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Investigation on Thermo-Mechanical Behaviour of E Glass Fibre and Iron Oxide Filler Particles Reinforced Epoxy Composite

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***Abstract:** Composite materials reinforced with iron oxide particles have greater potential and play an important role in different applications. This paper is aimed to study the mechanical and thermal behaviour of epoxy composite laminate when it is reinforced with fibre and iron oxide particles at different compositions. The composites were fabricated by hand layup technique. The samples that have been prepared were subjected to mechanical investigation to find out various properties like tensile strength, compressive strength and flexural strength. The experimental tests were performed according to the ASTM standards using Universal testing machine. Thermal stability test was carried out for the composite laminate by differential scanning calorimetry to find out the glass transition temperature. From the investigation it has been observed that, the addition of iron oxide particles with glass fibre* **epoxy results in reducing the mechanical strength of the composites whereas the thermal properties are increased.**

***Keywords:** Composite laminate, Iron Oxide particles, Thermal stability, Glass transition temperature.*

I. INTRODUCTION

A lot of research work has been done by the researchers in the field of composites to produce a promising composite material with enhanced properties like physical, chemical, mechanical, thermal and so on. Composite materials have a wide range of applications in many fields. Polymer matrix composites have wide spread of applications in the field of structural, automobile and aerospace industry. In polymer matrix composite, property enhancement should be done based on the application. Polymers can be strengthened by addition of fibre and particles. These fibre toughened polymer composites are highly preferable due to high strength to weight ratio. In addition to that filler particles added polymer composites serves in solar energy conservation, magnetic storage, magnetic shielding, and dielectric heating. Epoxy resins are more attractable because of its excellent adhesion, insulation, and chemically inactive properties. Iron oxide particles have better mixing with matrix due to surface porous. The dispersed iron oxide in epoxy matrix will increase heat dissipation hence it could be used as a heating element. This research work investigated the mechanical and thermal properties of the epoxy composite when it is strengthened with the fibre and iron oxide particles. Hand layup technique is used to fabricate the composite laminate and the properties have been tested by universal testing machine and differential scanning calorimetry.

II. EXPERIMENTAL PROCEDURE

The materials used for the fabrication of composites are E glass fibre (Woven mat), Epoxy resin and iron oxide particles. Glass Fibre is commonly used as an insulating material and it is also used as a reinforcing agent and has roughly comparable properties when compared to other fibres. Glass fibres not strong or rigid as carbon Fibre but it is very cheaper and less brittle. Epoxy resins contribute strength, durability and chemical resistance to a composite. They possess high performance at elevated temperatures with hot or wet service temperatures up to 121°C. Epoxies come in liquid, solid and semisolid forms and typically cure by reaction with amines or anhydrides. They are not cured with a catalyst, like polyester resins, but instead use a hardener. Iron oxides are prevalent metal oxides and they are widely used as they are inexpensive. It plays an imperative role in many biological and geological processes. The three most common forms of iron oxides in nature are magnetite (Fe_3O_4), maghemite (γ-Fe_2O_3), and hematite (α-Fe_2O_3) which plays a vital role in the field of scientific technology. In this research work, epoxy resin used was liquid diglycidyl ether of Bisphenol-A type Araldite LY556 with an equivalent weight per epoxide group of 195g/mol having viscosity of 12000 cps and density of 1.2g/cm3 at 25 $^\circ$C and Hardener HY951. E Glass fibre continuous woven roving (0-90°) with density of 2.54g/cm3 was used. Iron oxide particles with an average particle size of 600mesh with density of 5.2g/cm3 were used to fabricate the composite. The Composite laminates are fabricated by Hand layup technique of size 200*200*3mm. It is a simple and least expensive technique in which the fibre reinforcements are placed and resin is applied with the help of cotton roller to remove air bubbles. The filler particles are added uniformly. The curing of composite was done at room temperature about 24 hours. Four composite laminates were fabricated with different compositions.

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TABLE I
MATERIAL COMPOSITION OF SAMPLES

Sample	**Material Composition (Vol %)**
Sample 1	90% epoxy + 10% fibre
Sample 2	85% epoxy + 15% fibre
Sample 3	88% epoxy+ 10% fibre + 2% iron oxide particles
Sample 4	86% epoxy+ 10% fibre + 4% iron oxide particles.

III.RESULTS AND DISCUSSIONS

The samples are prepared from the composite laminate are tested according to the ASTM standards and subjected to various mechanical testing like tension test, compression test and flexural test. Universal testing machine is used for testing the composite laminate and DSC is to find out the glass transition temperature.

A. *Compression Test*

A compression test determines the behaviour of materials under crushing loads. The specimen is compressed and deformation at various loads is noted. Universal testing machine is used for testing the composite. The ASTM standard used for testing is D695.

TABLE II
RESULTS OF COMPRESSION TEST

Sample	Compression load in KN
Sample 1	69
Sample 2	85
Sample 2	79
Sample 4	61

Fig. 1 Samples of Compression Test

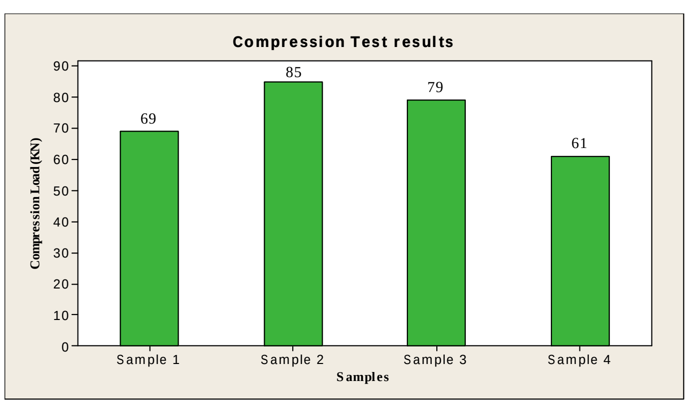

Fig. 2 Results of Compression test

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B. Tensile Test

Tensile test is a destructive method in which the specimen is subjected to an axial load until it gets failure. The equipment used for the tensile test is Universal testing machine. The ASTM standard used for testing is D3039.

TABLE III
Results Of Tensile Test

Sample	Tensile Strength (Mpa)
Sample 1	119
Sample 2	135
Sample 2	127
Sample 4	105

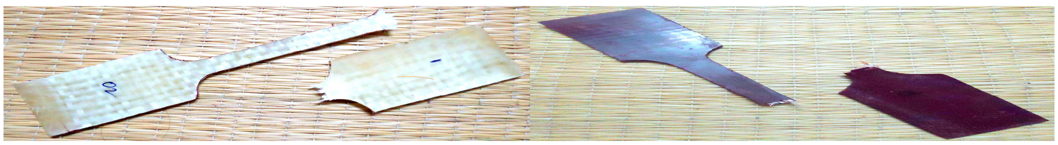

Fig. 3 Samples of Tensile Test

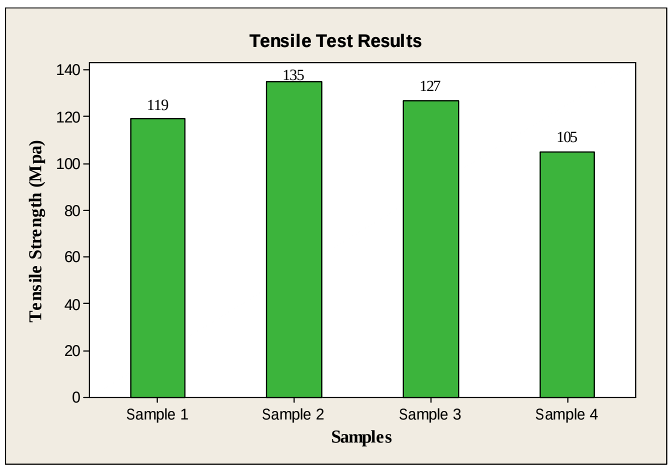

Fig. 4 Results of Tensile test

C. Flexural Test

Flexural test also known as three point bending test. In this testing the specimen were horizontally placed on two supports and load was applied at the centre. The deflection was measured by the gauge placed, under the specimen, at the centre. The ASTM standard used for testing is D790.

TABLE IV
Results of Flexural Test

Sample	Flexural Strength (Mpa)
Sample 1	203
Sample 2	227
Sample 3	198
Sample 4	163

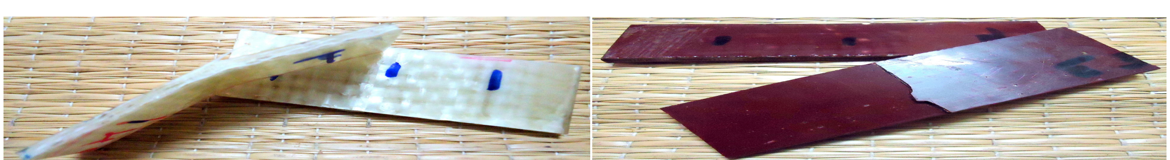

Fig. 5 Samples of Flexural Test

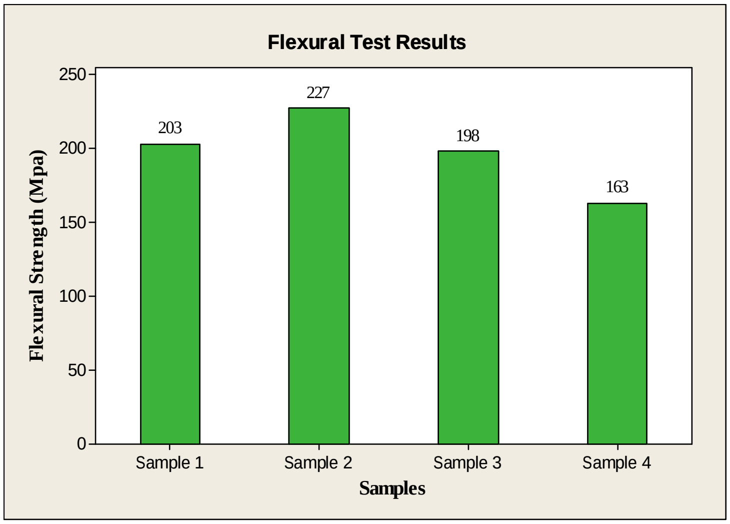

Fig. 6 Results of Flexural test

D. Thermal Stability Test

Thermal stability test was conducted to study the glass transition temperature of composites. In this technique the heat flow into or out of a sample is measured as a function of temperature or time, while the sample is exposed to a controlled temperature program.

TABLE V
THERMAL STABILITY TEST APPARATUS

Instrument Used	STA 449F3 Jupiter
Temperature Range	RT to 500^0C
Heating /Cooling Rate	10K/min
Atmosphere	Nitrogen
Sample Carrier	TG-DSC Sample carrier
Sample Crucible	TG-DSC Alumina crucible with lid.

Glass transition temperature is very much required to know the initial stability of polymer. The tests were conducted for sample 1 and sample 3.The temperature reaches its peak at 359.2^{o}C and residual mass of 36.61 % at 547.7^{0}C for sample 1 and 352.1^{o}C and residual mass of 18.70 % at 577^{0}C for sample 3. The addition of iron oxide particles into the epoxy composite reduces the mass loss stability when compared to glass fibre epoxy composite. This is due to the agglomeration of particle. The thermal stability was increased by adding iron oxide in to the epoxy matrix and this change is due to increase of cross linking density of epoxy by the affinity of iron oxide particles with resin. Further addition of Iron oxide particles will increase the thermal stability of resin.

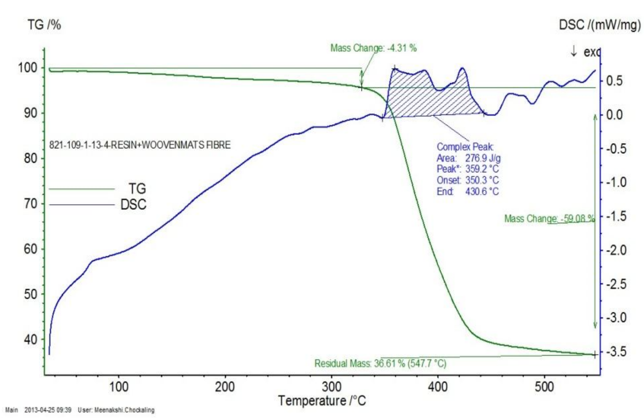

Fig .7 Glass Transition temperature of Sample 1

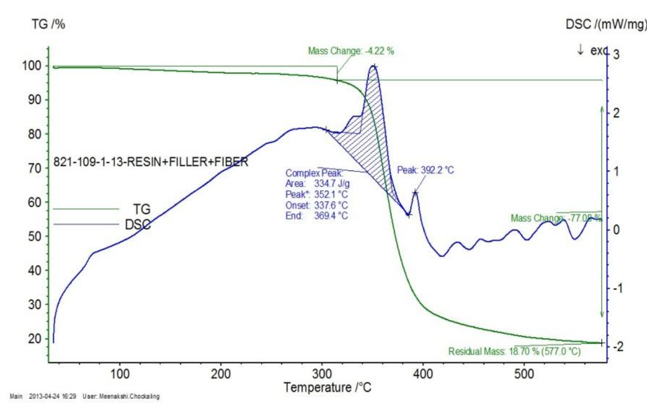

Fig.8 Glass Transition temperature of Sample 1

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TABLE VI
Thermal Properties of the composites

Composition	Initial decomposition (^{0}C)	Middle decomposition (^{0}C)	Final decomposition (^{0}C)	Residual Mass %
Sample 1	350.3	359.2	430.6	36.61
Sample 3	337.6	352.1	369.4	18.70

IV. CONCLUSION

The experimental investigation of this research work shows the following results the addition of glass fibre with the epoxy resin has improved the mechanical properties of the composite. The addition of iron oxide particles in the epoxy resin results in a significant decrement in strength of the composite. This is due to the chemical reaction of particles with epoxy resin affects the original molecular structure of epoxy and the formation of more cross link makes the resin more brittle and leads to immediate breakage of the composite. Iron oxide particles dispersed with E glass fibre in epoxy composite gives improved thermal stability than glass fibre in epoxy composite. The glass transition temperature is higher. This is due to the enhanced catalytic effect of particles that promotes more gas adsorption during thermal oxidation reactions. In order to enhance the thermal properties of the composite, the particles can be characterized and synthesized by characterisation technique and those characterized particles can be used in fabricating composite for testing for better improvement in thermal properties.

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