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RESEARCH ARTICLE

Fire Properties of Hybrid Composites

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ABSTRACT
Thermal conductivity of a components subjected to high temperature is an important property to be considered in a materials to be used in automobile and aerospace fire designated zones; likewise, it is availability, cost, stiffness, resistant to corrosion, and its strength. The main aim of the study is to investigate the fire behavioral properties of fiber metal laminates (FML) composite of a metal, synthetic, natural and polymer matrix. The composites were fabricated in a mould using hand lay-up method and allow curing before test. The fire property test was carried out using the standard properties test equipment as ISO 2685 propane burner, thermocouples, and heat flux meter. The result of the properties test shows a remarkable increase in the properties of only natural fibre metal laminate composites, with a slight decrease in the properties of pure synthetic fiber metal laminates. Flax composite has a high percentage of 21.43% of thermal conductivity and withstands the flame temperature for 15 minutes using an ISO 2685 standard, while kenaf composite fail at 10 minutes 30 seconds. Conclusively, the composites can be used as the component in fire designated zones of automotive, aerospace and other machines.

Keywords: Automotive; burner; calibration; heat flux; thermal conductivity.

Introduction

The fibre-metal laminate (FML) composite consists reinforced fibre (synthetic or natural such as carbon fiber, glass fiber, Kevlar, flax, kenaf, coir, date palm, cotton, hemp, bamboo, jute, abaca, kapok, etc.), with different types of polymer matrix. The combination of metal alloy with reinforced fibres find application in different structural components both in civil and mechanical engineering; due to it is high properties such as its strength, stiffness thermal conductivity, water absorption among other properties such as physical structures as reported in Joseph (2022). FML composites uses as a composite for constructing different structural components (Abu Talib & Mohammed, 2019; Mohammed & Abu Talib, 2021; Mohammed & Abu Talib, 2020; Mohammed et al., 2018. Vogelesang & Vlot, 2000). The type of this composites was constructed to replace the existing steel, monolithic aluminium alloys and other metals due to its properties such as starting fatigue crack and growth of crack with measure, weight, corrosion among other properties (Mohammed & Abu Talib, 2021; Mohammed & Abu Talib, 2019; Mohammed & Abu Talib, 2018). Among the types of FML composites fabricated and used today in different part of machine were Kevlar composite (ARALL) that have the drawback of brittleness that limits its application on the primary structures, carbon fiber and glass fibre reinforced composite (CARALL and GLARE) with excellent properties were developed and been used widely now a day in various industries (Jumahat et al., 2015; Li & WU, 2017; (Mohammed & Abu Talib, 2021; (Mohammed & Abu Talib, 2019).

The glass and carbon fibers reinforced plastic (CFRP and GFRP) composites has been used for many past decade due to its high mechanical, thermal and impact properties in terms of stiffness and strength (Matthews & Rawlings, 1999; Mohammed et al., 2017). These reinforced fibers were in different structures (pre-perg and woven), with carbon fiber been more stronger and lighter than glass-fibre, while in terms of health issues glass fibre is more harmful than carbon fibre. These two composites when used in a structural member reduce the weight of the component, withstand damage tolerance for a high specific time and in turn reduce fuel consumption by increasing the fuel efficiency. Also, the composites withstand a high temperature with low thermal conductivity (Mohammed & Rachid (2022); Mohammed et al., 2018).

Natural fibres such as kenaf and flax were now a day been used in automotive and aerospace industries since its abundant in nature and greener; also, its mechanical and physical properties were very close to that of synthetic fibers. Its limitations were mostly low strength and moisture absorption; therefore, its combination with reinforced synthetic fiber produce a composite with higher mechanical, thermal, and impact properties, which boost the fabrication process of the composites and eliminate/reduces the health et al., 2017; Souza et al., 2011). Bast fiber is the most recognize natural fiber used in hybridization with synthetic fiber as reported by Salman et al. (2015), uses as in form matting or cord; the fiber has flexible and finest form that can be used various form and can be machined easily. Bandaru et al. (2015) study the effect of hybridization of natural/synthetic reinforced fiber on the ballistic impact of armors composite.

This study considers the FML composite of flax and kenaf fiber, carbon fiber and aluminum alloy 2024-T3 bonded with TA/B epoxy resin and hardener. The combination yield a high strength and stiffness composite that has no or little moisture absorption, (Chang et al., 2008). The main aim of this study is to investigate the fire behavioral and thermal conductivity properties of the fabricated composites using an ISO2685 propane-air burner. ISO 2685 propane burner was used in fire behavioral test on the plate were the propane and air were the fluid used in test. The natural/synthetic composites will have excellent properties that almost compete with some types of synthetic composites more in terms of fire behaviors properties.

Materials and Methods

The composite was fabricated using 2024-T3 aluminum alloy, natural fibre (kenaf and flax) carbon fibre and polymer matrix. Two types of composites were fabricated: carbon fibre kenaf reinforced composite and carbon fibre flax reinforced composite.

Aluminium alloy 0.4mm with two layers at the front and rear face of the kenaf and flax composites, four layers of 0.25mm carbon fibre on each composite and two layers each of kenaf and flax of 0.7mm each intersecting the carbon fibre in each composite.

The ratio of resin to hardener is 65:35 mix together before bonding the composites and the weight ratio to polymer to fibre is 70:30 is the weight ratio of polymer to fibre.

risk problem during fabrication (Mohammed et al., 2018; Prabhakaran et al., 2013; Sivakumar

In producing the composites, sheets of aluminum alloy, carbon fiber, kenaf and flax fiber were all cut 400mm x 400mm x 4mm and fabricated in a mould of 400mm x 400mm x 4mm, using a hand lay-up method. The epoxy resin/hardener was mixed accordingly and spread on each laid layers by use of the brush.

The fire test was conducted using a propane burner according to ISO 2685 standard. The test was started by calibrating the burner using and R-type thermocouples to measure the flame temperature and a heat flux meter (SBG01) to measure the heat flux according to the standard. The standard stated a flame temperature of 1100±80ºC and a heat flux of 116±10 kW/m^2. The burner was calibrated using seven thermocouples for temperature calibration that were 1-inch apart from each other and SBG01 for heat flux at a distance of 3 inches from the burner face. The calibration was started by turning on the propane gas and igniting the burner, then turning on the primary air and secondary air according to the stated gauge of the standard (propane 440Pa, primary air 4265Pa and secondary air 2940Pa)..

After the burner calibration, the fire test commences using a composite of 200mm x 200mm x 4mm each, three samples from each composite were tested and the average results were recorded using a data logger for each sample. The distance between the burner face and the plate sample was maintained at 3-inch, the samples undergo the fire test for 15 minutes. The composite that withstands the 15-minute flame fire was termed as fireproof composite while the one that fails before 15 and after 5 minutes was termed as fire resistant composite. Three K-type thermocouples were used to measure the rear face temperature of the plates; the thermocouples were placed at the centre of each plate, 1½-inches below the centre and 1½-inches left to the centre. Figure1 shows the burner assembly.

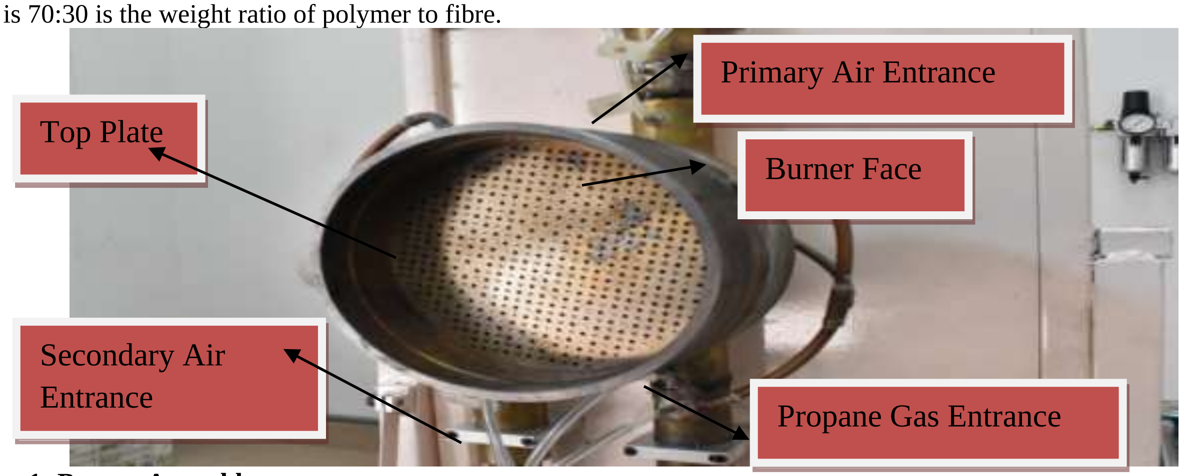

Figure 1: Burner Assembly

Result and Discussion

The properties result of all the composites considered in this investigation was presented in this section, which shows the result of fire behavioural properties of the two composites.
The fire test result of the two composites was recorded as presented in this section. The test was carried out using an ISO 2685 standard, which states the property of the material that withstands a flame fire of 1100±80ºC and a heat flux of 116±10 kW/m^2 for 15 minutes as fireproof materials and less than 15 minutes but greater or equal to 5 minutes as fire-resistant materials. The test uses a propane-air burner and the burner was calibrated before conducting the test; the calibration result shows that the burner was within the standard ranges for the flame temperature and heat flux. Table I shows the average result properties of the two composites under study.

Table I: Fire Properties of the Composite

Composites	Burn-through Time (s)	Observation
Flax	>900	Fireproof
Kenaf	630	Fire Resistant

The result obtained from the table shows that one of the composites was fireproof properties while the other one shows the fire resistant properties. From this result, it is clearly shown that the flax composite could be used in a high-temperature application for at least 15 minutes, whereas the kenaf composite can also be used in high-temperature application composite but with less burn-through time. The two composites could be used in aerospace and automobile industries, to prevent the flame fire from penetrating the component, for example in fire designated zone of an aircraft engine, where there is a required of high flame temperature blanket (firewall). Three K-type thermocoupleswere used to read the temperature of the rear face of the plate as stated in Mohammed et al. (2016) and it records the temperatures using a data logger, the result of the two composites was shown in Figure 2.

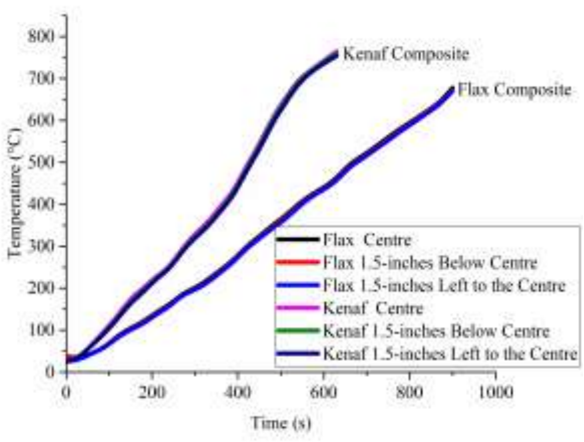

Figure 2: Rear face Temperature for the two composites

The relationships that exist between the time and flame heat temperature conduction is linear as seen from the graph. It is observed that the during the test aluminium alloy melts first before the flame reaches the fibres composite, which is in an agreement with the result reported by Bartlett & Stratford (2001). After the melting of metal alloy the flame was decelerated by the fibre bonded with epoxy resin and hardener, as the flame continues to impinge of the fibre composite a foam and charring formed and prevent the flame from much destruction for a time being, this nature was also reported by Sánchez-Carballido et al. (2017); Mohammed & Abu Talib (2019); Mohammed et al., (2018). After some minutes the flame penetrates the kenaf composite, but the flax composite withstands the standard flame up to 15 minutes.
The thermal conductivity of the two composites was determined using Equation 1 as:

$$K = \frac{W_x D}{A_x \Delta T} \qquad (1)$$

Where K is the thermal conductivity,W is the heat flow D is the thickness of the plate, A the area of the plate, and ΔT is the change in temperature. The thermal conductivity of the flax composite was found to be 1.1 W/mK which is 20.6% better than kenaf composite which is 1.4 W/mK.

Conclusion

The objective of the study was achieved by investigating the behavioural properties of the fabricated fibre metal laminates composites based on reinforced natural/synthetic fibres with thin sheets of aluminium alloy 2024-T3 at the top and bottom of the composite and a polymer matrix. The properties test results obtained shows that the fibre metal laminate composites under study will be capable to be used as a structural component due to its resistant to corrosion, lightweight material, high strength and stiffness and a flame resistant properties. The properties tests result indicates that flax composite, presents good properties result than the kenaf composite. Almost, the two composites considered show the same properties with the same behaviour during the test, but with a little or no differences. The fireproof behaviour of flax composite indicates that the properties of the flax natural fibre were a little bit similar to the properties of synthetic fibres more especially glass fibre. It is clearly seen that a greener fibre would be used in near future to replace the synthetic fibres due to its low cost, properties after treated and it is abundant in nature, required less fabrication process.

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