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子計畫一：奈米碳管加勁複合材料揚聲板之研製

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計畫主持人：金大仁

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小型奈米碳管加勁複合材料平板式揚聲器研發-子計畫

計畫編號：94-2212-E-009-021-

執行期間：94 年08 月01 日至95 年07 月31 日

主持人：金大仁　教授

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中文摘要

本計畫主要研究可用於微揚聲器之奈米複合材料三明治板。計畫中利用超音波攪拌來分在樹脂中的奈米二氧化矽顆粒，並將參有奈米二氧化矽顆粒之樹脂以網版印刷的方式披覆於珍珠板的面層。最後利用非破壞地敲擊試驗測量其頻率並反求其材料常數，由結果可觀察出奈米複合材料對於板材確實有加強之作用。

Abstract

Method for the fabrication of nano-composite sandwich plates and determination of the elastic constants of the sandwich plates are presented in this paper. The ultrasonic mixing technique is used to disperse the nano-particles in the epoxy resin. The resin mixed with nano-SiO_2 particles is used to make the face sheets of sandwich plate. An impulse vibration test technique is used to nondestructively identify the elastic constants of the sandwich plates. The results have shown that the use of nano composites can increase the stiffness of the sandwich plates.

Introduction

In recent years, nano composites have become important materials in engineering applications. For instance, nano composites have been used to reinforce the matrix or structures. Recently, Iizuka [1] has studied the W_2C nano-particle reinforced Si_3N_4 matrix composite, Wu [2] has studied the properties of PP/nano-SiO_2 composite materials, Wang [3] has studied the characterization of nano-SiC particles reinforced TiC/SiC_{nano} composites. The determination of the mechanical properties of the nano composites or the products made of such materials has also become an important topic of research.

Recently Lee and Kam [4,5] have applied a multi-start global optimization algorithm together with an impulse vibration testing technique to identify the material constants of composite plates. In this paper, a method for fabricating nano-composite sandwich plates is presented. The material constants of the nano-composite sandwich plates are determined using the previously proposed nondestructive identification technique.

Manufacture of Nano-composite Sandwich Plate

The nano-composite sandwich plate is composed of two same thin nano-composite face sheets and the foam core. The face sheet is the mixture of the epoxy and SiO_2 nano-particles (4%wt.). Fabrication of nano-composite was carried out in the following five steps. In the first step, the epoxy (Shell epoxy resin Epikote 828) was mixed with 4% wt. 12nm SiO_2 nano-particles (Degussa Taiwan Ltd. AE200). The mixing of the resin and nano-particles was carried out mechanically (Fig. 1) at 80℃ and 800 rpm blending cycles for 4 hours to disperse the nano-particles in the resin. In the second step, the mixing was carried out by using the sonicator (Misonix sonicator 3000) around 90-120 Walt for 30 minutes (Fig. 2) to disperse the nano-SiO_2 particles in the epoxy resin. In the third step, the nano-SiO_2 epoxy was blended with the hardener (D230) at the weight ratio of 1:0.32 for 15 minutes. The fully blended nano composite resin is then adhesively attached to the surface of a foam plate through a printing technique (Fig. 3). In the fourth step, the foam plate coated with nano composite resin is vacuumed to reduce the bubbles in the resin for 30 minutes (Fig. 4). In the final step, the face layer of the sandwich plate was covered by the Teflon sheet to be cured under room temperature for 24 hours (Fig. 5).

Experimental study and Investigation

A number of nano-composite sandwich plates were fabricated for experimental investigation. The dimensions of the nano-composite face layer are 20 cm × 20 cm × 0.02 mm. The foam core thickness is 0.169 cm. The mass densities of the core and face layer are 49.1 Kg/m^3 and 2400 Kg/m^3, respectively. The variation of the face sheet thickness is too small to be negligible.

The elastic constants identification of the nano-composite face sheet is performed using the impulse vibration testing technique. In this technique, the nano-composite sandwich plate hung by rubber bands is subjected to the impulsive vibration testing as shown in Fig. 6. The data acquisition system (B&K 3560C and B&K Pulse Labshop Version 6.1) is used to process the vibration data from which the natural frequencies of the sandwich plates are extracted. Fig. 7 shows a typical frequency response spectrum of the square nano-composite sandwich plate. A global optimization method is then used to determine the elastic constants of the sandwich plate using the measured natural frequencies of the plates. Table 1 lists the experimental and theoretical natural frequencies of the nano-composite sandwich plate and foam plate with free edges. Table 2 lists the identified material constants of the nano-composite face layer using experimental natural frequencies. Table 3 lists the identified material constants of the foam plate and face layer of the nano-composite sandwich plate using experimental natural frequencies.

Conclusion

A method for fabricating nano-composite sandwich plate has been presented. The fabrication process including techniques for mixing, blending, curing, and coating has been developed successfully. Experimental frequencies have been used to identify the elastic constants of the nano-composite sandwich plates. The identified elastic constants have been found to be acceptable.

Fig. 1 Mechanical stirring process

Fig. 2 Ultrasonic mixing process

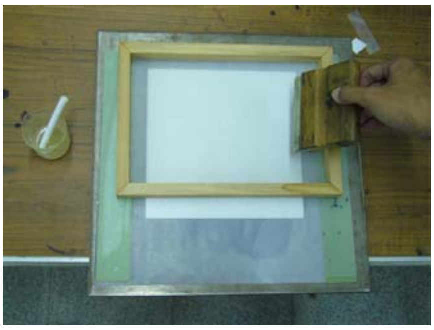

Fig. 3 Printing coating method

Fig. 4 Bubbles-reduced process

Fig. 5 Cured Process

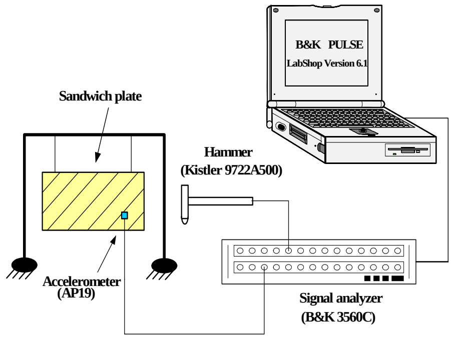

Fig. 6. Impulsive vibration testing devices

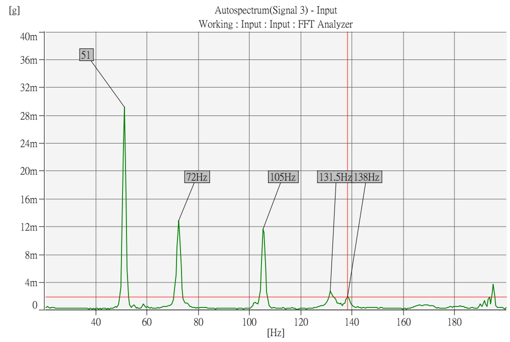

Fig. 7. Frequency response spectrum of the square nano-composite sandwich plate

Table 1. Experimental and theoretical natural frequencies of free nano-composite sandwich plate and foam plate

Case	Natural frequency (Hz)		
	1st	2nd	3rd
I	33.38[a] 33.054[b] (-0.98%)[c]	45 48.625 (-7.45%)	64.63 62.671 (3.12%)
II	51 50.433 (1.12%)	72 72.861 (-1.18%)	

[a] Experimental natural frequency; [b] Theoretical natural frequency; and [c] Percentage difference.

Case I: Foam Plate

Case II: Nano-composite Sandwich Plate

Table 2. Identified material constants of the nano-composite material by using experimental natural frequencies

Starting point no.	Stage	System parameter		No. of iterations
		E (GPa)	ν	
1	Initial	16.606	0.2778	52
	Final	3.05	0.2803	
2	Initial	12.693	0.4167	59
	Final	3.048	0.2803	
3	Initial	9.514	0.3952	54
	Final	3.048	0.2803	
4	Initial	4.349	0.2622	60
	Final	3.049	0.2803	
Global minimum		3.049	0.2803	Probability 0.992

Table 3. Identified material constants of foam plate and the face layer of nano-composite sandwich plate by using experimental natural frequencies

Case	No. of starting points	Average no. of iteration	System parameter	
			E	ν
I	4	26	79.485 (MPa)	0.3447
Ⅱ	4	56	3.049 (GPa)	0.2803

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