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Technical Report

Comparison of four test methods to measure damping properties of materials by using piezoelectric transducers

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ABSTRACT

This article presents the experimental results of damping loss factor and Young's modulus obtained for stiff and flexible materials through the use of four different methodologies: the Central Impedance Method, the Modified Oberst Method, the Seismic Response Method, and the simply supported beam method. The first three methods are based on the ASTM standard but using different experimental setting and different Frequency Response Functions. The fourth method corresponds to a non-resonant technique used in the characterization of materials at very low frequencies. In this work, the results of damping loss factor and Young's modulus obtained through these four methods are compared, the variability of results is studied and the sensitivity of each technique when facing controlled temperature variations is verified.

1. Introduction

The study of structural properties in materials is becoming more and more important in different disciplines of engineering and mechanical design [1]. A number of investigations have been carried out to modify the molecular structure of materials aimed at enhancing their internal damping without altering their other physical constants. These kinds of improvements involve developing adequate methods to measure damping loss factor [2].

Stiffness and damping are some of the most important design criteria for mechanical components and systems. Frequently, performance of a component or a structure is determined by combination of its stiffness and damping. This is particularly evident when designing the dynamic characteristics of modern machines since their increased speed and power, combined with lighter structures, may result in intense resonances and in the development of self-excited vibrations [3].

In general, materials selection and component design are two parallel streams followed when a mechanical component is designed. Firstly, a tentative material is chosen and data for it are assembled either from data sheets or from data books. In design, a choice of material can determine the price of a product and production paths. Later, a more detailed specification of the design and of the material is required. At this point it may be necessary to get detailed material properties from possible suppliers or to conduct experimental tests [4].

Damping loss factor is defined as the ratio between the energy dissipated within the damping layer and the energy stored in the whole structure, per cycle of vibration [1]. Use of constrained and unconstrained damping material layers has been a helpful tool for structural designers concerned with mitigating stress or displacement amplitude in vibrating systems. In addition, some research has been specifically aimed to optimize the damping of these layers [5].

The methodology established by ASTM [6] corresponds to a standardized test to measure loss factor and Young's Modulus in materials. This test is based on the analysis of peaks in the Frequency Response Function (FRF) measured without interfering with the system being analyzed. Consequently, this method implies the use of some specialized measurement instruments that could make the experimental setup highly expensive.

On the other hand, there is a variety of different contacting measuring approaches that can be employed for characterizing materials by resonance and non-resonance tests. Moreover, use of piezoelectric transducers is quite common in some of these tests, where accelerometers and force sensors are by far the most traditional and widely used piezoelectric sensors employed in modal testing [7]. Thus, carrying out tests using this type of transducers becomes an alternative worthy to be analyzed.

Particular studies of contacting measuring approaches for characterizing materials are abundant in the technical literature, but comparative studies have not been reported. This work aims to fill in this gap by presenting a comparison of four methodologies to estimate the characteristics of damping and stiffness in materials. For the purpose of comparable results among different

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