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EXPERIMENTAL AND COHESIVE ZONE MODELLING ANALYSIS OF ADHESIVELY-BONDED STEPPED JOINTS

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ABSTRACT

This work consists of an experimental and numerical study of stepped adhesive joints under a tensile loading. The experimental work involves the evaluation of different types of adhesives and geometric parameters such as the overlap length (L_O), enabling optimization of the joints. The numerical work consists of a detailed stress and failure analysis by the Finite Element Method (FEM) and Cohesive Zone Models (CZM). As a result of this work, the CZM technique for strength prediction was tested and validated for the simulation of the stepped joints. It was shown that the type of adhesive has a high influence on the maximum load (P_m) predictions, with brittle adhesives showing a better behavior for smaller L_O values and ductile adhesives with a higher performance for bigger values of L_O. The CZM analysis revealed good predictive capabilities and enabled a full understanding of the joints' behavior.

Keywords: FEM, cohesive zones models, adhesive joints, stepped joint.

INTRODUCTION

The most traditional joining methods are fastening, riveting, welding and bonding. Joints with structural adhesives are currently one of the most widespread bonding techniques in advanced structures (automotive, aerospace, aeronautics and sports equipment, among others). Adhesive joints do not require holes and distribute the load over a larger area than mechanical joints. However, they tend to develop peel and shear peak stresses near the ends of the overlap because of the differential deformation effect of the adherends and the load asymmetry. As such, premature failures may occur, especially if a brittle adhesive is used. In addition, adhesive bonds are very sensitive to the surface treatment, service temperature, humidity, and aging. Single-lap joints are the most common due to the ease of manufacture, although they are characterized by an eccentric transmission of loads. This results in the existence of significant stress concentrations and consequent limited strength. The use of stepped joints enables decreasing the stress gradients along the adhesive because of the reduction of the differential deformation and asymmetry effects, which leads to a higher strength (Akpinar 2014). However, due to the difficulty of machining the steps or the ramps in this type of joints, the manufacturing process has higher costs than single-lap joints. Despite this fact, in the case of stepped joints with composite adherends, the fabrication process becomes simpler by creating the steps during the stacking procedure of the individual composite plies.

The experimental part of this work consisted of analyzing three structural adhesives: the brittle and strong Araldite® AV138, the moderately ductile and strong Araldite® 2015 and the ductile but least strong Sikaforce® 7752 in joints with four values of LO: 12.5, 25, 37.5 and

50 mm (thus making a total of 12 joint configurations). Five tests were equated for each joint configuration, to make a total of sixty fabricated and tested joints. The FEM/CZM analysis involved the analysis of peel and shear distributions in the overlap region, the study of the damage variable evolution during the damage process and the strength prediction and respective comparison with the experimental values of P_m for validation of the numerical tool.

RESULTS AND CONCLUSIONS

The results from the tensile tests for the joints bonded with the brittle adhesive Araldite® AV138 are shown in Fig. 1, as an example. By comparing the performance of the different adhesives, it was shown that the best results for short L_O values was attained for the Araldite® AV138 and 2015, with P_m≈6 kN for L_O=12,5 mm, whilst the Sikaforce® 7752 provided worse results (P_m≈4.5 kN for L_O=12,5 mm). The reported difference in behaviour is justified by the higher influence of the adhesive strength on P_m rather than the ductility for short overlaps, because in these conditions stresses are practically uniform along the steps.

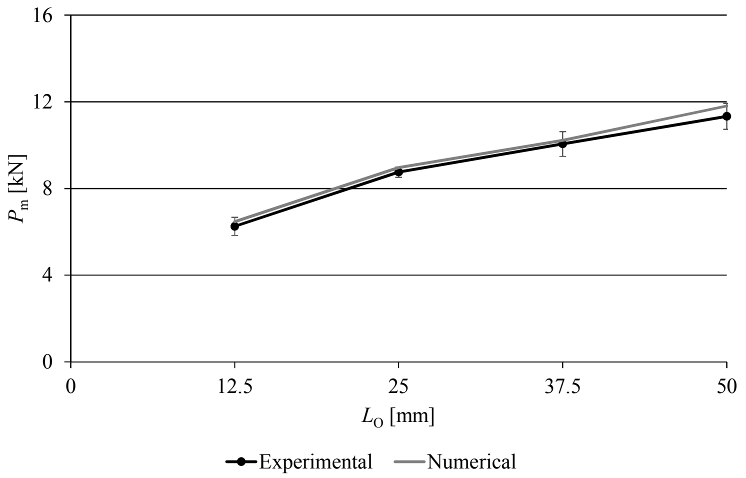

Fig. 1 - Tensile test results for the adhesive Araldite® AV138

On the other hand, the joints' behavior was markedly different with bigger L_O. In fact, for the strong but brittle adhesive Araldite® AV138 revealed a relatively low P_m improvement with L_O (Fig. 1; P_m≈12 kN for L_O=50 mm), while the moderately ductile Araldite® 2015 and the ductile Sikaforce® 7752 showed a higher strength improvement by increasing L_O (up to ≈18.5 kN and 14.3 kN, respectively). This is because ductile adhesives behave better for higher L_O by absorbing the peak stress due to plasticization effects. The CZM strength predictions were generally accurate, at is can be confirmed in Fig. 1 for the adhesive Araldite® AV138, showing that this numerical technique can be successfully used for the strength prediction of stepped adhesive joints.

REFERENCES

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