EXPERIMENTAL AND NUMERICAL ANALYSIS OF ADHESIVELY BONDED-WELDED HYBRID SINGLE-LAP JOINTS: EFFECT OF THE ADHESIVE TYPE

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ABSTRACT

This work relates to the adhesive selection for single-lap adhesive joints by the bonding and hybrid (bonded and welded) techniques with different overlap lengths ($L_O$) and adhesives. The experiments were compared against a Finite Element (FE) study coupled with Cohesive Zone Modelling (CZM). The results validated the numerical technique and also showed varying strength improvements of the hybrid joints over bonded joints depending on the adhesive.

Keywords: Hybrid, fracture, finite element analysis, mechanical testing, cohesive zone modelling.

INTRODUCTION

Hybrid joining consists of merging adhesive bonding with another technique to produce weld-bonded, rivet-bonded or bolt-bonded joints. The main purpose is to gather the benefits of different joining techniques while overcoming their individual limitations. Weld-bonded joints are used in several critical components in aeronautical applications, missile shells, spaceship sounders and car industry (Shen et al. 2012). This technique is studied in the literature for static (Liu et al. 2011) and fatigue loads (Fujii et al. 2011). These joints are particularly difficult to simulate using analytical models on account of the complex geometries. Thus, experimentation and the FE method are the main tools found in the literature to investigate the behaviour of such hybrid techniques.

In this work, single-lap joints were tensile tested between steel adherends. Three structural adhesives were considered: the brittle epoxy Araldite® AV138, and the ductile epoxy Araldite® 2015 and polyurethane Sikaforce® 7752. The geometrically non-linear FE/CZM analysis was performed in Abaqus®. Decohesion was promoted in the triangular CZM elements representative of the adhesive and weld-nugget, while the adherends were modelled by continuum elements. The analysis was fully 3D, although with longitudinal symmetry.

RESULTS AND CONCLUSIONS

Fig. 1 depicts the maximum load ($P_m$) for the joints with the adhesive Araldite® AV138 (a), Araldite® 2015 (b) and Sikaforce® 7752 (c). The $P_m$ increase with $L_O$ of the joints bonded with the adhesive Araldite® AV138 is less significant because of this adhesive being stiffer and more brittle. However, for bonded joints with $L_O$=15 mm, the Araldite® AV138 features a $P_m$ value not far from that observed for the Araldite® 2015 and Sikaforce® 7752. This is because short overlaps distribute shear stresses more evenly, which makes a higher strength adhesive, although brittle, to provide comparable $P_m$ to a ductile but lower strength adhesive.
The $P_m$ improvement was highest for the joints with the Sikaforce® 7752, followed by the Araldite® AV138 and the Araldite® 2015. This variation is related to the ductility of the adhesive, but also with the occurrence or not of adherend plasticization, which induces premature failure of the adhesive. As the Araldite® AV138 is brittle, the $P_m$ increase in the respective joints was lower than with the Araldite® 2015. Because of this, the joints with the Araldite® 2015 suffered adherend plasticization before $P_m$, which resulted in an adherend plasticization-induced failure of the adhesive layer for the hybrid joints, unlike happened for the Araldite® AV138. Thus, the strength improvement for the joints with the Araldite® 2015 was smaller than that of the AV138. Adherend plasticization also occurred in the joints with the Sikaforce® 7752, but the significantly higher adhesive ductility still enabled a superior behavior to the other two adhesives. The FE/CZM technique for the design of hybrid joints was also positively validated, with accurate results being found for all joint configurations.

REFERENCES

