Curing is an important step in production of carbon fiber tubes and has an impact on the mechanical performance of the final product. One of the main problems due to uncontrolled curing is having incomplete cured matrix. Heat transfer analysis during curing allows monitoring the behaviour of the system and defining the critical parameters to optimize this process.

**Motivation**

- Model the cure kinetics of thermostet epoxy resin, TP135
- Establish a heat transfer analysis for composite tubes based on prepreg technology
- Monitor and model the real cure cycle using environmental chamber
- Implement the method at NTPT Poland using industrial ovens

**Materials**

<table>
<thead>
<tr>
<th>Application</th>
<th>Material</th>
<th>Length × Thickness (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandrel</td>
<td>Stainless Steel</td>
<td>600 × 5</td>
</tr>
<tr>
<td>Shrink tape</td>
<td>PET</td>
<td>340 × 0.3</td>
</tr>
<tr>
<td>Composite tube</td>
<td>T800H CF</td>
<td>340 × 0.5</td>
</tr>
</tbody>
</table>

**Main Results**

- Cure Kinetics of TP135 was modeled based on the autocatalytic model
  \[
  \frac{da}{dT} = 2.81 \times \exp \left( \frac{-77.53}{RT} \right) \alpha^0.182 \left[ 0.0187T - 0.9334 \right] T = 60°C, \left( 1 - \alpha \right) = 0.0187T + 13.5481, \quad \alpha \geq 0.022, \quad T \geq 125°C
  \]
- The environmental chamber transfers the heat efficiently. (1 ≤ h ≤ 40 W/m²K for natural convection in gas)
- Shrink tape and composite layers are not strong heat barriers
- NTPT industrial oven was less efficient in transferring heat than the environmental chamber
- Introducing large mass of objects reduced the efficiency of oven for transferring heat

**Methodology**

**Thermochemical energy balance equation:**

\[
Q = C_p\rho_v v_c H_f \frac{dT}{dt} \left( k_f \frac{dT}{dR} \right) + \rho_f \frac{dT}{dt}
\]

**Cure Kinetics Modeling**

**Autocatalytic model:**

\[
\frac{da}{dT} = K \cdot a^m \cdot (1 - a)^n, \quad \text{where } K = A^* \exp \left( \frac{-E_a}{RT} \right)
\]

**Conduction**

\[
Q = k_f \frac{dT}{dR}
\]

**Convection**

\[
\frac{dT}{dt} = k_f \frac{dT}{dR} + \frac{Q}{hA_f}
\]

**Numerical results, using ABACUS and h=300 W/m²K**

**Experimental results, using environmental oven**

**Conclusion**

A methodology to monitor and analyze the heat transfer during curing of thin carbon fiber tubes in industrial scale was established.

**References**