Experimental Study on Effect of Heating Epoxy Resin on Mechanical Properties of Epoxy-$CaCO_3$ Composite

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Abstract— The present work deals with the experimental study of effect of heating of epoxy resin on mechanical properties of epoxy-$CaCO_3$ composite. Epoxy resin is heated to a temperature of 800C and $CaCO_3$ filler is mixed with it in various weight percentages. Specimens were developed according to ASTM standards by using open mould technique. The filler $CaCO_3$ is mineral filler with particle size of 0.73 µm. The mechanical properties like tensile strength and bending strength are determined. Also microstructure was analyzed at 100X using optical image analyzer with resolution range of 100X to 1000X. The mechanical tests were carried out in Universal Testing Machine (UTM) of maximum capacity 400 kN. The results show that heating of epoxy resin has a noteworthy effect on mechanical properties of the final composite. Tensile strength of composite was decreased by heating epoxy resin, whereas bending strength of composite was increased. Also as filler weight percentage is increased there is a reduction in both tensile and bending strengths. Microstructure analysis shows that tensile specimen got weakened very early as compared to bending specimens.

Key words: Heating Epoxy Resin, Epoxy-$CaCO_3$ Composite

I. Introduction

A composite can be referred to as a multiphase material that exhibits a critical bit of properties of every part such that by mixing these multiphase materials new better properties can be achieved. They have the parts that are artificially diverse and have distinct surface separating them.

Particulate reinforced composites find a great deal of applications in automotive systems such as body panels, intake manifolds and in consumer products such as appliances, electrical products, helmets etc.

Polymer-mineral fillers have become favourite hotspots for researchers because of their cost effectiveness and possession of desired properties that are required in various applications. Epoxy is the most popular polymer used because it better mechanical properties as compared to other polymers. Normally used mineral fillers include silica, mica and $CaCO_3$. These fillers help in enhancing the properties like tensile properties, bending properties etc.

A. Objectives of the Work

The main aim of this study is to find out the effect of heating epoxy resin on mechanical properties of particle reinforced composites. The objectives of the work are listed below.

- To fabricate the particulate reinforced composite with epoxy resin as matrix and calcium carbonate as reinforcing filler by varying the weight percentage of calcium carbonate by 0, 10 and 20%.
- Composites are to be fabricated by heating and not heating epoxy resin as per ASTM standards.
- To study the various mechanical properties of fabricated composites such as tensile strength, bending strength, hardness and also to study the microstructure.
- To study the microstructure of fabricated composites using optical image analyzer.
- Comparative study to identify the effect of heating of epoxy resin on mechanical properties of epoxy-$CaCO_3$ composites.

II. Specimen Preparation

A. Materials

Epoxy resin Lapox T-22 was used in the study which was supplied by Atul Ltd. The curing agent used in combination with epoxy resin was K-6 hardener. The mineral filler used was $CaCO_3$ supplied by Visso Trading Company.

Matrix	Lapox T-22 Epoxy resin
Hardener	K-6 Hardener
Filler	$CaCO_3$

Table 1: Materials

B. Fabrication

Required quantity of epoxy resin and CaCO3 are taken in bowl and they are mixed thoroughly. Then hardener is added to the mixer and the whole mixture is stirred properly. Mixture is poured into the moulds of required sizes and then allowed for curing. After removing the specimen from moulds they are allowed for post curing. Then specimens are cut on the basis of ASTM standards by using jig-jag cutter.

In case of heating epoxy resin, epoxy resin is heated in a induction furnace for about 4 minutes at a temperature of 80^0C.

Code	Epoxy-Filler Composition
M1	Epoxy+10% hardener
M2	Epoxy+10% hardener+10% $CaCO_3$
M3	Epoxy+10% hardener+20% $CaCO_3$
M4	Heated Epoxy+10% hardener
M5	Heated Epoxy+10%hardener+10% $CaCO_3$
M6	Heated Epoxy+10% hardener+20% $CaCO_3$

Table 2: Specimen Codes:

III. Testing

The specimens are subjected to following tests to study mechanical behavior of fabricated composites. Also microstructure analysis is done using optical microscope.

Sl. No.	Test	ASTM	Specimen Size (mm)
1	Tensile	D638	115×13×4
2	Bending	D790	110×25×6

Table 3: Details of tests carried out

A. Tensile Test (ASTM D638)

For tensile testing the specimens are fabricated and cut based on the ASTM standard D-638. ASTM standard D-638

gives the details of specimen that has to be subjected to tensile test. Tensile testing is done to determine the maximum load a material can withstand when it is subjected to a force in a direction parallel to its axis.

The data from tensile test is used for following purposes.

1) To determine tensile strength.
2) To determine Young's modulus.
3) To determine tensile strain.
4) To plot a graph of stress v/s strain.

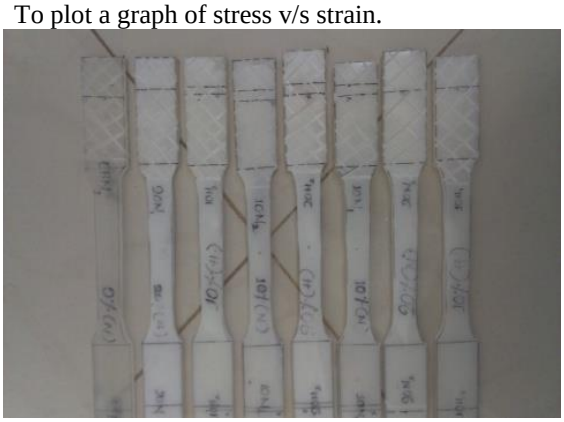

Fig. 1: Tensile test specimens

B. *Bending Test (ASTM D790)*

For bending test the specimens are fabricated and cut on the basis of ASTM standard D-790. ASTM standard D-790 gives the details of dimensions of specimen that has to be subjected to bending test.

Bending test is carried out to find out the maximum stress developed in the specimen when it is subjected to three point bending. This maximum stress is called as bending strength. In this test specimen is supported at the two ends and the load is applied at middle point of the specimen.

Data got from bending test is used for following purposes-

- To determine bending strength.
- To determine maximum deflection.
- To plot a graph of load v/s deflection.

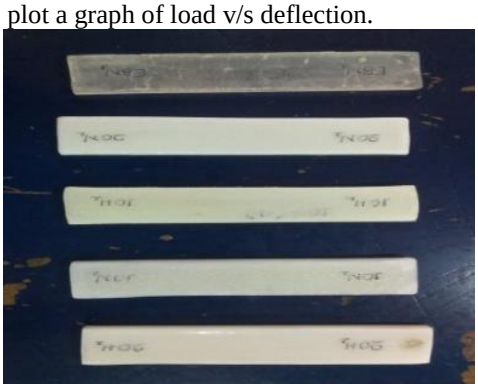

Fig. 2: Bending Test Specimens

C. *Hardness Test*

For hardness test specimens are fabricated and cut on the basis of ASTM standard D-2240. Hardness test is carried out by using Shore-D hardness tester. Shore-D hardness tester is used to find out the hardness of the plastic/polymer materials. The pointer is made to penetrate on surface of the specimen. The readings shown on the dial of the shore durometer are noted down.

Fig. 3: Shore Durometer

D. *Microstructure*

- Analysis of microstructure was done using optical image microscope which is having a resolution range of 100X to 1000X.
- Microstructure analysis was done for both tensile and bending tests.
- For observing the microscope flat specimens were made ready and microstructure was observed at 3-4 positions for a specimen.

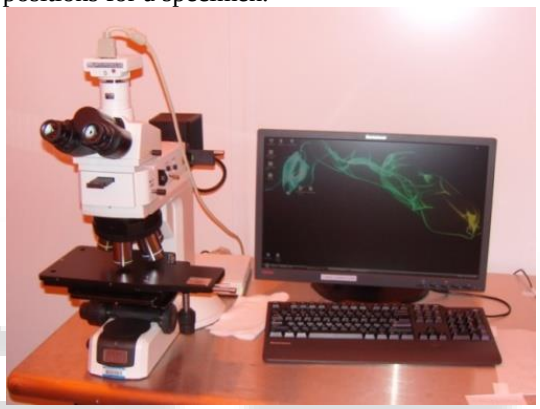

Fig. 4: Optical image analyzer

IV. RESULTS AND CALCULATIONS

A. *Tensile Test*

Composite	Tensile Strength (MPa)	% Elongation	Tensile modulus (MPa)
M1	42.3	12.9	331.3
M2	28.23	9.3	311.25
M3	21.67	11.84	183.02
M4	31.53	11.82	266.65
M5	25.64	8.24	314.62
M6	18.71	8.94	211.4

Table 4: Average results for tensile test

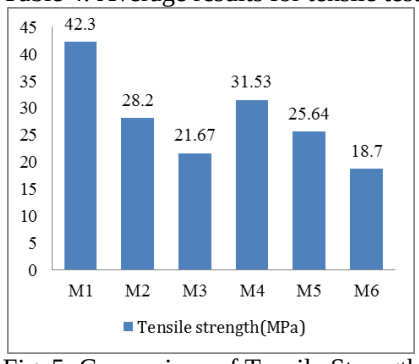

Fig. 5: Comparison of Tensile Strength

1) Discussion on Tensile Test

From average results it can be observe that tensile strength of composite is reduced when epoxy resin is heated. Cause for this may be interpreted as- when epoxy is heated atoms vibrate faster and hence they move from one another creating a large space. Due to this intermolecular force of attraction is reduced and because of this when heated epoxy composites are subjected to tensile load they break early.

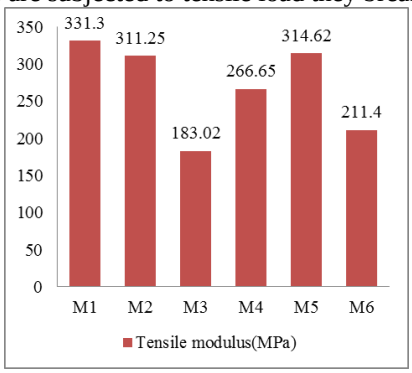

Fig. 6: Comparison of tensile modulus

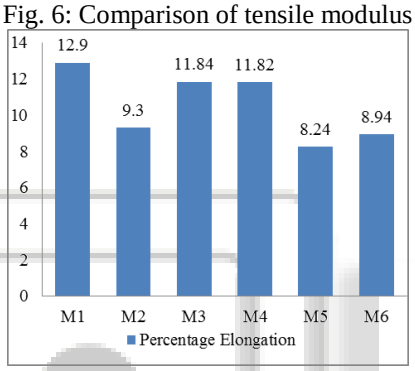

Fig. 7: Comparison of percentage elongation

Also pure epoxy composites have more tensile strength, whereas addition of fillers decreases the tensile strength of composites in case of both neat epoxy and heated epoxy. This may be because of voids created during fabrication. Also addition of filler increases brittleness of composite and it increases viscosity of composite. Because of increase in viscosity heat energy is localized and it creates defects on the surface. This leads to poor tensile strength of composites.

Composites with 10% $CaCO_3$ have more tensile strength as compared to composite with 20% $CaCO_3$.

Also we find that tensile modulus of neat epoxy composite is more than other composites. Here also filler addition has decreased the tensile modulus of composites. In case of heated epoxy, tensile modulus of pure heated is less as compared to composites with filler addition. With the addition of filler, tensile modulus of composite has been decreased.

B. Bending Test

Composite	Bending Strength (MPa)	Bending modulus(MPa)
M1	45.89	538.63
M2	54.44	1195.45
M3	39.66	900.68
M4	55.22	831.79
M5	68.83	917.22
M6	56	751.07

Table 5: Average results for bending test

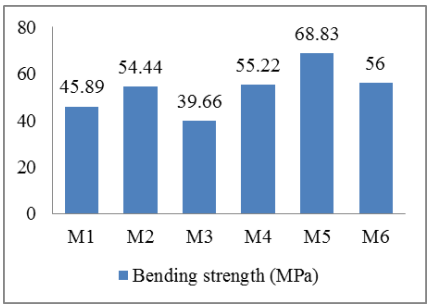

Fig. 8: Comparison of bending strength

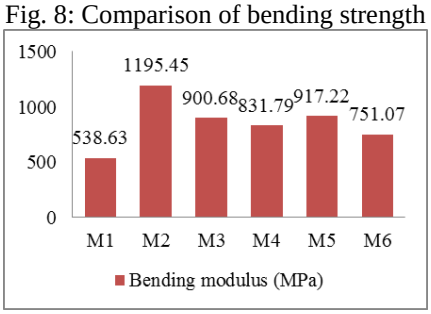

Fig. 9: Comparison of bending modulus

1) Discussion on Bending Test

We can observe from the average results that, heating of epoxy resin increases the bending strength of composites. Pure unheated epoxy has bending strength of 45.89 MPa whereas composite with heated epoxy has bending strength of 68.83 MPa. When epoxy is heated molecules vibrate very fast. As a result of this, molecules move from each other creating more space between them. Filler particles are fitted in this space and they are bonded to ad-joint epoxy molecules with more stiffness. This leads to better bending strength of composite.

From results obtained we can also observe that, filler addition decreases the bending strength of resulting composite. 10% weight percent of filler gives good bending strength whereas by the addition of 20% weight percent of filler decreases the bending strength of composite. Reason for this may be- as filler percentage increases, molecular chain bonding get disturbed more because of more proximity with particles.

C. Hardness Test

Average results for hardness test are as follows-

Composite	Hardness number
M1	84.9
M2	85.5
M3	85.3
M4	84.8
M5	87.8
M6	88.1

Table 6: Average hardness values

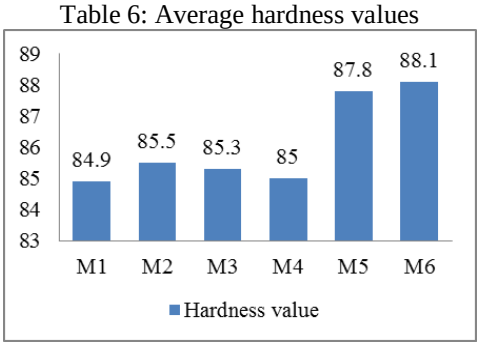

Fig. 6: Comparison of Hardness Values

1) Discussion on hardness Test

Shore D hardness tester was used to calculate the hardness of the specimens.

From the average values of hardness it can be observed that the hardness value is highest for composite with 20% $CaCO_3$ and heated epoxy combination.

Hardness value is least for composite with pure epoxy resin. Reason for this is that pure epoxy composite is having high value of tensile strength and composite with 20% $CaCO_3$ and heated epoxy resin has least value of tensile strength. Hence composite with 20% $CaCO_3$ is harder than the other composites.

Also it can be observed that the heating epoxy resin has increased the hardness of composites. Reason for this is that when epoxy resin is heated molecules move from each other creating more space between molecules. Hence filler particles will be fitted in the space with more stiffness. This leads to better hardness properties.

V. CONCLUSIONS

A. Tensile Test

Based on the tensile test carried out it can be concluded that

- Heating of epoxy resin decreases the tensile strength of the composite.
- Also tensile strength of composite decreases as the percentage of filler is increased.

B. Bending Test

Based on bending test following conclusions can be drawn out-

- As the percentage of filler increases the bending strength of composite decreases.
- Heating of epoxy resin increases the bending strength of the composite.

C. Hardness Test

Hardness leads to following conclusions-

- Hardness of the composite increases as the weight percentage of filler increases.
- Heating of epoxy resin increases the hardness of the composite.

D. Microstructure Analysis

Microstructure analysis was carried out on optical image analyzer. Analysis leads to following conclusions.

- It shows that specimen weakened early showing that tensile strength of the specimen is very less in case of both heated epoxy as well as pure epoxy.
- In case of bending, microstructure shows that, after the application of bending load, deflection of the particles was more i.e., bending strength of the specimen is more compared to tensile strength.

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