MEASUREMENT OF THE MECHANICAL PROPERTIES OF VISCOELASTICS BY THE DIRECT COMPLEX STIFFNESS METHOD

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ABSTRACT

Accurate material properties are essential for the design of viscoelastic damping treatments and material properties are often the predominant error source process when modal strain energy techniques are implemented.

The trade-offs between various test techniques are discussed with primary emphasis on a system developed at CSA Engineering for direct complex stiffness measurements on viscoelastic materials. Issues such as analog front-end design, temperature control, and system software are discussed.

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Measurement of the Mechanical Properties of Viscoelastics by the Direct Complex Stiffness Method

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Measurement of the Mechanical Properties of Viscoelastics by the Direct Complex Stiffness Method

Damping Designer Needs Accurate Material Properties

- Moduli and loss factor
- Typically want shear properties
- Need properties across broad ranges of temperature and frequency
- Material property accuracy is often the limiting factor in current damping design
  - Wide scatter common in viscoelastic test data

Damping Designer Needs Accurate Material Properties

Methods for Dynamic Mechanical Testing of Viscoelastics

- Resonant methods
  - material properties extracted from resonant system
  - cantilever beam tests
- Nonresonant methods
  - material properties calculated from specimen stiffness
  - measurements performed below resonant frequencies of test specimen
  - Direct Complex Stiffness test method

Methods for Dynamic Mechanical Testing of Viscoelastics

- Resonant tests imply stiffness from the natural frequency of a resonant system; the loss factor is extracted from the modal damping.

- With direct stiffness method (DCS), stiffness of specimen is the real part of the complex stiffness and loss factor is calculated from the phase angle between force and displacement.

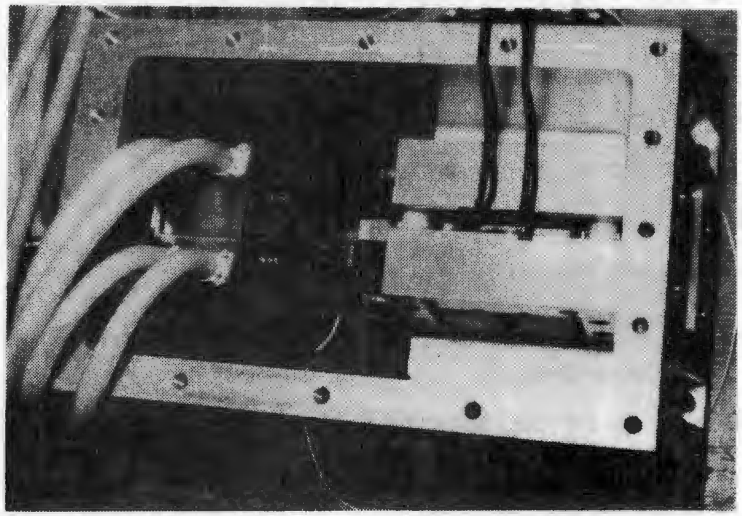
CSA Prefers DCS for Most Aerospace Applications

- No modeling assumptions
  - often introduce random and/or bias errors
- Excellent accuracy and repeatability
  - accuracy limited by
    - instrumentation
    - fixture design
- Resonant tests least accurate at highest damping levels

CSA Prefers DCS for Most Aerospace Applications

- Damping measurements become difficult as modal damping becomes large; however, modeling errors increase as strain energy in the viscoelastic is reduced. The combination of these effects make it difficult to obtain accurate measurements at the center of transition on many materials.

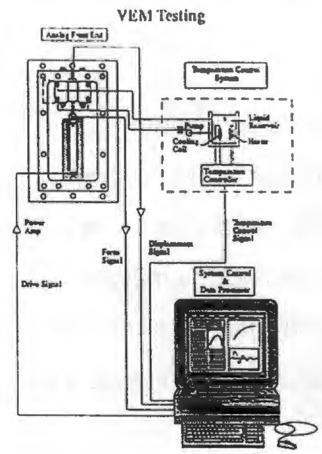
Current Prototype Employed by CSA Engineering



Current Prototype Employed by CSA Engineering

- Viscoelastic specimen is in dual shear.
- Cooling and heating are provided by liquid convection.
- Exterior box dimensions are 15" x 11" x 6"

Schematic of Prototype Test System



Schematic of Prototype Test System

- **Macintosh computer controls entire data acquisition process.**

Capabilities of New System

- 150 lbf
- 0.1 to 1000 Hertz bandwidth
- -85 to 500 F temperature control
- Wider dynamic range of stiffness
- Fast-Fourier transform analyzer
- Computer controlled data acquisition
- Characterization and data acquisition software run concurrently

Capabilities of New System

- Peak capacity of driver is 150 lbf with a 0.1 to 500 Hz broad band excitation.
- Temperature accuracy is plus or minus one degree Fahrenheit.
- Fast-Fourier Transform used to process data. Both random and sine excitation are available.
- Macintosh windowing environment allows data acquisition program to run concurrently with characterization software, and its tasks such as wicket plot display can be performed during data acquisition.

Computer Controlled Data Acquisition

- Automated test capability
- Sophisticated post-processing capabilities
- Error tracking routines in data acquisition and post-processing
  - inertia contaminated data
  - machine compliance
  - impure shear
- Exporting to characterization and database software

Computer Controlled Data Acquisition

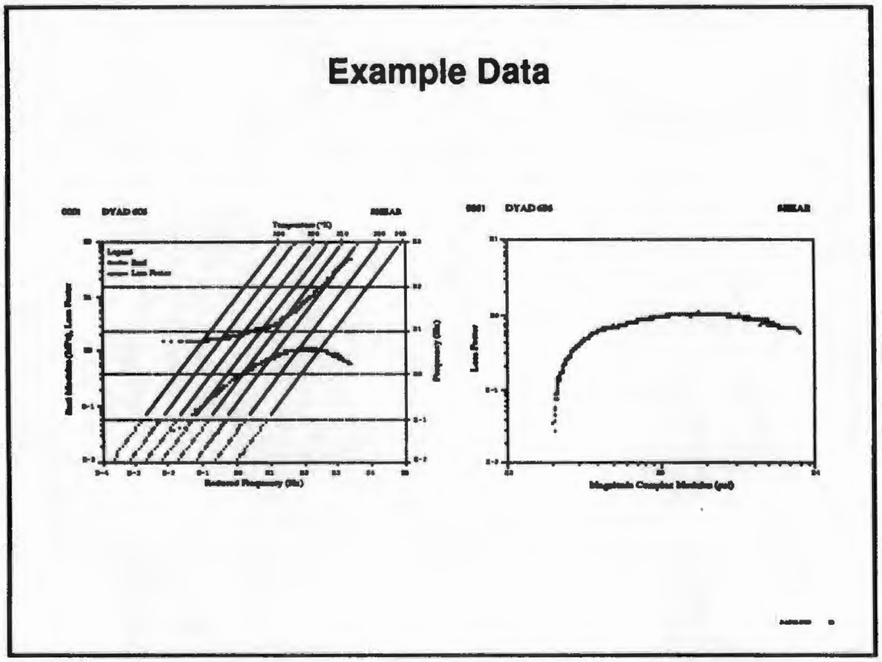
- **Data acquisition, temperature control, and post-processing are performed through a single Macintosh computer interface.**

Primary Design Objectives are Material Characterization

- Extended dynamic range of specimen stiffness to accommodate many materials and strain levels
- Wide temperature band
- Error tracking
- Computer controlled data acquisition
- Short data acquisition time

Primary Design Objectives are Material Characterization

- **Moduli of viscoelastic materials often change by greater than 1000:1 through transition. Therefore, the dynamic range of stiffness for the test machine is extremely important for broad band characterization.**



Example Data

- **Data shown was collected at only 8 isotherms and was thinned to display approximately one in four data points.**