Fire Performance of Composites and Rubber

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Fire behaviour of composites

- Unfortunately when fire is a likely hazard then their mechanical properties suffer a rapid loss compared to traditional material.
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Polymer
Fire behaviour of composites

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TGA Polyester GFRP

Weight loss [%]

Temperature [°C]

Rate factor

Average decomposition energy

\[ \frac{\partial \rho}{\partial t} = -A\rho_0 \left[ \frac{\rho - \rho_f}{\rho_0} \right]^n e^{-\frac{E}{RT}} \]

\[ (\rho C_p)_{\text{comp}} \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left( k_{\text{comp}} \frac{\partial T}{\partial x} \right) + \dot{m}_g C_{pg} \left( \frac{\partial T}{\partial x} \right) - \frac{\partial \rho_{\text{comp}}}{\partial t} \left( Q_p + h_{\text{comp}} - h_g \right) \]

Internal thermal energy

Conduction

Heat transfer due to gaseous mass flow

Endothermic decomposition
COMFIRE50-GUI

- 1D model
- N nodes
- N-1 FD elements

- Straightforward explicit finite difference method
- Time step calculated accordingly to the Fourier number chosen
Thermo-mechanical Modelling

- Two Layer Model

**Thermal**

\[
\left( \rho C_p \right)_{comp} \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left( k_{comp} \frac{\partial T}{\partial x} \right) + m_g C_{pg} \left( \frac{\partial T}{\partial x} \right) - \frac{\partial \rho_{comp}}{\partial t} \left( Q_p + h_{comp} - h_g \right)
\]

**Constitutive**

\[
\sigma_{c(comp)}(T, RRC) = \sigma_{c(0)} \left( \frac{x - x_c(T, RRC)}{x} \right) + \frac{x_c}{x} \sigma_{c(char)}
\]
Thermo-mechanical Modelling

- Average Strength Model

Thermal

\[
(\rho C_p)_{\text{comp}} \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} \left( k_{\text{comp}} \frac{\partial T}{\partial x} \right) + m_g C_{pg} \left( \frac{\partial T}{\partial x} \right) - \frac{\partial \rho_{\text{comp}}}{\partial t} \left( Q_p + h_{\text{comp}} - h_g \right)
\]

Constitutive

\[
P(T) = 0.5 \left( P_U + P_R - (P_U - P_R) \tanh(k(T - T')) \right) R^n
\]

Elasticity

\[
\overline{\sigma} = \frac{1}{t} \int_{0}^{t} \sigma(T) dx
\]
Fire-Under-Load Tests

Fire-under-load test setup

- Plates
- Hydraulic Pump
- Monitoring PC
- Hydraulic Cylinder
- Pressure Transducer
- Hot face thermocouple
- Compressive load
- Anti-buckling guides
- Propane burner
Modelling

Thermal Profiles and Time to Failure

Temperature profile for 70 kW/m²

- 30% FL
- 20% FL
- 10% FL
- Simulation

Normalized residual strength
EN45545-2

- Establish the **OC** and the **HL** level of the train (given by the operator and dependent on where the train is going to run: open air, tunnels, underground...);
- Check in **Table 2** of EN45545-2 if the component in combustible material is in the **listed products**;
- **If not**, **Table 3** in EN45545-2 is used instead of Table 2 to classify the product;
- Depending on Table 2 or Table 3, find the correct **detailed requirements** from **table 5** in EN45545-2;
- the component has to **comply** with the **requirement limits**, either from PDS, or by tests results from certified labs.
Rubber in rail vehicle

- **EN45545-2: Table 2**

<table>
<thead>
<tr>
<th>Product No</th>
<th>Name</th>
<th>Details</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td><strong>Flexible metal/rubber units</strong></td>
<td>Flexible metal/rubber units including elements in bogies</td>
<td>R9</td>
</tr>
<tr>
<td>M2</td>
<td>Hoses - Interior</td>
<td>Pipes and hoses for fuel, oils, hydraulics, pneumatics, water and drainage</td>
<td>R22</td>
</tr>
<tr>
<td>M3</td>
<td>Hoses - Exterior</td>
<td>Pipes and hoses for fuel, oils, hydraulics, pneumatics, water and drainage</td>
<td>R23</td>
</tr>
</tbody>
</table>

- a) Computer screens will be assessed as limited surface, IN2 and not assessed as electrical equipment.
- b) Downward facing surfaces up to 0,2 m² of folding tables shall be assessed according to the requirements of R2.
- c) When assessing a seat design, results from all F1 tests (F1, F1A, F1B, F1C, F1D, F1E) are required for complete validation (except driver's seat).
## Rubber in rail vehicle

<table>
<thead>
<tr>
<th>R9</th>
<th>T03.02</th>
<th>MARHE kWm(^2)</th>
<th>Maximum</th>
<th>90</th>
<th>90</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EX9; EX10; EX11; M1)</td>
<td>T10.03</td>
<td>(D_\theta) max. dimensionless</td>
<td>Maximum</td>
<td>–</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>T11.02</td>
<td>(CIT_G) dimensionless</td>
<td>Maximum</td>
<td>–</td>
<td>1.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R22</th>
<th>T01</th>
<th>Oxygen content %</th>
<th>Minimum</th>
<th>28</th>
<th>28</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>(IN16; EL2; EL6A; EL7A; M2)</td>
<td>T10.03</td>
<td>(D_\theta) max. dimensionless</td>
<td>Maximum</td>
<td>600</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>T12</td>
<td>(CIT_{NLP}) dimensionless</td>
<td>Maximum</td>
<td>1.2</td>
<td>0.9</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R23</th>
<th>T01</th>
<th>Oxygen content %</th>
<th>Minimum</th>
<th>28</th>
<th>28</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EX12; EL2; EL5; EL6B; EL7B; M3)</td>
<td>T10.03</td>
<td>(D_\theta) max. dimensionless</td>
<td>Maximum</td>
<td>–</td>
<td>600</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>T12</td>
<td>(CIT_{NLP}) dimensionless</td>
<td>Maximum</td>
<td>–</td>
<td>1.8</td>
<td>1.5</td>
</tr>
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</table>
Rubber in rail vehicle

4.7 Products to be approved on functional necessity

If it can be shown that any of the requirements specified above are not technically achievable with functionally suitable products, then existing commercially available products can be used until and unless a suitable product is developed. There shall be no requirement to consider products made available after the date of the contract.

The use of this paragraph has the following conditions:

— essential requirements in 4.1 shall not be compromised;

— this shall be verified by assessment; taking the proposed design into consideration; including the functional reason and limitation for using the material in question (e.g. climate and/or infrastructure).

NOTE

It can be necessary to use this process in respect of products such as:

- rubber tyres;
- rubber suspension components;
- intercommunication gangways;
- electronics devices on printed board;
- flexible metal/rubber units;
- window seals;
- seals for doors;
- brake hoses;
- pneumatic hoses;
- flexible fuel hoses;
- high voltage cables;
- data bus cables;
- the anti-spall layer for windscreens on the driver’s cab;
- windscreen washer water containers.
DreagonCoat

Non Coated Product

2 Minutes
6 Minutes
10 Minutes
14 Minutes
17 Minutes

With DragonCoat Applied

2 Minutes
7 Minutes
9 Minutes
11 Minutes
Flame Out 11:30 Mins (Approx)
DreagonCoat

- Heat Release (MAHRE) 180 seconds gained (EN ISO 45545 HL2)
- Smoke Toxicity 180 seconds gained (EN ISO 45545 HL2)
- Carbon Monoxide 180 seconds gained
- Carbon Dioxide 195 seconds gained
- The coated part was also shown to:
  - *Maintain* consistent suspension and *suspension performance*
  - *Retain* full *cohesion* between the *coating* and the *rubber* section of the spring
  - *Survive extreme* load and displacement test *conditions*
- Tests to the new *EN 45545* standards have shown *broad compliance* to *HL2* standards *without* any *effects on* the spring *performance*. The coating also *remained adhered* to the product during durability trials equivalent to the *service life* of the springs.
Thank you!

Any questions?