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Stiffness behavior of hybrid laminated composites with surface crack

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ABSTRACT

Purpose: The purpose of this paper investigates to stiffness behavior of hybrid laminated composites with surface crack.

Design/methodology/approach: Hybrid laminated composites has 18 layers and 90x25 mm size with two different layers line up. The low velocity impact test of hybrid laminated composites carried on 3 m/sec with a/t=0.4 and a/c=0.4 surface crack parameters.

Findings: The results are presented as the change of force-time and force-displacement graphs. As a result of this study, effects of stacking sequence on hybrid composite plates were analysed.

Research limitations/implications: The research of stiffness behavior or dynamic response of hybrid laminated composites can contribute to developing new composite materials.

Practical implications: These hybrid laminated composites materials could be used for different aviation areas.

Originality/value: This paper is based on studies from Selçuk University and all the experiments and results were conducted by me.

Keywords: Low velocity impact; Surface crack; Laminated composite

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MATERIALS

1. Introduction

Fibres/epoxy composites are increasingly used in an aircraft structures due to superior specific strength and stiffness. Impact loading from dropped tools, runway wreck, etc., may cause visible damage. Delamination could also appear during manufacturing due to non-perfect process [1-3]. Such damage is a serious problem since it may severely reduce the integrity of the structure without being detected [4-6].

Impact damage usually contains plural delaminations, which significantly reduce flexural properties of the laminated skin, as well as fractured fibres and matrix cracks. Surface cracks are usually common imperfection in many industry applications. While a common crack type, the amount of crack closure information available on surface cracks in comparison to through-thickness cracks is comparatively small. This is mostly due to difficulties in measuring these quantities experimentally. Under loading conditions, failure usually takes place at the bonded interfaces, with failure along such interfaces often involving cracks running at speeds comparable to the wave speeds of the constituent materials [7-11].

2. Material and method

The laminated composite plates were produced from Izoreel Company and have 90 mm x 25 mm dimension and 4 mm thickness. It was manufactured at two different configurations as seen in Figure 1. In the first, the carbon layer is positioned interior of composites and the second; the carbon layer is positioned out of the composites. All manufactured composites have same cost, equal size and different configurations. Surface cracks were created to composites plates with using carbon discs [3].

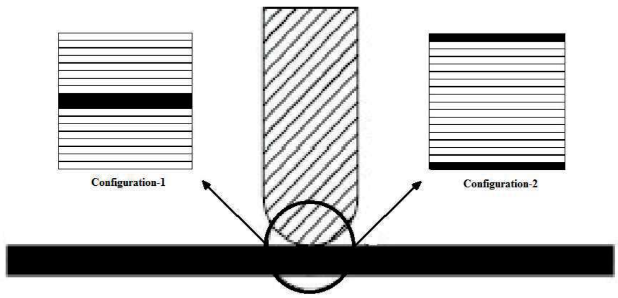

Fig. 1. Stacking sequence of laminated composite plates [3]

Laminated composites have been subjected to low velocity impact tests, separately. Impact tests were guided with a drop tower by varying the height of the dropped impact head. The impactor has a hemi-spherical tip with a mass 6.35 kg and diameter of 12 mm. The testing machine and impactor reputed to be perfectly rigid. The force signals were measured by a sensor in millivolts. The signals were amplified by a signal conditioner and transmitted to the data acquisition card installed on a computer. The variations of interaction force between the impactor and the sample versus time were obtained using NI Signal Express software [3]. The Newton's second law of motion was used to express the velocity and displacement of impactor versus time. When the impactor first hits the material, the kinetic energy of the impactor is partly transferred to the material. The remaining kinetic energy is used to rebound which makes the impactor to rise. This process continues until the kinetic energy of the impactor is fully expanded. The testing machine has an anti-rebound system which consents us to get only one impact. So, during the test the dropping weight has been catch immediately after it hits to the test specimens and following impacts have been refrained. The test specimens were placed into a fixture produced for placing and holding the test specimens at the point of impact. The low velocity impact tests were repeated three times under impact velocity of 3 m/sec, separately.

3. Results and discussion

The low velocity impact test results are given in Figures 2 and 3. Figure 2 shows the impact force-time behaviour for composite laminates subjected to different stacking sequences. Figure 3 shows that the impact force-displacement behaviour for composite laminates with different stacking sequences. When the loading is started, force increases linearly with displacement and reaches to its maximum rate. After this point the unloading stages starts with representing nonlinear behaviour. The incline of the loading phase of force-displacement curve is described as bending stiffness under loading. In the instance of delamination, bending stiffness decreases fundamentally and shows itself as depress in incline of force–displacement line. A fibre breakage generally results in decrease in stiffness associated with decrease in contact force [3,8].

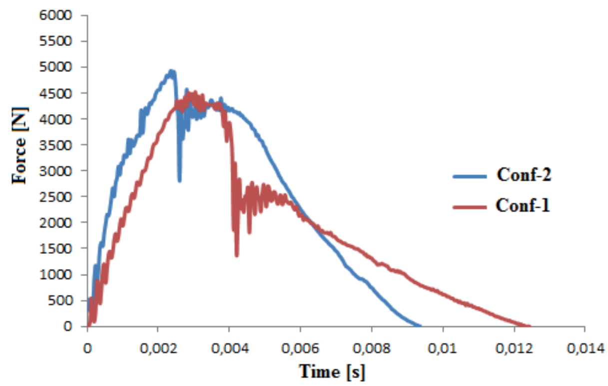

Fig. 2. Change of contact force versus time for different stacking sequences

Figure 4 show that the SEM (scanning electron microscopy) images of laminated composite plates after the low velocity impact test. As seen in Figure 4, surface cracks progressing from bottom of initial surface crack. In addition, we can see all the delamination of laminates and surface crack growth in Figure 4.

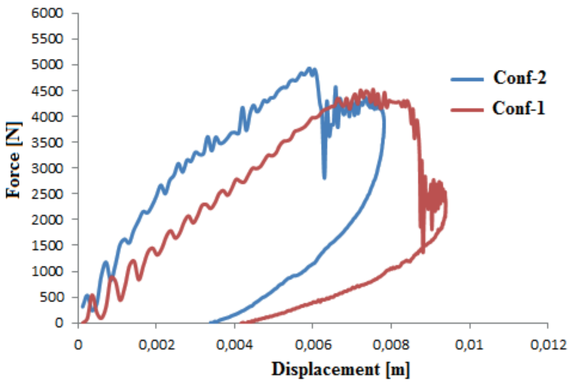

Fig. 3. Change of contact force versus displacement for different stacking sequences

As seen in Figure 2, the maximum contact force for configuration-1 is lower than that of configuration-2. It is also seen in Figure 2 that small oscillations take place which are indication of matrix cracking.

As seen in this figure, the composite plate starts to deformation with increasing load and the vertical displacement reaches its maximum when contact force reaches its maximum value. After reaching maximum force and deflection values, the deformation starts to decrease. However, if the material has permanently damaged, the deflection does not reach to zero. As sated before, damage starts with matrix cracking. After this stage, delamination has taken place and followed by fibre cracking on the back side of the composite plate due to tensile stresses as a result of bending.

Figure 4 shows the scanning electron microscopy images taken from surface crack tip of test specimen tested under 3 m/sec impact velocity. As seen in this figure, it is seen that damage formation is mainly consisting of delamination formation. It is also seen in this figure that, delamination starts at the tip of the surface crack and spreads out towards successive layers.

It is seen that two parallel cracks have formed near the crack tip. These cracks are basically delaminations starts at the tip of the surface crack and advance through transverse direction. These delaminations follow the shape of surface crack and then easily propagate through next layer. At the tip of a surface crack, stress intensity factors vary with respect to geometrical position depending on the shape and thickness factors of surface crack. It is essential that crack propagation starts where stress intensity factor is maximum. Since, delamination type crack propagation follows the shape of surface crack tip, it can be concluded that surface crack shows a tendency to keep its original shape.

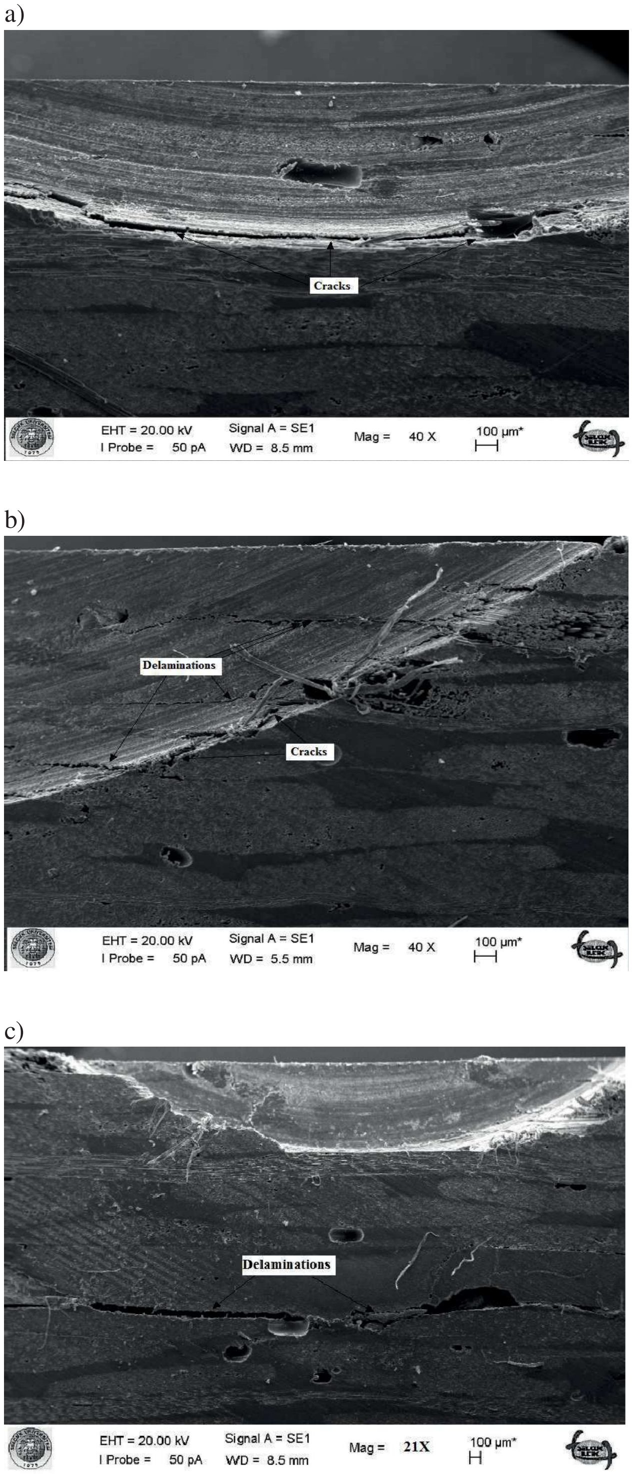

Fig. 4. SEM images of after the low velocity impact test fracture surface of produced laminated composite plates with surface crack (a, b, c)

It is observed that all of specimens investigated under SEM shows similar damage behaviours. It is also observed that some delaminated zones near surface cracked area take place. So, it is concluded that, low velocity impact loading mainly results in formation of delamination. However, the existence of surface cracks or crack like defects can result in relatively easy damage formation and intensification around surface crack.

Acknowledgements

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