscoelastic Dampers Z. Liang, M. Tong, and G. C. Lee	ECB
Modeling of Constrained Layer Damping in Trusses Dr. Daniel J. Inman, Joseph C. Slater, and W. Keith Belvin	ECC
A Strong Criterion for Testing Proportionally Damped Systems Z. Liang, M. Tong, and G. C. Lee	ECD
SESSION ED - Applications Abbreviated Papers	
The PACOSS Dynamic Test Article Russell N. Gehling	EDA
Retrofitted Damping Treatment for a Three Stage Booster System Dr. Daniel J. Segalman and E. L. Marek	EDB*
Damping Design for a Disk Drive Head Flexure Eric M. Austin, James C. Goodding, and William A. Driscoll	EDC
Damping Jet Engine Front Frame Struts Capt. Vance Johnson, Kurt Nichol, and Dennis Murphy	EDD*
Isolation Joint for Flexural and Compressional Isolation Al Wignall and J. Aron	EDE
Characterization of Viscoelastic Damping in an Antenna Structure Dr. Ephrahim Garcia, James M. Argento, and Robert Alan Carlin	EDF
Laminar Blade Damper Michael Koleda	EDG
Experimental Study on Noise Reduction due to Damping Treatments Ken Okada and Junichi Kanazawa	EDH*

	Paper No.
SESSION FA - DAMMPS 2	
Evaluation of Damping Concepts for Precision Mounting Platforms Dennis Hill, Clyde Stahle, and James Staley	FAA
Synergistic Design of Passive Damping and Metal Matrix Composites Earl D. Pinson, Eric M. Austin, and Michael L. Zeigler	FAB
A Three Element Viscoelastic Isolator Dr. Stepan S. Simonian	FAC
SESSION FB - Noise and Acoustics	
Integrally Damped Honeycomb Structural Concepts to Increase Noise Transmission Loss Jefferson F. Newton, Dr. Roy Ikegami, and D. J. Carbery	FBA
Reduction of Acoustic Responses Using Viscoelastic Damping Materials Dr. David Chu, C. Stahle, J. Staley, J. Peir, and M. McMeekin	FBB
Design Method of Damping Treatment for Structure-Borne Noise Reduction Iwao Honda, Tadao Nakamura, Yoshihiko Irie, and Kazuo Yamamoto	FBC*
SESSION FC - Civil Structures	
Earthquake Simulator Testing of Two Damping Systems for Multistory Structures Ian D. Aiken and James M. Kelly	FCA
Correlation of Experimental Results with Predictions of Viscoelastic Damping for a Model Structure T. T. Soong and Dr. Ming Lai	FCB

	Paper No.
Damping Capacity of Reinforced Concrete External Beam Column Connections Dr. Alexander G. Tsonos, Ioannis A. Tegos, and Prof. Georgios G. Penelis	FCC*
SESSION FD - Analysis and Damping Mechanisms Abbreviated Papers	
Eddy Current-based Vibration Damping for Aerospace Structures James Goldie	FDA
The Absolute Value Modal Strain Energy Method Daniel R. Morgenthaler	FDB
An Analytical Model for the Vibration of Viscoelastically Damped Curved Sandwich Beams Dr. Mohan D. Rao and Shulin He	FDC
Bibliography of Environmental Data Measured In-Flight Lt. Col. Raymond F. Hain, III	FDD
General Motion of an Inclined Impact Damper with Friction C. N. Bapat	FDE
The Shock and Vibration Information Analysis Center (SAVIAC) Harold D. Kohn	FDF
SESSION GA - Electro-Rheological Fluids and Fluids	
The Vibration Damping Effect of an Electrorheological Fluid Stephen A. Austin	GAB
Modelling of Nonlinear Dilatation Response of Fluids Containing Columns Plastic and Shear Relaxation Considered Dr. Bernd Wendlandt	GAC

^{*}Not available for publication

	Paper No.
Electro-Rheological Fluids Characterization by Dynamic Mechanical Thermal Analysis under Applied Fields Dr. R. E. Wetton and Dr. J. C. Duncan	GAD*
SESSION GB - Control Structure Interaction 2	
On Piezoelectric Energy Conversion for Electronic Passive Damping Enhancement Dr. Donald L. Edberg, Dr. Andrew S. Bicos, and J. S. Fechter	GBA
The Need for Passive Damping in Feedback Controlled Flexible Structures Dr. Andreas von Flotow and D. W. Vos	GBB
Passive Control of a Flexible Planar Truss Using A Reaction Mass Actuator Capt. Steven G. Webb and Lt. David R. Lee	GBC
SESSION GC - Damping Indentification	
A Identification Technique for Damped Distributed Structural Systems Using the Method of Collocation R. Chander, M. Meyyappa, and S. V. Hanagud	GCA
Correlation Techniques to Determine Model Form in Robust Nonlinear System Realization/Identification Greselda Stry and D. Joseph Mook	GCB
System Level Design and Analysis of Truss Structures Damped by Viscous Struts Dr. Y. C. Yiu	GCC
Damping Ratio Estimates from Autocorrelation Functions Prof. Luigi Balis-Crema and Prof. A. Agneni	GCD

	Paper No.
SESSION GD - Damping Materials	
Dynamic Moduli of Fluorocarbon Compounds Dr. Wayne T. Reader and Robert W. Megill	GDA*
Passive Vibration Damping with Noncohesive Granular Materials Dr. Monen Abdel-Gawad	GDB
VEM Database Program Bryce L. Fowler	GDC
Measurement of the Mechanical Properties of Viscoelastics by the Direct Complex Stiffness Method Bradley R. Allen and Dr. David A. Kienholz	GDD
The Effect of Porosity on the Microstructural Damping Response of a 6061 Aluminum Alloy Jinmin Zhang, M. N. Gungor, and E. J. Lavernia	GDE
Damping Properties of Aliphatic Polyurethanes from 4, 4' - Dicyclohexylmethane Diisocyanate John D. Lee, Gilbert F. Lee, and Bruce Hartmann	GDF
An Apparatus for Measuring the Low Frequency Dynamic Characteristics of Materials Mona P. Khoury and Francis Olivier	GDG
SESSION HA - Composite and Metal Matrix	
Controlling the Damping Behavior of Pitch-based Carbon Fibers Andrew J. Eckel and Steven P. Jones	НАА
Internal Damping of Metal Matrix Composites: A Technical Assessment Jacques E. Schoutens	HAB
Vibration Suppression of Thin-Walled Composite Tubes Using Embeded Viscoelastic Layers F. M. Belknap and Professor J. B. Kosmatka	НАС
*Not available for publication xv1	

	Paper No.
SESSION HB - Tubes and Shells	
Directional Damping of the Global Vibration Modes of Tubular Struc- tures by Constrained-Layer Treatments Stanley S. Sattinger	НВА
Damped Response of Viscoelastic Thick Cylinders of Infinite Extent Dr. Hamid Hamidzadeh, D. J. Nunez, and D. E. Chandler	нвв
SESSION HC - Circular Plates	
Dynamic Analysis of Finite, Three Dimensional, Linear, Elastic Solids with Kelvin Viscoelastic Inclusions: Theory with Applications to Asymmetrically Damped Circular Plates Prof. C. D. Mote, Jr. and I. Y. Shen	НСА
Modal Analysis of Kelvin Viscoelastic Solids Under Arbitrary Excitation: Circular Plates Under Moving Loads I. Y. Shen and Prof. C. D. Mote, Jr.	НСВ
Response of a Circular Plate with Patch Damping Prof. Douglas Muster, Mahmoud Mezache, and G. H. Koopmann	нсс
SESSION IA - Viscous	
Development of the PACOSS D-Strut David Cunningham	IAA
Design, Analysis, and Testing of the PACOSS D-Strut Truss Daniel R. Morgenthaler	IAB
An Advanced D-Strut L. Porter Davis and Dr. Steve Ginter	IAC

	Paper No.
Testing of a Viscous Damped Isolator Bradley R. Allen and David Cunningham	IAD
SESSION IB - Experimental Measurements	
The Effect of Source Impedance on Damping Measurements Using Resonance Dwell Testing Ralph E. Tate	IBA
The Dependency of Vibration Energy Dissipation on the Amplitude of Structural Motion Dale L. Jensen	IBB*
Low-deflection Loss and Hysteresis Measurements on a Spacecraft Test Joint Eric M. Austin, James C. Goodding, and Timothy L. Flora	IBC
Damping Ratio Measurements in Kevlar Sandwich Samples Prof. Luigi Balis-Crema, Prof. A. Castellani, and Prof. A. Agneni	IBD
SESSION IC - Metals	
Characterization of the Damping Properties of High Damping Alloys Dr. Iain G. Ritchie and Z-L. Pan	ICA
Viscoelastic and Structural Damping Analysis Prof. Harry H. Hilton	ICB
Analysis of Strain Dependent Damping in Metals via Modeling of Material Point Hysteresis Dr. E. J. Graesser and C. R. Wong	ICC
Non-Obstructive Particle Damping Tests on Aluminum Beams Dr. Hagop V. Panossian	ICD

^{*}Not available for publication

	Paper No.
SESSION JA - Experimental Measurements of Damping	- -
Complex Dynamic Modulus of Nitinal-reinforced Composites Dr. Amr M. Baz, R. Deigan, and Dr. J. Gilheany	JAA*
Estimation of Nonproportional Damping from Experimental Measurements Dr. T. K. Hasselman and Jon D. Chrostowski	JAB*
Load Unit Deflection Correction for Forced Vibration Test System Kirk R. Biegler	JAC
SESSION JB - Friction	
An Analytical Approach to Designing Friction Dampers in Turbomachinery Blading Joe Panovsky, D. Hendley, and R. MacKay	JBA
Micro Slip Damping Mechanism in Bolted Joints Prof. M. Groper	JBB*
SESSION JC - Analysis and Design 4	
On a Theory of Complex Damping Z. Liang, M. Tong, and G. C. Lee	JCA
An Iterative Method in Dynamic Structural Analyses with Nonproportional Damping Dr. Wan T. Tsai and J.T. Leang	JCB

