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ADHESIVE FRACTURE IN DOUBLE-LAP ADHESIVE ASSEMBLIES

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ABSTRACT. A comparative analysis of various double-lap assembly configurations was realized using a refined analytical model for the stress distribution. All the components of the stress field were defined function of the $\sigma_{xx}^{(1)}(x)$ stress in the first element and then introduced into the potential energy formulation. Using this analysis method allow to establish a Tsai-Hill type failure criterion.

Keywords: *adhesives, double-lap joints, fracture criterion*

INTRODUCTION

Starting with the work of Volkersen [1], other authors [2 - 12] have developed various models for single lap or double lap adhesive bonded joints. Some complex studies about various analytical models are compared by daSilva et al. [13]. By including the shearing strains, neglected until there, Tsai and Oplinger [14] were developed the existing models. Mortensen and Thomsen [15, 16] refined the approach for the analysis and design of various joints adhesively bonded by taking into account the influence of the interface effects between the adherents.

Performing a three-dimensional stress analysis on double-lap adhesive bonded joints under uniaxial tension, Bogdanovich and Kizhakkethara [17], have been determined the stress variation in the joint structure with a comprehensive three-dimensional numerical study, considering adhesive layers as 3-D elastic entities.

The model developed by Diaz Diaz et al. [18] assumed that the adhesive thickness is small compared to that of the adherents and the stresses to be uniform through the adhesive thickness. This model was validated by comparing the model results with those of a finite element calculation.

Minimizing the potential energy associated with the stress field and applying a variational method with some simplifying assumptions, the authors [19-21] developed and validated a new analytical model for a fast adhesive assembly analysis.

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This work use a technique based on the minimization of the potential energy applied on various assembly configurations. After results analysis we can establish an adhesive failure criterion of Tsai-Hill type depending on the adhesive nature and properties.

RESULTS AND DISCUSSION

The analytical model developed by minimizing the potential energy [20] associated with the stress field will be used in the present study to analyze the influence of various parameters affecting the intensity and distribution of the stresses in double-lap adhesive assemblies. This analysis will be reduced to a study of the influence of materials type, adhesive type and thickness and overlap length. The adhesive thickness in the assembly is showed in figure 1 and the assembly parameters are presented in Table 1. The adhesive used in all those configurations is an epoxy adhesive, multipurpose, one component, heat curing thixotropic paste adhesive of high strength and toughness (Araldite AV 119) with the properties showed in Table 1.

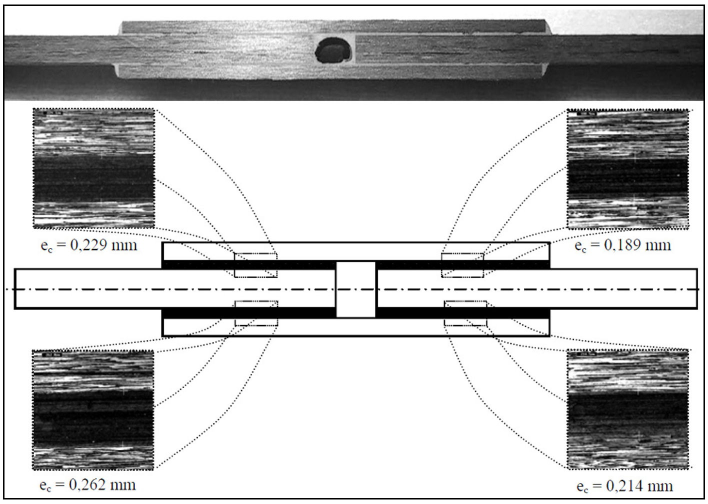


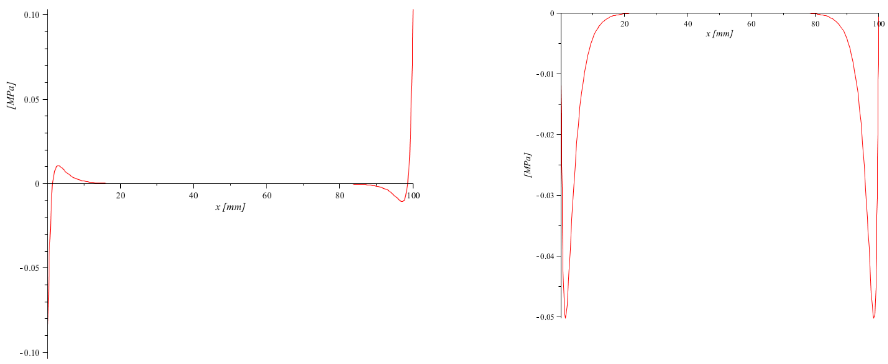
Figure 1. Adhesive thickness in double-lap adhesive bonded joint assemblies.

The stress distributions in the adhesive (Figure 2), for the analyzed configurations, shows the distributions of the peeling and shear stresses for the configurations showed in Table 1. We notice that for σ_{yy}, the maximum values are obtained on the free edges (z = 0, z = L) (Figure 2a) and they are localized at the edges. The balance between the maximum values are function of materials configuration and for τ_{xy}, we observe (Figure 2b) two peaks of stresses

Table 1. Double-lap adhesive assemblies configuration.

N°.	Substrate 1	Adhesive	substrate 2	e_1 [mm]	e_c [mm]	e_2 [mm]	L [mm]	F [N/mm]
1.	Titanium TA 6V E = 105000 MPa G = 40385 MPa υ = 0.3	Araldite AV 119 E_c = 2700 MPa G_c = 1000 MPa υ_c = 0.35	Titanium TA 6V E = 105000 MPa G = 40385 MPa υ = 0.3	2	0.1	2	100	1
2.	Aluminium AU 4G E = 75000 MPa G = 28846 MPa υ = 0.3		Aluminium AU 4G E = 75000 MPa G = 28846 MPa υ = 0.3	2	0.1	2	100	1
3.	Glass/Epoxy ± 45° E_x = 14470 MPa E_y = 14470 MPa G_{xy} = 12140 MPa υ = 0.508		Glass/Epoxy ± 45° E_x = 14470 MPa E_y = 14470 MPa G_{xy} = 12140 MPa υ = 0.508	2	0.1	2	100	1

located at equal distances from the two free edges. The maximum value is varying function of assembly configuration and it is between 1 and 10 % of the applied force. The peaks do not have the same intensity because of the difference of rigidities of the two bonded adherents.



a **b**

Figure 2. Stress distributions in the adhesive: a) Peeling stress (σ_{yy}); b) Shear stress (τ_{xy}). Config 3. (Table 1).

We note that the peeling stresses are greater than the shear stresses. The use of a fracture criterion for the adhesive bonded joint must take into account not only the shear stress τ_{xy} but also the peeling stress σ_{yy}. We can establish a failure criterion of the Hill-Tsai type as follows:

$$K_T = \underbrace{\left(\frac{\sigma_{yy}^{(c)}}{\sigma_R^{(c)}}\right)^2}_{K_\sigma} + \underbrace{\left(\frac{\tau_{xy}^{(c)}}{\tau_R^{(c)}}\right)^2}_{K\tau} \quad (1)$$

$$K_T \rightarrow \begin{cases} \geq 1 \text{ - failure} \\ < 1 \text{ - no failure} \end{cases} \quad (2)$$

As showed in Figure 2 it should be noted that taking the peeling stresses into account is of primary importance.

The influence of adhesive thickness (e_c = 0.05; 0.1; 0.3; 0.5; 1 mm) on the intensity and distribution of shear and peeling stresses is shown in Figures 3 and 4. We observe that as the thickness of adhesive increases, the values of the stresses decrease at the free edges. The distribution tends to become uniform.

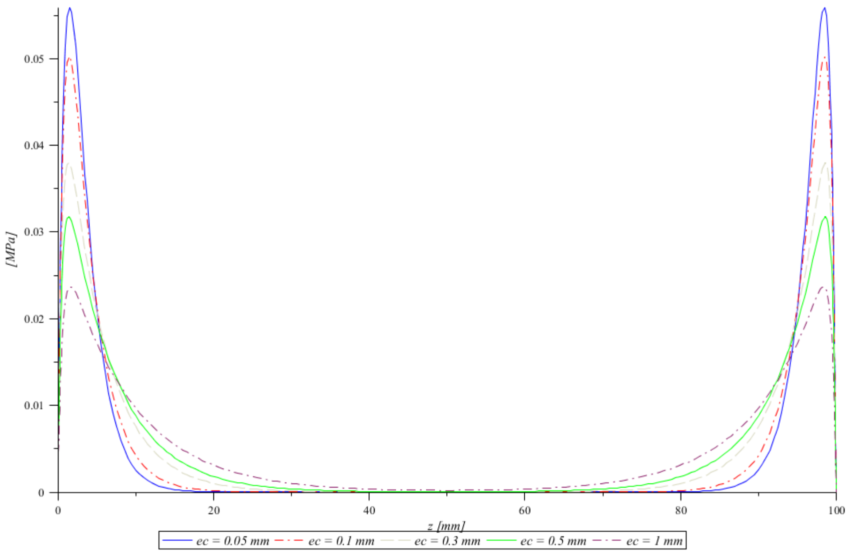


Figure 3. Shear stress (τ_{xy}) variation according to adhesive thickness length for config. 3 (Table 1).

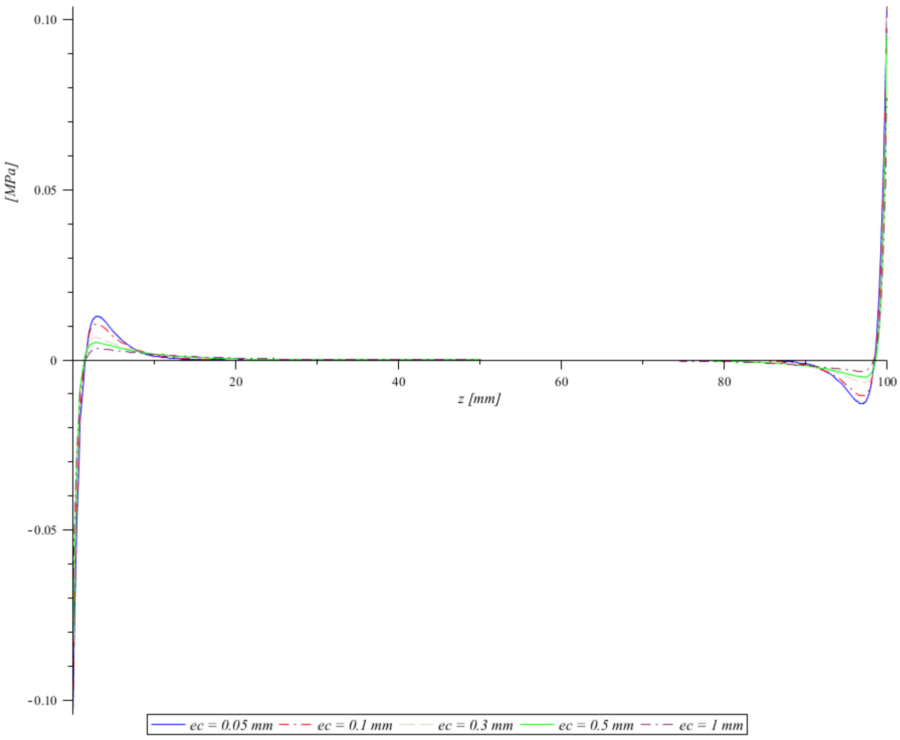


Figure 4. Peeling stress (σ_{yy}) variation according to adhesive thickness length for config. 3 (Table 1).

After the analysis of the suggested configuration and the influence of geometrical and physical parameters on the stress field we can observe that bonded composite assemblies have the same behaviour as metal adhesive-bonded joints.

CONCLUSIONS

Adhesive joining is a simple method of assembly where the adhesive properties define the performance of the adhesive bonded joints. The latest generations of adhesives, delivered in the form of film, make it possible to minimize the number of operations and increase the mechanical behaviour.

This analysis was carried out on the stress distribution in the substrates and the adhesive joint. The stress distribution in the adhesive remained very close to the solution given by finite elements performed by our research group [22]. This model is reliable and allows a fast analysis of double-lap adhesive joints assemblies.

ACKNOWLEDGEMENTS

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