Comparative Study Of Mechanical Properties Of E-Glass/Epoxy Composite Materials With Al_2O_3, $CaCo_3$, SiO_2 AND PBO Fillers

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Abstract

Machining of the composites materials is difficult to carry out due to the anisotropic and non-homogeneous structure of composites and to the high abrasiveness of their reinforcing constituents. In this comparative study of the mechanical properties of E-glass/Epoxy composite materials with fillers (Al_2O_3, $CaCo_3$, SiO_2 and PbO) has targeted to investigate the materials added to the matrix help improving the mechanically operating properties of a composite. The mechanical characteristics of these composite materials, is examined by Tensile Strength Test by UTM, Torsion Strength Test by Torsion Testing Machine, Hardness Test by Vickers Hardness Testing Machine and Charpy Test by Impact Testing Machine. The results of various mechanical characterization tests are reported here. It is evident from the results Lead Oxide (PbO) as a filler material added in resign and Fiber composites (52% Resin + 13% PbO + 35% Fibre) has a better mechanical tensile properties as compared to others, Silica Oxide (SiO_2) as a filler material added in resign and Fiber composites (52% Resin + 13% SiO_2 + 35% Fibre) has a better mechanical torsion properties and hardness properties as compared to others, resin and fiber composite without filler (65% + 35% Fibre) has a better mechanical energy absorbed properties as compared to others.

Keywords: E-glass, Epoxy, Composite Materials, Fillers Materials.

1. Introduction

Composites are made by combining two or more materials with different properties to get their useful properties and reduce their weaknesses. In general, the properties of composite materials are superior in many respects, to those of the individual constituents. This has provided the main motivation for the research and development of composite materials. The composite materials have advantage over other conventional materials due to their higher specific properties such as tensile, impact and flexural strengths, stiffness and fatigue characteristics, which enable structural design to be more versatile.

By definition "A composite material is considered to be one that contains two or more distinct constituents with significantly different macroscopic behaviour and a distinct interface between each constituent. It has characteristics that are not depicted by any of the components in isolation".

Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties.

Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

2. Literature Survey

Mukul Kant Paliwal, Sachin Kumar Chaturvedi et al (2012), Composites materials are used in almost all aspects of the industrial and commercial fields in aircraft, ships, common vehicles, etc. Their most attractive properties are the high strength-to-weight ratio. However, these materials also have some problems such as fiber fracture, matrix cracking and delamination. Matrix cracks and fiber fractures play an important role in laminates under tensile load. Delamination may be formed due to a wide variety of foreign object impact damage, poor fabrication process, and fatigue from environment cycle. Materials added to the matrix help improving operating properties of a composite. This experimental study has targeted to investigate the tensile strength of glass fiber and epoxy resin based composite with CaCO3 as a filler. E-glass/epoxy composites were first manufactured to fabricate the specimens, using Hand lay-up technique. The tensile tests were carried out on the specimen for the determination of its mechanical properties.

Ramesh Chandra Yadaw, Sachin Chaturvedi et al (2012), the use of polymer based composite materials is increasing because of their light weight, good mechanical and tribological responses. In the present work the two bodies sliding wear of Silica (SiO2) filled glass fibre reinforced epoxy resin composite has been discussed. Two body sliding wear test has been carried out to calculate the wear rate of the composite. The effect of SiO2 filler on the wear properties has been studied and found that wear loss of silica filled composite is very less than the unfilled composites even at higher loads. The E-glass fibre epoxy composite has been fabricated by hand lay-up method by with and without adding SiO2 filler (5-15% in a gap of 5%). Along with sliding wear mechanical properties such as tensile, flexural, impact and hardness tests were performed and it is found that the hardness and flexural strength has increased and tensile strength and impact energy has reduced significantly due to the addition of the silica filler.

2.1 Objectives of the Present Research Work

The present research work is undertaken to develop a new class of E-Glass/Epoxy Composite Materials With Al2O3 , CaCo3 , SiO2 and PbO filler and to study their mechanical behavior. Attempts have been made to explore the potential use of glass fiber as reinforcement in polymer composites.

The literature survey presented above reveals the following knowledge gap in the research reported so far:

1. Though much work has been done on a wide variety of fibers for polymer composites, very less has been reported on the reinforcing potential of glass fiber in spite of its several advantages over others.

2. A number of research efforts have been devoted to the mechanical and wear characteristics of either fiber reinforced composites or particulate filled composites.

However, a possibility that the incorporation of both particulates and fibers in polymer could provide a synergism in terms of improved performance has not been adequately addressed so far.

The knowledge gap in the existing literature review has helped to set the objectives of this research work which are outlined as follows:

1. Fabrication of unfilled and calcium carbonate filled glass fiber reinforced epoxy composites.

2. Evaluation of mechanical properties of both unfilled and particulate filled composites such as tensile strength, impact strength flexural strength, and micro-hardness etc.

3. To study the fracture surface morphology using SEM study for mechanical properties samples and eroded samples.

3. Materials and Methods

The details of processing of the composites and the experimental procedures followed for their characterization and behaviour evaluation. The raw materials used in this work are:

1. E-glass Fibre (Glass 35%)
2. Epoxy Resin (Polyester 62.4%)
3. Aluminum Oxide (Al2O3)
4. Calcium Carbonate (CaCo3)
5. Silica Oxide (SiO2)
6. Lead Oxide (PbO)

3.1 Fabrication of the Composites (Step by Step)

1. We used unsaturated Resin in liquid form = Polymer + Additive

2. Additive = Hardener (Conc. Cobalt 0.6%) and Catalyst (MEKP (Methyl Ethyl Ketone Peroxide)

3. Calculation for Composition of the composites materials are as follows:

    a. 65% Resin + 35% Fibre
    b. 65% Resin + Additives (Al_2O_3/ $CaCo_3$/ Sio_2/ PbO)
    c. Additive is by volume method is 20% of Resin - 65*20/100=13%
    d. Resin is 65% – 13% = 52%

4. The final compositions of the composite material with the following MR:

Mixing Ratio (MR) = 52% Resin + 13% Additive +35% Fibre

So compositions of the composites materials are as follows

a. 65% Resin + 35% Fibre
b. 52% Resin + 13%Al2O3+35% Fibre
c. 52% Resin + 13%CaCO3+35% Fibre
d. 52% Resin + 13%SiO2+35% Fibre
e. 52% Resin + 13%PbO+35% Fibre

3.2 ORIENTATION OF FIBER

a. Fibre orientation in sheet form 0-90.
b. Fibre used- Chopped Slandered Mat(CSM)/E-Glass.
c. Fibre orientation in cylindrical rod is random.
d. Fibre used- Glass Roving

3.3 Required Specimens of Composites Materials

a. Dimensions of specimen for tensile test on tensile testing machine is 250 mm x 65 mm X 5 mm

b. Dimensions of specimen for torsion test on torsion testing machine is Length : 200 mm and Diameter: 20 mm

c. Dimensions of specimen for Vickers Hardness Test on Vickers Hardness Testing Machine is 85 mm x 25 mm X 5 mm

d. Dimensions of specimen for Charpy Test on Impact Testing Machine is 55 mm x 10 mm X 10 mm and Notch: 2 mm at 45^0 Angle

4. Results and Discussions

The mechanical properties of the E-glass fiber reinforced epoxy composites with Al_2O_3, $CaCo_3$, SiO_2 and PbO Fillers prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous chapter.

The results of various characterization tests are reported here. This includes evaluation of tensile strength, torsion test, hardness test and impact test has been studied and discussed. The interpretation of the results and the comparison among various composite specimens are also presented.

4.1 Surface Morphology of the Composites

4.1.1 E-Glass fiber reinforced epoxy composites without filler (Resin and Fiber):

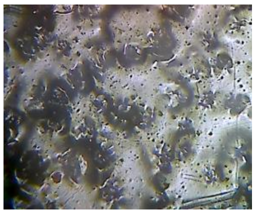


Figure 4.1: Resin and Fiber Composite Material at 10x Zoom, Mechanical Microscope

4.1.2 E-Glass fiber reinforced epoxy composites with filler Al_2O_3:

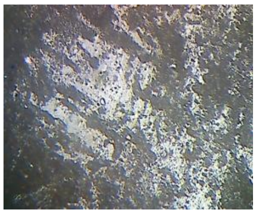


Figure 4.2: Al_2O_3 Composite Material at 10x Zoom, Mechanical Microscope

4.1.3 E-Glass fiber reinforced epoxy composites with filler $CaCo_3$:

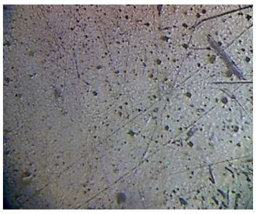


Figure 4.3: $CaCo_3$ Composite Material at 10x Zoom, Mechanical Microscope

4.1.4 E-Glass fiber reinforced epoxy composites with filler SiO_2:

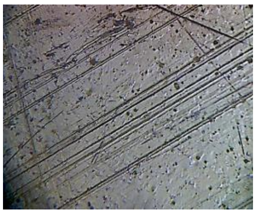


Figure 4.4: SiO_2Composite Material at 10x Zoom, Mechanical Microscope

4.1.5 E-Glass fiber reinforced epoxy composites with filler PbO:

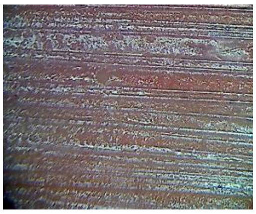


Figure 4.5: PbO Composite Material at 10x Zoom, Mechanical Microscope

4.2 Mechanical Characteristics of Composites

4.2.1 E-Glass fiber reinforced epoxy composites without filler (Resin and Fiber):

The mechanical properties of the E-glass fiber reinforced epoxy composites without filler with different fiber loading/test under this investigation are presented as follows.

a. Tensile Strength from Tensile Test is 2100 kgf = 20594 N
b. Torsion Strength from Torsion Test is 0.8 kg.m = 7.84 N.m
c. Hardness from Vickers Testing Machine is 39.1 HV
d. Energy Absorbed from Charpy Test is 58 J = 58 N.m

4.2.2 E-Glass fiber reinforced epoxy composites with filler Al_2O_3:

The mechanical properties of the E-glass fiber reinforced epoxy composites with filler Al_2O_3 different fiber loading/test under this investigation are presented as follows.

a. Tensile Strength from Tensile Test is 2150 kgf = 21084 N
b. Torsion Strength from Torsion Test is 0.4 kg.m = 3.92 N.m
c. Hardness from Vickers Testing Machine is 60.7 HV
d. Energy Absorbed from Charpy Test is 22 J = 22 N.m

4.2.3 E-Glass fiber reinforced epoxy composites with filler $CaCo_3$:

The mechanical properties of the E-glass fiber reinforced epoxy composites with filler $CaCo_3$ different fiber loading/test under this investigation are presented as follows.

a. Tensile Strength from Tensile Test is 2200 kgf = 21574 N
b. Torsion Strength from Torsion Test is 0.5 kg.m = 4.90 N.m
c. Hardness from Vickers Testing Machine is 40.6 HV
d. Energy Absorbed from Charpy Test is 50 J = 50 N.m

4.2.4 E-Glass fiber reinforced epoxy composites with filler SiO_2:

The mechanical properties of the E-glass fiber reinforced epoxy composites with filler SiO_2 different fiber loading/test under this investigation are presented as follows.

a. Tensile Strength from Tensile Test is 2050 kgf = 20103 N
b. Torsion Strength from Torsion Test is 3.2 kg.m = 31.38 N.m
c. Hardness from Vickers Testing Machine is 65.9 HV
d. Energy Absorbed from Charpy Test is 52 J = 52 N.m

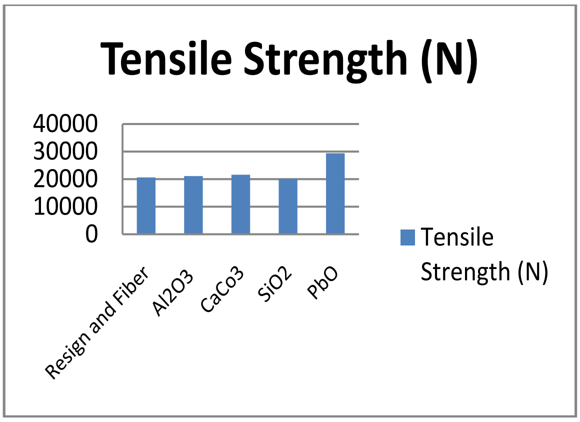
4.2.5 E-Glass fiber reinforced epoxy composites with filler PbO:

The mechanical properties of the E-glass fiber reinforced epoxy composites with filler PbO different fiber loading/test under this investigation are presented as follows.

a. Tensile Strength from Tensile Test is 3000 kgf = 29419 N
b. Torsion Strength from Torsion Test is 2.6 kg.m = 25.49 N.m
c. Hardness from Vickers Testing Machine is 39.9 HV
d. Energy Absorbed from Charpy Test is 24 J = 24 N.m

4.3 Comparisons between Mechanical Characteristics of Composites with Discussion

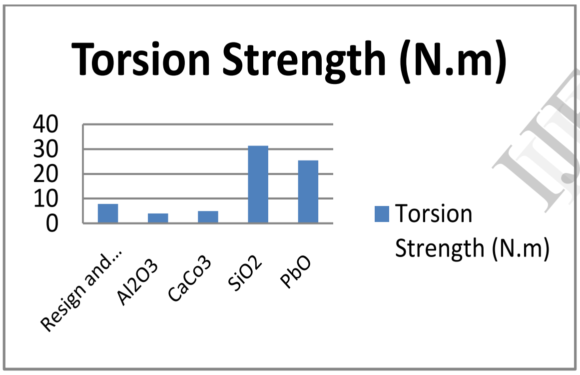
a. Comparisons between Composites with respect to tensile strength:



Graph 4.1: Comparisons between Composites with respect to tensile strength

It is evident from the Graph 4.1 that Lead Oxide (PbO) as a filler material added in resign and Fiber composites (52% Resin + 13% PbO + 35% Fibre) has a better mechanical tensile properties as compared to others.

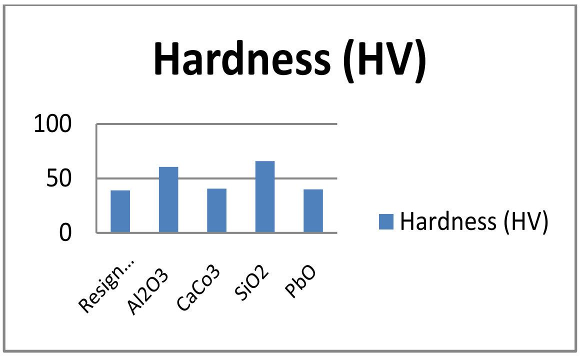
b. Comparisons between Composites with respect to torsion strength:



Graph 4.2: Comparisons between Composites with respect to torsion strength

It is evident from the Graph 4.2 that Silica Oxide (SiO2) as a filler material added in resign and Fiber composites (52% Resin + 13% SiO_2 + 35% Fibre) has a better mechanical torsion properties as compared to others.

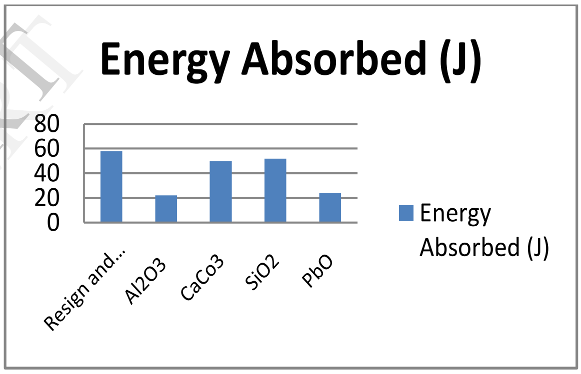
c. Comparisons between Composites with respect to Hardness:



Graph 4.3: Comparisons between Composites with respect to Hardness

It is evident from the Graph 4.3 that Silica Oxide (SiO_2) as a filler material added in resign and Fiber composites (52% Resin + 13% SiO_2 + 35% Fibre) has a better mechanical hardness properties as compared to others.

d. Comparisons between Composites with respect to Energy Absorbed:



Graph 4.4: Comparisons between Composites with respect to Energy Absorbed

It is evident from the Graph 4.4 that a resin and fiber composite without filler (65% + 35% Fibre) has a better mechanical energy absorbed properties as compared to others.

5. Conclusions

The present investigations of mechanical behavior of Al_2O_3 , $CaCo_3$, Sio_2 and PbO filled in E-glass fiber reinforced epoxy composites leads to the following conclusions:

1. The E-glass fiber reinforced epoxy composites filled with Al_2O_3 , $CaCo_3$, Sio_2 and PbO filler has been successful fabricated by simple hand lay-up technique. It has been noticed that the mechanical properties of the composites such as hardness, tensile strength,

torsion strength, impact strength etc. of the composites are also greatly influenced by the filler content.

2. The morphology of fractured surfaces is examined by using mechanical microscope at 10x zoom after various testing. From this study it has been concluded that the good interfacial bonding is responsible for higher mechanical properties.

References

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