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Comparative Study of Jute, E-glass and Carbon Kevlar Fabric Reinforced Polypropylene Composite

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Abstract In this experiment, three types of fabric such as jute, E-glass and carbon Kevlar were selected to manufacture composites taking polypropylene (PP) as matrix material. The objective of this study is to compare the examined properties such as tensile modulus (TM), elongation at break percentage (EB %), E-Modulus (EM) of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. The properties of manufactured composite were evaluated experimentally using computerized UTM machine according to ASTM standards. Fourier transform infrared spectroscopy was used to identify the surface groups of the composites. Water absorption and fire retardant behavior of the composites were also performed. The results revealed that the tensile strength, E-Modulus and water absorption of carbon Kevlar composite were exhibited higher than the jute and E-glass fabric reinforced composites. Different scenario has observed for elongation percentage at break. The capacity of fire retardant was noticed higher in jute fabric composite than E-glass and carbon Kevlar.

Keywords Composite, Tensile Properties, Water Absorption, Jute Fabric, E-glass Fabric, Carbon Kevlar Fabric, Polypropylene (PP), Fire Retardant

1. Introduction

Nowadays, composites materials are broadly used in different diversified applications area because of their excellent and unique combination of physical and mechanical properties [1, 2]. Composites are extensively used in the civil constructions, chemical equipment and machinery constructions, electrical and electronic equipment, automobile and marine industries, aircraft manufacturing and many more [1, 3-6]. A lot of research works have been done on fibre reinforced composites with the synthetic matrix and synthetic reinforcements like glass, carbon, nylon and Kevlar fibres. Synthetic fibre reinforced thermoplastic composites are dominating over natural fibre reinforced composites due to their improved strength, stability, corrosion and moisture resistance properties [7-10].

Natural fibres have several advantages; for example, they have its low cost, low density, stiffness, high specific strength and modulus, recyclable, biodegradable, no health risk, easy and safe handling, light weight, easy availability, renewability, non-abrasiveness, easy processing, non-toxicity, high flexibility, acoustic insulation and much lower energy requirement for processing [11-17]. Among all the natural fibres, jute has comparatively better properties and appealed worldwide attention as a potential reinforcement of polymer composite because of its inherent properties such as high tensile strength, low density, inexpensive and abundantly available in tropical countries [1, 18-20].

Many researchers have investigated the various mechanical, thermal and physical properties of jute fibre reinforced composites. Different matrix materials were used in different research such as polyester resin, natural rubber, polypropylene, polyethylene, polycarbonate, epoxy resin, phenol formaldehyde etc [10, 21-28].

Glass fibers are used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced polymer (FRP) composite material called glass-reinforced plastic and most common types of used glass fibre is E-glass [29-33]. Many researchers explored many article regarding matrix comprised and properties of composites [34-39]. The wide application area including electronics, home and furniture, aviation and aerospace, boats and marine, medical, automobiles etc. of glass fibre reinforced composites has also discussed elaborately [29].

Kevlar fibre, due to its unique properties has become very popular as reinforcement in composite materials and its application has growth considerably. It is mainly popular for its increasing applications in industrial and advanced technologies like ballistic armor, helicopter blades, pneumatic reinforcement, sporting goods, etc. Compared to other synthetic fibers, it possesses significantly lower fiber elongation and higher tensile strength and modulus. Many researchers have been conducted characterization of Kevlar fibre and its composites in recent years [40-43].

The objective of this research work is to study the mechanical properties of jute, E-glass and carbon Kevlar fabric by incorporating them into polypropylene matrix to prepare the composites. Another goal of this investigation was to compare the properties between natural and synthetic fabric reinforced polypropylene composites. The composites were tested to evaluate the tensile properties such as tensile modulus, elongation percentage, and E-Modulus. Water absorption percentages and fire retardant property were also investigated.

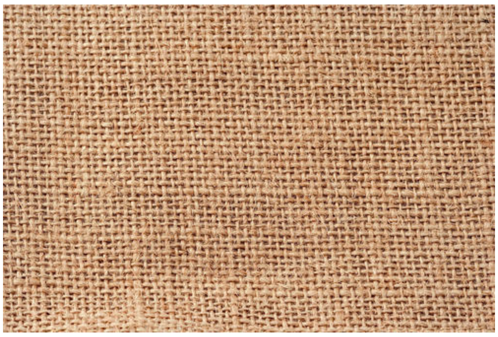

Figure 1. Jute fabric

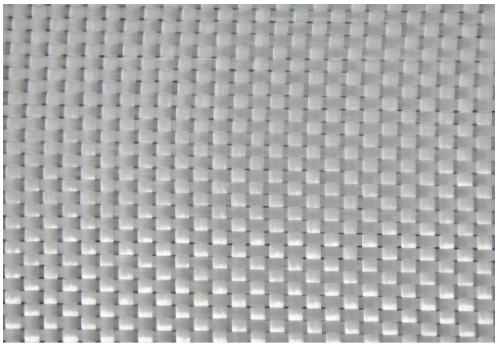

Figure 2. E-glass fabric

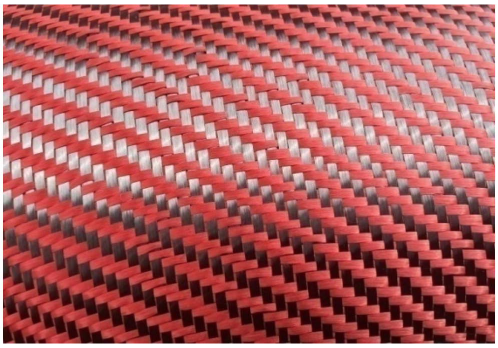

Figure 3. Carbon Kevlar fabric

2. Materials and Methods

2.1. Materials

2.1.1. Matrix

Polypropylene (PP) was used as matrix material in this experiment. Polypropylene (trade name: Cosmoplene) was purchased from Polyolefin Company Private Ltd., Singapore.

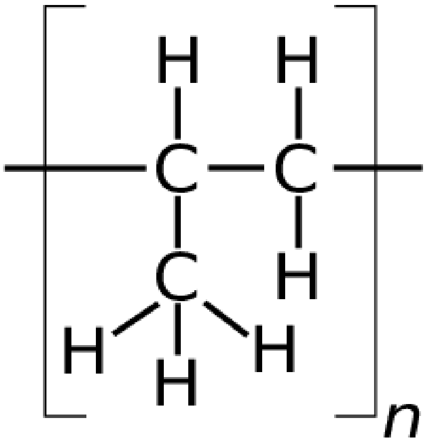

Figure 4. Molecular structure of poly-propylene (PP) [44]

2.1.2. Reinforcements

Three types of fabric such as jute, E-glass and carbon Kevlar were selected as the reinforcement in this study. Jute fabrics having plain weave structure were collected from Jute Research Institute, Dhaka, Bangladesh. E-glass fabric of plain weave structure and carbon Kevlar fabric of twill weave structure were purchased from Nasim Plastic Industries Limited, Dhaka, Bangladesh. Figure 1, 2 and 3 show the images of fabrics used in this experiment. The ends per inch (EPI), picks per inch (PPI) and areal density (GSM) of the jute, E-glass and carbon Kevlar fabrics are mentioned in the figure 5, 6 and 7 respectively.

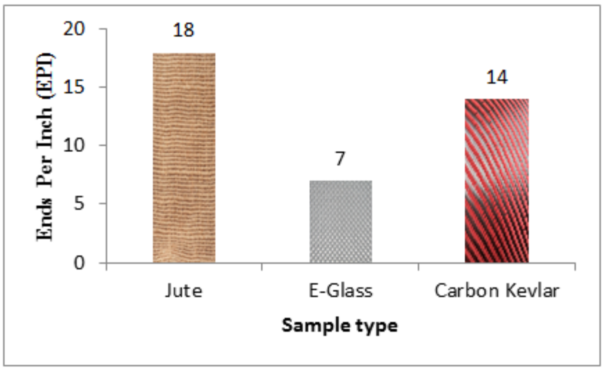

Figure 5. EPI of jute, E-glass and carbon Kevlar fabric

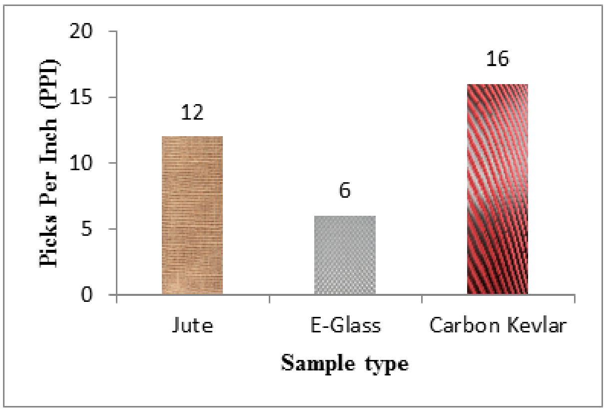

Figure 6. PPI of jute, E-glass and carbon Kevlar fabric

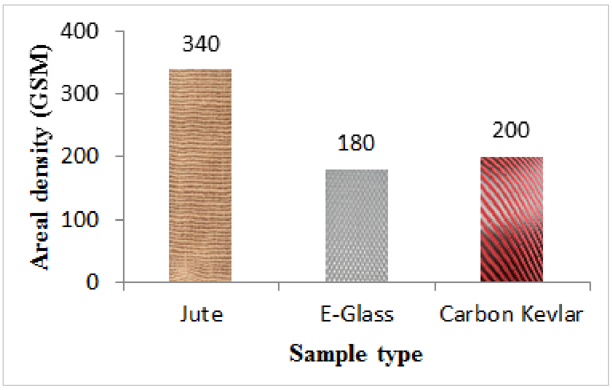

Figure 7. Areal density of jute, E-glass and carbon Kevlar fabric

2.2. Methods

2.2.1. Sampling

Different samples are identified as mentioned table 1.

Table 1. Sample Identification

Sample types	Identification
Jute fabric composite	JC
E-Glass fabric composite	GC
Carbon Kevlar fabric composite	CKC

2.2.2. Fabrication of Composites

Firstly, Polypropylene sheets were made from granules by placing them in between two steel plates in a heat compression molding machine maintaining the temperature 220 degree and pressure 5 ton for 10 minutes. The model of the machine was 3856, Carver Incorporation, USA. Cooling was done another compression molding machine of the same model for 5–7 min at room temperature using 5 metric ton pressure. The resultant polypropylene sheets were cut to the desired size (12 cm × 12 cm) for composite manufacturing. Then, Jute, E-glass and Carbon Kevlar fabric reinforced composites were prepared by using polypropylene sheet in both sides. Here, the temperature and pressure were kept as 220 degree and 8 ton respectively for 10 minutes. The silicon paper was used for making both polypropylene sheet and composites. Testing specimens were prepared from the composite sheet by cutting with grinding machine carefully. Here, matrix to reinforcement ratio was maintained as 80:20 for preparing all composite samples.

2.2.3. Testing of Samples

2.2.3.1. Determination of Tensile Strength, Elongation at Break and E-modulus

The tensile properties such as tensile strength (TS), elongation at break percentage (EB%) and E- modulus (Y) of the prepared composites were evaluated by a universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD, series S, UK) at Institute of Radiation and Polymer Technology Laboratory, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. The specimens were prepared according to ASTM D638 standard. Crosshead speed of 10 mm/min and a gauge length 20 mm were maintained during testing. Equation 1, 2 and 3 were used for measuring the tensile strength, elongation at break percentage and young's modulus respectively [28, 45]. Prior to testing all the testing specimens were conditioned at 25°C and 50% R.H for two days. All the mechanical properties of composites were tested under the similar conditions. The average value of five samples was taken as the final value of all tests.

$$\text{Tensile strength, (TS)} = \frac{\text{Fmax}}{\text{A}} \tag{1}$$

Where, F_{max}= Maximum load applied to the sample and A= Cross-sectional area of the sample.

Percentage of elongation-at-break was obtained by the following relation:

$$\text{EB (\%)} = \left(\frac{\Delta L_b}{L_0}\right) \times 100 \tag{2}$$

Where, ΔL_b = Extension at break point and L_0= Original length of the sample.

$$\text{E-modulus, (Y)} = \frac{d\sigma}{d\varepsilon} \tag{3}$$

Where, dσ = Stress at yield point and dε = Strain at yield point

2.2.3.2.Water Absorption

Water absorption ability of composite samples was carried out in de-ionized water. The experiment was done at room temperature (25 °C) into a glass beaker containing 100 ml water. The size of the specimens was 20 mm× 10 mm× 2 mm. The samples were dried in an oven at 105°C for 24 hr. before dipping. Then cooling was done in desiccators and immediately weighed. Then, composite samples were immersed in a static water bath at 25 °C for time interval of 1 hour (up to 4 hours). After certain periods of time, samples were taken out from the bath and wiped by tissue paper, then weighed. Water uptake percentage was calculated by using the equation 4 [45].

$$\text{Water absorption (\%)} = \left[\frac{W_f - W_i}{W_f}\right] \times 100 \qquad (4)$$

Where, W_i= Initial weight (oven dry weight) and W_f= Final weight (after immerse in water).

2.2.3.3. FTIR-ATR Spectroscopy Analysis

In order to investigate the possible changes in the chemical composition of the composites, FTIR-ATR analysis was done on the Perkin Elmer SPECTRUM BX in the range of 4000-400/cm.

2.2.3.4. Flammability Testing

Flammability test methods measure how easily materials ignite, how quickly they burn and how they react when burned. The materials are placed over a Bunsen burner horizontally and then calculate the rate at which the specimen burns.

3. Results and Discussion

3.1. Tensile Properties

3.1.1. Tensile Strength

Figure 8 depicts the tensile strength of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. Concerning the tensile strength, the samples orders were found as JC<GC<CKC. It is clearly evident from the figure 8 that the tensile strength of the samples GC and CKC were 74.61% and 200.16% higher respectively than the sample JC. The figure 8 also confirms that the tensile strength of carbon Kevlar fabric composite is higher than E-glass fabric composite.

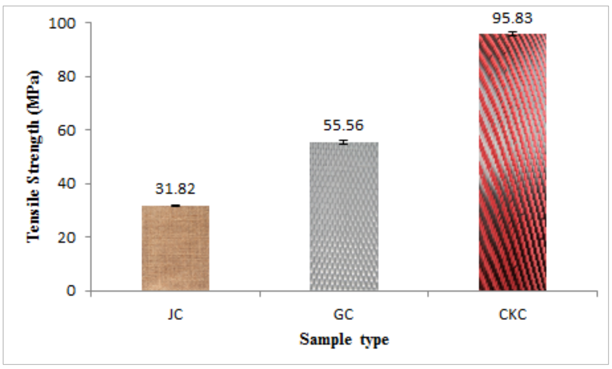

Figure 8. Tensile strength of Jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composite

3.1.2. Elongation at Break

The elongation percentages at break of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite specimens are presented in figure 9. Regarding elongation%, the samples orders were found as CKC<JC<GC. It is observed from the figure 9 that the percentages of elongation at break of the sample GC is 12.65% higher and 0.98% lower for the sample CKC than JC.

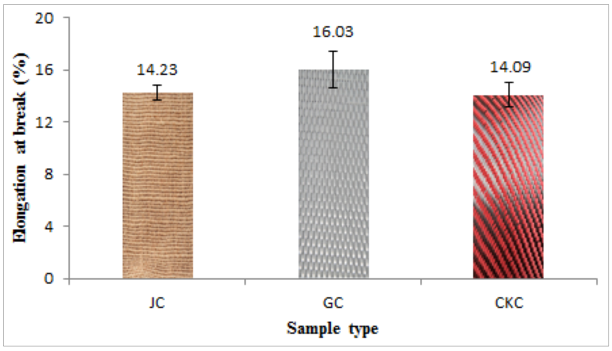

Figure 9. Elongation% of Jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composite

3.1.3. E-Modulus

Figure 10 illustrates the E-Modulus of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. The samples orders were found as GC<JC<CKC depending on E-Modulus. The E-Modulus of the sample GC is 20.14% lower and 128.34% higher for the sample CKC than JC.

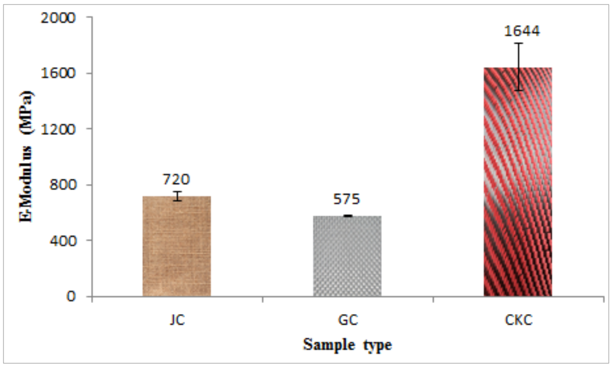

Figure 10. E-modulus of Jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composite

3.2. Water Absorption

Water absorption test is very important for determining degradability of the material in moist condition. The water absorption percentages of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite specimens are shown in figure 11 for different soaking time. The water absorption percentages were increased with the increasing soaking time. The samples of carbon Kevlar fabric composite were exhibited higher water absorption than jute and E-glass composite. The maximum water absorption (7.35%) was observed for the sample CKC at 4 hours soaking time.

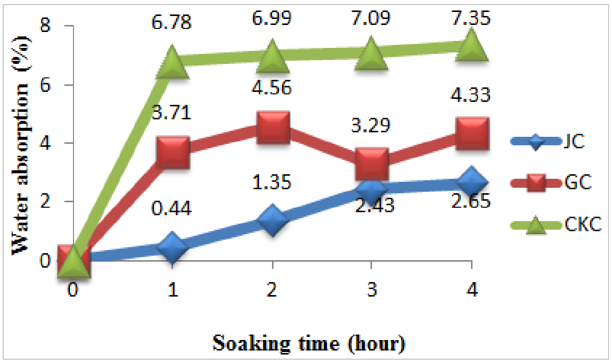

Figure 11. Water absorption of Jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composite

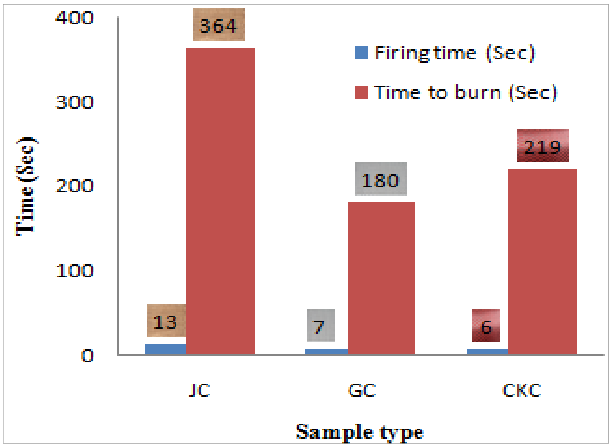

Figure 12. Fire retardant of Jute, E-glass and Carbon Kevlar fabric reinforced polypropylene composite

3.3. Fire Retardant Property

Figure 12 illustrates the fire retardant property of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite. The samples orders were found as JC>GC>CKC depending on firing time and GC<CKC<JC were found depending on burning time. The firing time of the samples GC and CKC were observed 46.15% and 53.85% lower respectively than JC. Accordingly, the burning time was detected as 50.55% lower for the sample GC and 39.84% lower for the sample CKC compared to JC.

3.4. FTIR-ATR Analysis

To examine the presence and the type of interfacial bond in the composites, FTIR experiments were performed at the range from 4000 to 400 cm^{-1}. Figure 13 represents the FTIR-ATR spectra of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composites.

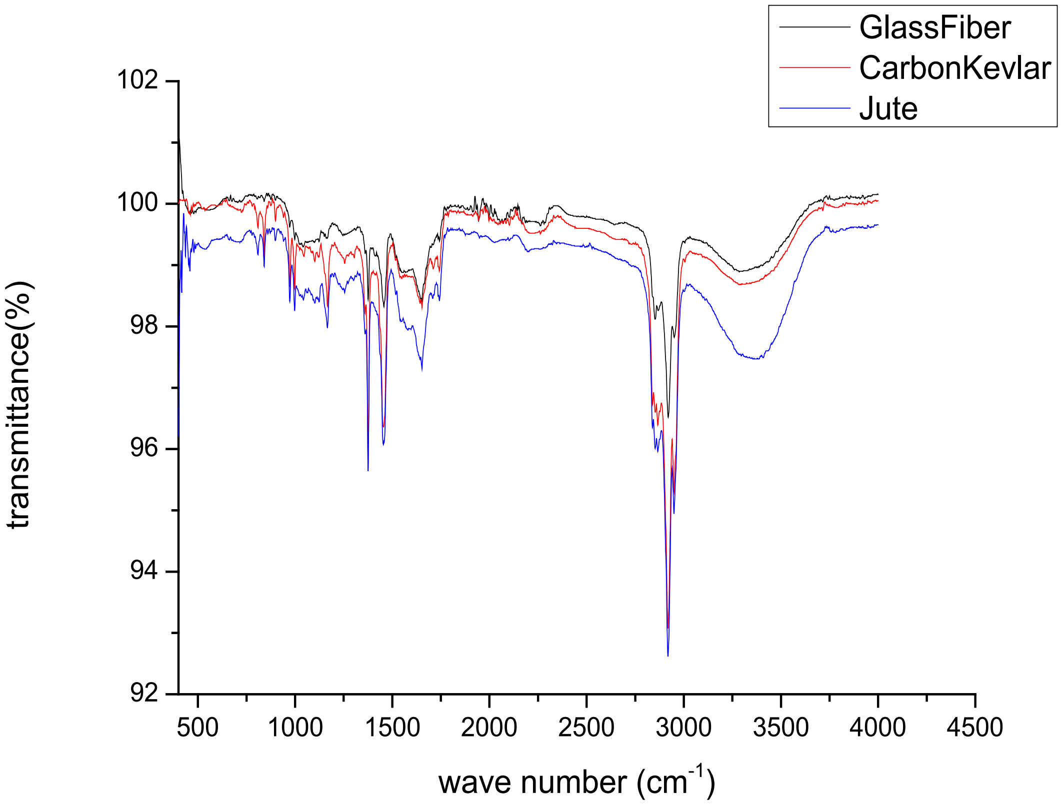

Figure 13. FTIR-ATR spectra of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composite

3200-3550 strong and broad peaks indicate O-H stretching bond for alcohol which is intermolecular bonded and 2500-3000cm^{-1} adsorption could be by alkane C-H bond, aryl or vinyl C-H bond, aldehyde C-H or carboxylic acid C-H bond. All alkane, alkene and alkyne C-H bonds have many tiny peaks. Alkene have very sharp peak around at 3300cm-1. Evidence of the presence of an aldehyde can be found around 2700-2900cm^{-1} mark (doublet peak) . And, carboxylic acid O-H bond appears as a wide, broad peak in the spectrum. Therefore, near 2900cm-1 peak is neither for sp2, sp hybridization nor aldehyde and carboxylic acid. Since, 2840-3000 cm-1 peak is due to alkane, therefore adsorption peak near 2900cm-1 is responsible for alkane. Peak on 1465 is due to C-H bending of alkane for methylene group and 1450 cm-1 C-H bending of alkane for methyl group. In conclusion, it is clear, peak near 2900cm-1 is due to alkane, near 1450 for C-H bending of methyl group and 3200-3500 cm^{-1} because of O-H group [46].

4. Conclusions

In this study, tensile, water absorption and fire retardant properties of jute, E-glass and carbon Kevlar fabric reinforced polypropylene composites were investigated. The tensile strength as well as E-Modulus and water absorption of carbon Kevlar composite were exhibited better results than the jute and E-glass fabric reinforced composites. Different scenario has observed for elongation percentage at break. The capacity of fire retardant was noticed higher in jute fabric composite than jute and E-glass. Further investigation will be done to improve processing, to expand the application fields for jute E-glass and carbon Kevlar composites.

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