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HYBRID ADHESIVELY-BONDED SCARF JOINTS: EXPERIMENTATION AND COHESIVE ZONE SIMULATIONS

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ABSTRACT

The main goal of this work is the experimental and numerical study of hybrid scarf joints (composite/aluminium adherends) with varying scarf angles (α) and adhesives. The experimental study consists of performing tensile tests and obtaining the load-displacement (P-δ) curves. The numerical analysis by Finite Elements was performed to obtain peel (σ_y) and shear (τ_{xy}) stresses, using the software Abaqus®. Cohesive Zone Models (CZM) were used to predict the joint strength. The maximum load ($P_{máx}$) was significantly affected by the angle α and the adhesive type. The CZM technique was considered suitable to use as a design tool, although the cohesive law should be revised and improved for ductile adhesives.

Keywords: Finite Element Method, cohesive zones models, scarf joint, hybrid joint.

INTRODUCTION

The recent enhancements in structural adhesives technology, namely in the strength and toughness, enabled the use of adhesive joints and repairs in several industrial fields, namely the automotive and aerospace industries. There are various advantages to this joining technique, such as weight reduction, more uniform stress distributions, absence of damage in the bonded parts and ability to bond different materials. However, bonded joints are yet not reliable in critical joints because of issues like fatigue and long-term behavior uncertainties, and large scatter in the failure loads. There are many established and over-studied bonded joint geometries, in which the single-lap joint is the most discussed because of the fabrication ease. However, this joint suffers from load eccentricity, which largely affects σ stresses and consequently the strength. The scarf configuration suppresses this limitations, and its constituents can be either metal, composite or hybrid structures between these two with the distinction between scarf joints (i.e., by directly bonding the two adherends) or repairs (i.e., union of two adherends by a tapered patch). The scarf joint or repair is the most efficient respectively to the bonded area because of potential for suppression of σ and τ peak stresses, arising from the tapered adherend edges (Chiu and Chaudhuri 2011).

The experimental part of this work consisted of analyzing two structural adhesives: the brittle and strong Araldite® AV138 and the moderately ductile and less strong Araldite® 2015 in hybrid scarf joints with five values of α: 10, 15, 20, 30 and 45º (thus making a total of 10 joint configurations). Five tests were equated for each joint configuration, to make a total of fifty fabricated and tested joints. The FEM/CZM analysis involved the analysis of peel and shear distributions in the overlap region and the strength prediction and respective comparison with the experimental values of $P_{máx}$ for validation of the numerical tool.

RESULTS AND CONCLUSIONS

The results for the hybrid scarf joints bonded with the brittle adhesive Araldite® AV138 are shown in Fig. 1, as an example. In both cases the reduction of α exponentially increased $P_{máx}$, which is mainly related to the corresponding increase of the bonded area and reduction of peak stresses. For the Araldite® AV138, the obtained $P_{máx}$ for α=45° were 3245 N (CZM) and 2822 N (average experimental). If the comparison is made for α=10°, the predicted value is 9936 N, which can be compared to the experimental value of 9224 N.

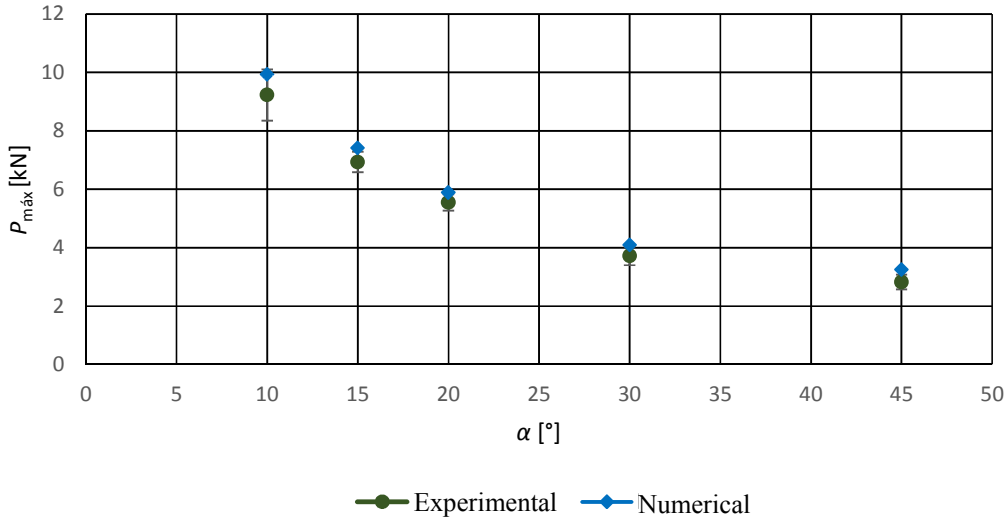

Fig. 1 - Experimental/numerical comparison of $P_{máx}$ for the scarf bonded joints with the adhesive Araldite® AV138

The same exponential trend was found for the joints bonded with the adhesive Araldite® 2015, although with higher $P_{máx}$ due to the higher ductility of this adhesive. By assessing the predictive capabilities of the numerical technique, for the adhesive Araldite® AV138, the numerical predictions were slightly above the average experimental values of $P_{máx}$, although generally within the range of the test results. The average standard deviation for the five joint configurations was 7% for this adhesive. For the joints bonded with the adhesive Araldite® 2015, the numerical overshot the tests up to 10%, which was accredited to using a triangular CZM law for an adhesive with some degree of ductility. Nonetheless, the obtained differences were within acceptable deviations. As a result of this analysis, the behavior of the hybrid scarf joints as a function of the adhesive type and α value was comprehensively evaluated and the numerical tool positively validated for design purposes.

REFERENCES

[1]-Chiu, S.-H. J. and Chaudhuri, R. A. 2011. A three-dimensional eigenfunction expansion approach for singular stress field near an adhesively-bonded scarf joint interface in a rigidly-encased plate. Engineering Fracture Mechanics 78: 2220-2234.