# DAMPING DESIGN FOR A DISK DRIVE HEAD FLEXURE

Eric M. Austin[1]
James C. Goodding
*CSA Engineering, Inc., Palo Alto, CA*

William A. Driscoll
*3M ISD Laboratory, St. Paul, MN*

## ABSTRACT

This paper describes the work done by 3M and CSA Engineering (under contract to 3M) that lead to the design of a high-performance damper for load beams in disk drive head suspensions.

3M has supplied dampers for such applications for the past eight years. While the current damper designs do a good job of attenuating the first bending mode of the load beam, they do only a satisfactory job of attenuating the first torsion mode and a less than satisfactory job of attenuating the sway mode. Unfortunately, disk drive design changes have caused the sway mode to become one of the more dominant modes in the load beam during operations of the drive. If excited, this is the most severe mode with regard to operation of the disk drive servo heads. After the drive is manufactured, if a resonant condition occurs in the load beam of the servo suspension, the drive is rendered useless and has to be reworked.

The purpose of this work was to design a damping treatment that attenuates all three modes in a satisfactory manner. The paper describes the four phases that are typical in the design of a damping treatment for attenuating resonant vibrations: 1) mathematical modeling of the undamped system, 2) incorporation of a damping treatment into the mathematical model, 3) arriving at the optimum design for a damping treatment, and 4) preparing and experimentally evaluating the design.

[1]Senior Engineer, CSA Engineering, Inc., 560 San Antonio Road, Suite 101, Palo Alto, CA 94306, (415) 494-7351

# Damping Design for a Disk Drive Head Flexure



Eric M. Austin
James C. Goodding
CSA Engineering, Inc.

William A. Driscoll
3M / Industrial Specialties Division

EDC-2

Presented February 14, 1991
Damping '91, San Diego, CA

# The Purpose of a Flexure Damper

Obvious benefits of adding damping to a head flexure system are that responses of the read/write head to a given excitation can be reduced. This translates into increased accuracy, fewer read/write errors, increased gain margin, and increased reliability of the drives.

Significant components of the example head suspension system shown are the load beam, slider, and flexure. The terminology for these an components often varies. For this paper, the load beam is basically a cantilevered stainless steel beam (consistent with the figure), the slider is a block containing the read/write transducer that supports the air bearing that "floats" the head above the rotating disk, and the gimbal spring is the very compliant interface between the slider and the load beam. The overall assembly is called either a head flexure or head suspension system.

# The Purpose of a Flexure Damper

- Increase servo bandwidth by adding modal damping to the structure: Increase gain margin and lower access times

- Reduce read/write errors caused by head suspension structural dynamics

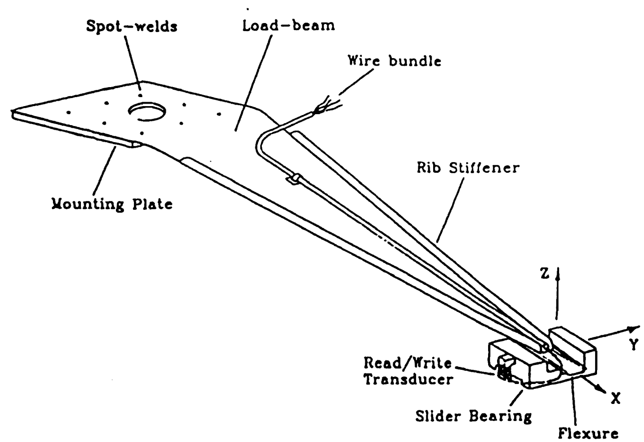
- Increase the reliability of the drives

# The Purpose of a Flexure Damper

- Increase servo bandwidth by increasing modal damping in the structure:  Increase gain margin

- Reduce read/write errors caused by head suspension structural dynamics

- Increase the reliability of the drives



# Objectives

3M currently markets several different head flexure dampers, each designed for a specific application. The end goal of this study was to reduce the number of unique flexure damper designs needed by optimizing a single design that will serve most applications. Of particular importance are treatments that perform well at typical operating temperatures near 160 deg F.

As a first step, existing designs of flexures and flexure dampers were studied using finite element analysis. Trade studies evaluated details about the viscoelastic materials, the constraining layers, and the placement of the dampers.

# Objectives

- Evaluate current flexure dampers designs
  - viscoelastic materials
  - constraining layers
  - position of damping treatment
- Determine a flexure damper design with high performance for a broad range of applications
- Verify analytical predictions via a simulated in-service test, particularly at typical operating temperatures (~160° F)

## Approach

The approach was dictated by the final objective: to recommend an improved design of flexure dampers to 3M. A finite element model was built to evaluate both existing and new designs for flexure dampers. As much emphasis was placed on testing resulting designs as on the analysis and design. The goals of the testing were to measure the frequency and damping in key modes and to compare this measured modal data with the analytical results.

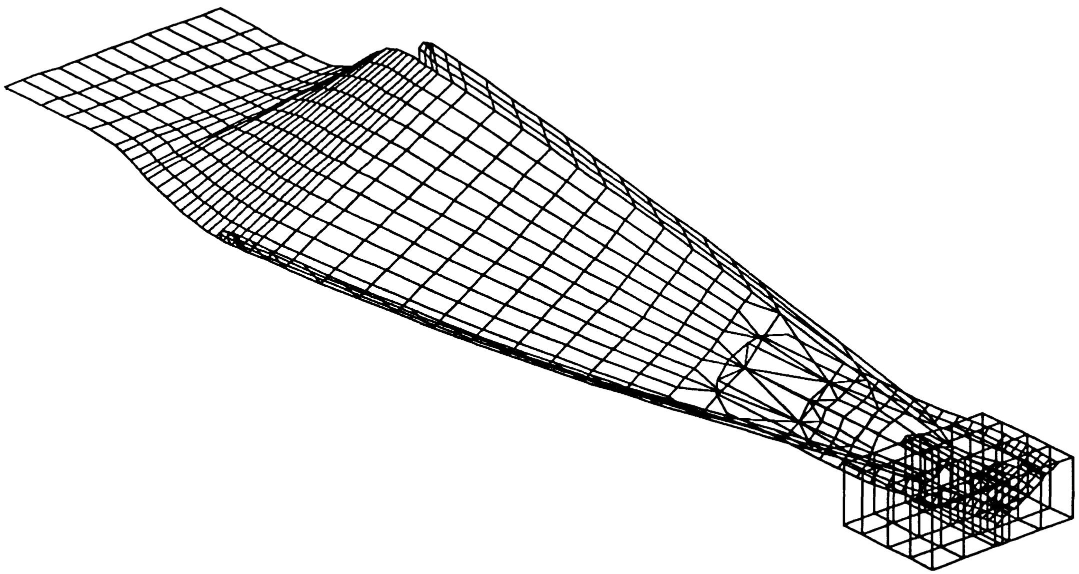
# Approach

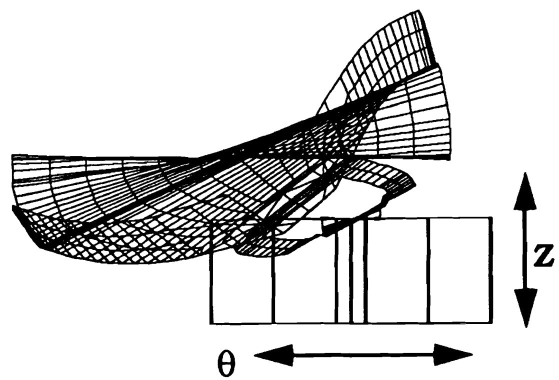
- Develop a finite element model of the undamped flexure
- Analyze candidate damping treatments
- Make design recommendations for improving damping performance to 3M, who will subsequently fabricate the design
- Verify damping design by test
- Measure flexure modal properties, including air-bearing effects
- Qualify important mode shapes against measured modal data

# Primary Modes of Interest

The modes of most interest to disk drive manufacturers are modes where the slider (read/write head) translates side to side (theta direction shown in slide).

# Primary Mode of Interest
## (Produces time-based error)





## Damping Design Trade Studies

Given complete freedom, design parameters in a damping design are the location of the treatment, the constraining layer material, the constraining layer thickness, the material for the VEM layer, and the thickness of the VEM layer. However, some of these can not be changed without having a large impact on the manufacturing process and disk drive performance. For instance, the bend radius is tuned so that the slider rides at a precise height above a spinning disk. This cannot be changed by a bulky damping treatment. This restricted the constraining layer thicknesses to only 0.001" or 0.002" of stainless steel. In addition, only standard VEM thicknesses of 0.002" and 0.005" were considered. In the end, the main design parameters were the stiffness and loss factor of the VEM and the damper placement.

# Damping Design Trade Studies

- There are a variety of different constraining layer damping designs used to solve resonance problems of the load beam

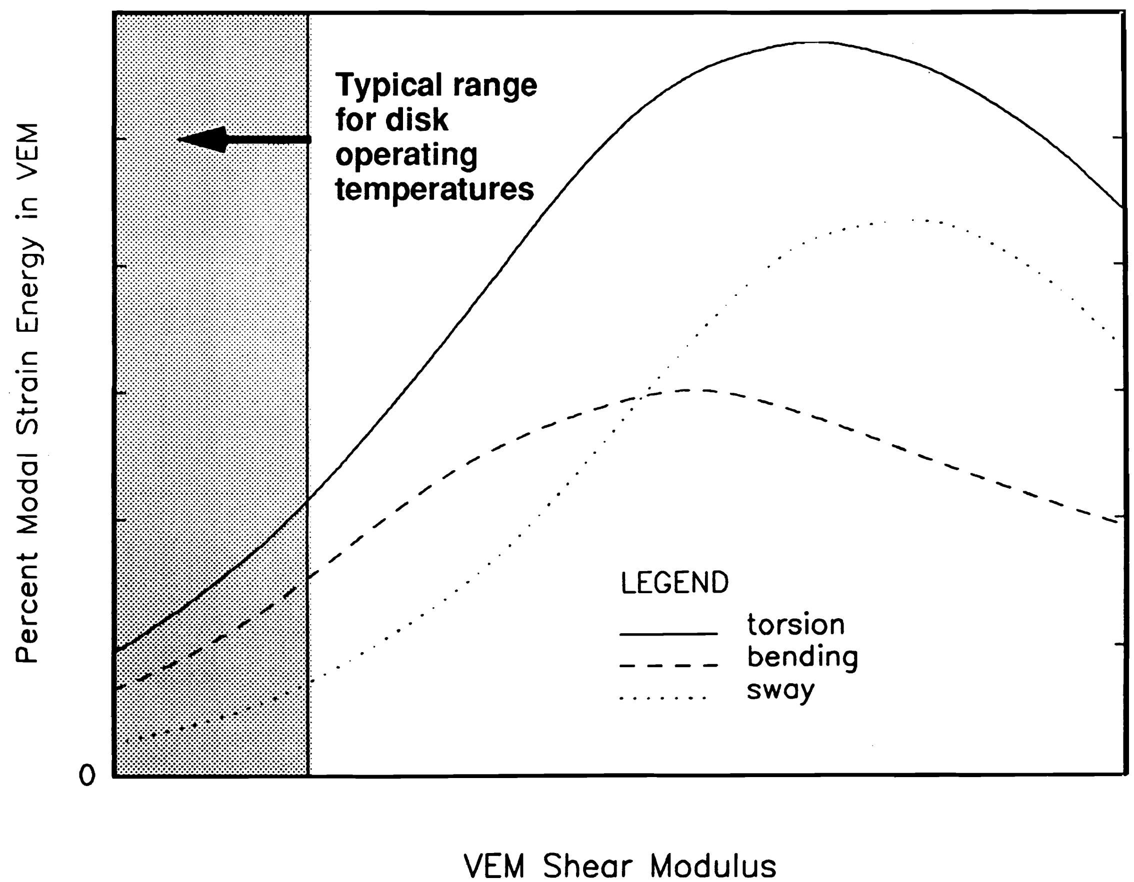
- Investigated VEM thicknesses of 0.002" and 0.005; investigated constraining-layer thicknesses of 0.001" and 0.002"

- Trade studies concentrated on the modulus and loss factor of viscoelastic material

# Variation of VEM Strain Energy with VEM Shear Modulus

The graph shows how the modal strain energy in the viscoelastic material varies as a function of VEM shear modulus. Using the Modal Strain Energy Method, the loss factor of the mode (1/Q) is the loss factor of the VEM times this percent modal strain energy. Without going into specifics of the values, it was found that the viscoelastic materials used in most commercial head flexure dampers were much softer than the analysis identified as optimum. Ideally, the damper design should utilize VEM's who's loss factors peak near the normal operating temperatures and frequencies. The slide shows the approximate effectiveness of most current VEM's.

# Variation of VEM Strain Energy with VEM Shear Modulus



## Viscoelastic Determination

Once the specification of VEM modulus and loss factor was recommended to 3M, the task of formulating the VEM commenced. Once complete, the mechanical properties of the VEM were verified (by 3M), and sample flexure dampers were prepared for testing.

# Viscoelastic Determination

- Determine chemistry to produce desired material properties
- Viscoelastics prepared; three candidates with different shear moduli
- Dynamic mechanical properties measured to verify modulus and loss factor

## Test Sample Preparation

Three sets of sample flexure dampers, each with a different modulus, were fabricated by 3M for testing. Each was die-cut and had a stainless steel constraining layer. They were applied to typical load beams in two slightly different configurations: one over the bend radius and the other not. The resulting damped flexures, along with two of a current configuration, were supplied to CSA for testing.

# Test Sample Preparation

- Prototype flexure dampers made with three candidate viscoelastic materials (stainless steel constraining layers)
- Dampers die cut
- Applied to load beams (two locations for each candidate material)
- Supplied to CSA along with two current configurations to serve as benchmarks

# Text-Fixture Design

The test fixture was designed so that the critical sway and torsion modes were sure to be excited by the base excitation. The fixturing was mounted directly on an electrodynamic shaker to provide a method to excite modes with strong theta-direction motion of the slider. Transmissibility functions were measured; the base motion sensed by an accelerometer and the response motion transduced by a noncontact optical displacement sensor. The modal properties were derived from the measured transmissibility functions.

In efforts to simulate in-service conditions as closely as possible, the air-bearing effect was simulated with by blowing air through a piece of porous bronze under the slider. In addition, the operating temperature near 160 deg F was achieved by a forced-air system.

# Test-Fixture Design

- Concentrate on modes that affect disk drive performance
  - Important modes: first torsion and first sway
  - First bending normal to disk relatively unimportant
- Obtained modal properties from measured transmissibility functions
  - Input: Base motion
  - Output: Motion at points on load beam and slider
- Simulate operating conditions
  - Temperature: 158°F nominal
  - Slider support in air film bearing

## Test Apparatus

The test rig was designed so that a base excitation could be applied directly to the base of the flexure in either the "Z" (producing weak-axis bending) or "theta" (producing sway and twist) directions. The optical sensor was mounted on a structure separate and vibration isolated from the shaker with a three-axis micrometer stage to position the fotonic probe accurately. The temperature was controlled by forced air and was measured with a standard thermocouple.

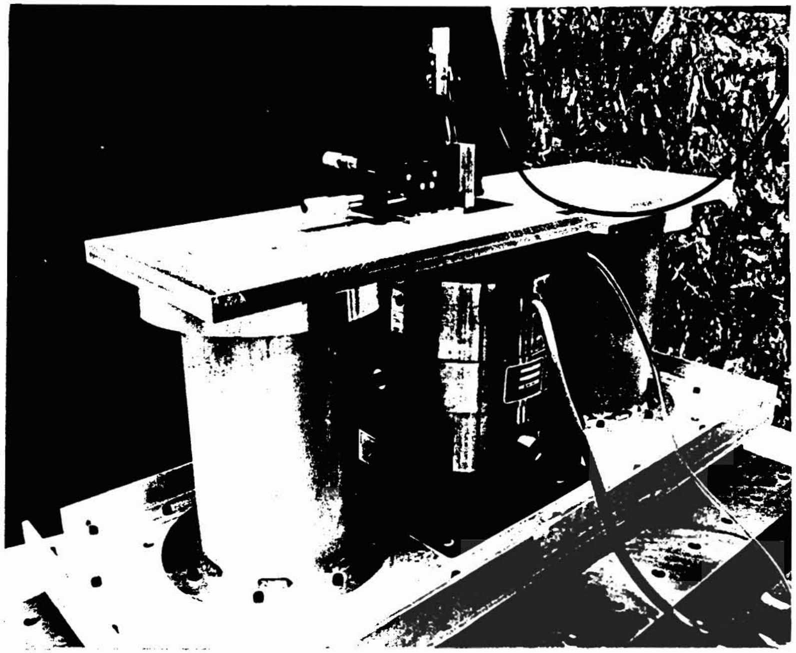
# Test Apparatus

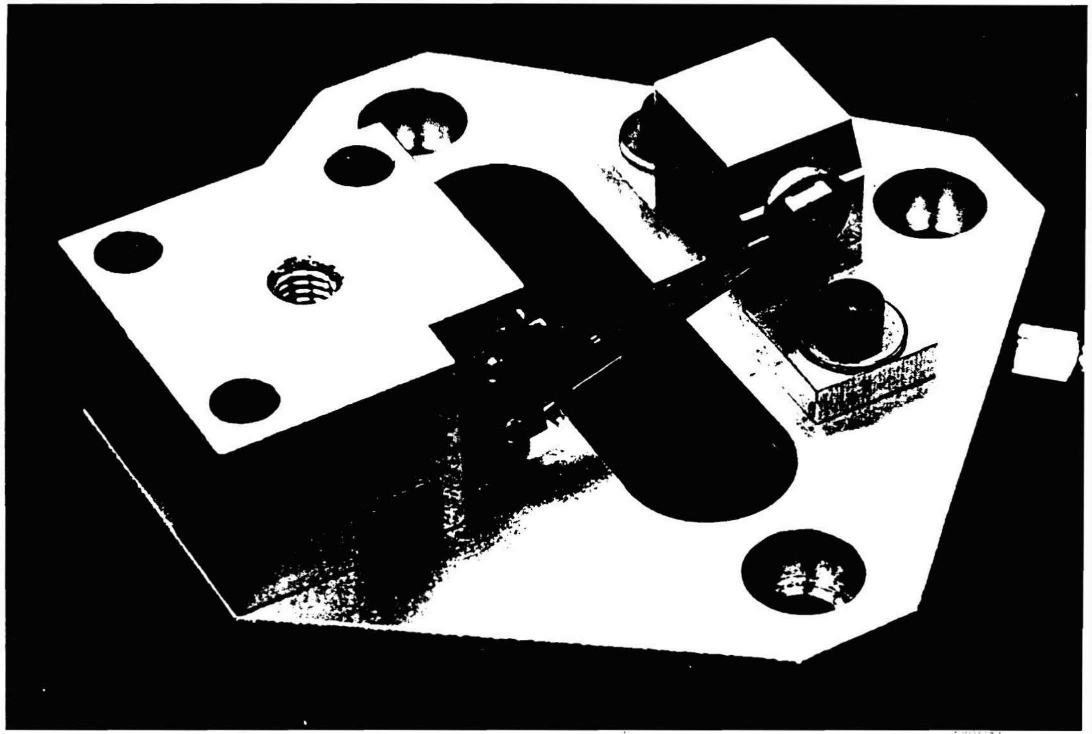
- Flexure-holding fixture mounted on shaker
- Fixtures to shake flexure in either Z or theta direction
- Three-axis micrometer stage to position response sensor accurately
- Measured, controlled input: Flexure base motion transduced by accelerometer
- Flexure response transduced by noncontacting optical sensor: fotonic probe
- Transmissibility measured via FFT analyzer
- Temperature control: Forced air with thermocouple

## Head Flexure Test Rig

This slide shows the complete test setup on the left and a close-up view of the moving head assembly on the right. The fixturing was designed to have integral damping so that it would not corrupt the measurements by its own resonant responses. The fotonic probe, seen on top of the platform on the left, was mounted on a damped sandwich plate, using 3M's ISD 110 as the middle VEM layer. The lower plate was also a three-layer sandwich assembly.

# Head Flexure Test Rig





- "Backdoor vibration path" and fixture resonances major concerns
- Both shaker and fixturing are supported on vibration isolators
- Plates damped with 3M ISD 110

EA-D91-3M-12

# Results

In conclusion, it was determined that damping treatments extending over the bend radius of the flexure worked better than those that did not. As reported earlier, analysis has predicted that viscoelastic material having much higher values of shear modulus are needed.

# Results

- Geometric design of damper established
- Placement of damper must be over the bend at the root of the load beam in order to damp the sway mode effectively
- Both finite element and experimental analyses suggest that high-modulus viscoelastic materials will improve damping performance in torsion and sway modes
- Near-term plans are to test improved flexure dampers in actual disk drives