BIO-BASED STRUCTURAL COMPOSITE MATERIALS FOR AEROSPACE APPLICATIONS

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ABSTRACT

The growing environmental awareness throughout the world has triggered a shift towards designing environmentally friendly materials from sustainable renewable resources. Natural fibre reinforced composites are already being used for construction and automotive applications and now can play a significant role as secondary structures in the next generation of aircrafts – a necessary driver as per European Union's Clean Sky initiative. The advantages of using natural fibre composites are environmental gains, reduced energy consumption, light weight, insulation and sound absorption properties and reduction in the dependence on petroleum based materials. Currently, one of the research programs at CSIR is focused on developing composites from natural fibre and phenolic matrices to be used as commercial panels for cabin interior. Efforts are underway to solve the issues related to strength, adhesion between fibre and matrix, moisture and thermal durability besides compliance to meet with airworthiness standards. The latter part of the program will deal with biopolymer matrices which would lead to development of green composites for aerospace applications. The present paper will discuss approaches and methodology used and some preliminary results highlighting the challenges involved.

1. INTRODUCTION

The use of advanced composite materials in primary and secondary structures in commercial transport has continued to increase with the introduction of each new product over the past 30 years. One of the primary challenges facing the aerospace industry in the next decade is to fully obtain the performance benefits of composite materials while dramatically lowering production and operating cost with a minimal impact on the environment.

Airframe structures have to fulfil extreme requirements during a very long product life. The materials that are currently in use are metal alloys, carbon fibre composites and hybrid laminates like GLARE and ARALL. The drawbacks of these materials are their high density, cost and low impact behaviour.

The advantages of using natural fibre composites in aerospace are:

- High efficiency is achieved through reduced fuel burning and reduced emissions due to lower weight considerations
- Composite materials have high specific strength and stiffness enabling the design of complex shapes that are more aerodynamically efficient than metals.
- Composite materials do not have the corrosion problems associated with aluminium, potentially reducing the airline maintenance cost.
- Biodegradable nature of plant fibres

This project focuses on the development of a new generation of composites based on natural fibres and/or bio-composites to be used for secondary structures in cabin and cargo areas.

2. OBJECTIVES

The project is divided into two phases:

Phase 1

Develop composites based on natural fibres and phenolic resins

Phase 2

Develop composites based on natural fibres and biopolymers

Composites will be developed by sandwiching honeycomb cores with resin impregnated natural fibre mats. Honeycomb cores are preferred as they provide high mechanical properties at low density and are resistant to buckling and bending[1].

3. EXPERIMENTAL

Woven flax fabric was procured from Libeco, Belgium. The AIRBUS recommended phenolic resin was supplied by Hexion Speciality Chemicals, Germany. Nomex honeycomb cores were supplied by AIRBUS.

4. RESULTS AND DISCUSSION

4.1 Flame retardant treatment

The most important regulation in aerospace applications is maintaining the fire, smoke and toxicity (FST) standards. Flax is a flammable material and it was necessary to apply a flame retardant prior to incorporation of the fabric in the composite. Flame retardants for cellulose fibres include phosphates, for example ammonium and guanidine phosphates, phosphoric acids and those based on tetrakis(hydroxymethyl)phosphonium salts (THPX) or N-methylol functional phosphorus esters, antimony-halogen combinations, boron and nitrogen compounds and mixed oxides, such as stannic oxide [2,3]. Tin compounds, generally have low toxicity, have been shown to be effective flame retardants and smoke suppressants for natural fibres and synthetic polymers[4] and phosphates have long been used for flame retarding cellulosic materials[2] In this study, a suitable flame retardant (FR), selected from screening trials, was padded onto the woven flax fabric and then dried.

4.2 Composite sandwich panels

The woven flame retardant flax fabric was impregnated with the phenolic resin to form the prepegs. Composite panels were prepared by sandwiching honeycomb cores between layers of phenolic resin impregnated flax fabric followed by compression moulding at 135°C for 75 minutes. Figure 2 (a) shows the front view of the composite panel.

Figure 2: Composite Panel

4.3 Cone calorimeter testing

Flammability behaviour of the composite panel was tested using a Fire Testing Technology dual cone calorimeter. A constant incident heat flux of 35 kW/m² was used and an electronic ignition source was used to ignite any volatile gases evolved from the specimen. Specimens were conditioned at an ambient temperature of 23 ± 3°C and a relative humidity of 50 ± 5% before being tested in the horizontal position, using a retainer frame. Some of the components of the panel were also tested. Quantities measured included: Time to ignition (TTI) which is a measure of ease of ignition; Heat release rate (HRR) which relates to fire growth, smoke and toxic gas emissions; Peak heat release rate (PHRR), a measure of how large a fire will grow; Total heat release (THR); Mass loss; Total smoke release (TSR), an indicator of smoke production, and carbon monoxide (CO) and carbon dioxide (CO_2) yields which can give an indication of the completeness of combustion[5,6]. The results are given in Table 1. Plots of HRR and smoke production rate (SPR) are given in Figures 3 and 4 and Figure 5 shows the composite panel after cone calorimeter testing.

Table 1. Fire performance of composite panel and components (250 second time period from start of test).

Sample	Time to ignition (s)	Mean HRR (kW/m2)	Peak HRR (kW/m2)	PHRR at (s)	FIGRA (kW/s)	THR (MJ/m2)	TSR (m2/m2)	Mean CO yield (kg/kg)	Mean CO2 yield (kg/kg)	Mass loss (%)
Composite panel	DNI	6.87	11.2	158	0.1	1.7	44.26	0.0002	0.89	15.7
Honeycomb	17	25.21	80.6	25	3.2	6.3	31.13	0.0006	3.54	75.9
Honeycomb sandwiched between FR flax fabric	68	14.32	40.29	85	0.5	3.6	47.24	0.0004	1.52	19.2
FR flax fabric	DNI	14.19	24.25	95	0.3	3.6	41.02	0.0008	1.71	74.4

* DNI: Did not ignite, FIGRA: Fire growth rate index

The composite panel out-performed the component parts in all areas, having the lowest FIGRA, HRR, PHRR, THR and CO and CO_2 yields. The panel did not ignite and all layers charred, with a mass loss of only 15.7%. The honeycomb core ignited (TTI = 17 seconds) as did the honeycomb sample which was sandwiched between two pieces of FR flax fabric, however, this arrangement resulted in delayed TTI (68 seconds) and lower HRR, PHRR, THR and percentage mass loss. The FR fabric on its own did not ignite and the fabric charred, however, the percentage mass loss was high as was total smoke production.

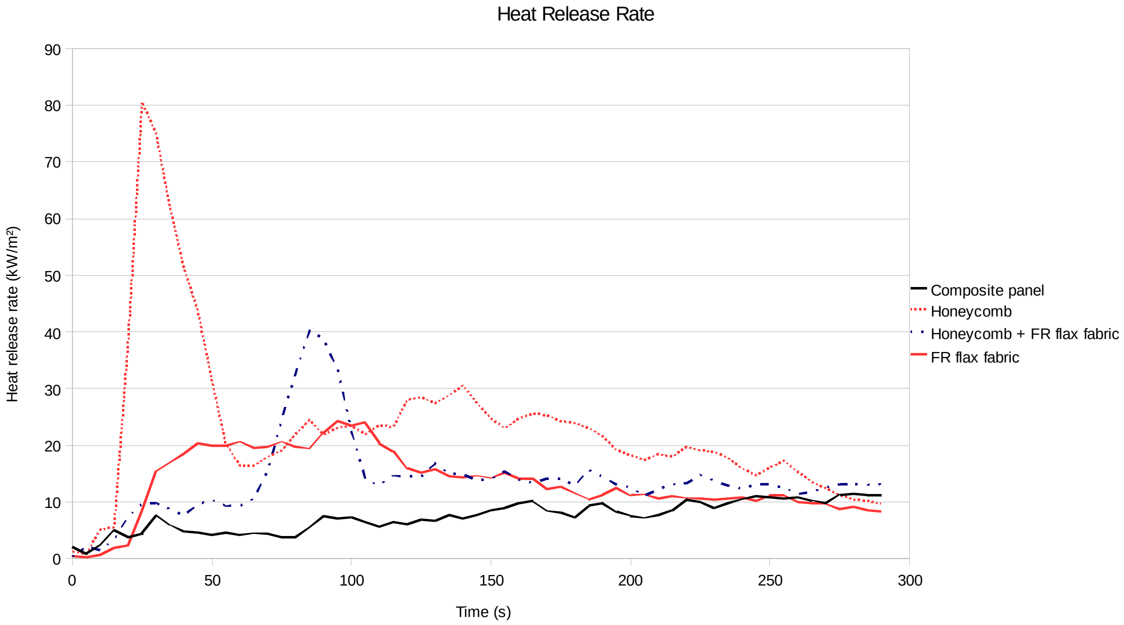

Figure 3: Heat release rate curves.

In Figure 3, the elevated peaks marking the combustion period of the honeycomb and honeycomb / FR flax sandwich are clearly visible. The curve for the composite panel shows the lower heat release rate and a slight increase in HRR over time.

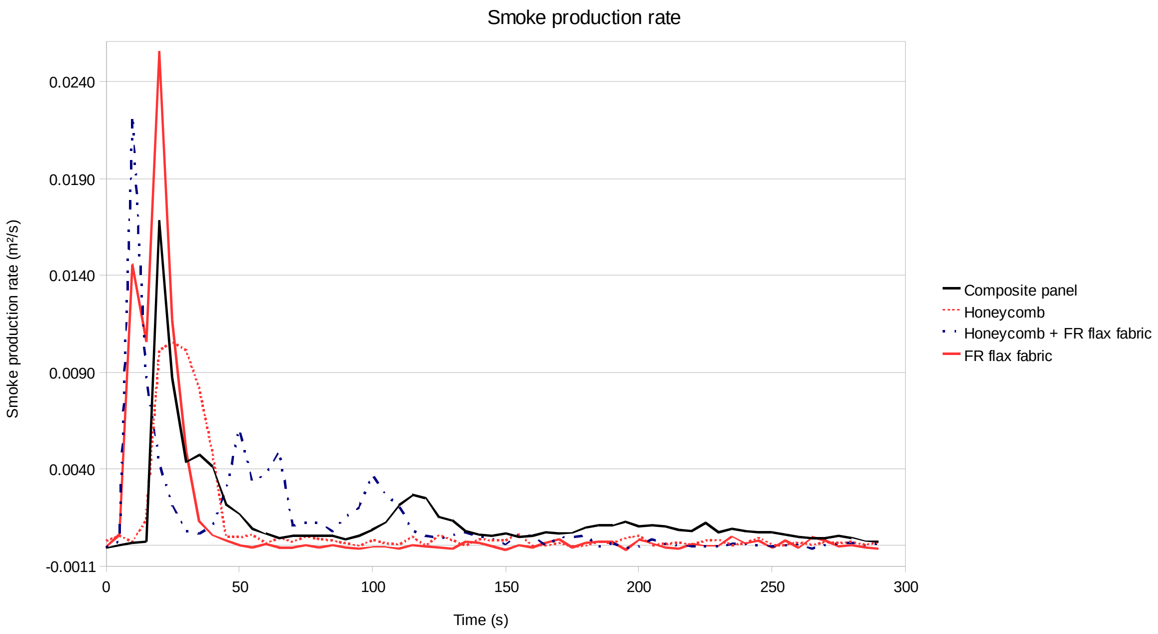

Figure 4: Smoke production rate curves.

The smoke production rate curve for the composite panel showed two main peaks, one between 20-45 seconds and the other between 110-120 seconds. It is likely that these peaks relate to the charring of the two phenolic coated FR fabric layers. The FR flax fabric sample showed a high initial peak, indicating a high level of smoke production during char formation, possibly a result of incomplete combustion of volatiles. The honeycomb / FR flax sandwich had a lower initial peak compared to the FR flax fabric, probably because this was only a single layer of fabric versus the two layers used for FR flax fabric test. Two smaller peaks occurred before and after combustion of the sample. The honeycomb sample showed a smoke production increase at the time of combustion.

Figure 5: Composite panel after testing in the cone calorimeter. Note charring of all layers.

4. CONCLUSIONS

Preliminary experiments have shown that natural fibre based sandwiched honeycomb structures are promising materials for aerospace applications in the near future. However, they are partially environment friendly but they enable a weight saving property which is a prerequisite for intended applications. The flame retardant treatment on the flax fabric decreased the heat release rate and CO_2 and CO yields. Studies are in progress to address challenges in developing nanofillers to impart inherent flame retardant characteristics to fibres and modification of bio-resins to meet flammability and mechanical standards.

5. REFERENCES

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