THE RESEARCH OF DEBONDING DAMAGE IDENTIFICATION FOR FOAM CORE SANDWICH USING WAVELET PACKET ENERGY METHOD

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Introduction

Fiber reinforced plastic (FRP) sandwich composite plate has great potential for wider application in aerospace industry. However, internal defects can occur during the manufacturing process in the form of voids and during the service life in the form of delamination in the skin or debond between the core and the skin. If these defects are not identified early on, it can lead to rapid structural degradation.

Researchers in engineering have been paying more and more attention on wavelets. A wavelet uses a windowing technique with variable-sized regions. Wavelet transform is a powerful technique to decompose time series in time-frequency domain. The wavelet transform-based method for vibration signal analysis is gradually introduced in many fields due to its good time-frequency localization. Despite of the extensive studies of vibration analysis on damaged plate, the problem is still not fully understood especially for the multiple size and location of damages.

This paper focuses on the study of a practical method for effective detection of internal delaminations in foam core sandwich by combining numerical analysis on structural strain energy. A Damage Index is constructed to examine multi damages.

Damage Index for Multiple Damage Identification

The strain energy was used as a damage characteristics parameter. A Damage Index was constructed by the decomposition of wavelet packet method to the difference of the strain energies between the intact plate and the damaged plate.

The strain energy spectrums were analyzed, which could increase the sensitivity to the damage, especially in the initial of damage. It can be presented as a second ordor norm,

$$\|f\|_2^2 = \int_R |f(t)|^2 \, dx \qquad (1)$$

Where f(t) is the response signal of the sandwich.

A damage index DI was constructed by the four layers wavelet packet decomposition to the difference of the strain energies between the intact plate and the damaged plate.

$$DI = \sum_{i=2^0}^{2^4} \frac{\eta_{4i}^d - \eta_{4i}^o}{\eta_{4i}^o} \qquad (2)$$

Where η denoted the strain energy corresponding to the location and the excitation.

Numerical Analysis

To illustrate the application and effectiveness of the method, a example of the damages identification for a foam core sandwich was given.

The sandwich plate with laminate faces and PMI core was shown in figure 1. The plate was clamped on one edge and other three edges were free. There were three assumed damages located on A, B and C of the plate. The finite element method (FEM) was used to compute the strain response for a sine excitation in Z direction on the free edge opposite the clamped edge as shown in figure 2. And the damage was modeled by the modulus deduction. Four degrees of damage were researched, e.g. respectively 90%, 80%, 70% and 60% deduction of the modulus.

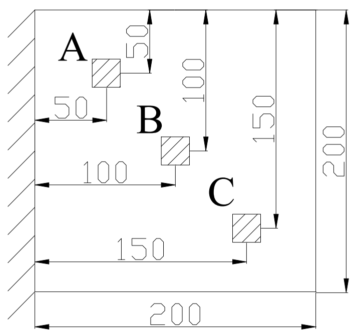


Fig.1 3 damages on the sandwich plate (unit: mm)

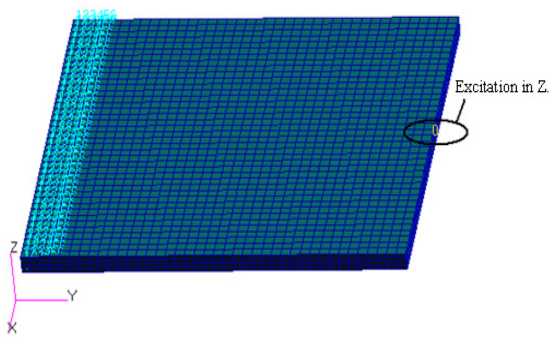


Fig. 2 The finite element model with excitation

As shown in the figure 3, the strains of the plate in the blue girds and the corresponding strain energies were calculated.

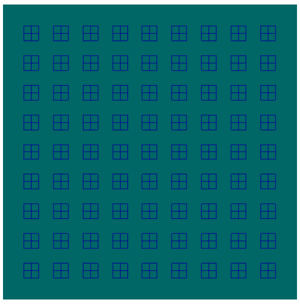
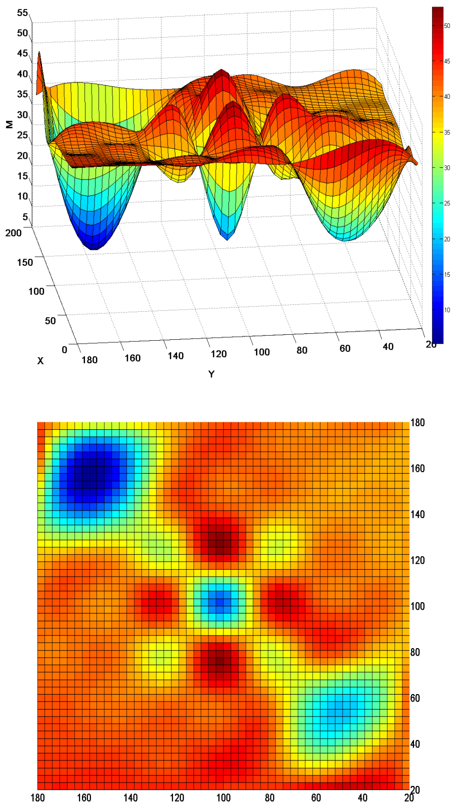


Fig.3 Target elements for strain analysis (blue grids)

The damage index for the 60% degree plate was demonstrated by a three dimension map in figure 4. The three wave valleys indicated the three locations of the damages in the plate. The maximum DI in the lowest valley was used to represent the degree of the damage. The DI of the multi- damages and theirs locations were given in Table 1. And the curve indicating the relationship of the Damage Index to the degrees of the damage was given in figure 5. It was show that the DI by this method could effectively recognize the damages, as well as their degrees and locations



60%

Fig.4 3-dimensional DI map for damage degree 60%

Table 1 Maximum damage indexes and locations of multi-damages plates

Modulus	DI			Corresponding Location		
Reduction	A	B	C	A	B	C
90%	24.17	25.56	33.96	(55.2,48.8)	(100,100)	(157.6,157.6)
80%	17.59	20.61	29.59	(52,48.8)	(100,100)	(157.6,157.6)
70%	11.32	16.73	24.79	(52,48.8)	(100,100)	(154.4,157.6)
60%	5.271	14.06	19.63	(52,48.8)	(100,100)	(154.4,154.4)

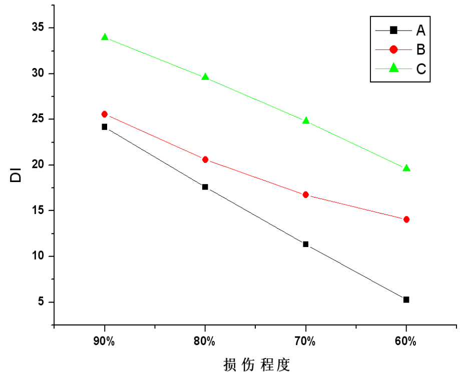


Fig.5 Damage index to the damage degree

Conclution

The multiple damage identification was studied by numerical analysis of strain energy using wavelet packet energy method. The characteristic parameter was built by vibration strain energy and decomposed by the wavelet packet. The damage index was than constructed and can effectively identify the locations and the degrees of multiple damages in the foam core sandwich plate.

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