Studies on Mechanical Investigation of Carbon Fiber/Fly Ash Reinforced Epoxy Hybrid Composites

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ABSTRACT

EDAX and SEM images studies of fly ash reveals the chemical constituents present as spherical formed particles with diameter of less than 5 μm. The constituents of fly ash are calcium, alumina, silica and traces of other elements. The use of polymer matrix namely the epoxy (thermosetting) has been prepared by many researchers to develop polymer matrix fly ash particulate composites by using the basic properties of fly ash and light weight of polymers. Such composites have some poor mechanical properties stability. To prevail over these drawbacks, in carbonaceous matrix, the carbon fibers were added as additional reinforcement along with the fly ash formed particles at varying weight percentage. The hybrid composite laminates were fabricated by hand layup method. The mechanical characters of samples prepared as per ASTM were studied, such as tensile, flexural, impact and hardness. Among the samples fabricated and tested involving optimized percentage of fly ash filler present in hybrid, the mechanical assessment revealed to have higher strength, hardness and lower impact strength as compared to other of hybrid fly ash filled particulate composites.

Keywords: *Carbon fiber, Fly ash filler, Thermosetting, Hybrid.*

1. INTRODUCTION

Composites materials has always been answer for many engineering problems which is composed of matrix, helps in providing the binding action, protect the composite from external surrounding and many other things, whereas the reinforcement play the major role of forming physical part of the material system and also helps sustaining various mechanical loads when applied, thus showing its strength and stiffness of the composite. For many engineering areas, composite have providing solutions namely the automotive, electrical, electronics, marine and other field also [1].

The composite can be produced by using various matrix systems namely metal, ceramic and polymer type. Among those matrix materials, the polymer matrix finds the most common used to achieve the desired requirements for a designer or researchers. One type of polymer matrix being used at the most for higher property in the composites is thermosetting based. They provide improved results when compared with thermoplastics due to various technical advantages [1].

The present world is quite depending on hybrid materials, which can give better and enhanced properties in material system so it can solve problems faced in industries, to build modern world. The composite has shown new paths to researcher, when it comes to hybridization. The hybrid composites have given wide scope for material developers or designers to explore the newer way of developing the hybrids that can lead the engineering world to its greater heights [1].

Most of the engineers have made attempts to contribute more on fiber reinforced polymer type hybrids that can reduce the cost, improved quality and better properties. To develop newer hybrid system in polymer based composite has always a challenging task for the researchers. Normally, the hybrid system calls for different reinforcements with single matrix system or vice versa [1].

The advances in the hybrid has lead to use of fillers materials, that can act as secondary reinforcement to improve the especially mechanical properties, enhance thermal stability, provide good toughness, strength etc… The filler material has helped researcher to look at newer material that can promise in some betterment in the hybrid system [2].

The polymer composite fiber reinforced based category with filler has shown new trend in developing materials. The polymer (thermosets - epoxy) composite has been key factor in the world of composites, due to its ability to produce tailored made material with better properties. The reinforcement material, especially the fiber based has always stood up to the mark, as its nature is to provide good mechanical and other properties. The fiber reinforcement namely carbon fiber, Kevlar, glass and much other fiber has been proven materials for engineering fields [1].

The use of fillers into the composites has remarkable improved the material ability to sustain the various mechanical environments'. Filler can be organic or inorganic based; with different shapes and sizes with proven abilities when added in right proportion to the main material system. Fillers namely silicon carbide, graphite, boron nitride and many more have put in use in composite. Now days, researcher have also concentrated on using Fly ash – an thermal power plant by-product processed to meet the requirement are also trending in the research [2]. Many attempts have been made to understand the basic effect of fly ash on the composite by researchers and addressed its pros and cons of using it. Still it is also a filler system, where new researchers can concentrate and try to modify its nature that may help the materials world. Material properties requirement may change time to time in the engineering areas for which we need to strive and provide newer once.

Literature survey has been carried out on the previous work done by researchers to understand the effect of fly ash as a filler in fiber reinforced polymer hybrid composites at different proportions.

Rao et al. [4] have studied the effect of macro fillers including the fly ash which resulted in increasing the strength and durability of a composite with modified matrix system. Gollakota et al. [5] have presented a review on use of fly ash and its effects on the environment and still calls for better utilization of the material. [6] Kumar et al. in their mechanical investigation on carbon fiber reinforced with epoxy in addition of fly-ash particulate at micron sizes has revealed the lowering of the impact and tensile strength. Sangamesh et al. [7] have worked on Synthesis of fly ash with epoxy composite and also made a study of mechanical behavior of the material system. The results showed better properties in fly ash reinforced over silica particles. Verma et al. [8] have mechanical assessed properties of epoxy filled E-glass fiber in addition of fly ash filler hybrid composites and resulted in improved in flexural strength of the material. Bhandakkar et al. [9] conducted the fracture test of category Mode I Interlaminar fracture toughness on glass fiber reinforced epoxy filled fly ash at 10% wt. The tested hybrid samples showed improved toughness by the addition of fly ash. Srivastava et al. [10] investigation revealed that flyash particles have decreased the fracture properties and the modulus of elasticity as the increased addition of flyash into hybrid was done. Ramakrishna et al. [11] have conducted the mechanical test on the fly ash epoxy composites, the results reveals that the fly ash in the toughened matrix system inhibit the improved compression modulus over pure epoxy–fly ash composites. Mishra et al. [12] investigated the mechanical properties of fly ash based hybrid composites which revealed the tensile property can be improved as filler addition is increased. Works of many researchers seems to have some gap that can be worked upon.

Considering this, an attempt is made to understand the Mechanical abilities as per ASTM standards [3] of hybrid composite which consists of carbon fly filled at varying weight percentages with epoxy reinforced hybrid composites fabricated by hand layup technique.

2. Materials and Methods
2.1 Materials

Epoxy (L-12) with hardener K-6 was used as resin matrix as matrix system. Carbon fiber with 300 gsm was selected as fiber reinforcement for and fly ash filler as shown in figure 1. Fly ash is used as secondary filler with particle size less 5 microns at 10%, 20% and 30% of weight fraction for fabrication of Hybrid laminates of hybrid composites with ±6 mm thick.

Figure 1. Fly ash Particles

2.2 Fabrication Method

The hybrid laminates composite were fabricated at using hand layup technique and were cured at room temperature and later cut in water jet machining to maintain samples according to ASTM standards [3] as shown in Figure 2.

Figure 2. Samples

2.3 Energy Dispersive X-Ray Analysis (EDAX)

Energy Dispersive X-Ray Analysis (EDX), referred to as EDS or EDAX, is an x-ray technique used to identify the elemental composition of materials. The EDAX result analysis revealed a rough estimate of the composition of the fly ash containing more amounts of potassium, present followed by silica, carbon, aluminum contents present in the received fly ash particles as shown in figure 3.

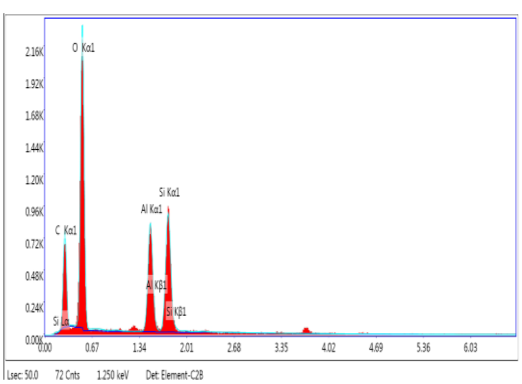

Figure 3. EDAX result of fly ash filler

2.4 SEM - Morphology of Fillers

From the SEM images the particle size were measured and was found to be circular shape of the filler and it measured less than 5 microns as shown in figure 4.

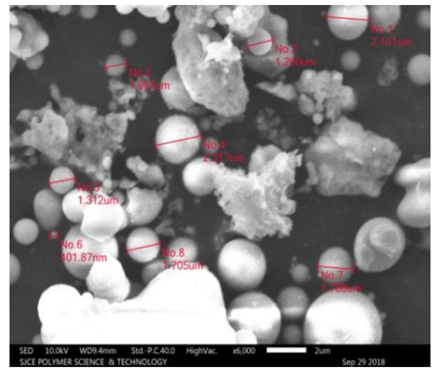

Figure 4. SEM of Fly ash Particles

3. Mechanical Testing

3.1 Tensile Test

The tensile testing of hybrid composite specimens was conducted on 100 KN capacity Kalpak universal testing machine. The tensile testing was carried out at 5 mm/min cross head velocity as per ASTM D638 [3].

3.2 Flexural Test

The flexural testing of hybrid composite specimens was conducted on 100 KN capacity Kalpak universal testing machine. The flexural testing was carried out at 0.3 mm/min cross head velocity as per ASTM D790 [3].

3.3 Impact Test

The Charpy Impact testing of hybrid composite specimens was conducted on Pendulum impact tester according to ASTM D256 [3].

3.4 Hardness Test

The Shore-D Hardness testing of hybrid composite specimens was conducted on Shore D hardness tester according to ASTM D2240 [3].

4. Results and Discussions

The tensile strength of hybrid composite at 20% wt. fly ash filler, the ultimate tensile strength is 140.12 Mpa which seems to show a better value than when compared to others. There is a possibility of tensile properties has improved at increased filler addition in the material system as shown in the table 1 and figure 5.

Table 1. Tensile test result of Hybrid Composites

Material	Maxim. Load in N	Ultimate Tensile Stress in MPa
CGE10F	9856.382	127.040
CGE20F	10728.098	140.126
CGE30F	8782.089	139.292

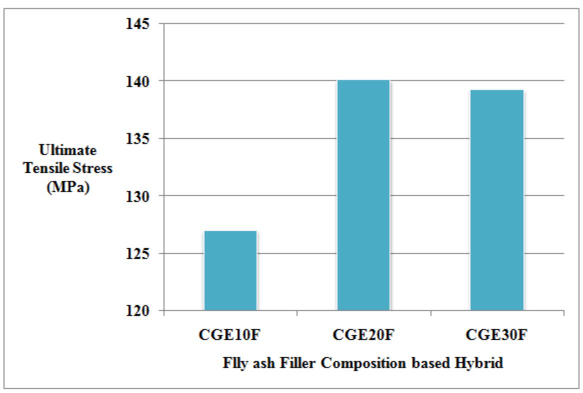

Figure 5. Comparison of ultimate tensile stress of Hybrid Composites

The flexural test – a three point bending was carried out on the hybrid. The results reveal that the, maximum flexural strength is of 11472.15 MPa at 30% fly ash, which has significant effect on the flexural property of the hybrid system as it is added further at 30 percentage by weight, as it shows from the table 2 and figure 6 on comparison with other samples of different laminates .

Table 2. Flexural test result of Hybrid Composites

Material	Maxim. Load in N	Maxi. Flexural Strength in Mpa
CGE10F	1357.390	8013.830
CGE20F	1154.421	6,847.428
CGE30F	767.937	11472.158

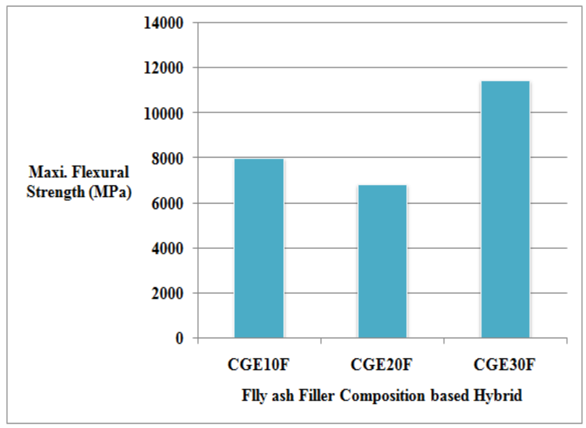

Figure 6. Comparison of Maxi. Flexural Strength of Hybrid Composites

The charpy impact test results reveal that at 20% of fly ash hybrid the impact strength is higher of 56.78 kJ/m² as shown in the table 3 when compared with other samples of laminates.

Table 3. Charpy Impact test result of Hybrid Composites

Material	Charpy Impact Strength (kJ/m²)
CGE10F	41.60
CGE20F	56.78
CGE30F	39.56

The shore D hardness of hybrid laminate at 10% fly ash filler content has resulted in hardness of 83 value when compared with others as shown in the table 4. It seems the filler has played less role in providing higher hardness in the hybrid has the filler addition increased.

Table 4. Shore D Hardness result of Hybrid Composites

Material	Shore D Hardness Number
CGE10F	83
CGE20F	80
CGE30F	78

CONCLUSION

The fabrication of hybrid composite laminates at 10%, 20% and 30% fly ash filler weight percentages has been done. Their mechanical assessment was carried out as per ASTM standards. The following conclusion was drawn are as follows:

a. From the tensile test, it is observed that as the percentage of fly ash increased at 20%, the tensile stress of the sample reached its optimized level.

b. Fly ash particles have very less effect on the hardness of the hybrid composites.

c. From the flexural test, it is observed that as the percentage of fly ash increased at 30%, the maxi. Flexural strength of the sample reached its highest level.

d. It is also seen from the EDAX and SEM details the fly ash particles have approximately spherical form and greater percentage of calcium has some effect on tensile, flexural and impact strength of the hybrid.

e. We expect the filler distribution would not taken place uniformly due to manual stirring while mixing it to the matrix system.

f. Out of all these samples, may be the sample with 20% of fly ash may be suitable for mechanical applications.

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