Investigation of Mechanical, Thermal Properties of Camel wool Fiber and Chopped E-Glass Fiber Reinforced Epoxy Resin with and without Addition of Iron Oxide

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ABSTRACT - Composites are an excellent alternative to metal alloys due to their high strength-to-weight ratio. It's awesome that researchers are working on biodegradable and recyclable fiber-reinforced composites. Each natural and synthetic fiber has advantages and disadvantages, but combining different fibers alters the properties of composite materials. In this project, we used camel wool fiber and chopped E-glass to make a hybrid composite with epoxy as the matrix. Combining different fibers in composite materials, it is possible to alter their properties and create materials with specific characteristics. Additionally, adding fillers to composites can further enhance their characteristics, such as improving strength, stiffness, and other mechanical and thermal properties. We also experimented with different amounts of iron oxide which resulted in these semi-biodegradable materials. The mechanical and thermal characteristics of these composites improved as the iron oxide powder content rose. The best part is that using iron oxide as a filler material can help reduce material costs.

Key Words: Chopped E glass (CEG), Camel wool Fiber (CWF), Filler, Differential thermal analysis (DTA), Thermogravimetric analysis (TGA), Derivative thermogravimetry (DTG).

1. INTRODUCTION

In today's world, the demand for materials with a wide range of properties is increasing due to the requirements of modern technologies. Traditional metal alloys may not be able to meet all of these demands, which is why researchers are actively exploring the development of hybrid composites. These hybrid composites are created by combining different types of fibers, both organic and inorganic, to create a material that has a unique combination of properties. The matrix material acts as the binding material that holds the reinforcement fibers together. It provides dimensional stability and enhances the overall performance of the composite. Glass is one such commonly used matrix material, known for its excellent mechanical properties and resistance to chemical attack [1,2]. By carefully selecting and combining these different types of fibers and matrix materials, researchers are able to tailor the properties of the hybrid composites to meet specific application requirements. This allows for the creation of materials with high strength, high stiffness, high corrosion resistance, and other desirable characteristics that cannot be achieved by conventional metal alloys alone. The ongoing research and development in the field of hybrid composites hold great promise for advancing various industries, including aerospace, automotive, construction, and more. It's truly fascinating to witness the progress being made in this area. A detailed review has been conducted on the behavior of camel wool fiber, chopped e-glass, and iron oxide powder to understand the material properties. The interaction of these materials as reinforcement with different matrix materials is also studied. Chopped e-glass fibers have excellent resistance to corrosion and also have good electrical resistance properties [3,4,5]. There is an increase in research into the use of Chopped E-glass fibers due to their enhanced mechanical and thermal properties. Camel wool fiber is famous for its amazing insulation properties, which help keep our bodies cozy in cold weather conditions. It has a natural talent for regulating body temperature, ensuring that we stay comfortable no matter the climate. It's like having our own personal temperature controller [6,7]. Iron oxide offers versatility, stability, durability, and UV resistance, making it a valuable material in various industries [8]. The addition of SiC affects the composite's thermal and mechanical properties, providing insights into potential applications and optimizations for these materials in various engineering fields [9]. An understanding of composite materials and their specific properties for different industrial and technical applications is enhanced by the magnetic and thermal characteristics of nitrile butadiene rubber latex [10].

2. MATERIALS AND METHODOLOGY

2.1 Materials: In this piece of work, reinforcement materials consist of Chopped E-glass fiber, which is a synthetic substance, and Camel wool, which is a natural fiber. The Hybrid Composite uses Epoxy Araldite (LY556) as the matrix and Aradur (HY951) as the hardener, with an epoxy to hardener ratio of 10:1. Iron oxide powder, weighing between 5.5 and 11.3 grams, or 2.5% and 5% by weight, is utilized as a filler ingredient.

2.2 Methodology: During the fabrication process, dry fibers like Camel wool and Chopped E-glass are weighed to calculate the fiber-to-epoxy ratio. Resin and hardener are then blended manually at a 10:1 ratio. The fibers are manually put over a thin film coated with mansion polish, and the resin matrix is applied to the reinforcing materials using a brush. This technique is repeated until the appropriate fiber thickness has been achieved. In a hybrid composite, the fibers are arranged alphabetically, an epoxy mixture is combined with the necessary filler material, and the same procedure is carried out. Once the fibers are piled, a squeezer is used to improve the interface between the reinforcement and matrix, allow for uniform resin dispersion, and provide the necessary thickness. In the final step, the laminates are allowed to cure under usual atmospheric conditions.

2.3 Relative weights of the fibers and resins: The weight ratio of fiber to resin is 1:1 for Camel wool fiber and 1:1.5 for Chopped E-glass fiber.

Table -1: The Quantity of layers and the weight of each Fiber separately.

Fibers	No. of Fiber layers	Fiber wt. in gm	The Resin wt. in gm	Desired Thickness in mm
Camel wool Fiber (CWF)	4	63	216	4
Chopped E-glass (CEF)	3	124	216	4
Hybrid (CWF+CEG)	2+2	113	216	4
Hybrid (CWF+CEG+5.5gm)	2+2	113	216	4
Hybrid (CWF+CEG+11.3gm)	2+2	113	216	4

2.4 COMPOSITE HYBRID COMPOSITIONS

Table -2: The weight ratio of matrix and composite fibre.

Name of the Specimen	Composite Hybrid Composition by (wt. %)
Camel wool Fiber (CWF)	CWF (22.5%) + Epoxy (77.5%)
Chopped E-glass (CEF)	CEG (36.5%) + Epoxy (63.5%)
Hybrid (CWF+CEG)	CWF (15.6%) + CEG (30.9%) + Epoxy (53.5%)
Hybrid (CWF+CEG+5.5gm)	CWF (15.4%) + CEG (30.5%) + Epoxy (52.8%) + Iron oxide powder (1.3%)
Hybrid (CWF+CEG+11.3gm)	CWF (15.2%) + CEG (29.9%) + Epoxy (52.2%) + Iron oxide powder (2.7%)

When each of the composite's material percentages are added together, the overall weight percentage should be equal to **100%**.

3. RESULTS

3.1 MECHANICAL TEST RESULTS:

Table -3: Tensile Test Results

Name of the Specimen	Load at break (KN)	Cross Head Travel (mm)	Time taken to break(sec)	Ultimate Tensile Strength (MPa)
Camel wool Fiber (CWF)	6.62	4.62	125	82.75
Chopped E-glass (CEF)	11.76	8.93	179	147
Hybrid (CWF+CEG)	11.30	7.10	114	141.25
Hybrid (CWF+CEG+5.5gm)	10.26	5.14	88	128.25
Hybrid (CWF+CEG+11.3gm)	**11.90**	**6.50**	**180**	**148.75**

Table -4: Compression Test Results

Name of the Specimen	Max. load (KN)	Comp. Strain (mm/mm)	Young's Modulus (N/mm^2)	Comp. Strength (MPa)
Camel wool Fiber	5.64	0.00735	19183.6	19183.6
Chopped E Glass Fiber	5.60	0.0147	9523.8	9523.8
Hybrid	5.94	0.00735	20204.0	20204.0
Hybrid with 2.5% of filler material	6.3	0.0220	7159.0	7159.0
Hybrid with 5% of filler material	**7.18**	**0.0294**	**6105.4**	**6105.4**

Table -5: Flexural Test Results

Name of the Specimen	Max. load (KN)	Stress at max Flexural load (MPa)	Strain at Maximum Flexure stress (mm/mm)	Young's modulus (MPa)
Camel wool Fiber	5.44	5613.5	0.0428	131.15
Chopped E Glass Fiber	5.60	5778.6	0.0714	80.93
Hybrid	5.64	5881.8	0.0619	95.02
Hybrid with 2.5% of filler material	5.66	5840.5	0.0523	111.67
Hybrid with 5% of filler material	**5.70**	**5883.8**	**0.0476**	**123.56**

Table -6: Hardness Test Results at (100Kg load)

Name Of the Specimen	Load applied (N)	Average diameter of Indentation d (mm)	Diameter of Ball Indenter (mm)	Brinell's Hardness Number (BHN)
Camel wool Fiber	981	0.43	6.35	72
Chopped E Glass Fiber	981	0.435	6.35	73
Hybrid	981	0.41	6.35	79
Hybrid with 2.5 % of filler material	981	0.435	6.35	69
Hybrid with 5% of filler material	**981**	**0.41**	**6.35**	**81**

Table -7: Hardness Test Results at (150Kg load)

Name Of the Specimen	Load applied (N)	Average diameter of indentation d (mm)	Diameter of Ball Indenter (mm)	Brinell's Hardness Number (BHN)
Camel wool Fiber	**1471**	**0.45**	**6.35**	**102**
Chopped E Glass Fiber	1471	0.47	6.35	83
Hybrid	1471	0.44	6.35	98
Hybrid with 2.5 % of filler material	1471	0.48	6.35	81
Hybrid with 5% of filler material	1471	0.44	6.35	97

In the Brinell hardness test, the specimens are tested under two different weights, which are 100kg and 150kg. During calculations, the loads are converted into Newtons, which gives a value of 981 N for a 100kg load and 1471 N for a 150kg load. The impression is held on the specimen with the help of a ball indenter made of hardened steel whose diameter is **6.35mm.**

Table -8: Impact Test Result (Initial energy 300J)

Specimen label	Cross sectional area below The Notch (mm^2)	Reading after impact (J)	Actual energy (J)	Impact Strength J/mm^2
Camel wool Fiber	684	74	226	9.41
Chopped E Glass Fiber	684	76	224	9.33
Hybrid	684	70	230	9.58
Hybrid with 2.5% of filler material	684	62	238	9.91
Hybrid with 5% of filler material	**684**	**84**	**216**	**9.0**

Fig. 1 Presents a graph showing the ultimate tensile strength of the various specimens utilized in the investigation.

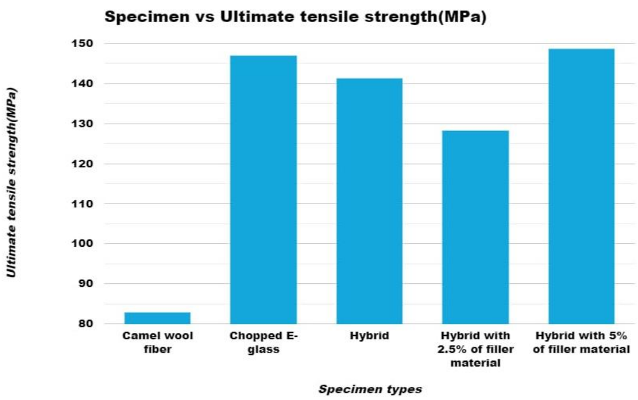

Fig.2 Graph between the name of the specimen and the tensile strength of the specimen.

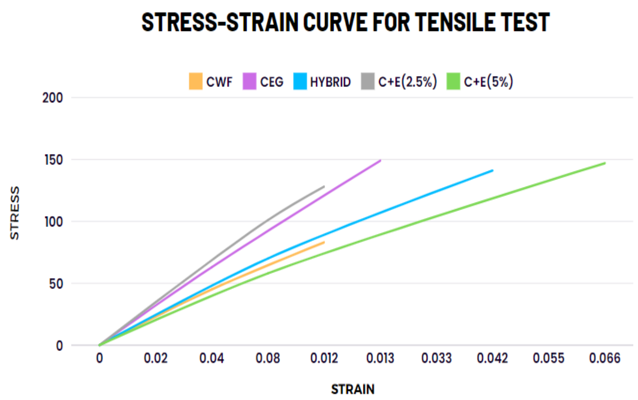

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Fig.3 Presents a graph showing the Compression strength of the various specimens utilized in the investigation.

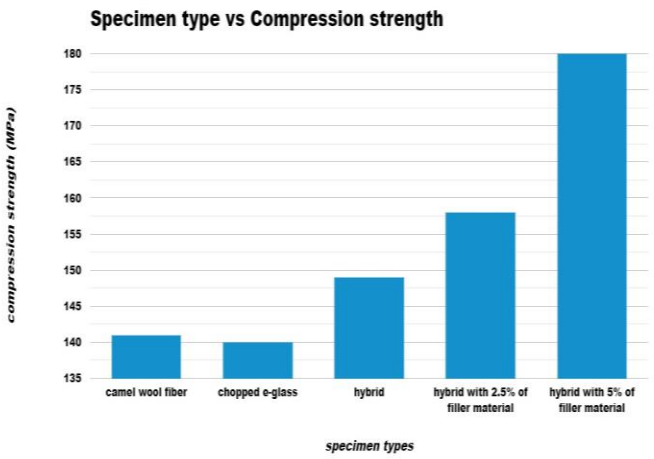


Fig.4 Presents a graph showing the Flexural strength of the various specimens utilized in the investigation.

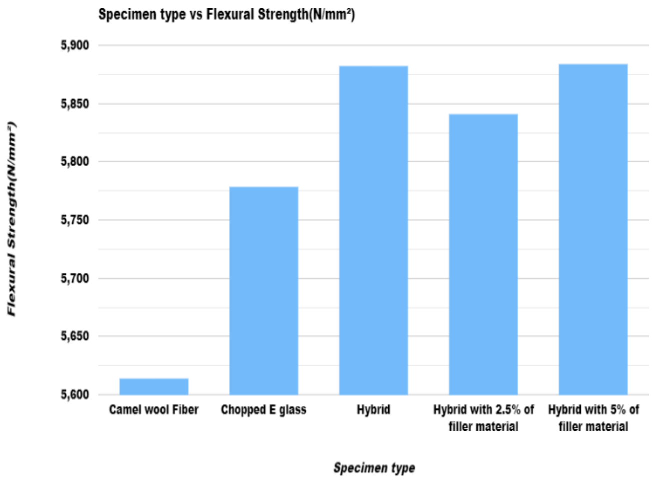


Fig.5 Presents a graph showing the Hardness of the various specimens utilized in the investigation.

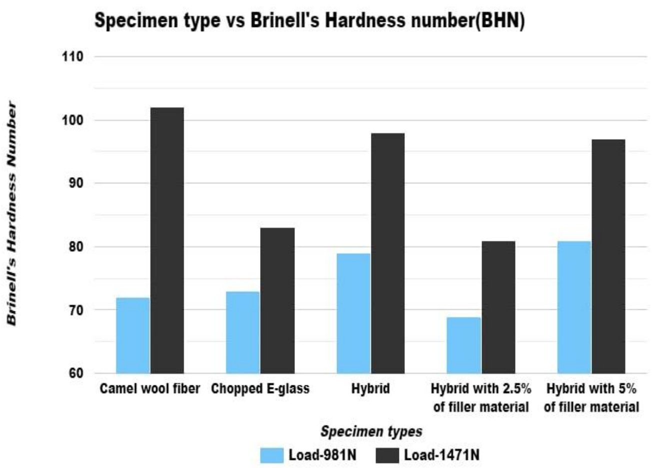
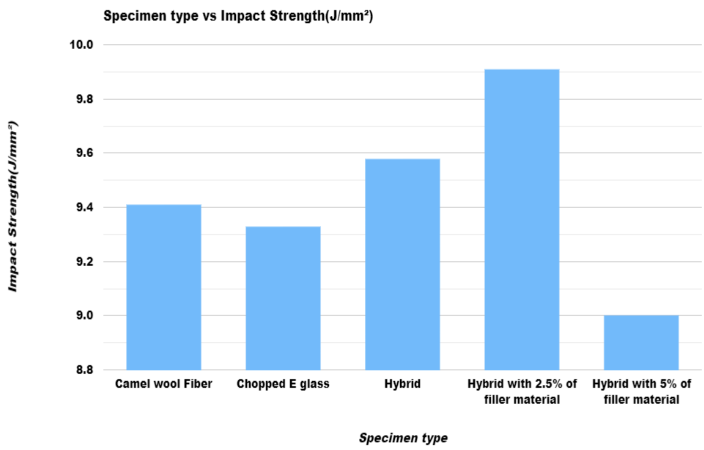


Fig.6 Presents a graph showing the Charpy Impact strength of the various specimens utilized in the investigation.



3.2 THERMAL TEST RESULTS:

Fig.7 Graph for Differential thermal analysis and Thermogravimetric analysis for Camel Wool Fiber

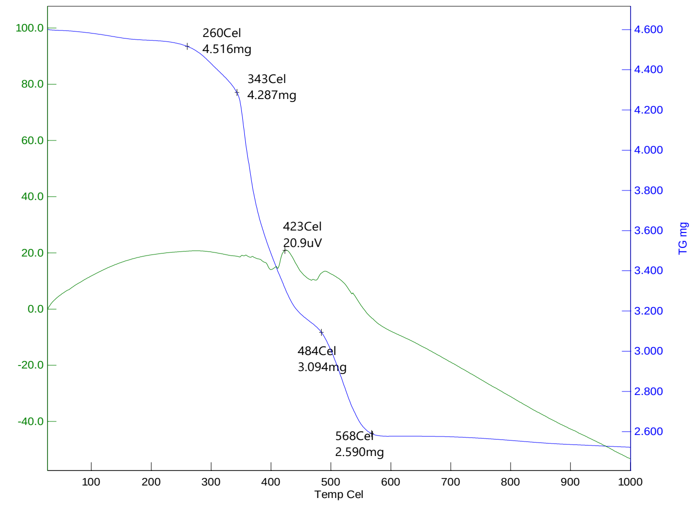


Fig.8 Graph for Derivative thermogravimetry For Camel wool Fiber

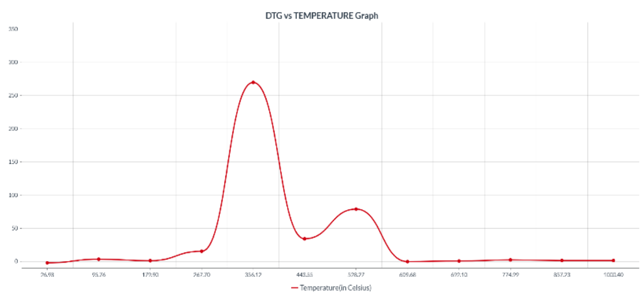


Fig.9 Graph for Differential thermal analysis and Thermogravimetric analysis for Chopped E-Glass Fiber

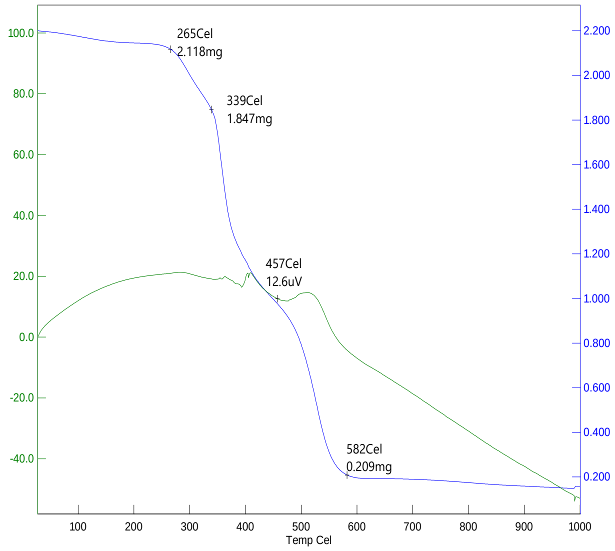


Fig.10 Graph for Derivative thermogravimetry for Chopped E-glass Fiber

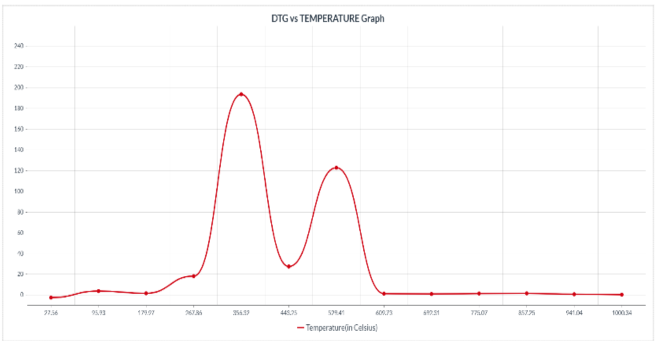


Fig.11 Graph for Differential thermal analysis and Thermogravimetric analysis for Hybrid (CWF+CEG)

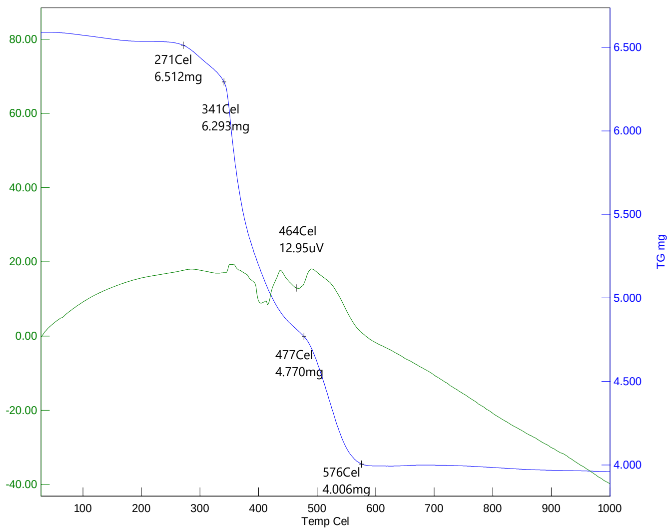


Fig.12 Graph for Derivative thermogravimetry for Hybrid (CWF+CEG)

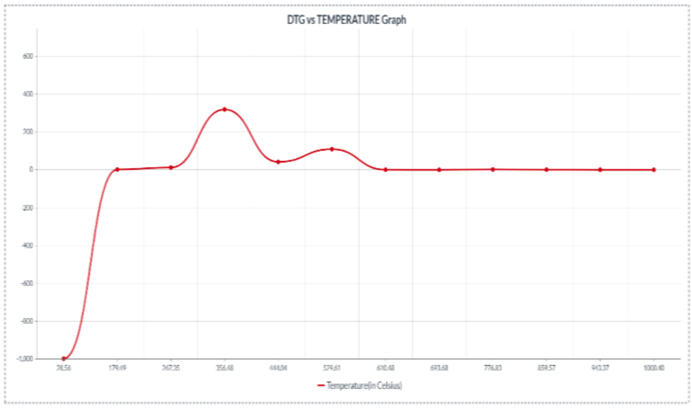


Fig.13 Graph for Differential thermal analysis and Thermogravimetric analysis for Hybrid 2.5% Filler

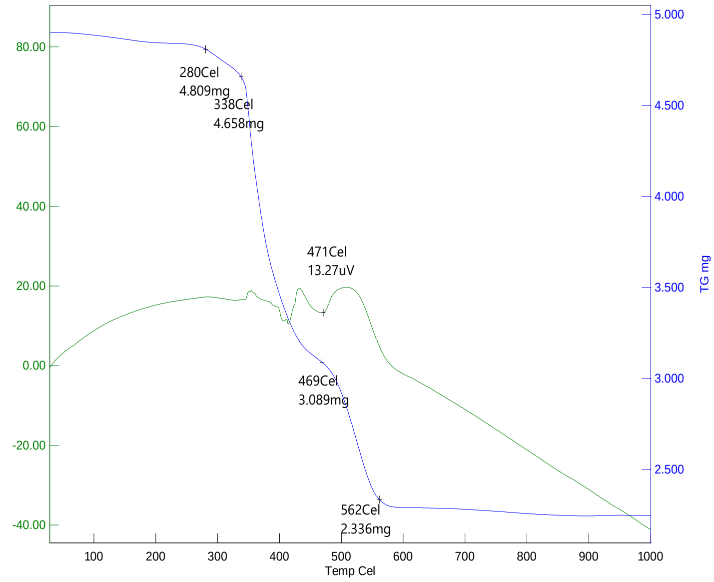


Fig.14 Graph for Derivative thermogravimetry Hybrid 2.5% Filler

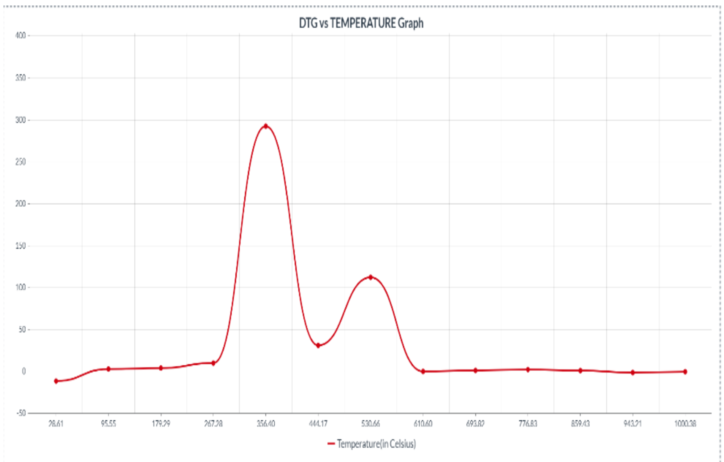


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Fig.15 Graph for Differential thermal analysis and Thermogravimetric analysis for Hybrid 5% Filler

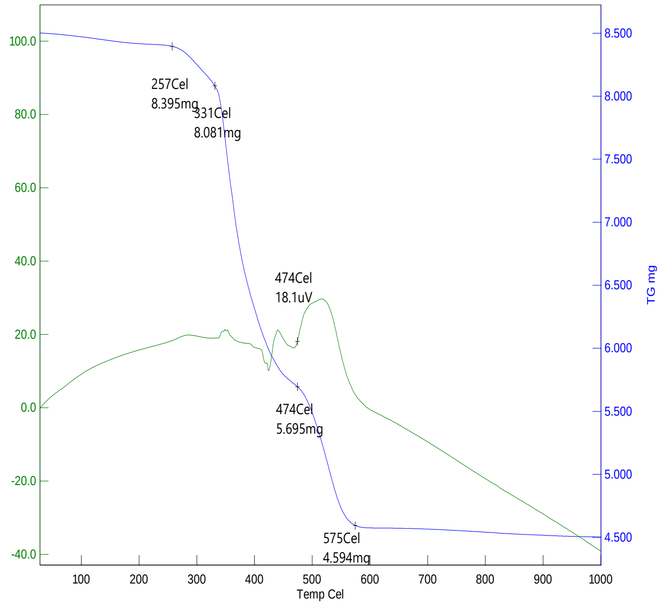
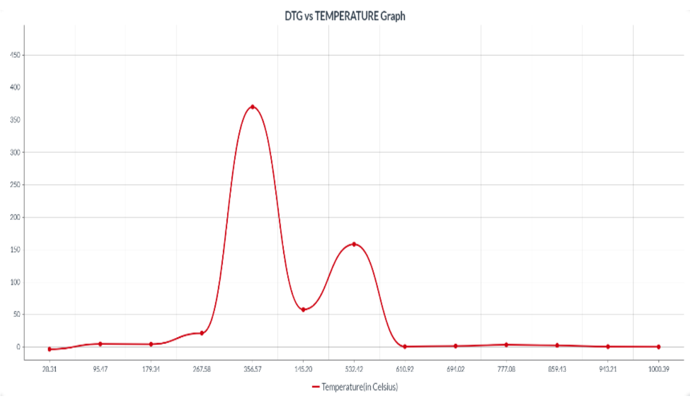


Fig.16 Graph for Differential Thermogravimetric analysis for Hybrid 5% Filler



4. DISCUSSION:

All of the specimens used in this study were dimensioned according to ASTM standards.

a) Figs. 1 and 2 show the ultimate tensile strength of various specimens utilized in the investigation and the stress vs. strain graph for the tensile test specimen. It is observed that hybrid composites with 5% filler material (11.3g) have an ultimate tensile strength of 148.75 MPa.

b) From Fig. 3, the compression strength of each specimen is investigated, and it reveals that a hybrid composite with 5% filler material has 179.5 MPa of compression strength, which is higher than other specimens.

c) Fig. 4 presents the flexural strength of the specimens, and this graph concludes that hybrid composites with 5% filler material have a higher flexural strength of 5883.8 MPa.

d) Fig. 5 presents a bar graph showing the hardness of various specimens used in this investigation. It concludes that hybrid composites with 5% filler material have the highest Brinell Hardness number of 81BHN at 100 kg load (981N), and camel wool Fiber has the highest Brinell Hardness number of 102BHN at 150 kg load (1471N).

e) In Fig. 6, the Charpy Impact test results of the specimens are shown, and it is concluded that hybrid composites with 2.5% filler material (5.5g) have shown the highest impact strength of 9.91 J/mm^2.

f) Figs. 7 and 8 are the DTA-TG and DTG graphs of a camel wool Fiber specimen, and it shows that the melting point of the specimen is 423 °C and the specimen weight has changed from 4.600mg to 2.590mg at 568°C before completely decomposing.

g) Figs. 9 and 10 show the DTA-TG and DTG graphs of chopped e-glass Fiber specimens, which show that the melting point of the specimen is 457 °C and the specimen weight has changed from 2.200mg to 0.209mg at 582°C before completely decomposing.

h) Figs. 11 and 12 are the DTA-TG and DTG graphs of the hybrid composite without filler material specimen, and it shows that the melting point of the specimen is 464 °C and the specimen weight has changed from 6.500mg to 4.006mg at 576°C before completely decomposing.

i) Figs. 13, 14, and 15, 16 represent the DTA-TG and DTG graphs of hybrid composites with 2.5% and 5% filler material, respectively. It concludes that the melting point is 471°C, the sample weight has changed from 4.900mg to 2.336 mg at 562°C for 2.5% iron oxide filler material, and for 5% filler material, the melting point is 474 °C, and the sample weight of 8.500 mg has changed to 4.594mg at 575°C.

j) Thermal test results finally conclude that hybrid composites with 5% weight of iron oxide filler material have shown the highest resistance to an increase in temperature with an increase in time.

5. CONCLUSIONS

Through this work, a hybrid composite is fabricated by using Chopped E-glass and Camel wool Fiber in varying amounts, and numerous tests are carried out. The work has been expanded to investigate the characteristics both with and without the iron oxide powder filler material. The test results are summarized as follows:

a) High properties have been reported in the hybrid composite containing 11.3 grams (5% wt.) of iron oxide filler material. Increases to 148.75 MPa for tensile strength, 179.5 MPa for compression strength, and 5883.8 MPa for flexural stress are achieved. The toughness and hardness reached 9.0 J/mm2 and 97 BHN, respectively.

b) Apart from mechanical tests, thermal tests such as DTA, TGA, and DTG are conducted on composites to find out how the material reacts to changes in temperature over time. The results revealed that the hybrid composite with 5% weight of filler material has the highest melting point of 474 °C, and the weight of the sample has changed from 8.500mg at 100°C to 4.695mg at 575°C before getting completely decomposed.

c) The addition of iron oxide powder improves the mechanical and thermal properties of the composite material, according to the results. By adding iron oxide powder, the hybrid composite material's characteristics are enhanced.

d) Combining natural Fibers with synthetic Fiber and iron oxide filler improves their characteristics, and it minimizes the price as the cost of hybrid composite materials is lower in comparison to conventional Fiber-reinforced composite materials.

e) The characteristics of these hybrid composite materials are further improved by the addition of a suitable amount of filler material.

6. FUTURE SCOPE

This paper examines the mechanical and thermal properties of the created hybrid composite. Images from a scanning electron microscope (SEM) can be used to advance this study.

To determine the ideal weight percentage for attaining the highest property values, this filler material percentage may be raised even more.

By incorporating calcium oxide into the produced material, this work can be investigated further in order to produce a nuclear disposable container.

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