STRESS FIELD ANALYSIS IN DOUBLE-LAP JOINT ASSEMBLIES

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INTRODUCTION

This assembling method distributes the stresses over the whole joining surface and removes the concentrations of stresses to the boundary of holes generated by bolting or riveting assemblies. The mechanical performance of an adhesive bonded joint is related to the distribution of the stresses in the adhesive layer. Consequently it is essential to know this distribution, which, because of its complexity, makes prediction of fractures difficult. Since the first work of Volkersen (1) until the more recent studies by finite elements many formulations allowed to better define the stress field in such assemblies. The model was developed by Gilibert and Rigolot (2 - 4) and Tsai and Oplinger (5). Mortensen and Thomsen (6, 7) developed the approach for the analysis and the design of the joints adhesive bonded. They held into account the influence of the interface effects between the adherents and they modelled the adhesive layer by assimilating it to a spring. Our model (8) used a technique based on the minimization of the potential energy.

DOUBLE-LAP JOINT MODELLING

All work has encountered difficulties in modelling the stress field in the vicinity of the ends of the joint. The method used to obtain the optimal field for this type of assembly consists of: Construction of a statically acceptable field, Calculation of the potential energy associated with the stress field, Minimization of this energy by variational method, Resolution of the differential equation obtained.

In this work we consider a double-lap joint subjected to a tensile load whose geometrical definitions are given in figure 1.

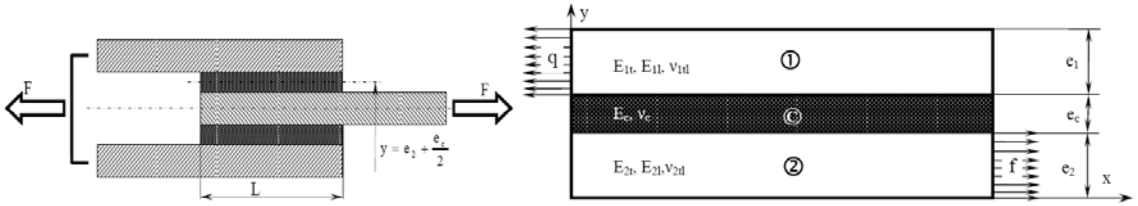

Fig. 1: Geometrical and material definition of the double-lap joint.

Where: $\mathbf{E_c}$, $\boldsymbol{\nu_c}$, Young's modulus and Poisson's ratio of the adhesive ©, $\mathbf{E_{tl}}$, $\mathbf{E_{ll}}$, $\boldsymbol{\nu_{tll}}$, longitudinal, transverse modulus and Poisson's ratio of the inner tube, $\mathbf{E_{2t}}$, $\mathbf{E_{2l}}$, $\boldsymbol{\nu_{tl2}}$, longitudinal, transverse modulus and Poisson's ratio of the external tube, $\mathbf{e_c}$, adhesive © thickness, $\mathbf{e_1}$, $\mathbf{e_2}$, adherents ① and ② thickness, **L**, joining length, **f** and **q**, tensile stresses following x axis, on the adherents. The constraints in various materials will be located by the index (i), where i = ①, © or ②. We are in the case of plane constraints and we will adopt the following assumptions: the state of plane stresses: $\tau_{zx}^{(i)} = \tau_{zy}^{(i)} = \sigma_{zz}^{(i)} = 0$; the $\sigma_{xx}^{(i)}$, $\tau_{xy}^{(i)}$ et $\sigma_{yy}^{(i)}$ stresses are independent of z variable; the $\sigma_{xx}^{(1)}$ et $\sigma_{xx}^{(2)}$ stresses are function only of x variable; the normal stress in the adhesive will be considered null: $\sigma_{xx}^{(c)} = 0$. The stress field is thus reduced to: adherent ①: $\sigma_{xx}^{(1)}(x)$, $\tau_{xy}^{(1)}(x,y)$, $\sigma_{yy}^{(1)}(x,y)$, adhesive ©: $\tau_{xy}^{(c)}(x)$, $\sigma_{yy}^{(c)}(x,y)$, adherent ②: $\sigma_{xx}^{(2)}(x)$, $\tau_{xy}^{(2)}(x,y)$, $\sigma_{yy}^{(2)}(x,y)$.

The objective of this study is to compare our analytical models of the adhesive-bonded joints with finite elements models. The double-lap joint assembly is modelled by 2D quadrangles of degree 2 finite elements with the axis symmetric assumption ($x \to z$, $y \to r$, $z \to \theta$). The displacements along x and y in face ② of the external tube and those along y in face ① of the internal tube are blocked. The load is applied as a pressure on face ①.

CONCLUSIONS

The objective of our study was to entirely develop analytical models for dimensioning adhesive-bonded joints. To this end we placed ourselves in the case of a double-lap joint assembly. The basis of our analytical model was the analysis of the stresses applied to an elementary volume of the assembly under consideration, observing the boundary conditions, the geometry and materials of the assembly. The application of an energy method made it possible to obtain the solution of the problem in stress in any point of the structure. The behaviour law enabled us to obtain the deformations. The problem in stress, deformation and displacements was thus entirely defined. The model validation is presented by comparison with finite elements models. For the assembly, the total force-displacement behaviour is well defined. Thus the analytical model makes it possible to determine the rigidity of the assembly and to obtain a simple formulation very quickly, which gives the total behaviour of the assembly. The analytical model underestimated the stresses in the adhesive leading to an over-estimate of the rupture forces. However, this model is reliable and allows fast analysis of this type of assembly.

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