# Mechanical Properties of Graphite And Graphene / Epoxy Resin (Ly -556) Nanocomposite Using Three Point Bending Test

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***Abstract-*** *Analysis of Carbon filler content over the Mechanical properties of epoxy resin nanocomposites. The carbon fillers used in this study were graphite and grapheme. Nano sized particles in following weight percentages: 10, 20 and 30 wt %. The Mechanical properties such as flexural modulus, flexural stress and flexural strain were determined by using three point bending test. Nano composite materials Formed by addition of graphite and graphene nanoparticle to the epoxy resin thermosetting polymer matrix has been fabricate and characterized for their mechanical properties the filler content and testing speed influence of mechanical properties study to three point bending test . The mechanical properties characterization has been done using three point bending test that provides values for the flexural modules, flexural stress and flexural strain. The tests were performed with a constant strain rate of 1, 5, 10, 25 and 50 mm per min.*

## I. INTRODUCTION

Now a days has been for researchers to use nano-sized particles to reinforce polymers in order to obtain materials with enhanced properties. Different types of nano sized particles were used as filler in polymer matrix to obtain better properties. Several studies reported significant changes in properties such as mechanical, optical, electrical, thermal by using clay, graphite, graphene and carbon nanotubes as filler in thermosetting polymer matrix. Improving the overall properties of resulted materials by addition of filler to a polymer matrix is requesting using nanoparticle due to its high contact surface but paying attention to the degree of dispersion of the filler in matrix system. It is well known the tendency of nanoparticle to agglomerate and to form clusters which is a challenge for the researcher to avoid this occurrence. Since its discovery, graphene became one of the most promising materials. Was reported in literature that by the addition of small amount of graphene nano particle to polymer matrix can be obtained significant enhancement of the overall properties .Epoxy resin is used for many applications due to its strength and durability, very low viscosity and the ability to cure at ambient temperature [. Epoxy resine is more suitable for application that required better chemical resistance and physical properties than polyesters.

## II. EXPERIMENTAL PART

The Epoxy resin type of LY 556 was used as matrix phase. The graphite and graphene was used as filler into the epoxy resin. The diameter of carbon nano sized particles was 2-4µm with more than 98 wt. % purity.

The mechanical mixing method used to obtain graphite and graphene / epoxy resin nanocomposite materials consist in the following: progressive addition of carbon nanoparticle in polymer matrix followed by magnetic stirring at room temperature for 1 hour at 600 rot/min to obtain a good homogenization; starting the polymerization using hardener of epoxy resin of Araldite **Hy 951** as initiator; to avoid the agglomeration, the mixture was exposed to ultrasonic waves for 5 min; after degassing the mixture, the mixing was poured into mould which consist of 12*4*50 mm sized 8 moulds at one piece. The specimen was prepared by the material of silicon rubber.

The mixed material contained mould was kept in oven at 60 to 80 degree celcius upto 4 to 5 hours. Then after that they kept in atmospheric temp (35-38) upto 24 hours.

Specimen dimensions are 12mm width; 4 mm height and 50 mm length were obtained by pouring in special dimensioned mould. A total of minimum 15 samples for each material has been obtained. Four samples of each material were tested for all testing speeds. The mechanical properties has been done using the three point bending test according to ASTM D790 that provides values for the flexural modulus, flexural stress and flexural strain. The tests were performed with a constant strain rate of 1, 10, 25 and 40 mm/min.

## III. RESULTS AND DISCUSSIONS

According to the standard requirements, all tests were performed on at four specimens. The results for flexural modulus, flexural stress and flexural strain determined using 3-point bending tests. The flexural modulus, flexural stress and flexural strain values was obtained in decreasing and increasing manner as shown in the below charts as a columns.

| FLUXURAL MODULUS (M PASCAL) | 1 mm/min | 10 mm/min | 25 mm/min | 40 mm/min |
|---|---|---|---|---|
| pure epoxy | 1065 | 1339 | 1558 | 1466 |
| epoxy+10% graphene | 3915 | 4797 | 4849 | 4440 |
| epoxy+20% graphene | 2760 | 3077 | 2841 | 2609 |
| epoxy+30% graphene | 1818 | 2196 | 2463 | 2000 |
| epoxy+10% graphite | 1769 | 1927 | 1713 | 1571 |
| epoxy+20% graphite | 2104 | 2201 | 2286 | 1918 |
| epoxy+30% graphite | 2920 | 3225 | 2981 | 2859 |
| epoxy+5% graphene+5%graphite | 3767 | 3996 | 3795 | 3707 |
| epoxy+10% graphene+10%graphite | 3259 | 3026 | 3058 | 2914 |
| epoxy+15% graphene+15%graphite | 4403 | 4195 | 3713 | 3629 |

**Table 2: THE COMPARISON OF FLEXURAL STRESS OF EPOXY RESIN / GRAPHITE AND GRAPHENE NANOCOMPOSITE WITH NEAT EPOXY RESIN**

The flexural modulus of graphene is shown in below tables. In the below chats shows as x-axis weight percentage of material and y- axis as units (m pascal).

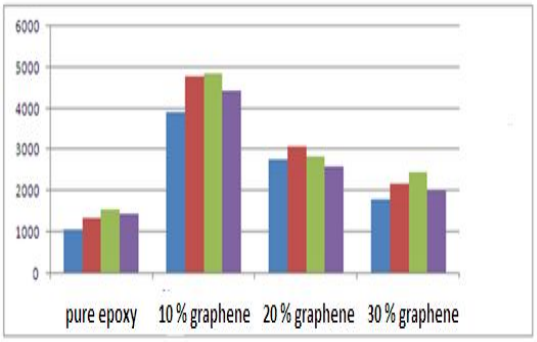


Fig 1 : flexural Modulus of graphene/epoxy resin nanocomposite with following weight percentage filler: 10,20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The pure epoxy resin values are in between 1000 to 1500 m pa according to standard values.

The graphene valuesof flexural modulus is increased in 10 wt % at 10 and 25 mm/min strain rates. The lowest values of flexural modulus are obtained at 30 wt % at 1 mm/min. the highest values of flexural modulus are 4849 m pa at 25mm/min and 4797 m pa at 10 mm/min. And the minimum values of flexural modulus are obtained at 30 wt % of graphene. The minimum values of flexural modulus are 1571 m pa at 40 mm/min strain rate.

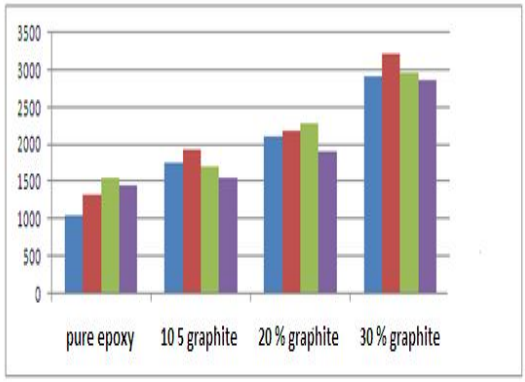


Fig. 2. Flexural Modulus of graphite/epoxy resin nanocomposite with following weight percentage filler: 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The graphite values of flexural modulus are increased in 30 wt % at 10 and 25 mm/min strain rates. The lowest values of flexural modulus are obtained at 10 wt % at 40 mm/min. the highest values of flexural modulus are 3225 m pa at 10 mm/min and 2981 m pa at 25 mm/min. And the minimum valuesof flexural modulus are obtained at 10 wt % of graphite. The minimum values of flexural modulus are 1818 m pa at 1 mm/min strain rate.

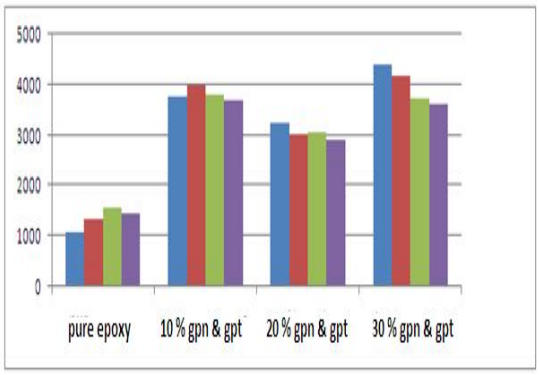


Fig. 3. Flexural Modulus for graphit and graphene /epoxy resin nanocomposite with following weight percentage filler: 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The graphite and graphene values of flexural modulus are increased in 30 wt % at 10 and 25 mm/min strain rates. The lowest values of flexural modulus are obtained at 20 wt % at 40 mm/min. the highest values of flexural modulus are 4403 m pa at 1 mm/min and 4195 m pa at 10 mm/min. And the minimum valuesof flexural modulus are obtained at 200 wt % of graphite and graphene. The minimum values of flexural modulus are 2914 m pa at 40 mm/min strain rate.

The all values of graphene and graphite of flexural modulus shows an increasing compared to neat epoxy resin. From the values the graphene has the highest values over the graphite and mixing of graphite and graphene.

In Fig 4 can be observed that the highest values of flexural stress of the epoxy resin +graphene , graphite and mixing of graphite and graphene nanocomposite was shown in table.

| FLUXURAL STRESS (N/MM) | 1 mm/min | 10 mm/min | 25 mm/min | 40 mm/min |
|---|---|---|---|---|
| pure epoxy | 20.14 | 24.02 | 26.23 | 25.31 |
| epoxy+10% graphene | 23.15 | 26.45 | 27.14 | 25.32 |
| epoxy+20% graphene | 33.52 | 35.87 | 35.2 | 34.42 |
| epoxy+30% graphene | 56.08 | 56.29 | 55.18 | 54.4 |
| epoxy+10% graphite | 29.86 | 38.95 | 34.86 | 32.39 |
| epoxy+20% graphite | 33.36 | 34.5 | 32.85 | 31.76 |
| epoxy+30% graphite | 35.28 | 34.46 | 36.43 | 34.03 |
| epoxy+5% graphene+5%graphite | 36.128 | 35.86 | 32.02 | 33.304 |
| epoxy+10% graphene+10%graphite | 34.55 | 36.67 | 23.91 | 22.31 |
| epoxy+15% graphene+15%graphite | 30 | 33.05 | 20.35 | 21 |

**Table 2: THE COMPARISON OF FLEXURAL STRESS OF EPOXY RESIN / GRAPHITE AND GRAPHENE NANOCOMPOSITE WITH NEAT EPOXY RESIN**

Comparison of the flexural stress with neat epoxy resin the maximum increasing is obtained at 40 mm/min speed at 30 wt % of graphene. The lowest values of flexural stress are obtained for 10 wt.% graphene nanocomposite at 1 mm/min . An increasing of flexural stress values for all epoxy resin /graphite nanocomposite are obtained for 1 and 40 mm/min test speeds at 30 wt % . Better results are also obtained for 30 wt.% graphene for all test speeds, compared with neat epoxy resin. The 10 wt.% graphite content show a decreasing for testing speed of 1, 10 and 25 mm/min.

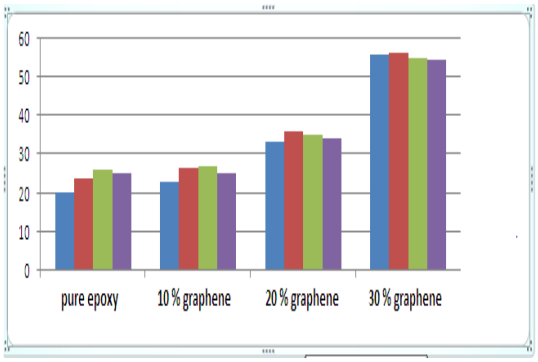


Fig.4 Flexural stress for graphene /epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The graphite values of flexural Stress are increased in 10 wt % at 10 and 25 mm/min strain rates. The lowest values of flexural stress are obtained at 20 wt % at 40 mm/min. the highest values of flexural stress are 38.95 n/min at 10 mm/min and 34.86 n/mm at 25 mm/min. And the minimum values of flexural stress are obtained at 20 wt % of graphite. The minimum values of flexural stress 29.86n/mm at 40 mm/min strain rate.

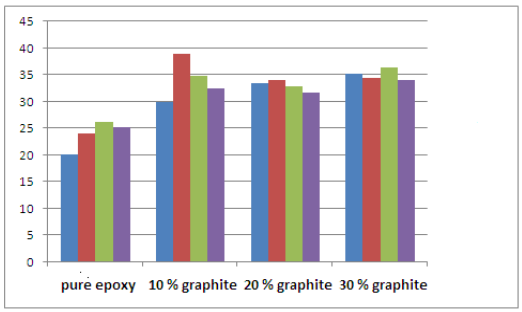


Fig.5 Flexural stress for graphite /epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

in this process the mixing of graphene and graphite has to mixed with equal at 5 ,20 and 30 .The graphite and graphene values of flexural Stress are increased in 10 wt % at 10 and 25 mm/min strain rates. The lowest values of flexural stress are obtained at 30 wt % at 25 mm/min. the highest values of flexural stress are 36.67 n/mm at 25 mm/min and 36.128 n/mm at 25 mm/min. And the minimum values of flexural stress are obtained at 30 wt % of graphite. The minimum values of flexural stress 20.35 n/mm at 40 mm/min strain rate.

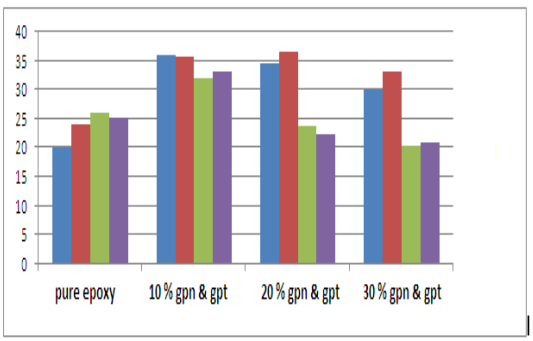


Fig.6 Flexural stress for graphite and graphene /epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

| FLUXURAL STRAIN | 1 mm/min | 10 mm/min | 25 mm/min | 40 mm/min |
|---|---|---|---|---|
| pure epoxy | 0.0028 | 0.0025 | 0.0024 | 0.0016 |
| epoxy+10% graphene | 0.0084 | 0.0072 | 0.0058 | 0.00499 |
| epoxy+20% graphene | 0.009 | 0.0075 | 0.0057 | 0.0049 |
| epoxy+30% graphene | 0.0087 | 0.0074 | 0.0057 | 0.004 |
| epoxy+10% graphite | 0.0048 | 0.0047 | 0.0039 | 0.003 |
| epoxy+20% graphite | 0.0048 | 0.0047 | 0.0039 | 0.00307 |
| epoxy+30% graphite | 0.0045 | 0.0039 | 0.0037 | 0.0024 |
| epoxy+5% graphene+5%graphite | 0.003 | 0.00259 | 0.00249 | 0.00201 |
| epoxy+10% graphene+10%graphite | 0.0029 | 0.0021 | 0.002 | 0.0018 |
| epoxy+15% graphene+15%graphite | 0.0026 | 0.002 | 0.0019 | 0.0016 |

**Table 3: THE COMPARISON OF FLEXURAL STRAIN OF EPOXY RESIN / GRAPHITE AND GRAPHENE NANOCOMPOSITE WITH NEAT EPOXY RESIN**

The higher values of flexural strain of the epoxy resin+graphene nano sized composite were obtained for 20 wt.% at 1 mm/min and 30 wt.% at 10 mm/min and the lower values for 30 wt.% at 40mm/min . Epoxy resin / graphene nano sized composite show a maximum of flexural strain for 20 wt.% at 10 mm/min and a minimum for 30 wt.% at 40 mm/min.

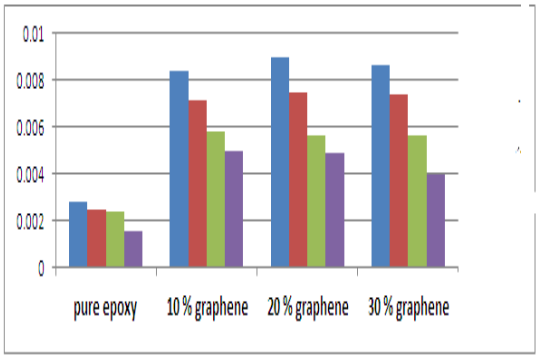


Fig.7 Flexural strain for graphene /epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The high values of flexural strain of the epoxy resin + graphite nanosized composite were obtained for 10 wt.% at 1 mm/min and 20 wt.% at 10 mm/min and the lowest values for 30 wt.% at 40mm/min . Epoxy resin / graphene nanosized composite show a maximum of flexural strain for 10 wt.% at 1 mm/min and a minimum for 30 wt.% at 40 mm/min .

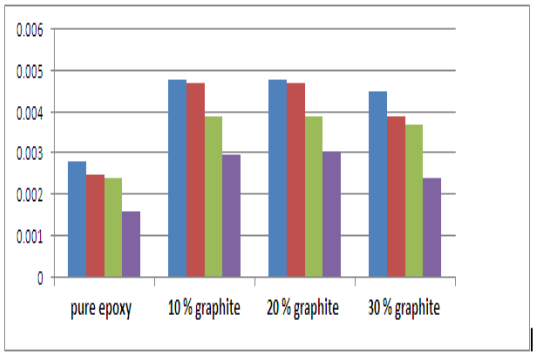


Fig.8 Flexural strain for graphite/epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

The high values of flexural strain of the epoxy resin + graphene/graphite nano sized composite were obtained for 10 wt.% at 1 mm/min and 30 wt.% at 10 mm/min and the lowest values for 30 wt.% at 50mm/min . epoxy resin / graphene nano sized composite show a maximum of flexural strain for 0.15 wt.% at 40 mm/min and a minimum for 20 wt.% at 40 mm/min .

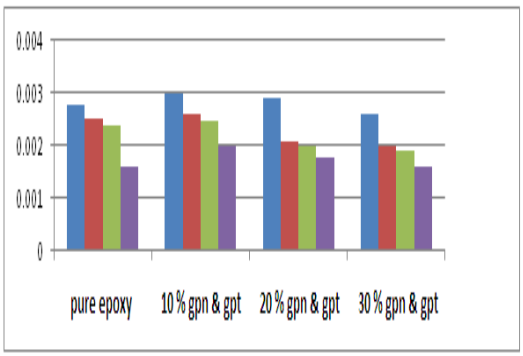


Fig.9 Flexural strain for graphite and graphene/epoxy resin nanocomposite with following weight percentage filler 10, 20 and 30 tested with a constant strain rate of 1, 10, 25 and 40 mm/min

## IV. CONCLUSIONS

Nanosized composite materials prepared by addition of graphite and graphene nano sized particle with the epoxy resin polymer matrix have been fabricated. It's characterized for their mechanical properties like flexural modulus, flexural stress, and flexural strain. Then the strain rates are plays the important role in three point bending test for calculation of mechanical properties. The 3-point bending test used to calculate the flexural modulus of epoxy resin / graphene and graphite nanocomposite increased compared to neat epoxy resin in all testing condition except for 10 wt. % graphite content at 1 and 10 mm/min test speed. The maximum values

has been achieved for 10 wt. % graphite at 1 mm/min and 30 wt. % graphene at 10 mm/min. The flexural stress values are high at 30 wt % of graphite and 10 wt % of graphene. Then the values are vary 10 to 30 wt %. The graphene and graphite+ epoxy resin are fine 20 wt % at each graphene and graphite. the max and min values are obtained at 10 and 30 wt % of mixing of graphene and graphite with epoxy resine. So the flexural stress is fine at 20 wt % at each. The strain values of graphene and graphite + epoxy resine has been alternatively changed at 10 20 and 30 wt %. So the strain values are depended at the deflection of the test piece at testing time.

Alternately to determined the flexural values by the mixing of graphene and graphite at same composition like total 10 wt % ( 5 wt % grphene and 5 wt % graphite ) + epoxy resin like that 10 and 30 wt % .

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