Effect of Glass Powder and MWCNTs on Mechanical and Wear properties of Epoxy based Hybrid Composites with Added Fillers for Elevated Temperature Applications

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Abstract— This research article presents the mechanical and wear properties of hybrid nano composites for elevated temperature applications. These materials offer higher / lower values of these properties than constituent materials because of the synergetic effect between them. In the proposed investigation it is intended to use Epoxy Resin - LY556 as matrix, along with its hardener HY – 951. This is because epoxy resin is traditionally known to have higher thermal stability when cured with an anhydrous agent. The reinforcing materials to bring in the above said properties are Al_2O_3, SiC, MWCNT's and (E-Glass Powder) EGP. Further its thermal stability could be increased by reinforcing them with (Nano Silica Powder) NSP which is thermally stable at elevated temperatures. Wear resistance of these materials which is an important characteristic could be improved by addition of other fillers like Metal Oxides and Silicates, Sintered Materials etc. Self-lubricating properties could be brought in by the use of Sulphides ($BaSO_4$). Thermal conductivity of the proposed composites could be improved upon by adding the constituents such as copper, aluminum etc. It is expected that, such hybrid polymers should possess high thermal stability, good wear resistance and mechanical modulus i.e., they should withstand degradation of properties over long period at elevated temperatures. The application areas for these proposed materials could be in Automobile parts, Aerospace industries, Missile cones and other parts where one can expect elevated temperatures in the range of 150°C-180°C.

Keywords- ***Epoxy resin, Glass Fiber (GF), Multi Walled Carbon Nano Tubes (MWCNTs), E-Glass Powder (EGP), Nano Silica Powder (NSP), Aluminum Oxide (Al_2O_3), Silicon Carbide (SiC), Barium Sulphate ($BaSO_4$), Elevated Temperature Resistance.***

1. INTRODUCTION

The coming of fiber-fortified composite materials has constituted a notable achievement in the development of lightweight structures. Specifically, huge advantages have been acknowledged in the aviation area to meet the serious execution necessities with stringent requests of unwavering quality. All aviation auxiliary segments air frames of contender flying machine, helicopters, control surfaces and balances of common air ship, different boards in satellites, radio wires, rocket engine, and some entire air frames of little flying machine are seeing an expanding utilization of the propelled composites. An essential mechanical improvement Revised 16 August 2004 that has contributed altogether to this development of composites are the advancement of solid and hardened filaments, for example, glass, carbon, and alongside simultaneous advancements in the polymer science, bringing about different polymeric materials to fill in as lattice materials. Specifically, the flexibility of the innovation of the carbon filaments having different properties has assumed a key part in this development. Further, flying machine structures in future, especially driving edges, might be required to suffer very high temperatures (350°C or above) as higher speeds and space. As the polymer matrix material is the most influenced (instead of the fortifying strands, for example, glass or carbon) by high temperature, it is the grid material that has been the focal point of consideration in the advancement of high-temperature polymer-matrix composites. As of now, the examination in polymeric frameworks over the recent decades has concocted frameworks which can perform agreeably up to 300°C. Further, the innovative work endeavors to deliver polymer-frameworks with higher administration temperatures up to 500°C have indicated empowering patterns. With each new polymer framework built up, the improvement of a procedure to make great quality composite segments has been a test and these structures a key element in the high-temperature polymer-network composites inquire about. Auxiliary segments in future fast transport airplane. As the polymer matrix material is the most influenced (as opposed to the fortifying strands, for example, glass or carbon) by high temperature, it is the matrix material that has been the focal point of consideration in the advancement of high-temperature polymer-framework composites. As of now, the exploration in polymeric lattices over the recent decades has concocted frameworks which can perform agreeably up to 300°C. Further, the innovative work endeavors to deliver polymer-lattices with higher working temperatures up to 500°C has demonstrated empowering patterns. With each new polymer framework built up, the advancement of a procedure to make great quality composite segments has been a test and these structures a key component in the high-temperature polymer-matrix composites examine.

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2. EXPERIMENTAL PROCEDURE

A. CALCULATION OF PROPORTIONS

Five different compositions of composites were made by blending all seven components and varying the percentage of Nano silica powder and MWCNTs. The content of each composition of composites is given in Table I as percentage basis. Using density formulae weight percentage is calculated.

For Example- **Considering Nano silica powder**

$$\text{Weight} = \text{Density} \times \text{volume}$$
$$\text{Density} = 2.4\text{gm/cm}^3 = 2.4\times10^{-3}\ \text{gm/mm}^3$$
$$\text{Volume} = 10\%\ \text{of the total volume of plate}$$
$$= (10/100) \times 176000$$
$$= 17600\ \text{mm}^3$$
$$\text{Weight} = 2.4 \times10^{-3}\times17600$$
$$= 42.24\ \text{gms}$$

Therefore, similar calculations have been made for all the varied volumes in the experimental investigation.

Table I: Composition used in the present investigation

Specimen No / Components By Percentage	1	2	3	4	5
Epoxy Resin	50	50	50	50	50
Aluminium Oxide	10	10	10	10	10
Nano silica powder	10	10	10	10	10
Barium Sulphate	10	10	10	10	10
Activated Carbon Powder	10	10	10	10	10
E-Glass powder	9.3	9.1	8.9	8.7	8.5
Multi-Walled Carbon Nanotubes	0.7	0.9	1.1	1.3	1.5
Total Percentage	100	100	100	100	100

Specimen No / Components By Weight	1 (gms)	2 (gms)	3 (gms)	4 (gms)	5 (gms)
Epoxy Resin	110	110	110	110	110
Aluminium Oxide	69.52	69.52	69.52	69.52	69.52
Nano silica powder	42.24	42.24	42.24	42.24	42.24
Barium Sulphate	79.2	79.2	79.2	79.2	79.2
Activated Carbon Powder	36.96	36.96	36.96	36.96	36.96
E-Glass powder	27.01	26.43	25.85	25.26	24.68
Multi-Walled Carbon Nanotubes	0.37	0.48	0.58	0.69	0.79
Total Grams	365.3	364.83	364.35	363.87	363.39

B. SPECIFICATION AND FABRICATION OF MOULD PLATE

A mild steel material is used to fabricate the mould plate of dimensions 310×260 outer which is helpful for grip and also to get the shape. Material inside the plate of dimension 160×200 is removed to fill the materials inside it and this will be the material plate which will be further cut into different specimens for testing according to ASTM standards. The Figure 1 (a) shows the design of the plate and Figure 1(b) shows the Mould plate.

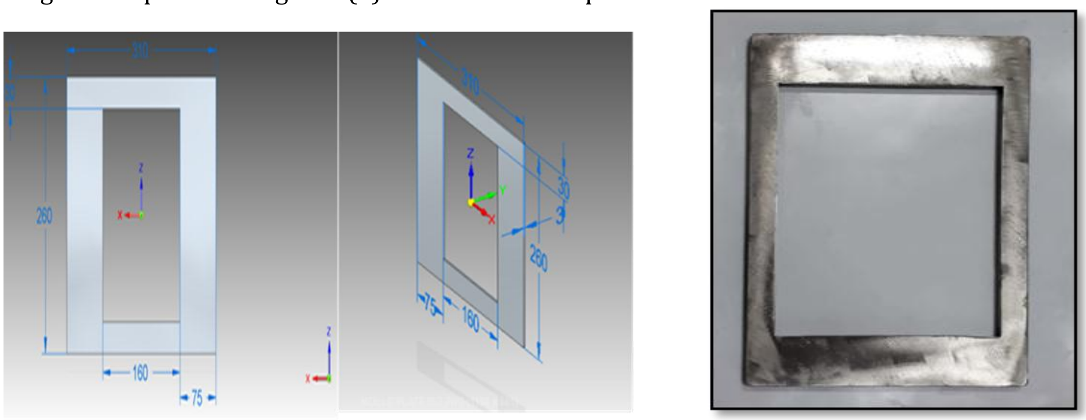


FIGURE 1 (a)Design of the plate and Figure 1(b) shows the Mould plate

C. FLOW CHART OF FABRICATION PROCESS IN THE PRESENT INVESTIGATION

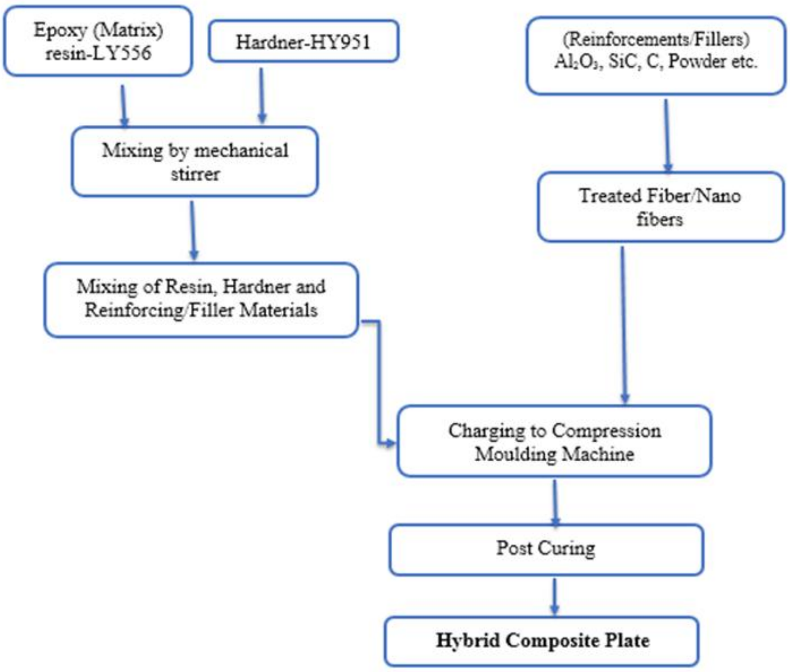


FIGURE 1(c) Flow chart of fabrication process adopted in Present experimental investigation

As represented above, the figure 1 (c) illustrates the flow chart utilized in the present investigation. The Glass fibers, MWCNTs, SiC, Al_2O_3 served as reinforcements. The filler materials such as carbon powder, barium sulphate was used to bring in the self-lubricating properties and to improve thermal conductivities along with effective properties with other imbibed materials at elevated temperatures. The higher the percentage of resistance is, the better wear resistance will be. All the composites had undergone mechanical tests like Tensile, Hardness, DMA and Impact test.

D. CONDUCTION OF TESTS

In order to investigate the mechanical and tribological properties, tests like tensile, DMA, impact, wear and hardness tests were conducted. In order to do these tests, the plate needs to be cut into different specimens as per the requirement of the tests and the sketch of different specimens on the plate is as shown in the Figure 2. Details of the experimentation and standards used for them are discussed below.

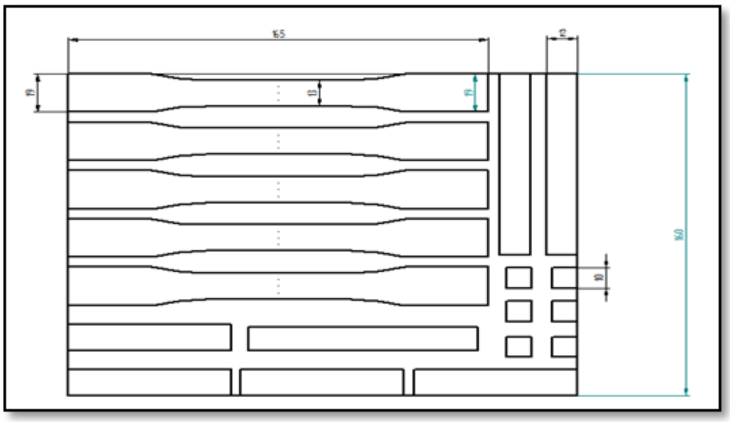


FIGURE 2 Plate with Test specimen dimension markings

Test Conducted	Tensile
Details	Tensile tests were directed rendering to the ASTM D-638. Mechanized UTM was utilized for this reason and the test experimental setup is appeared in Figure 3 below.

Table of Standards (ASTM Standards)

Sl No	Tests	Standards	Specimen dimension in mm (length×breadth×thickness)	Span Length in mm
1	Tensile Test	ASTM D-638	(165 mm x 19 mm x 3.2)	50

Figure 3

3(a)Tensile specimen

3(b)Tensile testing machine setup with band heater setup

Test Conducted	IMPACT TEST
Details	Izod impact tests were directed on V-notched composite example as indicated by ASTM D-256. A Pendulum impact analyser, appeared in Figure 4 below

Table of Standards (ASTM Standards)

Sl No	Tests	Standards	Specimen dimension in mm (length×breadth×thickness)	Type of notch
1	Impact Test	ASTM D-256	64 mm x 12.5 mm x 3.2 mm	V-Notch

Figure 4

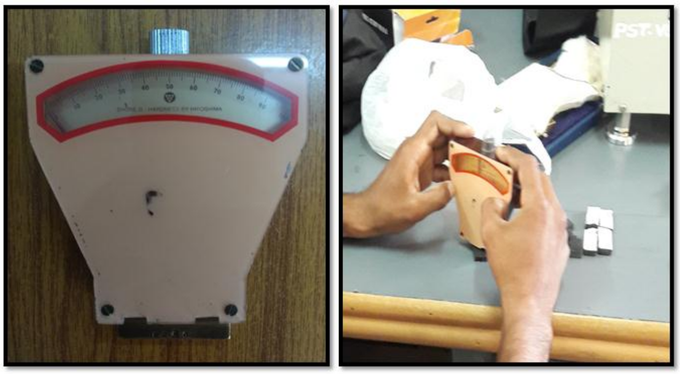
4(a) Impact Test Specimen.

4(b) Impact Test Apparatus

Test Conducted	HARDNESS
Details	The specimen used for impact test is shown in the Figure 5 below which was prepared according to ASTM standards.

Table of Standards (ASTM Standards)

Sl No	Tests	Standards	Specimen dimension in mm (length×breadth×thickness)	Type of Test
1	Hardness Test	ASTM D2240	10mm x 10mm x 3.2 mm	Shore-D hardness Testing

<table>
<tr><td>Figure 5</td><td>
5 (a) Shore-D hardness test equipment 5 (b) Conduction of test.</td></tr>
<tr><td>Test Conducted</td><td>WEAR TEST</td></tr>
<tr><td>Details</td><td>Wear test was carried out initially using regular procedures as per ASTM G-99-05 standards and some samples using Taguchi's Method using L-16 array.</td></tr>
<tr><td>Table of Standards (ASTM Standards)</td><td><table><tr><th>Sl No</th><th>Tests</th><th>Standards</th><th>Specimen dimension in mm (length×breadth×thickness)</th><th>Test evaluation method</th></tr><tr><td>1</td><td>Wear</td><td>ASTM G-99-05</td><td>(10×10×3.5)</td><td>Taguchi L-16</td></tr></table></td></tr>
<tr><td>Figure 6</td><td>

6(a) Specimen on Pin 6(b) Pin on Disc Apparatus</td></tr>
<tr><td>Test Conducted</td><td>DYNAMIC MECHANICAL ANALYSIS (DMA)</td></tr>
<tr><td>Details</td><td>Dynamic test apparatus is shown in Figure 7 below is a way that is extensively used to signify a cloth's properties as a characteristic of temperature, time, frequency, strain, surroundings or a mixture of these parameters.</td></tr>
<tr><td>Table of Standards (ASTM Standards)</td><td><table><tr><th>Sl No</th><th>Tests</th><th>Standards</th><th>Specimen dimension in mm (length×breadth×thickness)</th><th>ASTM</th></tr><tr><td>1</td><td>DMA</td><td>ASTM D4065</td><td>56 x 13 x 3 mm</td><td>Type I (Tensile Test Specimen)</td></tr></table></td></tr>
<tr><td>Figure 7</td><td>
DMA test apparatus</td></tr>
</table>

3. RESULTS AND DISSCUSSIONS

A. EFFECT OF E-GLASS POWDER AND MWCNTS ON TENSILE STRENGTH OF EPOXY BASED HYBRID COMPOSITE MATERIAL

Table demonstrates the tensile strength results all the five examples at elevated temperature.

TABLE II Tensile Strength of Epoxy based hybrid composites

SPECIMEN NO.	FILLER CONTENT	ULTIMATE TENSILE STRENGTH (MPa) at VARIOUS TEMPERATURES				
		27ºC	50ºC	100ºC	150ºC	180ºC
1	9.3% EGP, 0.7% MWCNT	12.999	8.267	4.353	4.954	4.011
2	9.1% EGP, 0.9% MWCNT	12.065	8.52	4.132	3.5	3.251
3	8.9% EGP, 1.1% MWCNT	14.099	14.125	6.867	2.44	2.213
4	8.7% EGP, 1.3% MWCNT	18.447	17.164	8.748	3.46	3.121
5	8.5% EGP, 1.5% MWCNT	23.943	20.444	9.365	3.467	3.314

From the Figure 8 and Table II, it can be perceived that, at room temperature (25ºC) the tensile strength is highest in the composite with 8.5% EGP and 1.5% MWCNTs and lowest in that with 9.1% EGP and 0.9% MWCNTs at same temperature (25ºC). One can observe from the graph that with increasing percentage of MWCNTs and decreasing percentage of EGP, the tensile strength is gradually increasing by 45.73% from 9.3% EGP, 0.7% MWCNT to 8.5% EGP, 1.5% MWCNT which is very remarkable. This is due to the fact that EGP has high hardness and MWCNTs have high elastic modulus there by supports in enhancing the tensile strength of the developed composites. The same pattern of results can be noticed when the temperature is increased from 25ºC to 50ºC where the tensile strength is increased from 8.26Mpa to 20.44Mpa (59.58%). As the test temperatures is further increased, (100ºC and 150ºC) there is a fall in tensile strength of the material which is due to softening of matrix material which is predictable.

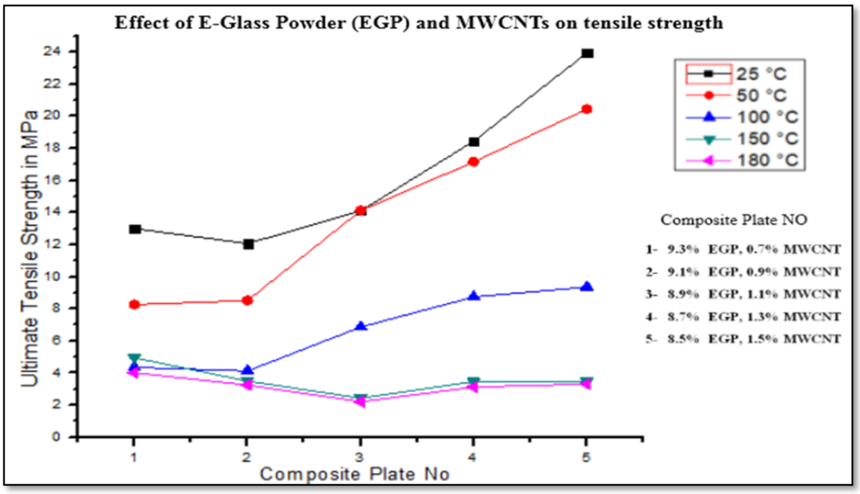


FIGURE 8 Effect of EGP and MWCNTs on Tensile Strength

One can also observe that even though the strength is deteriorating with elevated temperatures, the material is retaining its strength notably with increasing percentage of MWCNTs and reduced percentage of EGP. Also, it can be seen that the plate with 9.3% EGP and 0.7% MWCNTs has withstand high load and has given maximum strength at elevated temperature (180°C). It can also be observed from the graph that the material is retaining its strength at elevated temperatures (100°C, 150°C and 180°C) with the increasing percentage of MWCNTs, due to high tensile modulus and thermal conductivity of nano tubes along with the synergic combination between the matrix and reinforcing materials (barium sulpahte, ACP and Al_2O_3). Hence by increasing the percentage of MWCNTs, the Epoxy Based Hybrid Composite Material's ultimate tensile strength can be increased at elevated temperatures. Also, at 180°C one can observe that the ultimate tensile strength of the developed Composite Material is retaining its strength considerably due the presence of EGP which has high melting temperature (400°C).

B. EFFECT OF E-GLASS POWDER AND MWCNTS ON IMPACT STRENGTH OF EPOXY BASED HYBRID COMPOSITE MATERIAL

TABLE III Impact Strength of CGRP Composites

Specimen No.	Filler Content	Impact Energy (J) at			
		27°C	50°C	100°C	150°C
1	9.3% EGP, 0.7% MWCNT	0.2	0.16	0.14	0.12
2	9.1% EGP, 0.9% MWCNT	0.22	0.18	0.16	0.14
3	8.9% EGP, 1.1% MWCNT	0.25	0.2	0.17	0.15
4	8.7% EGP, 1.3% MWCNT	0.29	0.23	0.2	0.18
5	8.5% EGP, 1.5% MWCNT	0.34	0.27	0.22	0.21

From the Figure 9 and table III, it can be observed that the impact energy is maximum for the composite having 8.5% EGP, 1.5% MWCNTs (0.34J) at 27°C and is lowest for the composite having 9.3% EGP, 0.7% MWCNTs (0.2J) at 27°C. As the percentage of MWCNTs increases, there is a rise in impact energy by 70%. A similar pattern of results can be observed for the varying percentage of composition and also at varying temperatures (50°C and 100°C) where the impact energy steadily increases with increase in MWCNTs content. At 150°C maximum impact energy is obtained for composite with 8.5% EGP, 1.5% MWCNTs and minimum impact energy for 9.3%EGP, 0.7% MWCNT. It is also observed from the results that the impact resistance of the developed composites is comparatively lesser than expected which might be due the presence of glass powder making the material harder (brittle) but at the same time at elevated temperatures the glass powder with MWCNTs have helped in retaining the strengths which can be observed from the graph below (figure 9).

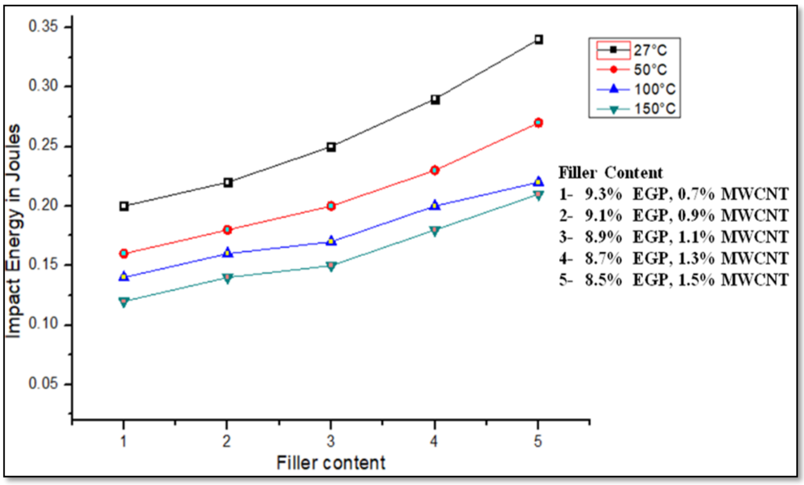


FIGURE 9 Effect of EGP and MWCNTs on Impact Strength

C. EFFECT OF E-GLASS POWDER AND MWCNTS ON HARDNESS OF EPOXY BASED HYBRID COMPOSITE MATERIAL

The table IV and Figure 10 shows that, the composite with 8.5% EGP, 1.5% MWCNTs at room temperature has the highest hardness and the composite with 8.9% EGP, 1.1% MWCNTs has the least hardness at 27°C. It can be observed from the above results and graph that as the temperature increases the hardness of the developed composites have declined. Also, the composites with 8.5 % EGP, 1.5% MWCNTs has highest hardness and lowest for composites with 9.1 % EGP, 0.9% MWCNTs number at 1800C. The hardness has dropped by 18.93% from 27°C to 180°C, but at each temperature values, the hardness value has increased progressively which can be clearly analyzed from the graph figure (10).

TABLE IV Effect of Temperature on Hardness

Specimen No.	Filler Content	Temperature (°C)				
		27	50	100	150	180
		Shore-D Hardness no.				
1	9.3% EGP,0.7% MWCNT	131	125	123	115	98
2	9.1% EGP 0.9% MWCNT	128	121	116	112	90
3	8.9% EGP,1.1% MWCNT	125	122	119	116	101
4	8.7% EGP 1.3% MWCNT	129	124	121	117	100
5	8.5% EGP 1.5% MWCNT	132	127	120	117	107

The impediment is that higher level of both EGP and MWCNT along with SiC (fixed at 10%) adds to preservation of hardness since thermal conductivity of ACP and MWCNT are predominantly higher. This makes ACP and MWCNT to lead away the heat all the more quickly along these lines holding its hardness. It tends to be seen that the Shore-D hardness number of all the above composites diminishes somewhat with an increase in the temperatures (27°C, 50°C, 100°C, 150°C and 180°C). At elevated temperatures the composites have significantly reserved its hardness which is due the presence of EGP and combined effect of other filler/reinforcing materials such as NSP, ACP and Al_2O_3.

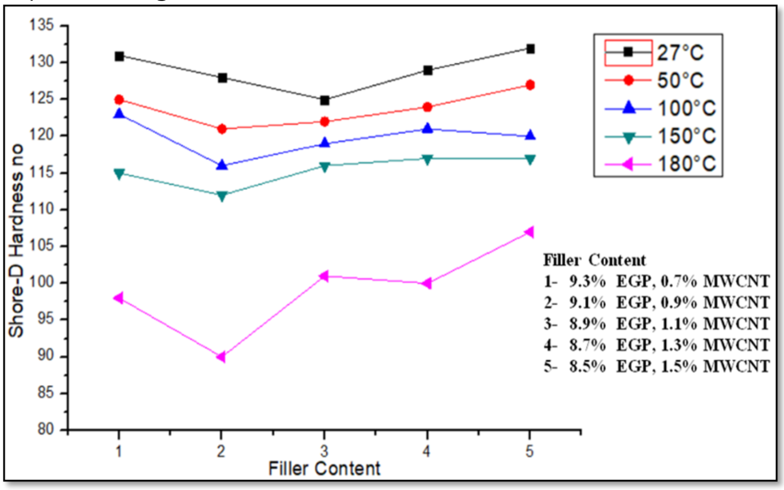


FIGURE 10 Effect of EGP and MWCNTs on Impact Strength

D. EFFECT OF E-GLASS POWDER AND MWCNT's ON WEAR PROPERTIES OF EPOXY BASED HYBRID COMPOSITE MATERIAL.

Minitab 18 Software was used to analyze S/N ratio of parameters used to build models in Compression Molding. The table V shows the results obtained from the Wear test based on Taguchis method.

TABLE V WEAR LOSS OF COMPOSITION WITH S/N RATIO

Composite Plate No.	Load	Speed	Sliding distance	Initial weight	Final weight	Wear loss	S/N Ratio
	N	m/sec	(m)	gms	gms	gms	
1	1	2	500	10.973	10.970	0.003	40.91
	2	3	1000	10.951	10.945	0.006	39.32
	3	4	1500	10.945	10.943	0.002	39.17
	4	5	2000	10.943	10.933	0.01	36.56
3	1	3	1500	18.273	18.266	0.007	43.09
	2	2	2000	18.266	18.251	0.015	35.62
	3	5	500	18.251	18.231	0.02	30.48
	4	4	1000	18.231	18.209	0.022	28.6

4	1	4	2000	11.356	11.345	0.011	28.24
	2	5	1500	11.345	11.336	0.009	28.01
	3	2	1000	11.336	11.311	0.025	26.56
	4	3	500	11.311	11.28	0.031	24.99
5	1	5	1000	11.915	11.91	0.005	24.95
	2	4	500	11.889	11.883	0.006	24.91
	3	3	2000	11.889	11.88	0.009	24.8
	4	2	1500	11.88	11.875	0.005	24.77

The experimental clarifications are transformed into signal-to-noise (S/N) ratios. There are several S/N ratios available reliant on the type of characteristics such as:

'Smaller-the-better' characteristic: $\frac{S}{N} = -10\log \frac{1}{n}(\sum y^2)$

'Nominal-the-better' characteristics: $\frac{S}{N} = 10\log \left(\sum \frac{\bar{y}}{s^2}\right)$

'Larger-the-better' characteristics: $\frac{S}{N} = -10\log \frac{1}{n}\left(\sum \frac{1}{y^2}\right)$

Where n is the number of observations, y is the observed data, Y is the mean and S is the variance. The S/N ratio for minimum erosion rate originates under 'smaller is better' characteristic, which can be calculated as logarithmic transformation of the loss function by using the above equation (smaller the better equation).

i. MAIN EFFECTS PLOT FOR SN RATIOS

Typical monitored response plots on wear test based on S/N ratio are shown in Figure 11. From the Figure the main effect plots for composite material is that, the factor speed has lowest effect on wear loss as the response variable. The ideal level for a factor is the level that gives lowest values in the experimental region.

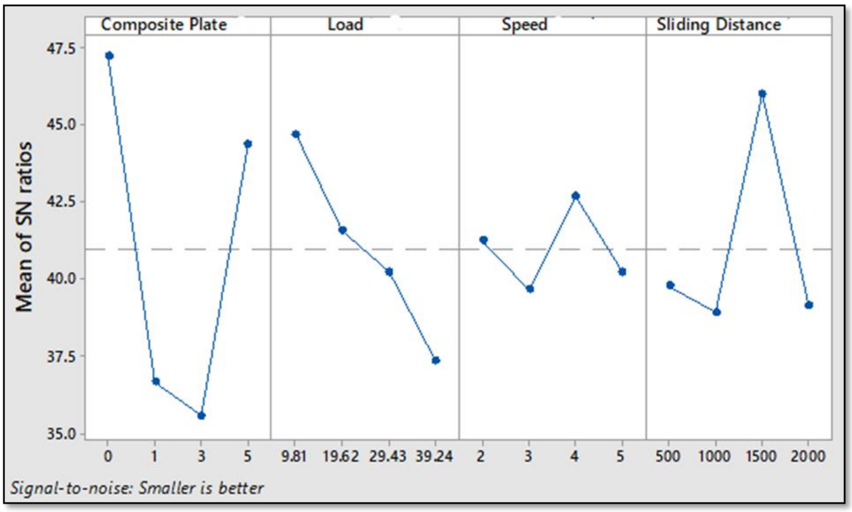


FIGURE 11 Mean Effect Plot For S/N Ratio

ii. TAGUCHI ANALYSIS:

RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS

The response table foe signal to noise ratio is shown in Table VI. From this table it can be found the Delta rank which will give the best response according to smaller is better.

TABLE VI RESPONSE TABLE FOR S/N RATIO

Level	Composite Plate	Load	Speed	Sliding Distance
1	47.22	44.69	41.25	39.76
2	36.68	41.57	39.66	38.91
3	35.58	40.23	42.69	46.00
4	44.35	37.34	40.23	39.14
Delta	**11.64**	7.35	3.03	7.09
Rank	1	2	4	3

iii. REGRESSION ANALYSIS:

Regression Equation:

ln (Wear Loss in g) =-5.300 + 0.027 Composite Plate + 0.0275 Load+ 0.000 Speed - 0.000120 Sliding Distance
The above experiments were carried out using L-16 orthogonal array by considering the factor as “smaller is better”. The table V shows the wear loss in comparison with S/N ratios. Also, from the response table for S/N ratios table VI considering against four factors (Levels), the results suggest that the material composition **(11.64)** plays greater role followed by load (7.35), sliding distance (7.09) and speed (3.03) as shown in figure (mean effective plots). Also, the regression analysis gives the best fit equation showing the mixing of proportions in right measures. The equation has not shown any secondary interaction which indicates that the experimentation and the selection of filler/reinforcements has been satisfying the literature review. The delta ranking (11.64) has rated the composition to be a major factor in reducing the wear loss. The graph of means indicates the distance between the maximum and minimum variable of the composition is fulfilling the interpretations assessed from the delta ranking which is in agreement with the earlier analysis done.

4. SEM MORPHOLOGY

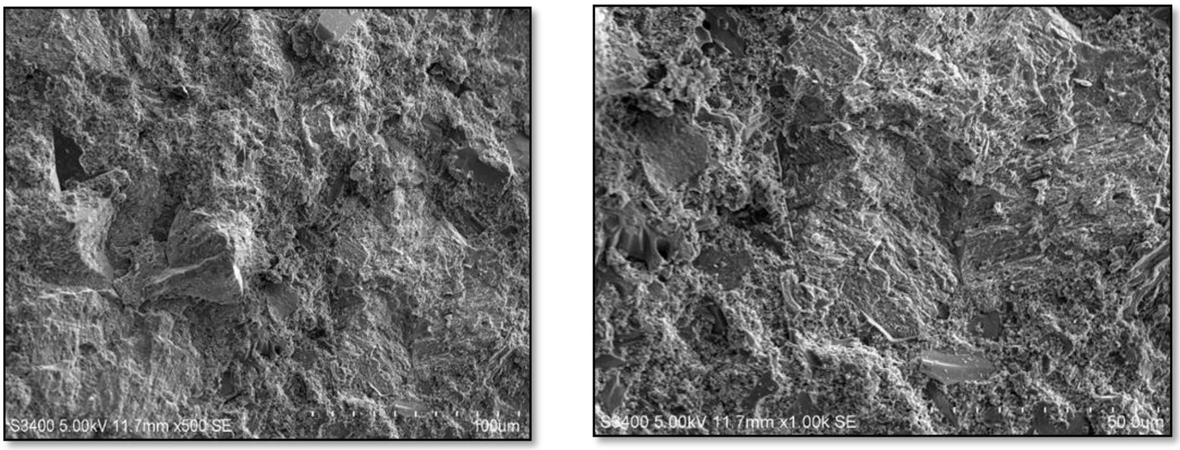


FIGURE 12 SEM micrograph of EBH composite of plate 1 subjected to tensile test of 500X (a) and 1000X (b).

Figure 12 is showing SEM micrographs for the specimen having 9.3% EGP, 0.7% MWCNT’s at the junction of failure. Figure 12 (a) shows the SEM micrograph with 500X and Figure 12 (b) shows the same with 1000X.

From SEM micrograph, it is seen that the specimen has failed due to brittle fracture form the ER matrix. Since the interfacial area between ER matrix and MWCNT’s loading is larger, the above-mentioned phenomenon occurs. MWCNT’s and carbon powder particles, which are seen as dark spots, have also contributed to increasing the modulus. Small dark spots are Barium Sulphate. Larger dark spots represent carbon particles.

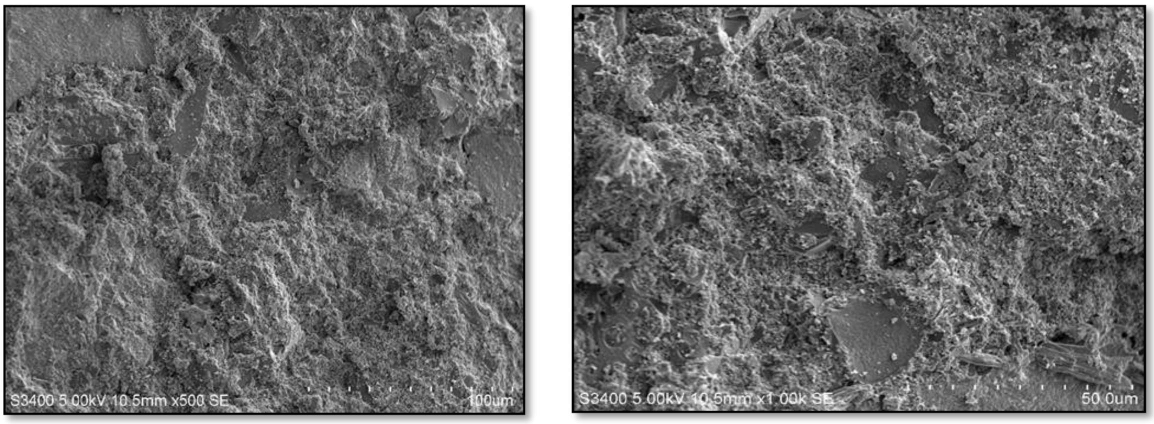


FIGURE 13 SEM micrograph of EBH composite of plate 1 subjected to impact test of 500X (a) and 1000X (b).

Figure 13 is showing SEM micrographs for the specimen having 9.3% EGP, 0.7% MWCNT's at the junction of failure. Figure 13 (a) shows the SEM micrograph with 500X and Figure 13 (b) shows the same with 1000X. Clearly one can observe that the type of failure has occurred due to brittle fracture/failure between the matrix and reinforcement.

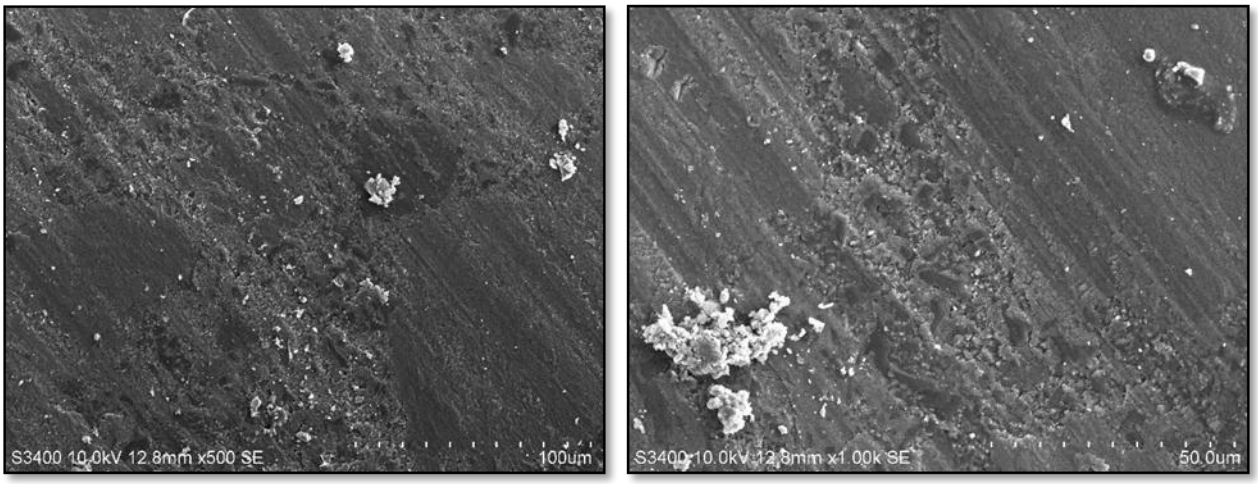


FIGURE 14 SEM micrograph of EBH composite of plate 1 subjected to tensile test of 500X (a) and 1000X **(b).**

Figure 14 shows SEM micrographs for the specimen having 9.3% EGP, 0.7% MWCNT's at the junction of failure. Figure 14 (a) shows the SEM micrograph with 500X and Figure 14 (b) shows the same with 1000X.

The wear Debris of Nano silica powder shows up as shorter more brilliant particles. Splendid littler speck refers to Al_2O_3 and to some degree bigger brilliant spots are speaking to SiC particles. Carbon and Barium Sulfide which have been utilized as ointments don't show up overwhelmingly for recognizable proof.

It can be observed from the micrographs that the wear fragments of Nano silica powder, glass powder and other filler particles have embedded on the dimensions formed outwardly of composite, the particles which are not worn are accessible in cloudiness sections of the SEM micrographs.

Higher heat conductivity of carbon powder has conciliated the system which reduced the lattice which empowered the advancement of levels, which have made a cautious shield against wear.

iv. EFFECT OF NANO SILICA POWDER AND MWCNT's ON DYNAMIC MECHANICAL ANALYSIS PROPERTIES OF ERHC

A DMA was used to perform three-point bending measurements, micro indentation and dynamic micro indentations. For the micro indentations, special DMA indenter holders were used for the tungsten needle and diamond indenter. The Graphs below show the DMA analysis with various parameters for composite materials with various compositions.

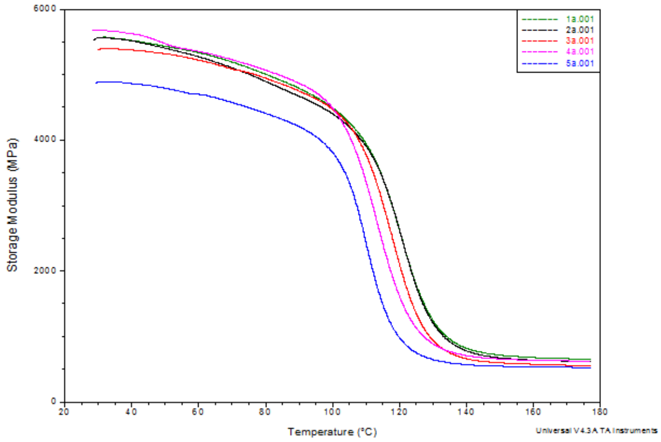


FIGURE 15(a) Effect of storage modulus vs Temperature

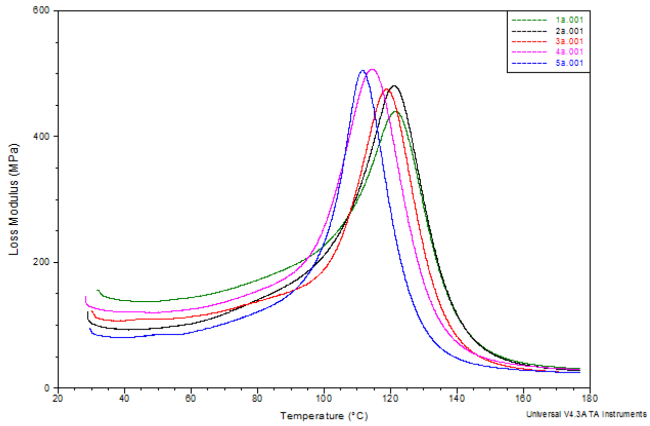


FIGURE 15(b) Effect of Loss modulus vs Temperature

1a- Is composition of plate 1 with 9.3% of NSP and 0.7% of MWCNT's
2a- Is composition of plate 2 with 9.1% of NSP and 0.9% of MWCNT's
3a- Is composition of plate 3 with 8.9% of NSP and 1.1% of MWCNT's
4a- Is composition of plate 4 with 8.7% of NSP and 1.3% of MWCNT's
5a- Is composition of plate 5 with 8.5% of NSP and 1.5% of MWCNT's

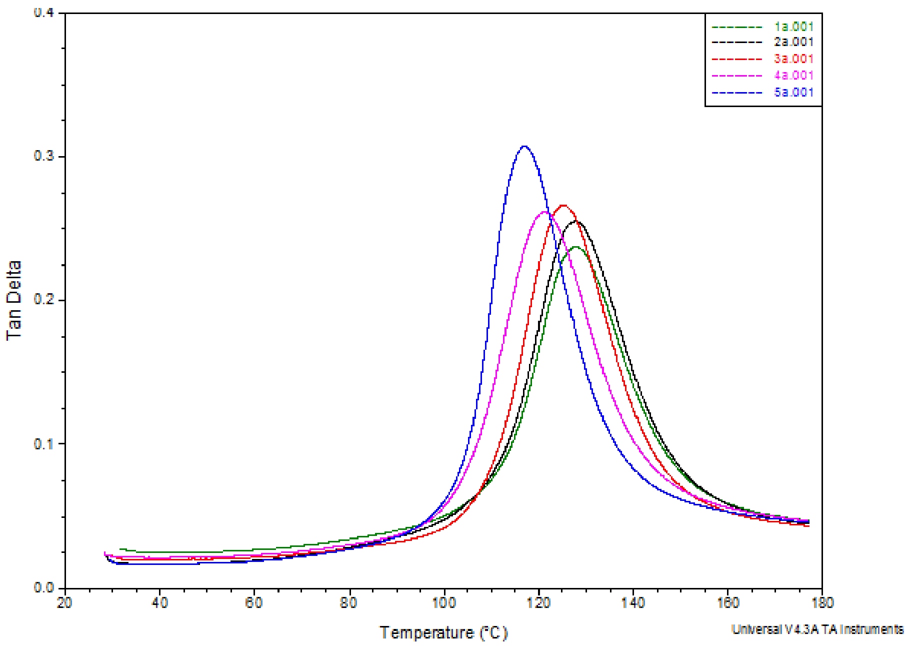


FIGURE 15(c) Effect of Tan Delta vs Temperatrure

The variation in storage modulus of the composites as a persistence of temperature at constant frequencies with different compositions is shown in figure 15(a). Comparable to storage modulus results, a substantial effect of variation in compositions were also observed on loss moduli of composites figure 15(b). It could be observed that peaks of loss modulus curve were found to increase with increase in MWCNT percentage. The maximum peak of loss modulus curve was shown for composite with composition with 8.7% of NSP and 1.3% of MWCNT's. The increase in maximum values of loss modulus curve could be due to increase in molecular mobility with increase in frequencies.

For different percentage of composition, the variation in composites as a function of temperature is shown in the figure 15(c). The maximum peak of damping was found to increase with increase in percentage of MWCNT, s, as shown in the figure above.

5. CONCLUSIONS

The current experimental investigations have led to the following conclusions:

1. The Ultimate strength diminished with increment in temperature. The ultimate strength for composite with 9.3% EGP and 0.7% MWCNTs (at 180°C) is found to be maximum, but as the percentage of EGP decreases and with increase in percentage of MWCNTs at elevated temperatures, a definitive strength increments was observed with MWCNTs and EGP combination and this phenomenon is called Synergism.

2. The Impact Energy designed for the composite having 8.5% EGP and 1.5% MWCNTs has appeared to have highest impact strength at room temperature and the same plate has given most noteworthy impact strength at 150°C, which is because of the fracture sturdiness of both EGP and MWCNTs are greatest in creation with different fillers.

3. The general conclusion is that, the inclusion of EGP and MWCNTs has fundamentally added to the improvement in hardness, Wear, Impact and tensile properties.

4. EGP and MWCNTs along with combined effect with other reinforcements/ fillers have played a dominant role in sustaining mechanical properties of the composites at elevated temperature (up to 180°C).

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