Proceedings of the
International Conference on Mechanical Engineeringand Renewable Energy 2015
(ICMERE2015) 26 – 29 November, 2015, Chittagong, Bangladesh

ICMERE2015-PI-216

CARBON/KEVLAR REINFORCED HYBRID COMPOSITE: IMPACT OF MATRIX VARIATION

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Abstract*-High performance composite materials are now being explored in wide scale for the application in aerospace and automotive industries. Different high performance fibers are extensively used for this purpose. Among the high performance fiber, carbon and Kevlar fibers have very high specific strength and toughness and provide wonderful mechanical properties. This experiment was performed using Carbon/Kevlar (CK) as a reinforcing materials along with polypropylene (PP), polyester (PE) and epoxy resin. CK/PE and CK/epoxy composite were fabricated by conventional open mold process whereas CK/PP composite were fabricated by hot compression technique. Three layers of CK were used with the three types of matrix system. Different mechanical properties such as tensile strength, tensile modulus, elongation at break, bending strength, bending modulus and impact strength was reported and compared. It was observed that CK/epoxy composite showed better mechanical properties than the other composite specimens.*

Keywords: Carbon/Kevlar, polypropylene, polyester, epoxy, mechanical properties

1. INTRODUCTION

The use of fiber reinforced composite materials are increasing day by day due to their excellent mechanical, corrosion and wear resistance properties. They are widely used in different high performance applications such as aerospace, naval, automotive vehicle, construction etc [1]. These composite materials are advantageous over conventional materials (iron, steel and aluminum alloys) because their light weight, good fatigue performance, design flexibility and low through life maintenance and processing costs [2]. Composites are two distinct type materials combine together to enhance their individual properties. A continuous phase are embedded by one or more discontinuous phase. The discontinuous phase support and provide strength to the composite called as reinforcement, whereas the continuous phase is known as matrix which hold the reinforcement together [3]. Different high performance fibers such as carbon, boron, graphite and kevlar have been emerged as a new generation of high performance materials in the last decade [4].

Carbon fibers yield superior strength and stiffness than other fibers but can often have limited extensibility and poor damage tolerance while Kevlar fibers have higher degree of toughness and damage tolerance and its hybridization could be a suitable solution to the limitations of carbon fibers [5]. Hybrid composites are identified as the use of two or more distinct materials combine in a single matrix. Hybrid composites show some unique features which cab used to meet the exact requirements of structure under consideration. Compared to monolithic composite hybrid composites have given technological advances because they provide more balanced properties. Some specific advantages of hybrid composite over monolithic composites include balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal distortion stability, reduced weight and/or cost, improved fatigue resistance, reduced notch sensitivity, improved fracture toughness and/or crack arresting properties, and improved impact resistance [6]. There are various types of hybrid composites identified as: (1) interplay- where two or more constituent types of fiber are reinforced together either regular or random orientation; (2) sandwich hybrids or core-shell- in this type of composites one material is sandwiched between two layers of another; (3) interply or laminated, where alternate layers of the two (or more) materials are stacked in a regular manner; (4) intimately mixed hybrids, in this type of composites reinforcing fibers are mixed randomly to ensure homogenous distribution; (5) other kinds or super-hybrid which are based on organic polymer and metal matrix [6,7].

Matrix materials play crucial role in fabricating composite materials. Load is transferred to reinforcement by matrix and provide the composites toughness, damage tolerance and impact resistance. Thermoset and thermoplastics are two distinct type of matrix commonly used in polymeric composite materials. Thermoset matrices includes PE, vinyl esters, epoxies, bismaleimides, cyanate esters, polyimides, and phenolics etc. On other hand Polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyphenylene sulfide (PPS), and PP are semicrystalline thermoplastics, while polyetherimide (PEI) is an amorphous thermoplastic matrices [8]. Matrices influences the ultimate thermo-mechanical characteristics of the composite and also have a major influence on the interlaminar shear, and on the in-plane shear properties [9]. While thermoplastic matrices dominates the short fiber reinforced composite; the long and continuous fiber reinforced composites are dominated by thermoset matrices due to their suitability in impregnating the fiber reinforcement. Although they are used very widely but they shows some shortcoming such as low storage temperature, complex and long curing process etc. result in defective manufacturing process. In this situation, thermoplastic matrices may be a good option but higher processing temperature is required. Hence viscosities make the processing difficult. In addition cost of thermoplastic matrices are higher than thermoset [10, 11]. In this regard variation in matrices affects the properties and processing of composite materials directly. The aim of this study is to investigate the effect of matrix variation on the CK hybrid composite by evaluating their different mechanical properties.

2. MATERIALS AND METHODS

2.1 Materials

Carbon-Kevlar (CK) fabric was collected from CHN Carbon Fiber Technology Co., Ltd., China. Carbon and Kevlar used in this experiment were T 300 (3K) and K 29 (1500D) respectively. The linear area density of the fabric was 195 gm/m2 and weave structure of the fabric was 2/2 twill using carbon in warp and Kevlar in weft as shown in the Fig. 1. In this weave structure a warp and weft were interlaced in in two upper and two lower alternating positions mutually perpendicular so a bi-directional orientation was established. Warp and weft density were the same and 5 filaments per 10 mm. Epoxy (Bisphenol A Di-glycidyl Ether) and epoxy hardener used in this experiment were supplied by Polyolefin Co. Ltd, Singapore. PP granules and unsaturated polyester resin manufactured by Cosmoplene Polyolefin Company Ltd, Singapore, were used as received. Methyl ethyl ketone peroxide (MEKP) used as hardener for unsaturated polyester.

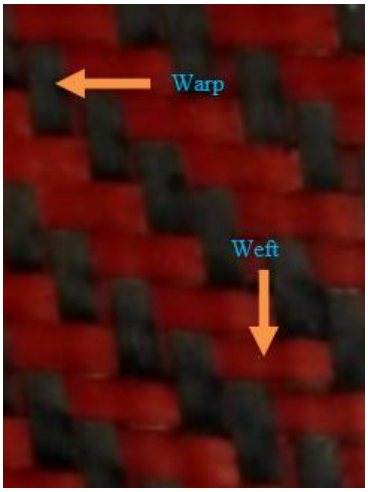

Fig.1: Digital image of CK fabric indicating the yarn position in the fabric

2.2 Methods

Composite Fabrication: PP sheet were produced by using granules of PP weight about 10 mg. Granules of PP were placed between two steel plates and then into the heat press (Carver Inc, USA, Model 3856). The heat press machine was operated at 180°C. Steel plates were pressed at 5 bar consolidation pressure for 7 min. The plates were then cooled for 5 min in a separate press under 5 bar pressure at room temperature. The fabricated PP sheet was cut into desired size for composite fabrication. Composite were prepared by sandwiching 3 layers of CK fabrics between 4 sheets of PP. The fabric weight fraction in the composites was 45:55. On the other hand, CK/PE was fabricated by conventional hand layup technique. The low temperature curing polyester resin and corresponding hardener were mixed by weight as recommended. For composite fabrication, the cast of each composite is cured under a load of about 20 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. To fabricate CK/epoxy composite same procedure was followed as like as CK/PE.

Mechanical testing of the composites: Tensile tests were conducted according to ASTM D 638-01 [12] using a Universal Testing Machine (UTM), Hounsfield series, model: INSTRON 1011, UK with a cross-head speed of 10 mm/min. The dimensions of the test specimen were (ISO 14125): 60 mm × 15 mm × 2 mm. Bending test of the composite was carried out according to ASTM D 7264 using the same machine as mentioned above at a cross head speed of 5 mm/min.

Impact test for different fabricated composites were carried out according to ASTM D-256. The length and width of the samples used in impact test were 61.5 mm and 12.7 mm respectively. CK samples prepared for tensile tests shown in the Fig. 2. Fig. 3 represents the CK samples after tensile strength test.

Fig.2. CK samples for tensile test

Fig.3. CK samples after tensile test

3. RESULTS AND DISCUSSION

Woven CK fabric was reinforced in thermoset and thermoplastic matrices by hand layup process and heat press technique respectively with fabric percentage of 45. The mechanical properties such as tensile strength, tensile modulus, elongation at break, bending strength, bending modulus, impact strength were evaluated. Five samples of different types of composites were tested and their average value were recorded.

3.1Tensile testing of the composite

Tensile strength and tensile modulus of CK composite as a function of various matrices are presented in the Fig. 4 and Fig. 5. It is found from the Fig. 4 that CK/epoxy has the maximum tensile strength than the other sample. On the other hand CK/PE shows lower tensile strength. The tensile strength of CK/epoxy is 76.40% higher than the CK/PE composite. The tensile strength of CK/PP composite is 224.0 MPa. Fig.5 depicts the tensile modulus of the fabricated composite specimens and it is observed that tensile modulus shows the same pattern as observed in tensile strength. CK/PE shows 66.85% decrease in tensile modulus than the CK/epoxy composite (2.607 GPa). CK/PP composite shows the moderate tensile modulus 1.479 GPa. This can be attributed to the higher tensile strength of matrix materials since matrices influence the composite directly. Therefore, the higher tensile properties of epoxy leads in higher tensile properties in composite materials.

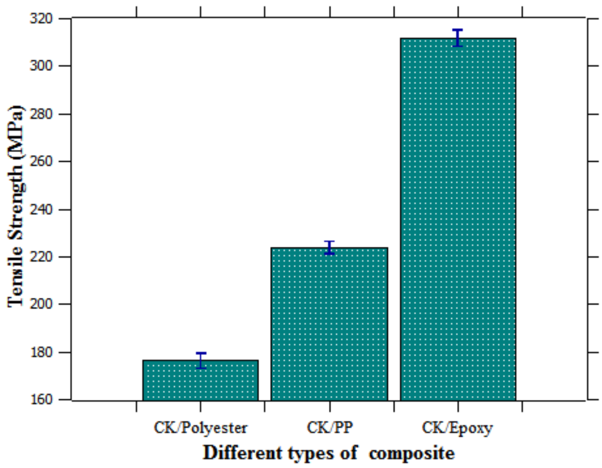

Fig.4: Tensile strength of CK composite against different matrices

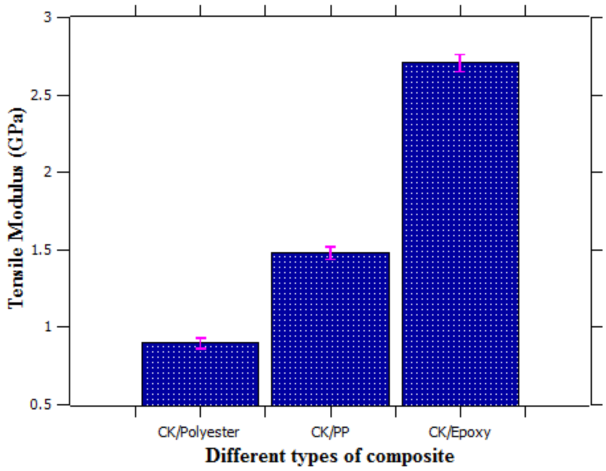

Fig.5: Tensile modulus of CK composite against different matrices

3.2 Elongation at break%

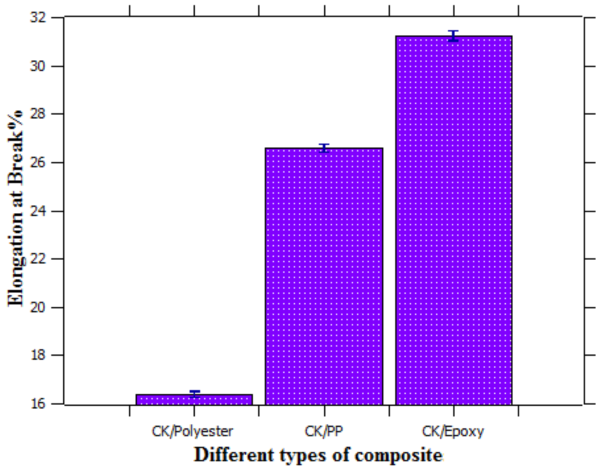

Fig.6: Elongation at break of CK composite against different matrices

Elongation at break% of different composite specimens is shown in Fig. 6. It is observed from the Fig. 6 that CK/PE shows very small amount of elongation% while

CK/epoxy shows higher elongation property. CK/PP composite shows 26.59% elongation before breaking. The reduction in failure can be attributed to the increase in stiffness of composite materials. The reason behind higher failure value is the flexibility of the reinforcement. In addition, when load is applied, matrices distribute the load across the reinforcement. Therefore, if the matrices fails to distribute applied load on it then composite break early without further elongation.

3.3 Three point bending test

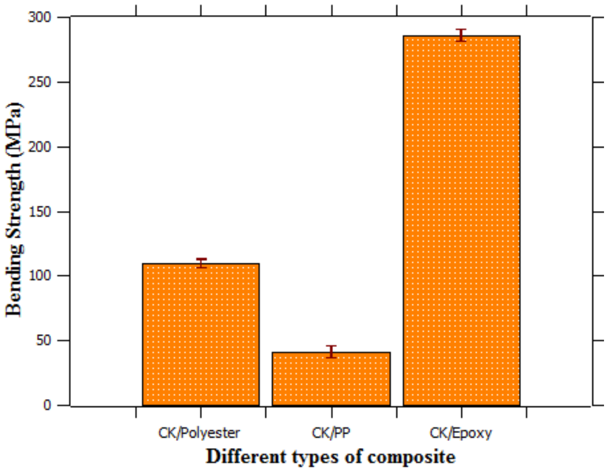

Fig.7: Bending strength of CK composite against different matrices

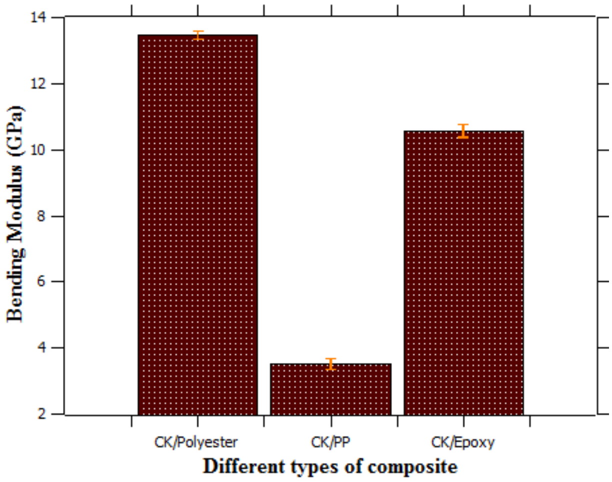

Fig.8: Bending modulus of CK composite against different matrices

In the next bending test of CK composite was performed and result is presented in the Fig. 7 and Fig. 8. Different mechanics such as tension, compression, shearing, etc. are experienced by the specimens under bending test unlike tensile test [13]. Three point bending test results of the composite samples show that bending strength of CK/epoxy composite is very high compared to other sample whereas CK/PP shows lower bending strength of 41.30 MPa. It is interesting to note that bending strength increased dramatically by almost 600% from CK/PP to CK/epoxy. CK/PE shows bending strength 109.80 MPa. Since bending properties is measured by shear force so in this case epoxy matrix composite can resist the maximum force applied on it due to its higher tensile strength and tensile modulus.

Bending modulus test result shows that CK/PE has the higher modulus whereas CK/PP shows the same result as like bending strength. CK/PP shows the lower bending modulus of 3.51 GPa. The decrease in bending modulus for CK/epoxy may be due to the poor fiber matrix adhesion in the composite sample.

3.4 Impact test

The excellent impact resistance properties of Kevlar fibers makes it suitable for impact related applications such as ballistic, aerospace, automotive, maritime and sports [14,15]. Designing perfect materials it is expected to increase the energy absorbing capacity of the materials along with light weight characteristics [16]. Impact strength is characterized by the total energy absorbed by the composite before final failure. Impact test result of different composite specimens are shown in the Fig. 7. It is found that CK/epoxy has the higher impact strength of 202.70 kJ/m2 compared to other samples. Impact strength of CK/PP decreases 40% compared to CK/epoxy. The impact strength of CK/PE is found to be 144.58 kJ/m2 which is around 19% higher than CK/PP.

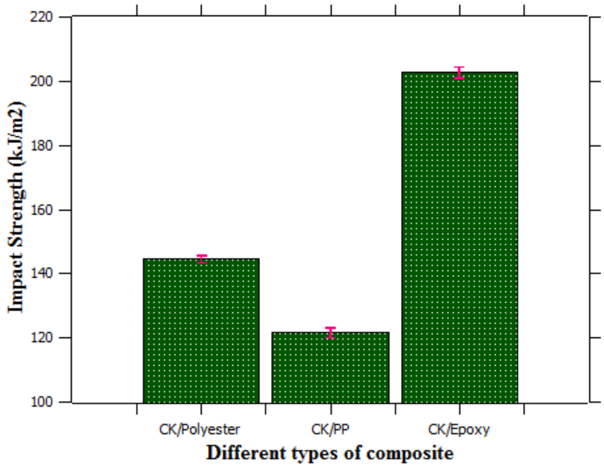

Fig.9: Impact strength of CK composite against different matrices

4. CONCLUSION

CK reinforced PP, PE and epoxy composite were successfully fabricated using compression molding machine and hand layup process and their mechanical properties were evaluated. A significant improvement in tensile and bending properties was obtained for various matrix materials. Maximum tensile as well as bending properties was exhibited by the CK/epoxy composite except bending modulus compared to other matrix material. Higher bending modulus was found for CK/PE composite materials. In general, CK/PP shows the poor mechanical properties compared its counter composite specimens.

5. ACKOWLEDGEMENT

The authors would like to thank Institute of radiation and polymer technology (IRPT) for providing the laboratory facilities to conduct this experimental study.

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