Damage detection in CFRP Composite Plate based on evolving Modal Parameters

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Abstract

Despite the good mechanical properties of composite structures, it is still prone to low impact damages resulting in defects such as delamination and the effect is usually not detected by visual inspection. Although the use of modal parameters for identification of damage in Carbon Fibre Reinforced Polymer (CFRP) composite laminates is not new, it is still a subject of discussion within the research community. In this study composite of different stacking configuration manufactured by hand lay-up and autoclave curing were used to conduct the free-free experimental modal analysis within the frequency range of 0 -- 400 Hz. The experiments were performed for both healthy and damage induced samples of same configuration. The effect of the modal parameters such as damping factors, natural frequencies, etc were assessed and the results presented here-in.

Introduction

Composite materials have gained a wide acceptance in various industries such as aerospace, marine, automotive, civil infrastructures, and sports equipment, due to their unique mechanical properties, namely strength and stiffness to weight ratios [1–3]. However, it is susceptible to damage in the through thickness direction that may be caused by a bird strike, hailstones, dropped tools during maintenance/manufacturing, and stones.

Typically, the low energy impact on the surface does not result in a mark other than a small indentation that is difficult to identify through visual inspection. However, the impact may have resulted in damage that propagates under different mechanisms through the thickness of the laminate down to the opposite side which is usually hidden. This could compromise the integrity of the structure, reduce its life cycle [4] and raise safety issues. Hence, it is pertinent to promptly identify and locate damages in composite in order to avert unexpected breakdown of structures

Several techniques have been developed over the years in an attempt to get a more efficient, simple and economical solution for the damage identification in composite structures. However, no single technique has proven appropriate for all circumstances. Each technique has its uniqueness, effectiveness and range of applications. This investigation reports the changes in the modal parameters of healthy and damage composite plates, coupled with the effect of stacking configuration.

Test Program

In this investigation, the laminates with dimensions as shown in Table 1 were manufactured and used to perform experimental modal analysis.

Table 1: The Stacking Sequence of Laminates

Stacking sequence	Dimension
$[0/\pm45/90]_s$	312×240×1.76 [mm^3]
$[90/\pm45/0]_s$	312×240×1.76 [mm^3]
$[90/0/\pm45]_s$	312×240×1.76 [mm^3]
$[90/0]_{2s}$	312×240×1.76 [mm^3]

The composite consist of carbon fibres as the reinforcement and epoxy as the matrix. These samples were manufactured using an autoclave and vibration test conducted.

Experimental Procedure and Results

The composite plate suspended under a free–free simulated configuration with strings of nylon as shown in Fig. 1. Attached to it is a force transducer and connected to a mechanical shaker through a pushrod (stinger). The response of the samples due to a multisine signal excitation for a frequency range of 0–400 Hz were obtained and a representative result is as shown in Fig. 2. The rigid modes between 0-20Hz shown on the receptance curve is likely because of the nylon strings used to suspend the test specimen for a free-free boundary condition.

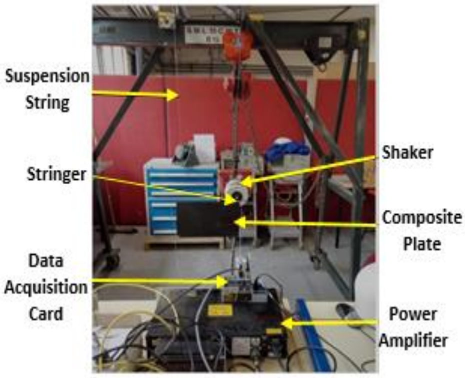

Fig. 1: Experimental set-up.

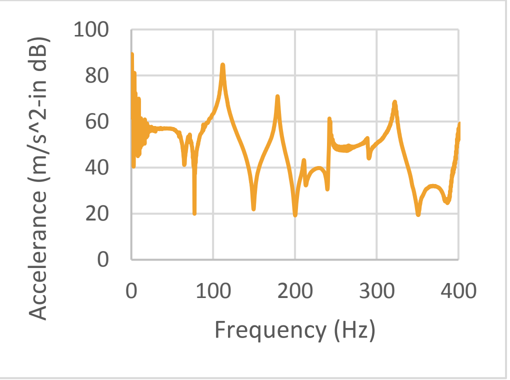

Fig. 2: Representative frequency response plot.

The frequency responses were measured using three lightweight PCB teardrop accelerometer, type 352A24, that weighs 0.8 g each, at the corner of the specimen to acquire the Frequency Response Functions (FRFs).

Concluding Remarks

In this study both undamaged and damaged composite samples were used for free-free vibration experiment and BetaLAB software was used to extract the modal parameters i.e. natural frequencies and damping factors. The result show changes due to the level of damage induced in the samples and stacking sequence also indicated some effect on the vibration data.

References

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