STUDIA UNIVERSITATIS BABEŞ-BOLYAI, CHEMIA, XLV, 2, TOM II, 2010

Dedicated to the memory of Prof. dr. Ioan Silaghi-Dumitrescu marking 60 years from his birth

ADHESIVE INFLUENCE ON DOUBLE-LAP BONDED-JOINTS ASSEMBLIES

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ABSTRACT. This work presents the influence of the adhesive on the double-lap joint assemblies. The adhesive characteristics and the influence on the stress distribution in double-lap adhesive bonded-joints assemblies' configuration are also presented.

Keywords: *structural adhesives, adhesive properties, double-lap adhesive assemblies*

INTRODUCTION

Adhesively bonded method distributes the stresses over the whole joining surface and removes the concentrations of stresses at the boundary of holes generated by bolting or riveting assemblies. Consequently, it is essential to know the stress distribution, which, because of its complexity, makes prediction of fractures difficult. To study the stress distribution it is very important to know the adhesive characteristics.

There are several models which try to define the stress distributions in double-lap [1 – 12]. Complex studies about various analytical models are compared by da Silva et al. [13].

Mortensen and Thomsen [14, 15] developed an approach for the analysis and design of various joints adhesively bonded. They took into account the influence of the interface effects between the adherends and they modelled the adhesive layer by assimilating it to a spring.

Diaz Diaz et al. [16] assumed in their classical double lap model that the adhesive thickness is small compared to that of the adherends and the stresses to be uniform through the adhesive thickness. The model can be considered as a stacking of Reisner-Mindlin plates and the equations based on this model were applied to the geometry of a symmetrical adhesively bonded joint. The model was validated by comparing the model results with those of a finite element calculation

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Using a variational method and some simplifying assumptions, the author of this work developed and validated a new analytical model for a fast pre dimensioning of adhesive bonded assemblies [17-21]. The first stage consists in building a statically acceptable stress field, i.e. verifying the boundary conditions and the equilibrium equations. Then, the potential energy generated by such a stress field is calculated. In the third stage, the potential energy is minimized in order to determine the stress distributions. Finally, the analytical model proposed for double lap adhesive by bonded joints was validated using numerical and experimental methods.

In this paper, the adhesive influence on the stress distribution in double-lap adhesive bonded-joints assemblies' configuration was studied.

RESULTS AND DISCUSSION

A theoretical model of calculation of assemblies joined with adhesive, based on an energy method was developed by the author and coworkers [17-21]. After the determination of the cinematically acceptable field of stresses, according to the applied load, a variational calculus on the expression of elastic potential energy leads to the complete expression of the stress field in the whole assembly.

A first parametric analysis (geometrical and physicals parameters) is carried out on an assembly and makes it possible to deduce the optimal length and the thickness of the adhesive.

The performance of the adhesive bonded joints depends on the performance of the adhesive. The latest generations of adhesives, delivered in the form of film, make it possible to minimize the number of operations to make the join and greatly increase the mechanical resistance.

However, the design engineer must have at his disposal methods and/or reliable computer codes for predimensioning with known margins.

Using this energetical model, some analysis was carried out. The first step was to characterize the adhesive by tensile tests (plastic behavior of the adhesive was shows in experimental part).

Adhesive elastic modulus influence

The stresses in the adhesive are very important to predict the failure moment. For that it is primordial to have their distributions.

Figure 1 represents the influence of the elastic modulus of the adhesive on the shear stress distribution. The maximum peaks increase slightly when the elastic modulus increases.

Adhesive thickness influence

Another important parameter in double-lap adhesive bonded-joints assemblies' characterization is the thickness of the adhesive.

Figure 2 shows the influence of adhesive thickness on the adhesive shear stresses distribution. When the adhesive thickness increases, the maximum stresses in the adhesive decrease and the distribution tends to be uniform over the entire overlap length.

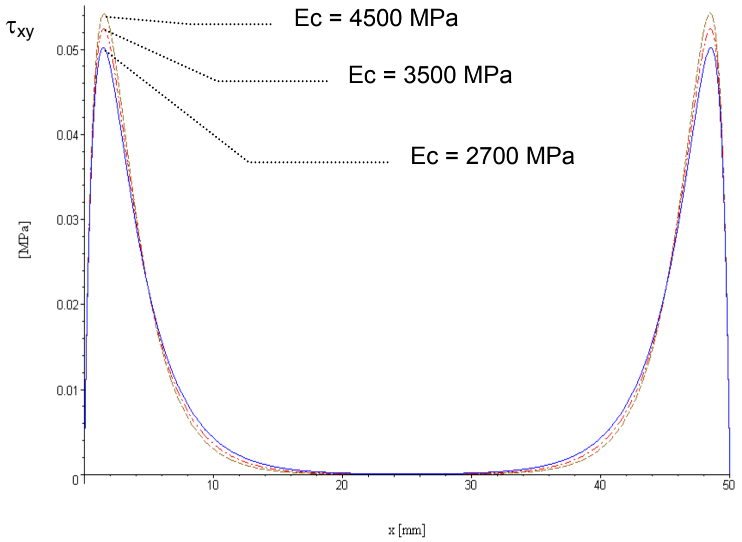


Figure 1. The influence of the elastic modulus of the adhesive on shear stress distribution in an AU 4G-AV 119-AU 4G assembly.

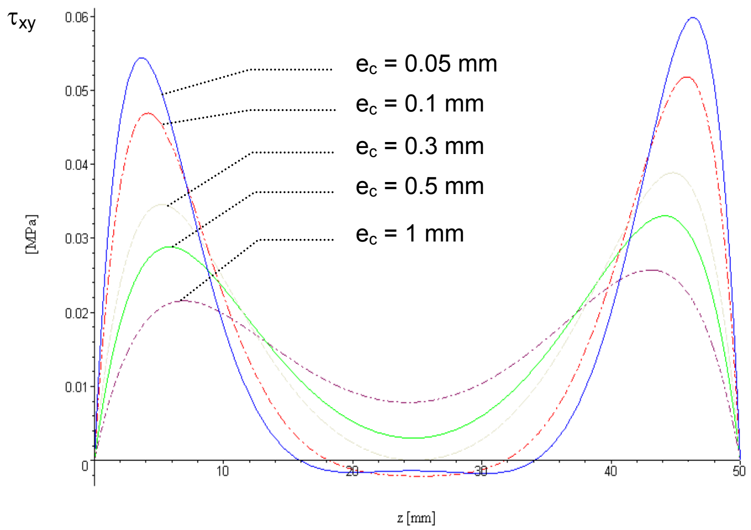


Figure 2. . The influence the of adhesive thickness on shear stress distribution in an AU 4G-AV 119-AU 4G assembly.
e_c = 0.05 mm, e_c = 0.1 mm, e_c = 0.3 mm, e_c = 0.5 mm, e_c = 1 mm

The analytical model underestimated the stresses in the adhesive, leading to an over-estimate of the forces at rupture. However, this model is reliable and allows fast analysis of this type of assembly.

EXPERIMENTAL PART

To obtain mechanical properties of the adhesive we have we carried out a plate with 10 layers of Redux adhesive film. The characteristics of the adhesive film, given by the manufacturer, are presented in table 1.

After the polymerization of the plate we cut out a piece with the following dimensions: 200x20x1.98 mm for tensile testing.

The tensile tests were carried out using an INSTRON 8862 system. The load is applied with imposed displacement at the speed of 0,5 mm/min. On certain tests we performed rises in cyclic loads (4 to 5 cycles).

The stress, displacement and deformations acquisition is carried out by a NICOLET-GOULD acquisition system.

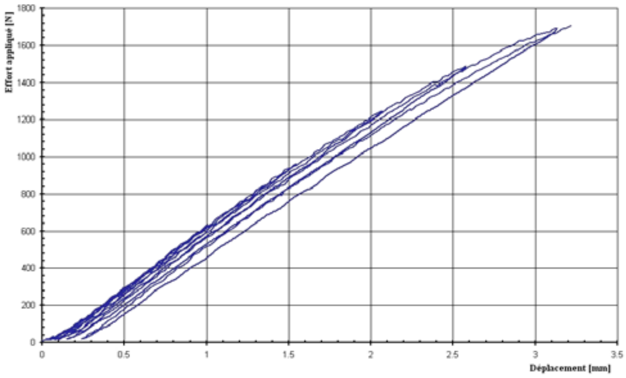
The mechanical characteristics obtained by the tests are given in table 2. The double-lap adhesive bonded assembly has the following elements: two aluminium substrates AU 2024 T3 and a layer of epoxy adhesive AV 119 from Huntsman.

Table 1. Adhesive film technical data*.

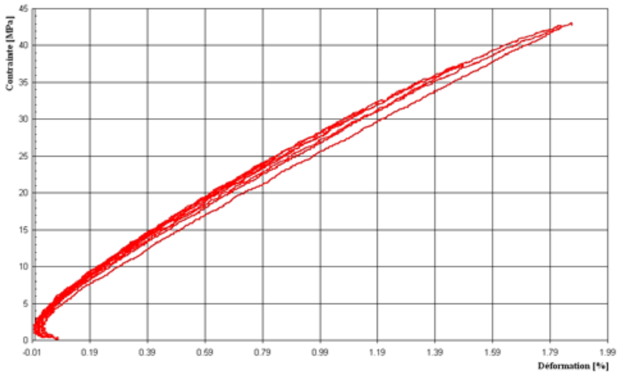
HEXCEL COMPOSITES Duxford Cambridge CB2 4QD, England			Product Type: Batch No.: Primes Type: Batch No.:	Redux 312/5 054917A Redux 112 V051196
ADHESIVE TEST REPORT				
Specification IFS 201-216			Test No.:	17845
	Lap shear strength (MPa)			
	22 °C	80 °C		
	37.9	29.4		
	40.3	27.4		
	38.6	29.5		
	37.8	28.8		
	39.5			
Mean	38.8 MPa	28.8 MPa		
Min Ind.	37.8 MPa	27.4 MPa		
Requirements – Mean	35.0 MPa	28.0 MPa		
Min Ind.	32.0 MPa	25.0 MPa		

*Hexcel Composites

Figure 3 shows the plastic behavior of the adhesive.



a)



b)

Figure 3. Adhesive tensile behaviour:
a) Applied load - displacement; b) Stress - deformation.

Table 2. Experimental results.

	$F_R^{(c)}$ [N]	$\sigma_{xx\,max}^{(c)}$ [MPa]	E_c [MPa]
1.	1730.47514	43.2618786	2014.07580
2.	2642.60815	44.7899687	2648.54446
3.	1708.61762	43.1469095	2750.00250

CONCLUSIONS

Based on presented case study, we can draw the following conclusions: the intensities of the peaks in the adhesive stress distribution are influenced by the elastic modulus of the adhesive. The maximum peaks increase slightly when the elastic modulus of the adhesive increase. As the adhesive thickness increases, the stresses in the adhesive decrease and the stress distribution is more uniform.

ACKNOWLEDGEMENT

The Ministry of Education and Research, Bucharest (ID-1100, PN II project) is thanked for the financial support of this work.

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