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EFFECT OF FIBRE ORIENTATION AND STACKING SEQUENCE ON THE INTERLAMINAR STRESSES OF COMPOSITE LAMINATES

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Abstract: *The complexity of designing laminated composites requires an appropriate selection of the parameters that influence their mechanical properties, such as fibre orientation angles, stacking sequence, fibre volume fraction and type of specially orthotropic lamina making the multi-layered composite. Since the interlaminar stresses have a significant importance on the interlaminar damage occurrence on composite laminates such as delamination, the effect of their main parameters on the variation of interlaminar stresses needs a special attention. The paper presents the numerical analysis of a balanced composite laminate subjected to a mode I fracture type. The results are presented in terms of interlaminar stresses distribution on each ply of the multi-layered element.*

Key words: *interlaminar stresses, fibre orientation, stacking sequence, balanced composite laminates.*

1. Introduction

The laminated composites are formed by stacking two or more composite laminae, having the same or different fibre orientations, tailored in such a way as to improve the bearing capacity of the element in the required directions [3, 8].

A balanced composite laminate is represented by a multi-layered composite which has an equal number of equal thickness layers with the fibre orientations of $+\theta_i$ and $-\theta_i$.

The influence of the laminated composites parameters, such as the stacking sequence and the fibre orientation angles on the mechanical response of multi-layered elements is still an actual concern for many researchers [2, 5-7].

2. Description of the Numerical Model of the Balanced Laminate

The numerical model of the laminated composite is realized in ANSYS Composite

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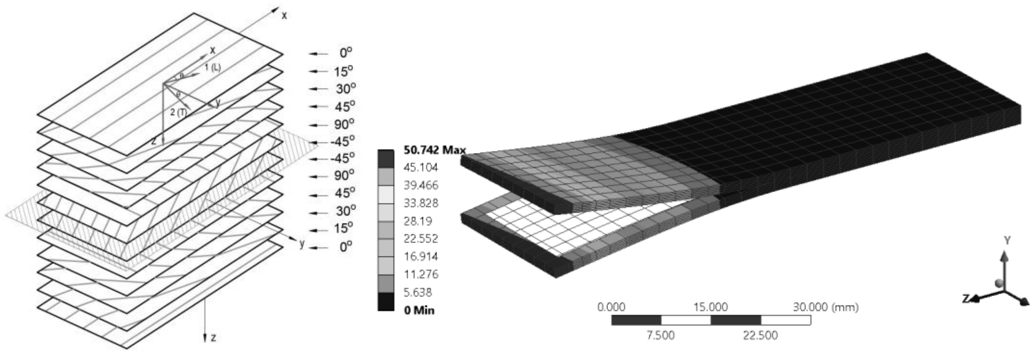
Pre/Post software [1]. The following configuration of the balanced composite laminate is selected, $[0/15/30/45/90/-45]_S$, in order to determine a gradual degradation of the element. The multi-layered composite is subjected to a tensile opening fracture mode, with an equal two-side imposed displacement of Δ = 40 mm. The stacking sequence of the laminated composite and the deformed shape corresponding to Mode I fracture type are shown in Figure 1.



a) stacking sequence *b) total deformation for an opening mode fracture*

Fig. 1. *The stacking sequence and the deformed shape of the balanced laminate*

The composite laminae are made of S glass fibres embedded in an epoxy resin matrix, the mechanical properties of the composite layers being presented in Table 1.

The constituent material characteristics [4] Table 1

Constituents' materials properties	Fibres	Matrix
	S glass	Epoxy
The longitudinal elastic modulus [GPa]	85.5	4
Poisson's ratio	0.22	0.35
The longitudinal tensile strength [MPa]	4580	75
The longitudinal compressive strength [MPa]	2450	150
The shear strength in (LT) plane [MPa]	-	70
The ultimate specific strain at longitudinal traction [%]	3.15	6.0

2.1. The influence of fibres orientation and stacking sequence on the interlaminar stresses distributions

The distribution of interlaminar stresses on the layers of the balanced composite laminate has a great importance on the interlaminar failure prediction such as delamination. The effect of several parameters, such as fibre orientation angles and stacking sequence, on the interlaminar stresses variation is discussed in this paper.

The interlaminar normal stresses σ_y and the interlaminar shear stresses τ_{xy} and τ_{yz} distributions on each ply of the balanced laminate are presented in Figures 2-4.

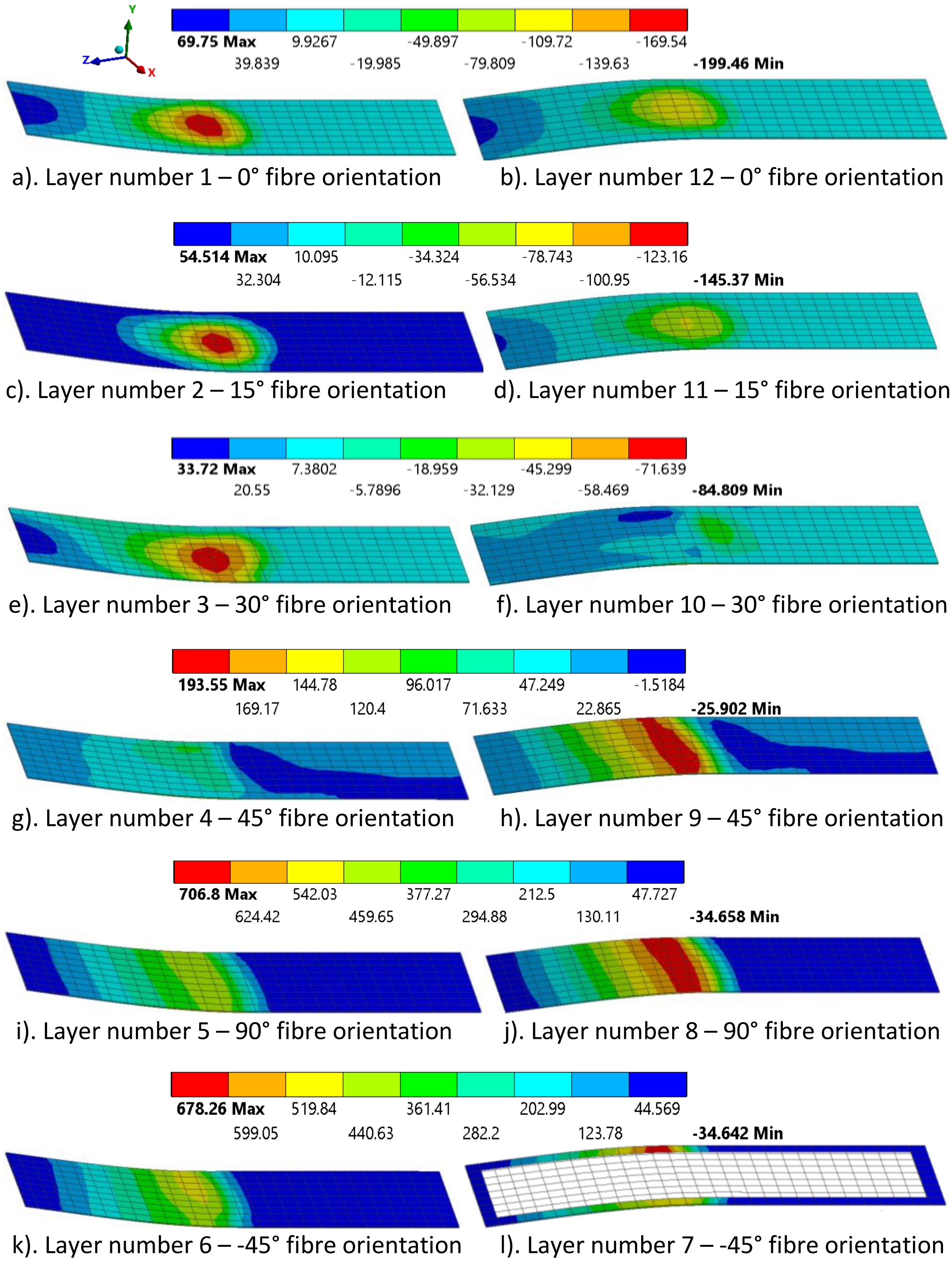


Fig. 2. *Interlaminar normal stresses σ_y distribution on the layers of the balanced laminate, [MPa]*

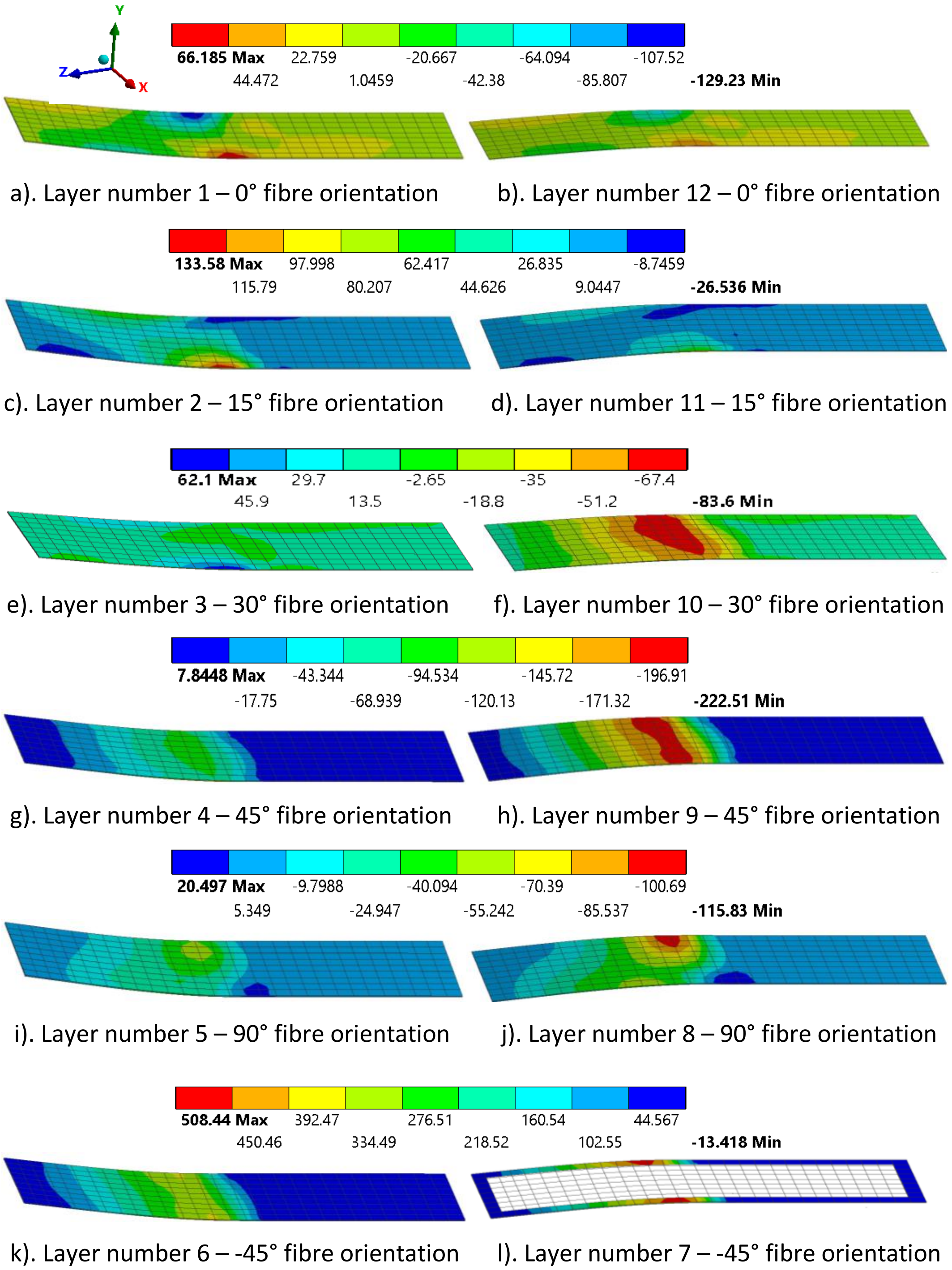
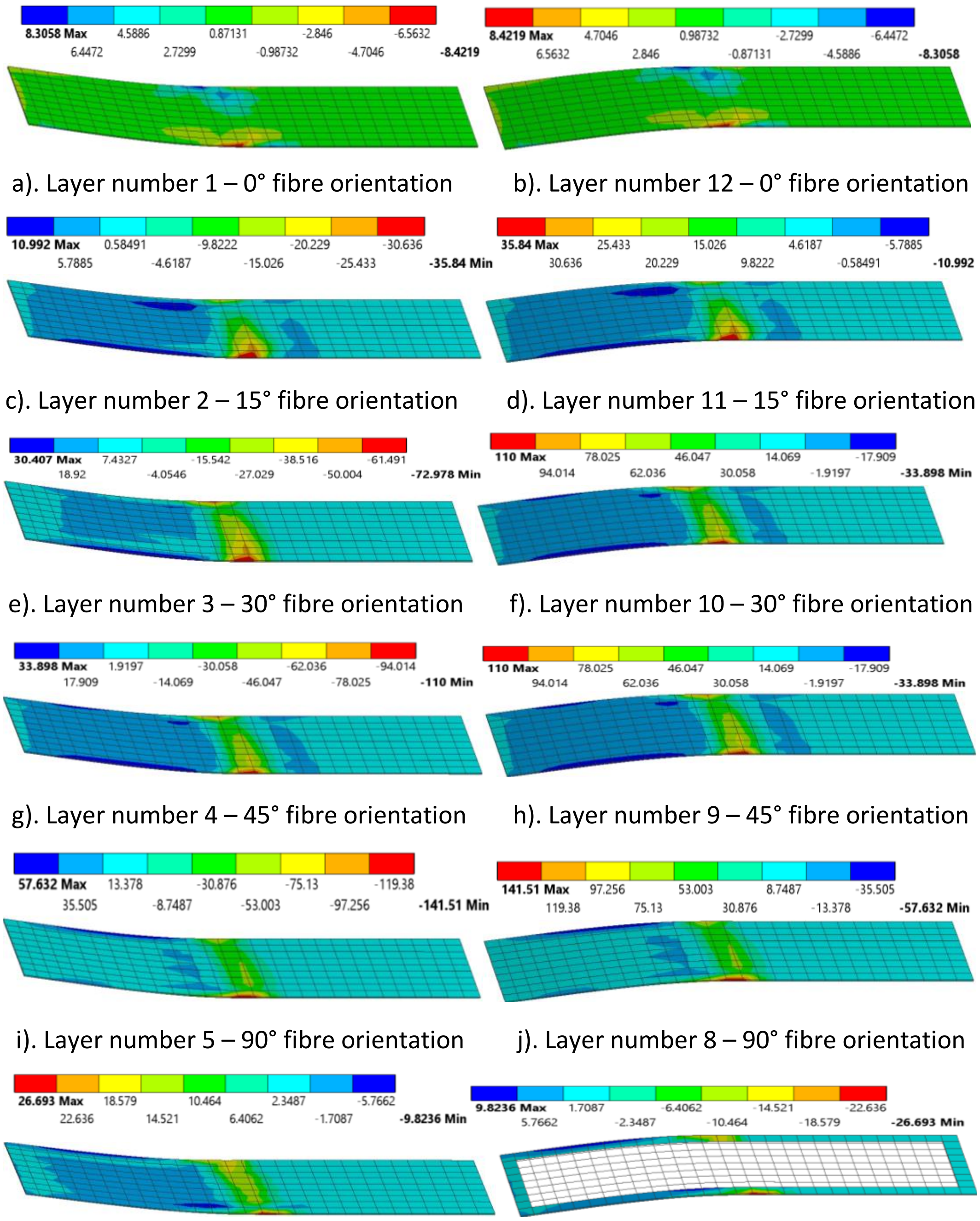


Fig. 3. *Interlaminar shear stresses* τ_{xy} *distribution on the plies of the balanced laminate, [MPa]*



a). Layer number 1 – 0° fibre orientation

b). Layer number 12 – 0° fibre orientation

c). Layer number 2 – 15° fibre orientation

d). Layer number 11 – 15° fibre orientation

e). Layer number 3 – 30° fibre orientation

f). Layer number 10 – 30° fibre orientation

g). Layer number 4 – 45° fibre orientation

h). Layer number 9 – 45° fibre orientation

i). Layer number 5 – 90° fibre orientation

j). Layer number 8 – 90° fibre orientation

k). Layer number 6 – -45° fibre orientation

l). Layer number 7 – -45° fibre orientation

Fig. 4. *Interlaminar shear stresses* τ_{yz} *distribution on the plies of the balanced laminate, [MPa]*

As shown in Figure 2, the interlaminar normal stresses are greater on the layers adjacent to the delaminated interface, compared to the exterior layers. The compressive interlaminar normal stresses range between 34.642 MPa and 199.46 MPa, while the tensile interlaminar normal stresses have the values included in the interval 69.75 MPa - 678.26 MPa. Therefore, significant differences are noticed between the compressive and the tensile interlaminar normal stresses. A decrease of the interlaminar normal stresses can be noticed, from the layer number 1 to the layer number 3, followed by a sudden increase (in case of the tensile stresses) until the interface.

In Figure 3 are presented the interlaminar shear stresses τ_{xy} distributions, being identified average values of the stresses, with a maximum value of 508.44 MPa, for the layer adjacent to the interface, with an orientation angle of -45°. The interlaminar shear stresses τ_{yz} show reduced values, with a maximum of 141.51 MPa.

3. Conclusions

The main objective of the paper was focused on the analysis of the fibre orientation angles and stacking sequence influence on the interlaminar stresses distributions on the layers of the composite laminates. These interlaminar stresses can be responsible for the delamination onset and delamination evolution of the composite elements.

The obtained results show that the higher interlaminar stresses are found in the plies that are adjacent to the delaminated interface, therefore the distribution of interlaminar stresses is very important on predicting the damage onset and damage propagation on the composite laminates.

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