Thermoplastic Forming

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What is thermoplastic forming?
Value: Manufacture high performance composites parts in $\approx 5$mins

Problem:
- Part complexity causes defects such as wrinkling and corner thinning
- Parts distort significantly so tool compensation is required

Approach:
Need to determine:
- Process and tool design which prevents defects
- Amount of tool compensation required
- Traditionally done with manufacturing trial and error
- Process simulation tools potentially offer cheaper and faster alternative
Manufacturing trials

Aim:
- Prevent wrinkling and corner thinning defects
- Determine part distortion
Part edge containment

- Walls successfully blocked the ejection of material out of the part edge
- Prevented corner thinning but not wrinkling
Tool thermal expansion compensation

- Tool thermal expansion was measured to be uniform
- Therefore cavity thickness remains uniform
- Tool thermal expansion ruled out as the cause of defects

<table>
<thead>
<tr>
<th>Horizontal Extensometers</th>
<th>Strain %</th>
<th>Vertical Extensometers</th>
<th>Strain %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exten 4</td>
<td>0.588</td>
<td>Exten 6</td>
<td>0.597</td>
</tr>
<tr>
<td>Exten 2</td>
<td>0.584</td>
<td>Exten 1</td>
<td>0.589</td>
</tr>
<tr>
<td>Exten 5</td>
<td>0.588</td>
<td>Exten 3</td>
<td>0.594</td>
</tr>
<tr>
<td>Average</td>
<td>0.587</td>
<td>Average</td>
<td>0.593</td>
</tr>
</tbody>
</table>
Process simulation

- Conduct trial and error design virtually to avoid cost of manufacturing trials
- Requires accurate prediction of defects and distortion
- Potential to link simulations together
Aniform forming simulation

- Wrinkling is not predicted in standard simulation set up
Aniform forming simulation

- Assumption that blank starts perfectly flat is not correct – it sags due to gravity

- Including sagging in Aniform requires artificially reducing bending stiffness

- Adhesion between plies must also be reduced, this also allows top ply to separate

- Wrinkling is predicted with these modifications
Residual stress and distortion simulation

- 6.9° spring-in predicted by thermo-crystallisation model.
- 0.3° spring-in measured in manufactured parts

Cause of discrepancy:
- Tool-part interaction stresses not modelled
- Material properties taken from literature
- Wrinkling causing reduced spring-in
Thank you
for your attention!