Chapter-8

COMPARATIVE STUDY OF UT, LVT AND NVT RESULTS
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8.1 INTRODUCTION

The effect of different types of thermal load together with the uniform pressure load on the in-plane stresses $\sigma_x$, $\sigma_y$ and $\tau_{xy}$, the interlaminar stresses $\tau_{xz}$, $\tau_{yz}$ and $\tau_{zx}$, at the free edge of the hole is discussed in this chapter.

As explained in the fourth chapter three different types of thermal loads, i) uniform temperature (UT), ii) linearly varying temperature (LVT) across the thickness and iii) non-linearly varying temperature (NVT) across the thickness of the plate are considered for the analysis.

8.2 DISCUSSION OF RESULTS

Figs. 8.1 to 8.6 show the variation of in-plane and interlaminar stresses with respect to $d/l$ ratio for various cases of loading mentioned above.

8.2.1 Variation of $\sigma_x$

Fig. 8.1 shows the variation of $\sigma_x$ with respect to $d/l$ for various types of loading. The effect of various parameters on $\sigma_x$ is discussed here.
8.2.1.1 Effect of temperature load type

For both thermal and combined loads the maximum values of the stresses are observed for the uniform temperature (UT) followed by LVT and NVT for all d/l values.

8.2.1.2 Effect of Load Type

It is observed that the stresses due to combined load are higher than their respective stresses due to thermal load for all d/l values.

8.2.1.3 Effect of d/l Ratio

The stresses due to thermal loading increases up to 0.2 of d/l and later decreases. In case of combined load there is a slight increase in $\sigma_x$ for UT and LVT up to $d/l = 0.2$ and later decreases. In case of NVT this stress decreases with increase in d/l ratio.

8.2.2 Variation of $\sigma_y$

Fig. 8.2 shows the variation of $\sigma_y$ with respect to d/l for various types of loading. The effect of various parameters on $\sigma_y$ is presented here.

8.2.2.1 Effect of temperature load type

In case of thermal load there is no significant variation in $\sigma_y$ for UT and LVT for the values of d/l between 0.1 and 0.3. As d/l increases from 0.3, the stress due to UT is more than the stress due to LVT. The
stress due to NVT is less when compared to UT and LVT at all d/l values.

In case of combined load there is no significant variation in $\sigma_y$ due to UT and LVT for all d/l ratios. This stress due to NVT is less when compared to its value due to UT and LVT for all d/l ratios.

8.2.2.2 Effect of Load Type

It is observed that the stresses due to combined load are higher than their respective stresses due to thermal load for all d/l values.

8.2.2.3 Effect of d/l Ratio

All the stresses decrease with increase in d/l ratio, except for thermal load in case of UT which shows increasing trend beyond d/l = 0.3.

8.2.3 Variation of $\tau_{xy}$

Fig. 8.3 shows the variation of $\tau_{xy}$ with respect to d/l for various types of loading. The effect of various parameters on $\tau_{xy}$ is explained below.

8.2.3.1 Effect of temperature load type

For both thermal and combined loads the maximum values of the stresses are observed for the uniform temperature (UT) followed by LVT and NVT for all d/l values.
8.2.3.2 Effect of Load Type

It is observed that the stresses due to combined load are higher than their respective stresses due to thermal load for all d/l values. However there is no significant variation of the stresses due to thermal and combined loads at d/l = 0.4 in all the three cases UT, LVT and NVT.

8.2.3.3 Effect of d/l Ratio

The stresses increase with increase in d/l up to 0.2 and later decreases in all the cases except for NVT in case of combined load, in which case it decreases continuously with increase in d/l ratio.

8.2.4 Variation of σz

Fig. 8.4 shows the variation of σz with respect to d/l for various types of loading. The effect of various parameters on σz is discussed here.

8.2.4.1 Effect of temperature load type

For both thermal and combined loads the maximum values of the stresses are observed for the uniform temperature (UT) followed by LVT and NVT for all d/l values.

8.2.4.2 Effect of Load Type

The stresses due to combined load are more when compared to their respective values due to thermal load in case of UT for all d/l
values. In case of LVT and NVT stresses due to thermal and combined loads are almost equal at d/l = 0.1 and later the stresses due to combined load are smaller than their respective stresses due to thermal load.

### 8.2.4.3 Effect of d/l Ratio

All the stresses increase with increase in d/l ratio.

### 8.2.5 Variation of \( \tau_{yz} \) and \( \tau_{zx} \)

Figs. 8.5 and 8.6 show the variation of \( \tau_{yz} \) and \( \tau_{zx} \) with respect to d/l for various types of loading. The effect of various parameters on these stresses is presented here.

#### 8.2.5.1 Effect of temperature load type

For both thermal and combined loads the maximum values of the stresses are observed for the uniform temperature (UT) followed by LVT and NVT for all d/l values.

#### 8.2.5.2 Effect of Load Type

The stresses due to combined load are more when compared to their respective values due to thermal load in case of UT for all d/l values. In case of LVT and NVT the stresses due to combined loads are smaller than their respective stresses due to thermal load.
8.2.5.3 Effect of d/l Ratio

All the stresses increase with increase in d/l ratio.

![Graph showing variation of σx with respect to d/l ratio](image1)

Fig. 8.1 Variation of σx with respect to d/l ratio

![Graph showing variation of σy with respect to d/l ratio](image2)

Fig. 8.2 Variation of σy with respect to d/l ratio
Fig. 8.3 Variation of $\tau_{xy}$ with respect to $d/l$ ratio

Fig. 8.4 Variation of $\sigma_z$ with respect to $d/l$ ratio
Fig. 8.5 Variation of $\tau_{yz}$ with respect to $d/l$ ratio

Fig. 8.6 Variation of $\tau_{zx}$ with respect to $d/l$ ratio
The situations where the stresses are maximum and minimum are given in the Tables 8.1 and 8.2.

### Table 8.1 Cases where the stresses are maximum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Stress</th>
<th>Type of Thermal Load</th>
<th>Load</th>
<th>d/l</th>
<th>From Fig. No.</th>
<th>Stress value (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\sigma_x$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.2</td>
<td>8.1</td>
<td>139.06</td>
</tr>
<tr>
<td>2</td>
<td>$\sigma_x$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.2</td>
<td>8.1</td>
<td>137.06</td>
</tr>
<tr>
<td>3</td>
<td>$\sigma_y$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.1</td>
<td>8.2</td>
<td>122.64</td>
</tr>
<tr>
<td>4</td>
<td>$\sigma_y$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.1</td>
<td>8.2</td>
<td>84.42</td>
</tr>
<tr>
<td>5</td>
<td>$\tau_{xy}$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.2</td>
<td>8.3</td>
<td>52.11</td>
</tr>
<tr>
<td>6</td>
<td>$\tau_{xy}$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.2</td>
<td>8.3</td>
<td>44.58</td>
</tr>
<tr>
<td>7</td>
<td>$\sigma_z$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.4</td>
<td>8.4</td>
<td>7.55</td>
</tr>
<tr>
<td>8</td>
<td>$\sigma_z$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.4</td>
<td>8.4</td>
<td>7.17</td>
</tr>
<tr>
<td>9</td>
<td>$\tau_{yz}$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.4</td>
<td>8.5</td>
<td>15.40</td>
</tr>
<tr>
<td>10</td>
<td>$\tau_{yz}$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.4</td>
<td>8.5</td>
<td>15.65</td>
</tr>
<tr>
<td>11</td>
<td>$\tau_{xz}$</td>
<td>UT</td>
<td>UT (cl)</td>
<td>0.4</td>
<td>8.6</td>
<td>14.14</td>
</tr>
<tr>
<td>12</td>
<td>$\tau_{xz}$</td>
<td>UT</td>
<td>UT (tl)</td>
<td>0.4</td>
<td>8.6</td>
<td>13.67</td>
</tr>
</tbody>
</table>

### Table 8.2 Cases where the stresses are minimum

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Stress</th>
<th>Type of Thermal Load</th>
<th>Load</th>
<th>d/l</th>
<th>From Fig. No.</th>
<th>Stress value (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\sigma_x$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.4</td>
<td>8.1</td>
<td>59.92</td>
</tr>
<tr>
<td>2</td>
<td>$\sigma_x$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.4</td>
<td>8.1</td>
<td>57.13</td>
</tr>
<tr>
<td>3</td>
<td>$\sigma_y$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.4</td>
<td>8.2</td>
<td>57.50</td>
</tr>
<tr>
<td>4</td>
<td>$\sigma_y$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.4</td>
<td>8.2</td>
<td>36.39</td>
</tr>
<tr>
<td>5</td>
<td>$\tau_{xy}$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.4</td>
<td>8.3</td>
<td>22.66</td>
</tr>
<tr>
<td>6</td>
<td>$\tau_{xy}$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.4</td>
<td>8.3</td>
<td>21.63</td>
</tr>
<tr>
<td>7</td>
<td>$\sigma_z$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.1</td>
<td>8.4</td>
<td>1.34</td>
</tr>
<tr>
<td>8</td>
<td>$\sigma_z$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.1</td>
<td>8.4</td>
<td>1.27</td>
</tr>
<tr>
<td>9</td>
<td>$\tau_{yz}$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.1</td>
<td>8.5</td>
<td>8.72</td>
</tr>
<tr>
<td>10</td>
<td>$\tau_{yz}$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.1</td>
<td>8.5</td>
<td>9.36</td>
</tr>
<tr>
<td>11</td>
<td>$\tau_{xz}$</td>
<td>NVT</td>
<td>NVT (cl)</td>
<td>0.1</td>
<td>8.6</td>
<td>7.38</td>
</tr>
<tr>
<td>12</td>
<td>$\tau_{xz}$</td>
<td>NVT</td>
<td>NVT (tl)</td>
<td>0.1</td>
<td>8.6</td>
<td>7.91</td>
</tr>
</tbody>
</table>
From the above tables it is observed that the in-plane stresses are maximum at the lower values of d/l and the interlaminar stresses are maximum when d/l is maximum. The in-plane stresses are observed to be minimum when the d/l ratio is maximum and the interlaminar stresses are minimum when the d/l ratio is minimum.

8.3 CONCLUSIONS

It is observed that all the stresses are maximum in case of uniform temperature load or its combination with the pressure load. This is because, in case of thermal loading with UT, every point of the loaded structure is subjected to the same amount of rise in temperature (100°C).

In the other two cases (LVT and NVT), the difference between the maximum and minimum temperatures given on the body of the plate is equal to 75°C and therefore the temperature gradient at various points of the plate are less than 100°C resulting in the lower values of the stresses.

The stresses are observed to be minimum in case of NVT loading or its combination with pressure loading.