Theoretical, experimental and computational study the off-axis elastic constants, fracture and strength of unidirectional fiber composite

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Abstract
In this work a theoretical/analytical, computational and experimental study of unidirectional glass-fiber reinforced epoxy composites is carried out. The concept of boundary interphase is used in order to determine the elastic constants of the composite. A finite element analysis is adopted in order to correlate with the derived theoretical values of the elastic constants. Finally, these results are compared with experimental findings obtained from tensile experiments performed on composites of the material used in order to predict the fracture of composites.

Key Words: Fibre reinforced composite, Fracture, Boundary interphase, Elastic constants, Finite element analysis.

1. Introduction
Fiber-reinforced polymer composites (FRP) have been used by engineers for a long time as basic materials to construct various engineering structures. In nowadays, their usage continues to increase, creating new applications. The growing development of nanoparticles, nanofibers and nanotubes and their usage as inclusions in polymers have rendered these composites significant materials for different present and future applications.
On the other hand, the response of these composites to an applied mechanical load is also related to the stress transfer mechanisms occurring at the fiber-matrix interface and the region created between the two constituent phases. Depending on the nature and properties of these two phases as well as on the interaction between them, the fiber-matrix interphase is a region characterized by impurities, microcracks, voids, reduced polymer molecules mobility due to the adsorption of polymer molecules on the fiber surface etc. As a result, the interphase in a composite is a phase with different properties compared to the main phases, acquiring properties from their properties as well as from their volume fractions that determine its extent and thus affect the properties of the composite.
In this study a theoretical, experimental and computational study was carried out in order to determine the off-axis elastic constants; and also, experimentally the strength and fracture of unidirectional fibre reinforced composites that constitute a significant issue [1].
For the development of the model the concept of a boundary interphase between the fibers and matrix which characterizes the adhesion [2, 3] was adopted.
A multiphase cylindrical model based on theory of elasticity where the composite consists of three phases namely fiber, interphase and matrix that had a sequence, was used. This interphase was considered to be heterogeneous with varying mechanical properties in the radial direction of the model [4].
For predicting the basic elastic constants, corresponding computational models were developed using the finite element analysis (F.E.A.) [5-8].
In the experimental part, tensile tests were conducted on a variety of off-axis angles of a unidirectional fibrous composite in order to obtain the elastic constants, the fracture and strength.
Finally, a comparison among the results obtained from theory, F.E.A. and experiments was performed in order to correlate and to assess possible discrepancies among them.

2. Results
Fig.1 illustrates the variation of the longitudinal Elastic modulus E_L as derived from the proposed model vs the fiber volume fraction, together with the FEM and some experimental results. It can be said that there is a good agreement between theoretical and FEM results in the major part of the

diagram. Also, their comparison with experimental results does not show significant discrepancies. In Fig. 2, the same results for the longitudinal Poisson ratio ν_{LT} are presented. It can be observed that, there are some discrepancies between theoretical and FEM analysis values, especially for higher fiber volume fractions. Their comparison with experimental results also shows some discrepancies.

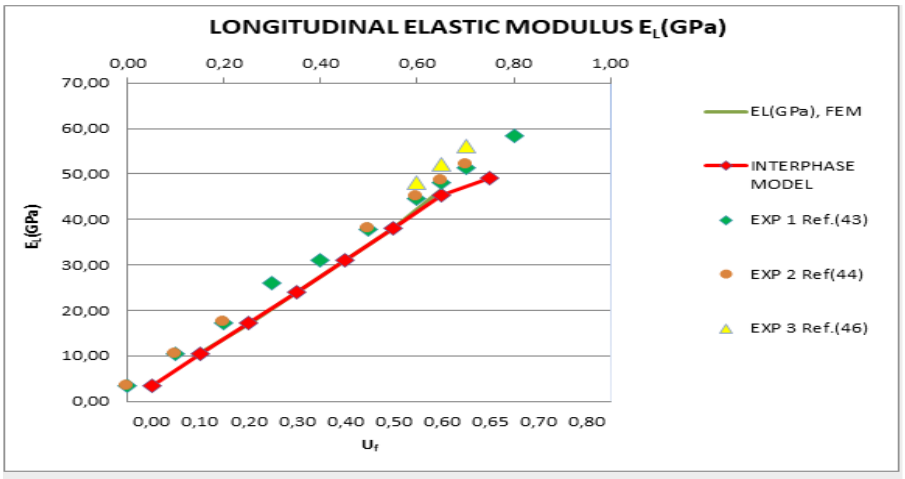

Fig.1 Theoretical predictions of the longitudinal elastic modulus E_L obtained by the seven-phase interphase model, compared with FEM results and with experimental values.

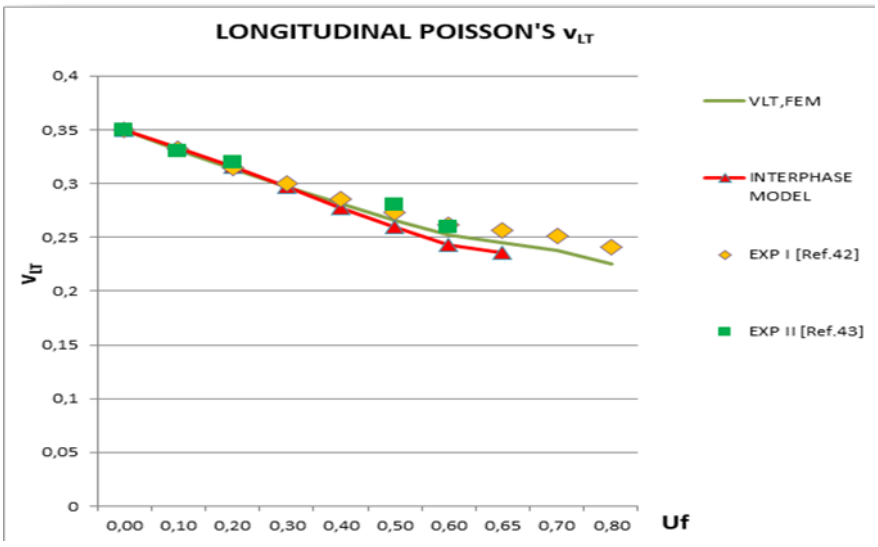

Fig. 2 Theoretical predictions of longitudinal Poisson's ratio ν_{LT} obtained by the interphase model, compared with experimental values.

3. Conclusions

In the present study, an interphase model was presented in order to determine elastic constants theoretically and by finite elements and then applied to a fiber-epoxy composite subjected to tensile test. Comparisons were performed among the results where discrepancies were observed in some cases.

It was observed that the interphase thickness and thus its volume fraction increases with the fiber volume fraction up to a certain point and then decreases. Also, the interphase modulus changes along the radial direction. Finally, it was found that the applied micromechanics model affects the macroscopic mechanical properties and the fracture of composite.

4. References

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