

# EVALUATION OF THE T-PEEL JOINT USING FINITE ELEMENT ANALYSIS

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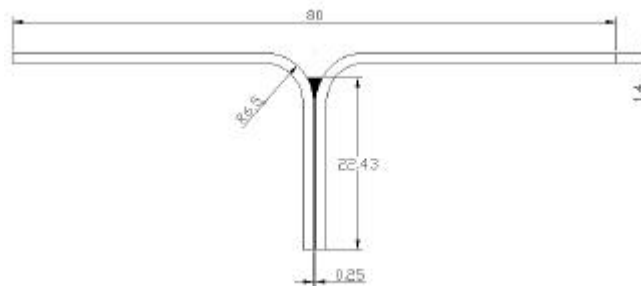
## ABSTRACT

This paper presents the results of a finite element analysis (FEA) study carried out on a T-peel joint. The study evaluates the effect of adherend properties, geometric parameters and environmental conditioning on joint performance. Parametric studies on the specimen geometry revealed that stress distributions are sensitive to adherend material properties, adherend thickness and to a lesser degree the flange radius. In general, stresses were reduced when changes in specimen geometry resulted in smaller joint displacements for the same load.

The effect of environmental conditioning on the joint performance was investigated using a sequentially coupled mechanical-diffusion finite element model, which incorporated continuously varying adhesive material properties. The numerical predictions revealed that the distributions of stresses become more uniform along the adhesive layer when the adhesive contains increased amounts of moisture. Peel stresses at the edge of the adhesive fillet were observed to decrease with increasing moisture content.

## INTRODUCTION

The primary purpose of the T-peel test is to determine the relative peel resistance of adhesive bonds between flexible adherends by means of a T-type specimen (Figure 1). This test geometry has been adopted by most standard bodies and is widely used for evaluating environmental durability of adhesively bonded systems (1-3). The T-peel test has been shown to discriminate between various combinations of pre-treatment and adhesives, although coefficients of variation are typically 20 to 30%, or higher.

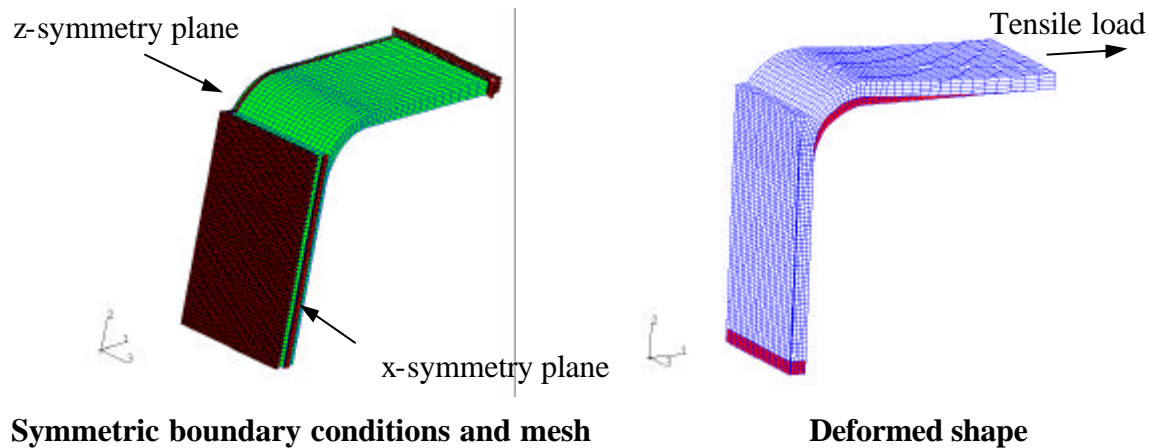


**Figure 1. T-Peel specimen.**

A major disadvantage of T-peel tests is that excessive extension of flexible adherends contributes to failure at the adhesive/adherend interface. The current procedures fail to account for the possibility of adherend deformation and unstable behaviour, which can cause difficulties in the interpretation and use of test data. This paper presents the results of a finite element analysis (FEA) study in which the effects of moisture and geometric parameters on stress distributions and joint deformation are evaluated.

## NUMERICAL MODELLING

Finite element analysis was used to perform a series of non-linear stress and deformation analyses of T-peel joints under tensile loading. Two- and three-dimensional finite element analyses were carried out on the test geometry shown in Figure 2. The finite element models were constructed and solved using the ABAQUS program while mesh generation was performed using the FEMGV pre-processor.



**Figure 2. Three-dimensional finite element joint model.**

Three-dimensional analysis proved to be more accurate than two-dimensional analysis in modelling out-of-plane deformation (Figure 2). The three-dimensional analysis also showed that the stress and strain distributions within the adhesive layer varied across the width of the specimen. However, three-dimensional analysis was far more computer intensive, and hence the two-dimensional analysis was preferred for the large number of FEA runs required for the parametric and environmental studies.

## EFFECT OF ADHEREND PROPERTIES

The effect of adherend properties on the joint behaviour was investigated for CR1 mild steel, 6Al-4V titanium, 5251 aluminium, and a plain-woven glass/epoxy composite. Elastic properties for the four materials are shown in Table I. The T-peel specimens were bonded with Araldite 2007® (also known as AV119), a single-part epoxy paste supplied by Ciba Speciality Chemicals. The FEA results show the deformation of the composite joint was greater than for the metal joints due to the lower stiffness of the composite adherends. As a result, higher peel stresses are developed within the adhesive with the Mises equivalent stress at the end of the overlap being 37% higher than in the steel joint for the same tensile load. The maximum stress within the adhesive decreased with increasing adherend stiffness.

The effect of adherend thickness (i.e. 1.4, 2.5 and 5.0 mm) on the stress distributions of CR1 mild steel joints bonded with Araldite 2007® was evaluated. Comparison of the FEA results revealed that, as expected, the overall displacement of the joint decreased with increasing adherend thickness, under the same tensile load. Stress magnitudes and adhesive plastic deformation decrease with increasing adherend thickness. The maximum equivalent stress within the adhesive layer was reduced by approximately 113% and 215% when the adherend thickness was 2.5 mm and 5.0 mm, respectively. The maximum stress value also moves away from the fillet as the adherend thickness is increased.

**Table I Elastic Properties of Adherends**

Property	CR1 Mild Steel	6Al-4V Titanium	5251 Aluminium	Woven Composite
$E_{11}$ (GPa)	206.0	120.0	72.0	25.2
$E_{22}$ (GPa)	206.0	120.0	72.0	10.7
$E_{33}$ (GPa)	206.0	120.0	72.0	25.2
$\nu_{12}$	0.38	0.38	0.35	0.40
$\nu_{13}$	0.38	0.38	0.35	0.14
$\nu_{23}$	0.38	0.38	0.35	0.40
$G_{12}$ (GPa)	74.6	43.5	26.7	3.25
$G_{13}$ (GPa)	74.6	43.5	26.7	4.41
$G_{23}$ (GPa)	74.6	43.5	26.7	3.25

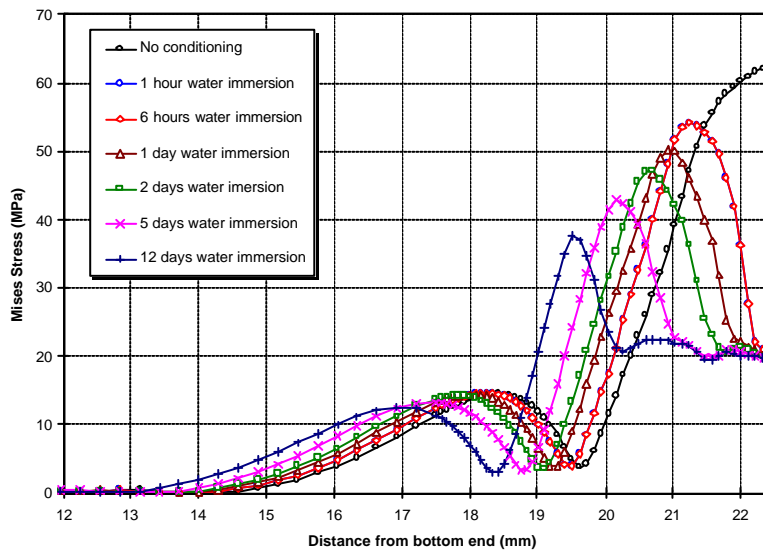
**EFFECT OF ADHESIVE FILLET AND FLANGE RADIUS**

FEA was conducted on the steel joints with the adhesive fillet occupying either half or all of the space between the steel substrates (Figure 3). It was observed that the joint with the 50% adhesive fillet deformed substantially more than the joint with the 100% fillet under the same tensile load. The Mises equivalent stress at the end of the overlap for the specimen with 100% fillet was reduced by 200% compared with the 50% fillet specimen.



**Figure 3. Schematic of the adhesive fillet geometries for the T-peel joint.**

The overall displacement of the joint was observed to increase when the flange radius was increased from 6.5 to 25.0 mm.. However, stress analyses revealed that the flange radius did not significantly influence the Mises equivalent stresses and peel stresses. The effect was more pronounced for the axial and shear stress components.



**Figure 4. Mises equivalent stress distribution along the centre line of the adhesive layer.**

## EVALUATION OF MOISTURE EFFECT ON JOINT PERFORMANCE

The effect of environmental conditioning on the performance of mild steel joints was investigated using a sequentially coupled mechanical-diffusion finite element model, which incorporated continuously varying adhesive material properties. The numerical predictions revealed that the distributions of stresses become more uniform along the adhesive layer when the adhesive contains increased amounts of moisture (Figure 4). Peel stresses at the edge of the adhesive fillet were observed to decrease with increasing moisture content. These changes were due moisture plasticising the adhesive, resulting in lower adhesive stiffness.

## CONCLUSIONS

Parametric studies revealed that stress distributions are sensitive to adherend material properties, adherend thickness and flange radius with the effect of changes in flange radius being less pronounced. In general, stresses were reduced when changes in the T-peel geometry resulted in smaller joint displacements for the same load. Numerical predictions revealed that the stress distributions within the adhesive layer become more uniform with increasing moisture content. The key finding of the parametric and environmental studies are summarised in Table II.

**Table II. Summary of Parametric Studies\***

Property	Moisture Content	Adherend Stiffness	Adhesive Fillet	Adherend Thickness	Flange Radius
Joint Stiffness	–	↑	↑	↑	↓
Equivalent Stress	↓	↓	↓	↓	–
Peel Stress	↓	↓	↓	↓	–
Axial Stress	–	↓	↓	↓	↓
Shear Stress	–	–	↓	↓	↓
Plastic strain	↑	↑	↓	↓	↑

\* Symbols ↑, ↓ and –, denote increase, decrease and no significant change in the joint properties, respectively.

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