MODELING OF NESTING EFFECT ON THE DELAMINATED SURFACE FOR WOVEN STRUCTURES

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Abstract

In this work the delaminated surface geometry of two woven structures will be evaluated for different nesting/shifting values. The analyzed woven composites are manufactured using the same resin-reinforcement and same architecture, but having different tow size (3K/12K). Three different shifting/nesting configurations are applied to the material at the fracture surface: zero shifting, middle shifting and maximum shifting. Mode I fracture tests are applied to the materials. Depending on the nesting/shifting value the delaminated surface waviness is different, and consequently the fracture toughness measured is also modified.

1 Introduction

In this work the relationship between nesting/shifting and fracture toughness values are going to be evaluated for woven structures. Depending on the shifting/nesting value the delaminated surface waviness will be different, and consequently the fracture toughness can be affected. Many authors have studied the relationship between the textile structure of the layers in a laminate and fracture toughness. Briscoe [1] for example analyzed the influence of fabric weave and fabric surface texture for mode I interlaminar toughness in aramid/epoxy laminates. The results of tests carried out by Briscoe showed higher fracture toughness for coarse fabric than for fine fabrics. Alif [2] also found that fibre bridging effect was happening in fracture surfaces of twill and satin weave, but he did not come across this effect in plain weave structures. Alif analyzed the interaction between weave pattern structure and fracture behaviour in plain, twill, 8H-satin and 5H-satin carbon/epoxy composite. Kim [3] linked delamination failure mechanisms taking place in woven materials to angle-ply prepeg tapes. He pointed out that propagation fracture toughness for 0º/0º interface in an angle-ply laminate is much lower than for 0º/90º interfaces or woven-fabric laminates. In a similar way, Gill [4] also saw that the toughness was higher when there were more 90º oriented tows in the direction of the propagation in 5HS woven structures, due to the 0º/90º interfaces created on the surface. He found that the fibre volume fraction variation had an effect on mode I delamination behaviour in 5HS woven materials, as the fibre content increased, the mode I toughness increased.

The objective of this work is to link experimentally the nesting/shifting value in the delaminated area with the fracture toughness. A finite element model using cohesive elements is created in order to correlate fracture toughness experiment values of the delaminated surface with the numerical results.

2 Material description and manufaturing

The material is a carbon fibre reinforced woven laminate made of 2/2 twill woven layers and it is manufacturated from prepeg sheet layers in an autoclave. The unit cell dimension for 12K is almost 3 times bigger than for 3K when dealing with the same thickness. Three different fracture surface configurations are manufactured controlling the shifting of the textile geometry between the middle layers in the material. The delaminated area´s configuration patterns are described in Figure 1. The symbols used for describing the configuration are related to the fibre angles between layers (Table 1). Measuring the shifting value of woven unit cells between layers, it is observed that for a randomly shifting manufacturated material the dispersion is quite high. The nesting value is larger for 12K material than for 3K, although shifting percentage is higher for 3K material. The conclusion is that a higher shifting percentage does not need to show higher nesting values when comparing materials of a different tow size. This is the reason why the relation between shifting percentage and nesting value must be checked for different woven size structures.

Symbol	Fibre angle configuration between layers (θ_1/θ_2)
o	0/90 or 90/0
+	0/0
-	90/90

Table 1. Relation between symbols and fiber angle configuration between layers.

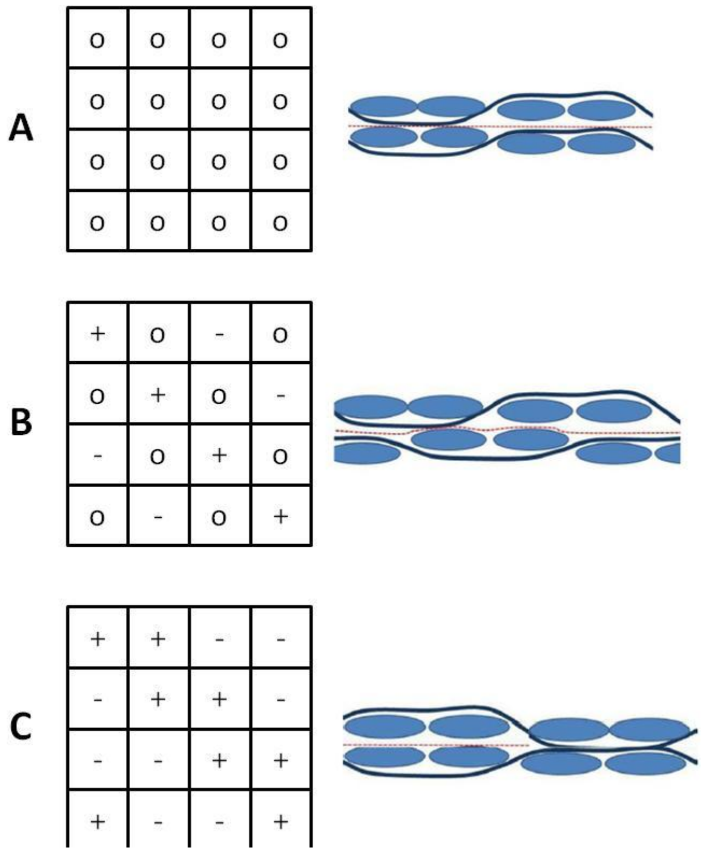

Figure 1. Three configurations manufactured on the delaminated surface.

During the manufacturing process the shifting of the layers has been controlled at the delamination crack front position in longitudinal and transversal direction (Figure 2). After curing the material in the autoclave, the samples are cut and the geometry definition is evaluated using images from the lateral faces. In Figure 3 three configurations are evaluated from the sides of the samples. The rest of the layers are positioned in a random position, without taking into account the shifting between layers.

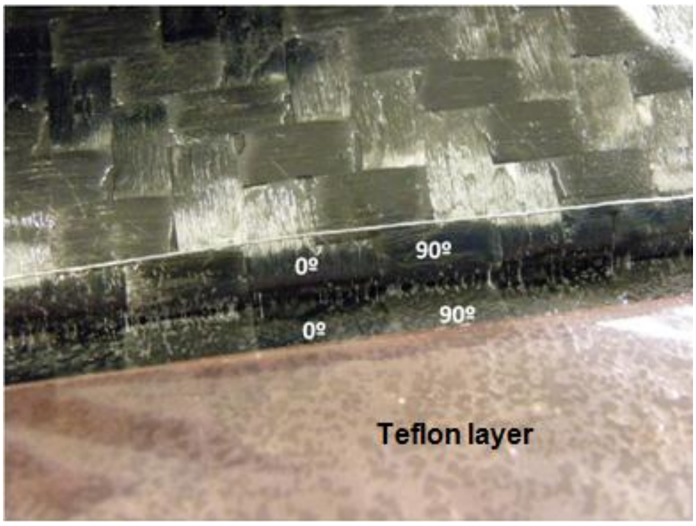

Figure 2. Detail of the delamination surface manufacturing positioning for configuration type C.

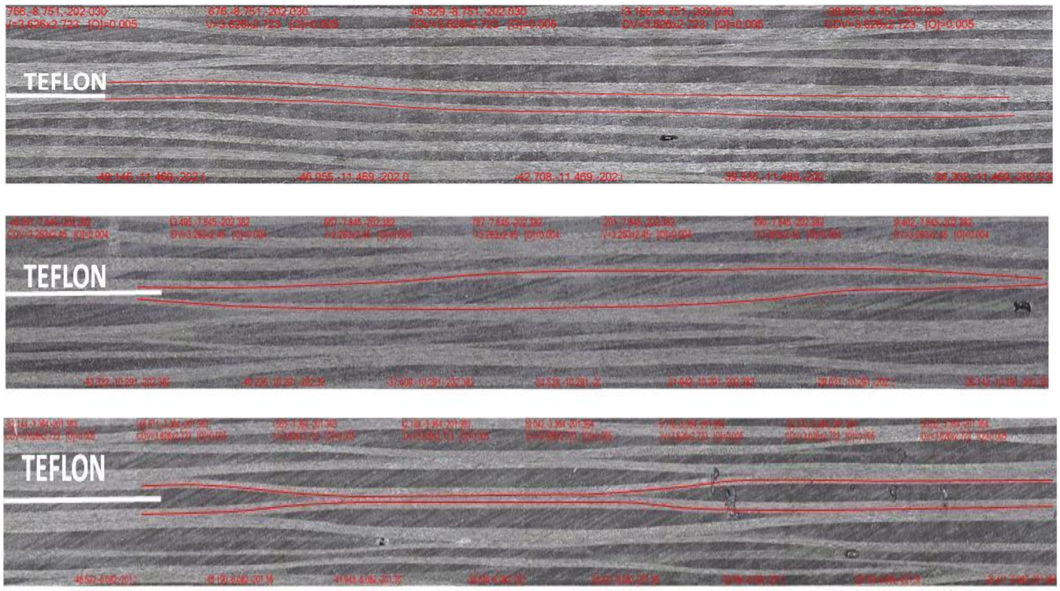

Figure 3. A, B and C configurations for 12K material.

3 Test

Mode I opening tests are performed following the international standard ASTM-D5528 [5]. The tests are performed using a Double Cantiveler Beam (DCB), where a non-sticking Teflon thin film is inserted as starter of the crack. The delaminated surface progression during mode I opening in this textile material is not smooth. As the load is applying on the sample, the crack is opening slowly in some areas and abruptly in other areas. The load-displacement diagram (Figure 4) shows load jump reductions during the test when the delaminated area progresses suddenly (jump size between 4-8 mm).

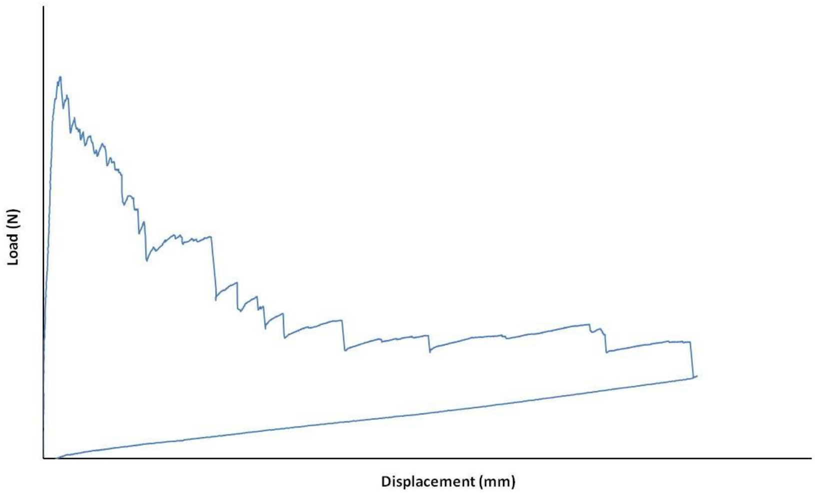

Figure 4. Load-displacement evolution during a DCB mode I test.

The results show differences on the 3 shifting values, having the same tendency for 3K and 12K materials. Higher toughness values are defined for A configuration and the lowest for C configuration.

4 Modelling

A finite element software (Ansys) is used for modeling the Double Cantiveler Beam test using cohesive elements. The model expressed the delamination behavior as a function of normal and tangential tensile forces in relation to separation distances: as the interfacial separation increases, a maximum traction point is reached, and then with increasing separation the traction is reduced until completed decohesion takes place. Depending on the fracture properties applied to the model at each contact zone (different for configurations shown in table 1) the fracture toughness of the material changes drastically. The delamination front also takes different shapes as the crack is propagating (Figure 5).

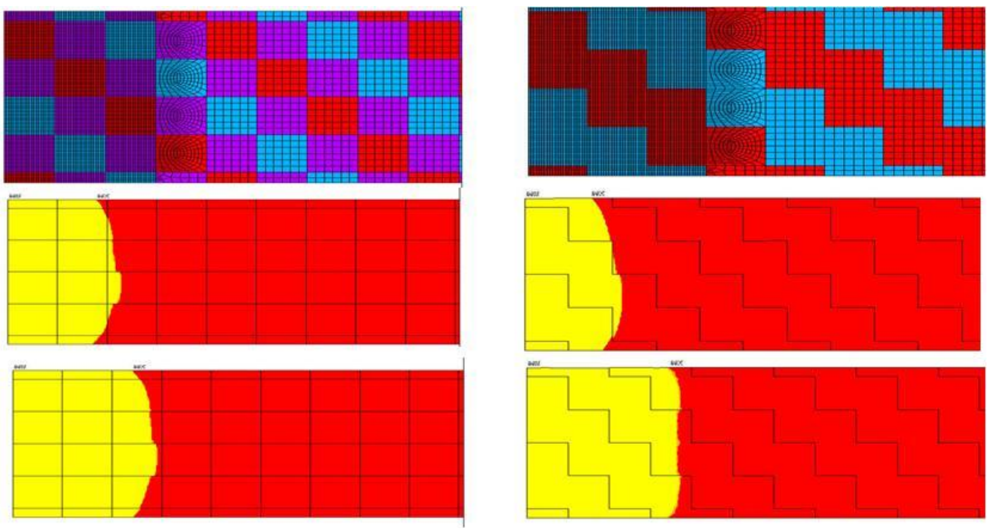

Figure 5. Delamination crack front for B and C configurations in Ansys.

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