FE Modeling and Analysis of Structural Adhesive T-joint at Elevated Temperature

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Adhesive bonding is a joining technique that offers great design flexibility as it can be easily integrated into almost all available industrial sequences of single-piece work.

This joining technique involves glues, epoxies, or various plastic agents that bond by curing a bonding with heat, pressure, or time.

Adhesively bonded joints provide many advantages over conventional mechanical fasteners.
INTRODUCTION

Figure 1: Granulator fluidization bed
• Adhesive is seldom used in high-temperature structural applications that exposed to extreme environment, particularly in the granulation application.

• Granulator fluidization bed is a main component of urea granulator system in fertilizer plant.

• Perforated plate and frame structure are normally joined together using plug welding techniques.
• Plug welding technique requires specific amount of heat and welding speed to avoid excessive metal melting (304L Stainless Steel) due to a thin perforated plate, i.e. 1.25 mm.
METHODOLOGY

a) Bulk Specimen

Bulk specimen shape and dimensions according to ASTM D 638-02 standard

b) T-joint Specimen

10 mm thick 304L stainless steel plate and 1.25 mm thick 304L perforated stainless steel
Specimen Preparation
• 5 sample for each test

Curing Process
• Room Temperature
• 18 Hours

T-joints Tensile Test
• Curing at each temp for 10 min before tensile loading
• Test in thermostatic chamber for RT-100°C
RESULT

a) Failure strength of adhesive T-joint at elevated temperature

Table 1: Failure strength of adhesive T-joint at elevated temperature

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>23°C</th>
<th>35°C</th>
<th>55°C</th>
<th>75°C</th>
<th>100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.288</td>
<td>1.572</td>
<td>0.794</td>
<td>0.613</td>
<td>0.409</td>
</tr>
<tr>
<td>2</td>
<td>0.734</td>
<td>1.731</td>
<td>1.350</td>
<td>1.069</td>
<td>0.794</td>
</tr>
</tbody>
</table>

- Adhesive T-joint at 35°C failed under highest load of 1.572 kN and 1.731 kN for adhesive thickness of 1.0 mm thickness and 2.0 mm respectively.
- There were the optimum failure strength of adhesive joint for each thickness.
### Table 2: Araldite Epoxy properties at different temperature

<table>
<thead>
<tr>
<th>Temperature, °C</th>
<th>Elasticity Modulus, (E) GPa</th>
<th>Poisson ratio,</th>
</tr>
</thead>
<tbody>
<tr>
<td>RT</td>
<td>1.392</td>
<td>0.380</td>
</tr>
<tr>
<td>35</td>
<td>1.257</td>
<td>0.392</td>
</tr>
<tr>
<td>55</td>
<td>0.426</td>
<td>0.463</td>
</tr>
<tr>
<td>75</td>
<td>0.227</td>
<td>0.480</td>
</tr>
<tr>
<td>100</td>
<td>0.185</td>
<td>0.484</td>
</tr>
</tbody>
</table>

**Figure 5:** Relationship of Elastic modulus and Poisson’s ratio at elevated temperature
RESULT

1. Determination of Failure Stress by FE Analysis

Table 3: Maximum Von-Misses Stress (MPa) by FE analysis

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>23°C</th>
<th>35°C</th>
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<th>75°C</th>
<th>100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.202</td>
<td>1.968</td>
<td>0.798</td>
<td>0.567</td>
<td>0.375</td>
</tr>
<tr>
<td>2</td>
<td>1.061</td>
<td>2.502</td>
<td>1.951</td>
<td>1.544</td>
<td>0.894</td>
</tr>
</tbody>
</table>

- FE analysis was carried out by tensile load from experimental which was applied on perforated plate and vertical plate constrained in all directions.
RESULT

2. Static Stress Analysis of Adhesive under Axial Tensile Load

- Temperature of 35°C has the highest value for both approach.
- It was slightly decreased from 35°C to 100°C for both thicknesses.
- From the results, it can be observed that the high temperature will reduce the adhesive T-joint strength.
- Adhesive becomes more elastic which results in adhesive bonding becomes weaker when the temperature increases near and beyond to Tg value of 90.09°C.
Figure 6: Maximum Von-Mises at 100°C for 1.0 mm bond thickness
CONCLUSION

• The strength of adhesive T-joint was studied in respect of the adhesive thickness and test temperature from room temperature to 100°C.

• As a conclusion, the adhesive T-joint strength decreases for temperatures over 35°C. This is because at high temperature, the failure is determined by the change of mechanical properties of adhesive.

• These results show relevance of material knowledge when testing under distinctive temperatures.

• Therefore, the epoxy adhesive used shows that it can be degraded essentially under specific conditions.