BIO-RESIN FOR NEW BIO-COMPOSITE PASSIVE FIRE PROTECTION FOR OFF-SHORE APPLICATION

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ABSTRACT

A small propane burner was used to compare fire protection performance of a newly developed furan resin in the Fire-Resist project grant agreement No. 246037. The bio composite, developed by TFC, is a thermoset resin based on polyfurfuryl alcohol (PFA) mixed with glass microspheres to make a light material with low thermal conductivity in order to make an effective, lightweight, green Passive Fire Protection (PFP) for off-shore applications. A comparison with a glass sphere-phenolic composite and simple Kaowool was made showing that the bio composite performs as good as the phenolic based PFP.

1 INTRODUCTION

In recent years composite PFP have seen a rapid increase in off-shore application and the industry have become more and more interested in their fire performance [1]. Fire resistance is usually assessed by full-scale fire test using big furnaces or jet fire tests which lasts for very long time, multiples of 30 minutes, depending on the certification class to be achieved [3-6]. Full-scale fire tests are then time consuming and expensive and most of the time they just give a pass or no pass information, with little or no valuable data to be used material development. To overcome these issues in this work a cheap small-scale fire testing procedure has been developed trying to comply with standardised fire testing conditions. This technique has been used to compare fire resistance performance of coupon size samples of the bio-composites against other two conventional passive fire protection (PFP): glass sphere-phenolic composite and some Kaowool

2 EXPERIMENTAL

2.1 Materials

In order to compare fire resistance of the furan based bio-composite PFP material, made of polyfurfuryl alcohol (PFA) mixed with glass microspheres, two different conventional PFP materials were used: Kaowool ceramic blanket and glass sphere-phenolic composite. The bio-composite was directly cast on steel plates of 12.5mm by 150mm square, creating a very good thermal contact between PFP and steel. Two different PFP thicknesses were used, 19mm and 50mm. The two conventional PFP materials were hold up against a steel plate of 12.5mm by 150mm square using some metal wire for the Fibrefrax and a thin layer of Araldite2015® for the phenolic based PFP. Thicknesses of the conventional PFP materials were 12.5 and 25mm.

Thermal properties of the PFP materials used are reported in Table 1. The Kaowool density was not available but according to literature, depending on the grade, it should be between 64 and 160 kg m\textsuperscript{-3}.

The other thermal properties have been evaluated using the thermal lag techniques and the density has been calculated as the ratio between the weight and the volume of the bio-composite.
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<table>
<thead>
<tr>
<th>PFP Material</th>
<th>Density [kg m(^{-3})]</th>
<th>Thermal conductivity [W m(^{-1}) K(^{-1})]</th>
<th>Thermal diffusivity [mm(^2) s(^{-1})]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaowool</td>
<td>64-160</td>
<td>0.08</td>
<td>2.33</td>
</tr>
<tr>
<td>Glass sphere-phenolic composite</td>
<td>-</td>
<td>0.12</td>
<td>0.39</td>
</tr>
<tr>
<td>Bio-composite</td>
<td>468</td>
<td>0.08</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Table 1: PFP thermal properties.

2.2 Heat flux calibration method

For the fire tests a bullfinch burner and propane gas was used. The heat flux calibration of the flame was performed following the principles suggested in ISO2685 [2]. The sample is substituted by a ceramic board and a type N thermocouple is positioned around 1cm far away from it, see Figure 1b) to have an idea. The gas is allowed to flow out of a bullfinch and the pressure adjusted to obtain the temperature corresponding to the desired heat flux according to Stephan-Boltzmann equation reported below, see Equation (1). Once the temperature of the thermocouple is stable at the desired temperature the signal from the thermocouple is registered for at least 3 minutes. The recording is then analysed to be sure that the average temperature or heat flux falls in the allowed range for the test to be run.

\[
\dot{q} = \varepsilon \sigma T^4
\]

where \(\dot{q} \ [W \ m^{-2}]\) is the heat flux radiated by the flames, \(\varepsilon\) is the emissivity of the flames typically between 0.7 and 0.9, \(\sigma\) is the Stephan-Boltzmann constant [W m\(^{-2}\) T\(^{-4}\)], and \(T\) is the temperature of the flames [K].

For the purpose of this study an average flame emissivity of 0.8 has been used. The distance used between the bullfinch burner and the sample surface was set at 320mm and never changed.

2.3 Testing method

All the samples were insulated on the sides using Fibrefrax®, see Figure 1 a), to ensure 1D heat conduction, and exposed to fire using a calibrated propane burner with a quasi-stable flame temperature of 1000 °C corresponding to 113kWm\(^{-2}\) [3], see Figure 1 b). The centreline temperature of the steel plate was monitored using a bonded K-type thermocouple for 30 minutes. Two tests for each PFP material thickness were performed.

Figure 1: a) bio composite sample back face; c) fire test in progress;
3 RESULTS AND DISCUSSION

Thermal profiles of the steel plates are reported Figure 2 below which shows that, although the actual thicknesses of the PFP materials were not directly comparable among each other, the bio-composite performs as well as the phenolic sample if we compare the 19mm bio-composite with the 25mm of the other two materials. Barely any smoke could be observed during the fire tests which is a very good fire reaction characteristic for off-shore applications.

It can be noticed in Figure 2 that the two composite PFP thermal responses are characterised by a longer initial thermal lag compared to the Kaowool thermal response suggesting that the thermal conductivity of the Kaowool is higher than phenolic and furan based PFP. Never the less after an initial higher temperature of the steel plate attached to the Kaowool, compared to the one attached to the phenolic composite, the temperature continues to rise with a lower slope compared to the composite PFP ones. This may be due to the fact that while Kaowool is an inert material which does not change significantly its thermal properties, composites degrade upon fire exposure and so their thermal properties change affecting the overall heat transport response.

All the materials and thicknesses with the exception of the 12.5mm thick phenolic based composites may have a chance to be classified as A30 according to Part 11 in the FTP-code [7].

Once cold, while removing the samples from the testing rig, the borders and corners started to crumble, see Figure 2 a), due to the complete decomposition of the furan resin since due to the high temperature and long exposure in air no char was noticeable. On the other hand, the glass
microspheres in the central area, where the hot gases were impinging with high velocity on the sample surface, were solidly attached together as if the combination of high pressure and temperature managed to sinter them together, see Figure 2 b). This created a glass porous hard network which is beneficial in limiting fire propagation. Similar effects could not be observed for the other two PFP materials.

4 CONCLUSIONS

A small scale fire test has been used to compare fire performance of PFP materials. This technique has potential to become a framework for material development before full scale fire testing. A bio composite has been successfully developed and has similar fire resistance performance compared to phenolic ones which are very well known for having very good fire performance. The main difference between phenolic and furan based composite is that while phenolic based composites use formaldehyde as a solvent, furan based composites use water as solvent which is environmentally friendly and does not require special H&S issues for workers to work with it.

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REFERENCES