43rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Con
22-25 April 2002, Denver, Colorado

AIAA 2002-1670

AIAA-2002-1670

Nonlinear Damping Identification in Smart Structural Systems Utilizing ER or MR Dampers

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Abstract

Smart fluids such as electrorheological (ER) and magnetorheological (MR) fluids can be incorporated into effective controllable vibration damping devices. MR and ER dampers exhibit both viscous and friction (Coulomb) damping. This paper focus on the identification of viscous and Coulomb damping simultaneously from the free vibration response of system. First, we derive the envelope of the free response of the system with combined viscous and friction damping and show that the damping components can be identified from the envelope signal. Three methods are proposed to calculate the envelope from the tested free response signal: Hilbert transform, short time Fourier transform, and wavelet transform. A single degree of freedom (SDOF) system is simulated to evaluate the three methods.

1 Introduction

Smart materials are widely applied in aerospace industries because of their ability to change the properties of structures such as stiffness and damping by applied fields. Electrorheological (ER) and magnetorheological (MR) fluids belong to the class of smart materials. They have unique ability to change the damping of systems when electric or magnetic field is applied. These controllable fluids have received considerable attention as components of engineering devices such as valves, clutches, brakes, suspensions, and dampers[1]. In helicopters, the MR based dampers have been proposed primarily for damping augmentation of the rotor systems[6]. These smart structural systems present nonlinear behaviors when the field is applied in the damper. Recent studies on MR and ER dampers suggested that a combined viscous and Coulomb damping characteristic is manifested as the field applied to the MR fluid is maximized[2]. An accurate and reliable method for identifying nonlinear damping mechanisms is needed to evaluate the damping performance of these systems.

Previous research into ER and MR dampers has shown many methods of modeling the fluid characteristics and the resulting damping forces. The most widely applied model is the Bingham plastic model. At the fluid level, the Bingham plastic model assumes a Newtonion fluid with a non-zero yield stress. At the damper level, the damper force becomes essentially a yield or Coulomb force added to a linear viscous damping force, which can be viewed as combined viscous and Coulomb damping.

Several studies have focused on identifying the combined viscous and Coulomb damping[3, 4, 5]. The proposed method used in these papers is similar to the logarithmic decrement method and is called the decrement method[5]. The exact solution of the free vibration was used in this method. The relationship between peak and valley points of the free vibration was determined from the exact solution. The viscous and Coulomb damping can then be calculated from this relationship. Unfortunately, the decrement method suffers greatly from the measurement error and noise.

In this paper, we develop another approach which identifies the combined viscous and Coulomb damping simultaneously from the envelope of the transient data record.

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