Effect of MWCNT and other fillers on Mechanical properties of Epoxy Based Hybrid Composites for Elevated Temperature Application

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***Abstract*- In the present study, possibility of improving mechanical properties of Epoxy Resin (ER) composites is investigated. Five ER based hybrid composites were made by varying weight percentages of BaSO4, activated carbon powder and MWCNTs. Hardness, Impact and Tensile tests were conducted on the hybrid composite at elevated temperatures. These properties improved significantly at 15.2% ACP, 4% BaSO4, 0.8% MWCNT. Epoxy Resins by varying MWCNT's, other Reinforcing and filler materials enhanced the said mechanical properties upto 150°C.**

***Index Terms*- EBHCM (Epoxy Based Hybrid Composite Material) MWCNT (Multi Walled Carbon Nano Tubes), Al2O3, SiC, BaSO4, ACP (Activated Carbon Powder), Elevated Temperature.**

I. INTRODUCTION

The most common and advanced composites are Polymer Matrix Composites (PMC's). A polymer is a large molecule, or macromolecule, composed of many repeated sub units, known as monomers. Because of their broad range of properties, both synthetic and natural polymers play an essential and ubiquitous role in everyday life. While the polymers are used extensively in everyday life, their industrial applications are few due to their low mechanical properties at elevated temperatures.

Recently, research has been carried out to evaluate the effect of nanoparticles on mechanical properties of polymer composites [1]. One of the promising Nano reinforcements is carbon Nanotubes (CNTs) [2,3,4,5] which gave exceptionally high mechanical properties improvement for polymer composites.

The main objective of this study is to investigate with experiments on Hybrid Composite materials at elevated temperatures [6,7]. The test specimens were prepared with Epoxy as matrix and Multi Walled Carbon Nano Tubes (MWCNT) with other constituents [8, 9, 10, 11] as reinforcements.

II. PROCEDURE

Five different compositions of composites were made by blending all seven components and varying the percentage of $BaSO_4$, Activated Carbon Powder and MWCNTs [1],[7]. The specimens were fabricated at Reinforced Plastic Industries, Bangalore, India. The content of each composition by weight in grams is given in Table 1.1

Table 1.1: Composition of specimen in weight in grams

Specimen No Components By Weight	1 (gms)	2 (gms)	3 (gms)	4 (gms)	5 (gms)
Epoxy Resin	200	200	200	200	200
Aluminium Oxide	40	40	40	40	40
Silicon Carbide	40	40	40	40	40
Chopped E-Glass Fiber	40	40	40	40	40
Activated Carbon Powder	14	29.6	45.2	60.8	76.4
Barium Sulphate	64	48	32	16	0
Multi-Walled Carbon Nanotubes	2	2.4	2.8	3.2	3.6
Total (gms)	400	400	400	400	400

First the materials were weighed as required. Then they were put together and mixed well. The mixture was then poured into a pre-prepared mould of the thickness as per ASTM D638 for tensile test specimen, ASTM D256 for Impact test specimen and

ASTM D 2240 for hardness test. Weighing and mixing of the constituents are shown in the Figure 1.

Figure 1- Weighing and mixing of the constituents.

The mixture was poured in excess into a pre-prepared mould and subjected to compression moulding technique which is shown in Figure 2.

Figure 2 -Preparation of Mould and Curing of composite.

III. EXPERIMENTAL WORK

A. Hardness test

Shore-D hardness tests were conducted on specimen according to ASTM D2240 using Durometer shown in Figure 3. The hardness tester was placed on the specimen and pressure was applied so that the flats underneath the tester touch the surface of the specimen. The readings were taken directly from the dial. The specimens were then heated to different temperatures and the readings were taken to determine the variation in the hardness of the specimen with respect to temperature.

Figure 3- Shore-D hardness testing machine

B. Impact Test

Izod impact tests were conducted on V-notched composite specimen according to ASTM D256. A Pendulum impact tester, shown in Figure 4 was used for this purpose. Dimension of the specimen was 64 mm x 12.5 mm x 3.2 mm. The pendulum impact testing machine ascertains the impact strength of the material by shattering the specimen with a pendulum hammer, measuring the spent energy and relating it to the cross section of the specimen. The respective values of impact energy of different specimen were recorded directly from the digital indicator and reported.

Figure 4-Izod Test

C. Tensile Test

Tensile tests were conducted according to the ASTM D-638. Computerized Universal Testing Machine (UTM) used for this purpose. The dimension of the tensile specimen was 165 mm x 19 mm x 3.2 mm. Gauge length was 50 mm. Results were used to calculate the tensile strength of composite samples.

Figure 5-Tensile Test

IV. RESULTS AND DISCUSSION

A. Effect of MWCNT and other constituents on Hardness Test

The hardness readings of the specimens were obtained directly from the Shore-D hardness tester. The specimens were heated to four different temperatures by a hot air oven and the readings were taken.

The Figure 6 shows that, Hardness at elevated temperatures the composite with 19.1% ACP,0% $BaSO_4$,0.9% MWCNTs has the highest hardness and the composite with 3.5% ACP,16% $BaSO_4$,0.5% MWCNTs has the least hardness. This is because of presence of high amount of both ACP and MWCNT. The inference is that higher percentage of both ACP and MWCNT contributes to retention of hardness since thermal conductivity of ACP and MWCNT are very much higher. This makes ACP and MWCNT to conduct away the heat more rapidly thereby retaining its hardness. Thus it can be said that the depletion of the amount of $BaSO_4$ does not have any effect on the hardness of the composite.

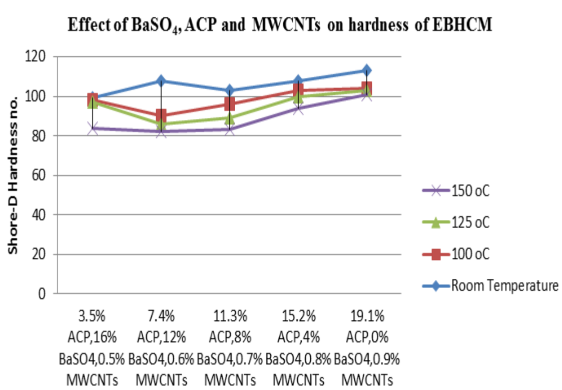

Figure 6- Variation of Hardness with Elevated temperatures

B. Effect of MWCNT and other constituents on Hardness Test

The material's resistance to fracture is known as toughness. It is the energy absorbed by the material before fracture and is expressed in terms of the same. A ductile material can absorb considerable amount of energy before fracture while a brittle material absorbs very little energy before fracture.

From the Figure 7 it can be observed that the impact energy is the highest for the composite having 15.2% ACP, 4% $BaSO_4$, 0.8% MWCNTs and is the lowest for the composite having 3.5% ACP, 16% $BaSO_4$, 0.5% MWCNTs. From the same table it can also be seen that the increment of activated carbon powder and multi walled carbon Nano-tubes, the fracture toughness rises correspondingly. It could also be seen that (Figure 7) the Impact strength is increased from the EBH composite with 3.5% ACP,16% $BaSO_4$,0.5% MWCNTs to EBH composite with 15.2% ACP,4% $BaSO_4$,0.8% MWCNTs by 63% and further the impact has reduced by 30%. This clearly shows that addition of ACP and MWCNTs increases the impact strength of designed composite significantly, this is due to the fact that breaking of ACP and MWCNTs particles require more impact load because the fracture toughness of both the ACP and MWCNTs are high.

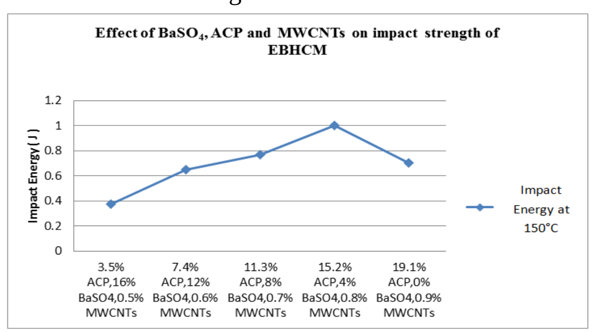

Figure 7- Variation of Impact strength with Elevated temperature 150°C

C. Effect of MWCNT and other constituents on Tensile Test

The tensile strength is an engineering value that is calculated by dividing the maximum load on the material by the initial cross sectional area of the test specimen. The Figure 8 shows the results obtained during the tensile test conducted on all the five specimens at elevated temperatures. From the graph it can be seen that tensile strength is the highest in the composite with 3.5% ACP, 16% $BaSO_4$, 0.5%

MWCNTs at room temperature and it can also be observed that the strength declines gradually at 120°C and 150°C and lowest in that with 19.1% ACP, 0% $BaSO_4$, 0.9% MWCNTs at room temperature. It can also be observed that the strength declines gradually at 120°C and 150°C. Since the $BaSO_4$ has high tensile modulus and can withstand more loads and can transfer load to adjacent particles. It also reduces the load concentration at points which in turn reduce the stress concentration, thereby increase the modulus of specimen. Hence by increasing the $BaSO_4$, the Epoxy Based Hybrid Composite Material's ultimate tensile strength increases at 120°C. Also at 150°C one can observe that the ultimate tensile strength of the Epoxy Based Hybrid Composite Material decreases with the decrease of $BaSO_4$. But at a certain point, when there is 0% of $BaSO_4$ present in the composite, the ultimate strength increases drastically due to presence of high amount of MWCNTs and this phenomenon is called Synergic effect.

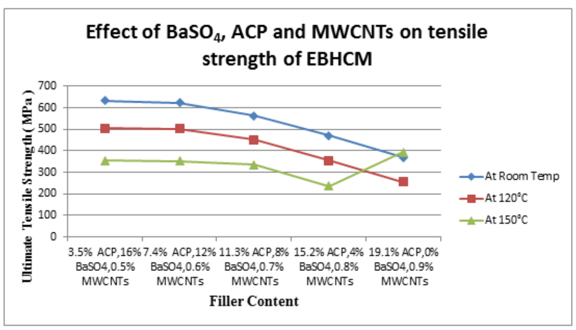

Figure 8- Variation of Tensile strength with Elevated temperatures

V. CONCLUSION

The present study and analysis of results has led to the following conclusions

1. The impact energy for the composite having 15.2% ACP, 4% $BaSO_4$, 0.8% MWCNTs at 150°C has shown the maximum impact strength, which is due to the fracture toughness of both ACP and MWCNTs are maximum in composition with other fillers.
2. The tensile strength increased very significantly. This is due to high tensile modulus of $BaSO_4$ but the ultimate strength increases drastically in the EBH composite 19.1% ACP, 0% $BaSO_4$, 0.9% MWCNTs (at 150°C) due to higher concentration of MWCNTs and this phenomenon is called Synergic effect.
3. At elevated temperatures higher percentage of both ACP and MWCNTs contributes to retention of hardness since thermal conductivity of ACP and MWCNT are very much higher. This makes ACP and MWCNT to conduct away the heat more rapidly thereby retaining its hardness.
4. The general conclusion is that the addition of ACP and MWCNTs has significantly contributed to the improvement in hardness and impact strengths and also addition of $BaSO_4$ improves the tensile strength.
5. MWCNTs play a dominant role in sustaining mechanical properties of the composites at elevated temperature (up to 150°C).

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