The Effect of Crack Geometry on the Nondestructive Fault Detection in a Composite Beam

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Defects in structures may be inherited from materials and manufacturing or they develop during service. Defects may cause catastrophic failure, which is why their detection and classification are important issues. Many aspects of defects have already been dealt with, but with wider applications of non-destructive testing methods to composite materials. However, the effect of arbitrary and random defect geometry on the applicability of these methods has been overlooked. In order to investigate this issue, this study carries out a free vibration analysis of a specially orthotropic cracked cantilever beam that was manufactured by Pultrusion. A new crack model, unlike the widely known V-shaped crack, is introduced and the effect of crack depth on the natural frequency is investigated, both experimentally and numerically. The results obtained from both the new- and the V-shaped models are compared with each other, and it is revealed that the results are not sensitive to the geometry change.

1. INTRODUCTION

Composites were used in various structural applications in the civil, automotive, and aerospace industries. One typical application of composites in structures are beams. A defect on a composite beam, which develops with time, can destroy it. Recent research has been directed to the detection or diagnoses of the development of defects in composites under dynamic loading. Initially, in composite failure detection research, Krawczuk et al.[1] found that natural frequencies of a cracked structural composite member beam were influenced by a crack in the member: the increase in crack depth had caused a decrease in the calculated natural bending frequencies. Song et al.,[2] on the other hand, analysed that the bending free vibration of a cantilever laminated composite beam was weakened by multiple surface cracks. The governing equations of the composite beam with open cracks were accounted for in transverse shear and inertia effects. Kisa[3] presented a new method for the numerical modelling of the free vibration of a cantilever composite beam that had multiple open and non-propagating cracks. The author had observed the frequency ratios to decrease under fibre angle increases. Wang et al.[4] studied the coupled bending and torsional vibration of a fiber-reinforced composite cantilever with an edge surface crack. They concluded that changes in natural frequencies and the corresponding mode shapes depended on fiber orientation and fiber volume fraction. Finally, Hamid and Hamada[5] investigated a composite beam with different fiber angles and a single crack. They stated that the natural frequency and the damping ratio increased when fiber angle rose for a constant crack location and depth.

Table 1. The mechanical properties of the pultruded GFRP composite beam.

E_1	E_2	E_3	G_{12}	G_{13}	G_{23}	v_{12}	v_{13}	v_{23}	Density
10^9 Pa						-			kg/m^3
25	8.5	8.5	3	3	3.9	0.23	0.23	0.09	1800

In this study, a new crack model is introduced together with the known V-shaped crack model in order to investigate the effect of defect geometry change on the natural frequencies and mode shapes under free vibration loading. These examinations were carried out using both experimental and finite element analyses.

2. MATERIAL PROPERTIES

Material properties in the principal material directions 1, 2, and 3 of the pultruded glass fibre reinforced composite beam were determined. The beam had a solid cross-section with 45 mm height, 29 mm width, and a length of 1400 mm. The 1-axis lies along the fibre's direction and the shear modulus G_{23} were calculated from Eq. (1):

$$G_{23} = \frac{E_2}{2(1+\nu_{23})}. \tag{1}$$

The properties are given in Tab. 1.

3. NUMERICAL MODELLING

ANSYS 8.1[6] finite element package had been used to model the beam with an assumed open crack. The crack was created at 745 mm away from the cantilevered end. Eight different crack depths, namely $d = 5, 10, 15, 20, 25, 30,$ and 35 mm,