

Accurate Measurement of Loss Factor and Young's Modulus for a Composite Structure Using a Multi Degree of Freedom Curve-Fitting Method

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ABSTRACT

Offshore and ship structures are under several dynamic loads. The reduction of structural vibration is one of the key design aspects and composite materials are used to reduce vibration. Understanding viscoelastic properties of composite materials is essential for the design and analysis of the structures. Specially, the loss factor and Young's modulus must be known to develop finite element codes for a composite structure with several damping materials. In this study, an advanced technique for obtaining accurate loss factor and Young's modulus of a composite structure is introduced based on a multi degree of freedom curve-fitting method and the RKU (Ross-Kerwin-Ungar) equations. The loss factor and Young's modulus of a composite structure are measured for different temperatures by performing the test in a vibration measurement room where temperature varies from 5 to 45 Celsius.

KEY WORDS: Modal parameter identification; Viscoelastic damping; curve-fitting; Loss factor; Composite structures; Damping material; Young's modulus.

1. INTRODUCTION

Composite structures with viscoelastic damping material are becoming widely used for ships, submarines and offshore structures for reducing vibration and noises. However, when composite structures are analyzed by commercial finite element programs, errors can be generated because commercial programs are lack analytical capability for a damping system. Therefore, understanding viscoelastic properties of composite materials is essential for design and analysis of composite structures. Specially, loss factors and Young's modulus must be known to develop finite element codes for a composite structure with several damping materials.

In addition, the examination of the effect of environmental conditions on structural vibration properties is important in order to

reliably apply parameter identification methods to composite structures. Specially, the changes in temperature affect viscoelastic properties of composite materials. Many researchers have studied the effect of environmental condition variations on viscoelastic properties of composite materials. Woo et al. (2002) proposed to use the non-resonance method for the analysis of viscoelastic material. The technique can measure loss factors which form a continuous function in a measurement domain. However, if there are resonance-points in a measurement domain, the accuracy of experiment results decrease. On the other hand, Park et al. (2007) used the resonance method based on Oberst beam technique. The technique can analyze viscoelastic properties of composite materials rapidly and easily. However, some errors occurred because a single degree of freedom (SDOF) curve-fitting method was used.

This paper presents an experimental analysis technique for the viscoelastic properties of composite materials. The modal properties of these materials are identified from the vibration tests for a cantilever beam with free layer damping. There are several techniques available for identifying the modal parameters such as Ibrahim Time Domain Technique (ITD), Least Squares Complex Exponential Method (LSCE), Non-Linear Least Squares Method (NLLS) (Min et al., (2007)). Here the NLLS method is adopted because it can analyze a high damping system.

2. NON-PROPORTIONAL DAMPING SYSTEM

The general equation of motion for a multi degree of freedom (MDOF) system of N degrees of freedom with viscous damping is as follows;

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{f\} \quad (1)$$

Where $[M]$, $[C]$ and $[K]$ are $[N \times N]$ mass, damping and stiffness matrices, and $\{x\}$ and $\{f\}$ are $[N \times 1]$ vectors of time-varying displacements and forces.

Next, one must define a new coordinate vector $\{y\}$ which is of