Mechanical Characterization of Synthetic/Natural Fibre Polymer Matrix Composite with Grey Relational Analysis Approach

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Abstract - *Natural fibres have recently paying close attention to synthetic fibres in a variety of areas, including building, packaging, and automobile. In comparison to thermoplastic and thermoset matrices, the use of natural fibres as reinforcement in composite materials has progressively increased. The present work is to validate the impact of E-glass and ramie fibre with epoxy matrix for cost effective composite materials. The composite material is processed through the hand lay-up with compression moulding process to make PMCs. Mechanical characteristics are examined by conducting tests such as tensile test, Flexural test, impact test and hardness on the produced samples of polymer matrix composite. Tensile test results of several laminates revealed that the specimen with 50% glass fibre and 40% ramie fibre has the highest tensile strength. In addition, equal amount of glass fibre and ramie fibre has shown better flexural strength and hardness. However, enhanced impact strength can be obtained with 50% wt. of ramie fibre. The mechanical characteristics obtained for glass and ramie fibres are validated with the analysis of grey relational model.*

Key Words: *Natural fiber, glass fibers, Hand layup, Grey Relational Analysis*

1. INTRODUCTION

Materials are the building blocks of human progress and well-being. Since the dawn of civilization, mankind have had access to and used many types of materials. Examining the development of human civilization reveals that it is built on human access to and use of materials, as well as science, technology, and social productive forces. It signifies humanity's power to understand and transform nature. Production flourishes and civilization progresses whenever a new epoch-making material is found. Thus, materials have come to signify human civilization's development, as well as a line that separates the past from the present. Elevated polymers and composites, which first arose in the twentieth century, have invaded the economic development and social units in a variety of industries at an unimaginable pace of development. They have replaced conventional materials and have demonstrated enhanced performance. Materials now play a major role in the national economy and military, thanks to fast advances in science and technology [1].

Interfacial adhesion between matrix and fibres is a major factor in determining the tensile characteristics of natural fiber-reinforced thermoplastics and thermosets, according to Ku & Wang et al [2]. As far as mechanical qualities are concerned, jute-reinforced polyester composites were shown to have superior strength than wood-composite materials when evaluated for their mechanical properties as reported by Gouda et al [3]. Joseph et al [4] also examined banana fibre and glass fibre with varied fibre length and composition. The mechanical characteristics of these composites were analyzed, and it was discovered that strong composites could be effectively made employing banana fibre as a reinforcing element. Pavithran et al [5] compared the impact characteristics of unidirectionally oriented sisal fiber-polyester composites to those of ultra-high-density polyethylene (UHDPE) and glass fibre composites. When the density of sisal fibre composites is considered, the work of fracture is similar to that of ultra-high-modulus polyethylene composites, and the toughness of sisal fibre composites is only 25% less than that of glass fibre composites. The abrasive wear behavior of bagasse fibre reinforced polymer (BFRP) composites has been described by Mishra and Acharya [6]. Abrasive wear rate is largely dependent on load and abrasive grain size, according to BFRP composite. The rate of wear grows as the load and grit size increase. Composites' wear rates are greatly affected by the orientation of their fibres. Yong et al [7] studied the natural fibers and biodegradable resins which were used to prepare environment–friendly biodegradable composites because of their advantages such as low density, low cost, acceptable specific strength and biodegradability. The recent researches and developments of green composites were reviewed in this paper. The goal of Rao et al [8] is to introduce novel natural fibres into polymeric matrixes so that composites for load-bearing constructions may be made economically and lightweight. An extraction procedure of vakka, date and bamboo fiber has been taken. Singh et al [9] studied mechanical behavior of banana fiber based hybrid composite. Increased elasticity and decreased tensile strength may be achieved by including banana fibre into the epoxy. The tensile strength, compressive strength, and in-plane shear strength of a carbon fibre reinforced polymer matrix were measured by Prashanth Banakar et al [10] at both room temperature and high temperature. The test results are examined statistically. Compared to specimens at room temperature, samples at elevated temperature were shown to have a lower level of strength. According to Nirmal et al [11], composite laminates with polyethylene fibre plies on the bottom face of unidirectional carbon fiber/Poly (methyl methacrylate) composite laminates have higher flexural strength than those with poly (methyl methacrylate) fibre plies alone in a hybrid composite. A study by Raghavendra et al [12] focused at the tensile, compressive, and in-plane shear strengths of woven glass fibre reinforced polymer matrix at ambient and high temperatures. An epoxy composite reinforced with glass and ramie fibres is tested for tensile strength, flexural strength, impact strength, and hardness, and the findings are then confirmed via the use of grey relational analysis.

2. MATERIALS SELECTION

Reinforcement in the material is provided only by glass fibres, which have been proven to have remarkable fiber-forming properties. Its high strength and stiffness, cheap cost, low density, high production rates, non-flammable, superior chemical resistance and heat resistance have made E-glass a popular fibre glass material. In polymer matrix composites, E-Glass is often utilized as a reinforcing material. Optimal strength attributes may be achieved when fibres are aligned in a single direction. Strength may be increased in multiple directions by constructing laminate structures with continuous fibres oriented appropriately. As a result, one of the reinforcing materials is E-glass fibre. Ramie is one of the oldest fibre and is a type of bast fibre. Because ramie fibre may be reinforced with a variety of composites, it can give improved mechanical qualities for a variety of applications. Hence, ramie fibre was also chosen as the reinforcing material and epoxy resin was chosen as the matrix material for this investigation. The materials are chosen based on the literature review conducted for different combinations of composite. Different mechanical characteristics are evaluated by conducting tests such as tensile test, flexural test, impact test and hardness on the produced samples of polymer matrix composite. The ASTM standards are used to prepare the samples for the tests. The evaluation of mechanical properties is carried out for individual PMC. The Natural & Synthetic fibers like Ramie, E glass fibre and Epoxy are procured from Go Green Products, Chennai.

3. EXPERIMENTAL DETAILS

The characteristics of the materials used and the procedures used to fabricate and test individual PMCs are discussed in depth in the existing work.

3.1Composite Preparation

The hand lay-up with compression moulding process is one of the most popular ways to make PMCs. Cleaning, gel coating, laying-up, curing, and component removal are all considered hand lay-up methods for processing PMCs. Following the selection of the foundation material, various weight proportions of reinforcements are used to prepare the structure. In this method, two matched metal moulds are used to fabricate composite product [13]. The base plate of a compression moulder moves, while the upper plate is stationary. The metallic mould is filled with reinforcement and matrix, and the entire assembly is held in place between compression moulders. For a certain amount of time, heat and pressure are applied in compatible with the requirement of composite. Due to the application of pressure and heat, the material placed between the moulding plates flows and precisely conforms to the shape of the mould cavity, depending on the mould design. At room temperature or at a higher temperature, the composite may be cured. After curing, the mould is opened and the composite product removed for further processing.

4. RESULT AND DISCUSSION

4.1 Tensile Test

Tensile tests are performed on fully standardized electromechanical or Universal Testing Machines (UTM) according to the ASTM – D638 standard [14]. Universal testing machines are widely available, with sizes ranging from 0.02N to 2000kN.

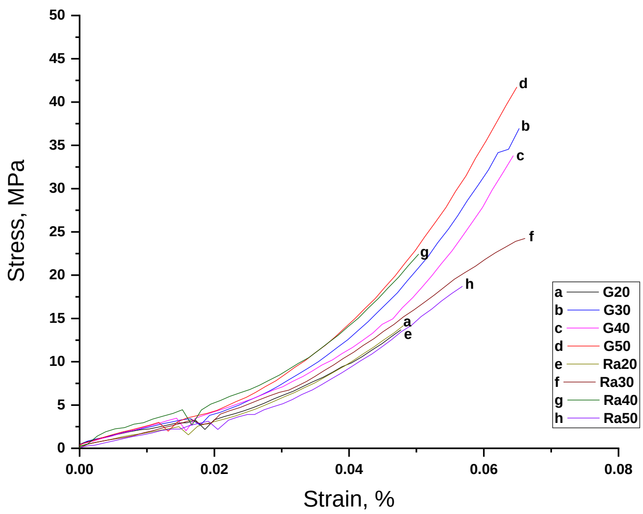
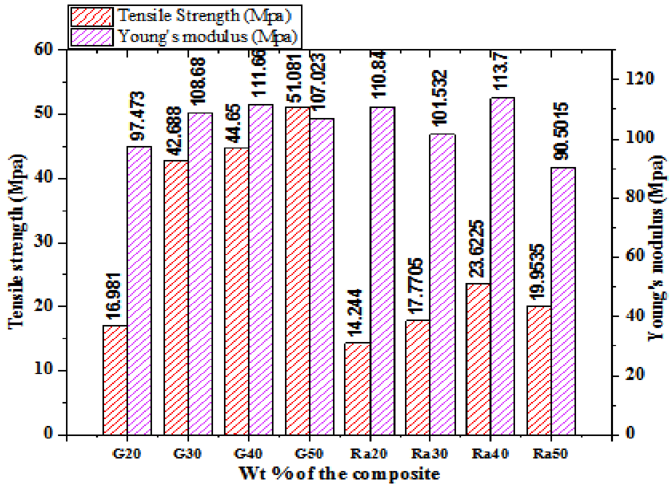
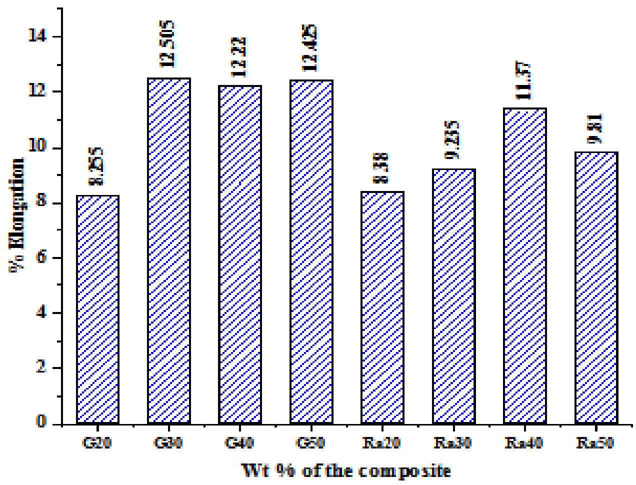


FIGURE 1. Effect of stress-strain curve on composite



(a)



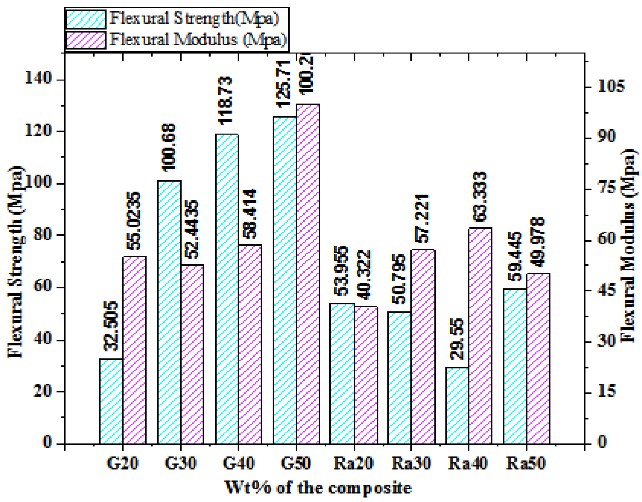
(b)

FIGURE 2. (a) Effect of tensile properties of composite (b) Percentage elongation of composite

Tensile test results of several laminates revealed that the specimen with 50% glass fibre and 40% ramie fibre has the highest tensile strength. Fig. 2 shows the results of the tensile test, which show that glass fibre with a weight of 50% has a higher tensile strength than other prepared composites. This is because the defects in the E-glass fibre have been reduced. The 40 percent wt. ramie fibre also has exceptional tensile strength, modulus, and percent elongation among the various compositions of ramie fibre [15-17].

4.2 Flexural Test

Flexural tests are commonly used to determine a material's flexural strength and modulus. Flexural modulus and flexural strength are both used to assess a material's ability to sustain bending forces.The most common flexural test performed on Universal Testing Machines is the three-point bending test (UTM). Standard specimens for flexural testing are prepared according to ASTM – D790 [18]. The flexural strength and % elongation as shown in figure 3 (a) and (b). Among the varied compositions of glass and ramie fibres, 50 %wt, of glass fibre showed the best break load and 20 %wt, of glass fibre showed the least break load. As a result, glass fibre with a weight of 50% has increased the specimen's flexural strength and flexural modulus. However, the laminate's flexural strength and modulus can be shown to follow a similar pattern to those of its tensile characteristics when the ramie fibre content is varied. Due to the greater number of fibre bundles present as a bridge, the resistance to load is greater when the composition of ramie is increased [19]. The loss of strength in the specimen with 20% wt. of glass fibre is due to agglomeration caused by poor bonding between the fibre reinforcement and the matrix material [15-17].



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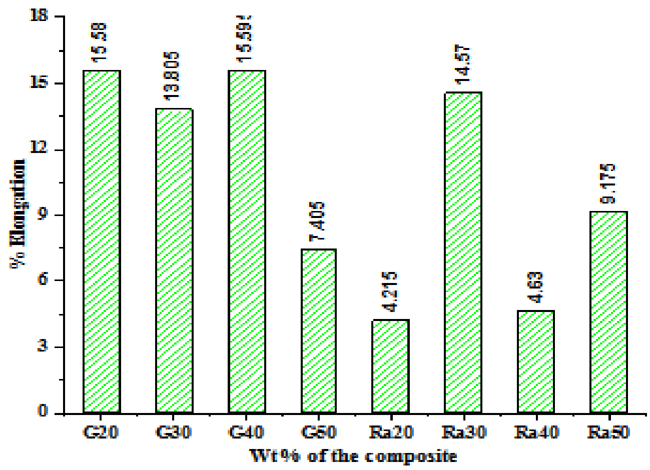

(b)

FIGURE 3. (a) Effect of flexural properties of composite (b) Percentage elongation of composite

4.3 Impact Test

The amount of energy absorbed during fracture is used in an impact test to measure the material's resistance or toughness. The most common application of impact testing is to validate material behavior at maximal deformation speeds. The impact test is carried out in accordance with ASTM D-256.

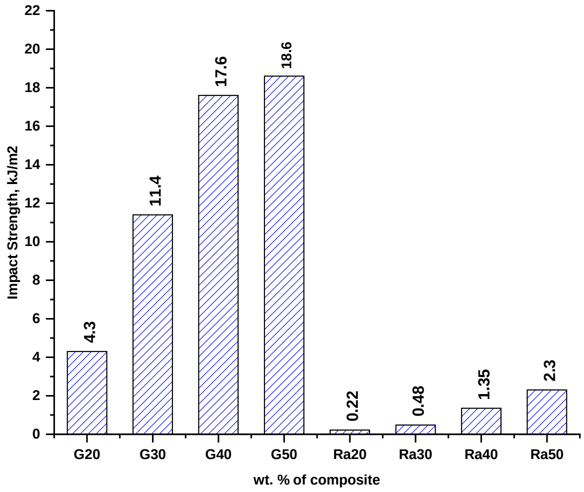

FIGURE 4. Impact strength of prepared composite

When the results of the impact test were analyzed, it was discovered that the impact strength of the ramie fibres was lower than that of the glass fibre reinforcement. As a result, fillers in glass fibres assisted in absorbing more energy during the impact test [20]. Glass fibre with a weight of 50% has absorbed more energy of 18.6kJ/m². Ramie fibre (20% wt.) absorbs the least amount of energy, as seen in figure 4.

4.4 Hardness Test

Materials hardness is a quality that allows it to resist plastic deformation, most commonly through penetration. However, hardness can also apply to bending, scratching, abrasion, or cutting resistance. To evaluate the hardness of a surface, the ASTM D2240 and D2583 standards are followed for Shore D and Barcol Hardness Test. Fig. 5 represents the hardness values obtained for the prepared samples. The maximum Shore D and Barcol hardness values of 89 and 32, respectively, were achieved with 50% wt. of glass fibre. Uniform fibre distribution has led to an increase in hardness.

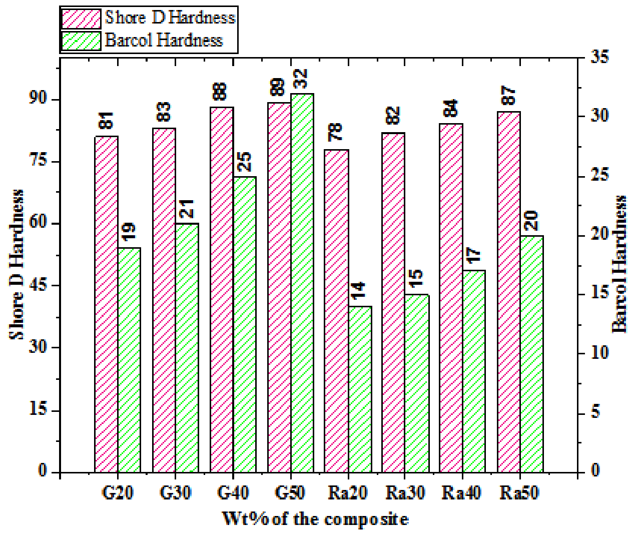

FIGURE 5. Shore D and Barcol hardness of composite

5. GREY RELATIONAL ANALYSIS OF MECHANICAL TESTED COMPOSITE

Grey Relational Analysis (GRA) is a technique for determining the optimal condition of numerous input parameters in order to acquire the highest possible quality features. GRA is often used in analyzing or appraising the performance of a complicated project when only a limited amount of information is available. By assigning weightages to individual responses, GRA may be used to determine the optimal condition for multi-objective challenges.

TABLE 1. Grey Relational Coefficients and Grey Grades of composite

Composition	Normalizing						Grey Relational Coefficient						Avg GRG	Rank
	Tensile strength	Tensile modulus	Flexural strength	Flexural modulus	Impact strength	Barcol Hardness	Tensile strength	Tensile modulus	Flexural strength	Flexural modulus	Impact strength	Barcol Hardness		
G20	0.074	0.431	0.031	0.245	0.222	0.278	0.351	0.468	0.340	0.399	0.391	0.409	0.393	6
G30	0.772	0.822	0.740	0.202	0.608	0.389	0.687	0.737	0.658	0.385	0.561	0.450	0.580	3
G40	0.825	0.926	0.927	0.302	0.946	0.611	0.741	0.871	0.873	0.417	0.902	0.563	0.728	2
G50	1.000	0.764	1.000	1.000	1.000	1.000	1.000	0.679	1.000	1.000	1.000	1.000	0.947	1
Ra20	0.000	0.000	0.254	0.000	0.000	0.000	0.333	0.333	0.401	0.333	0.333	0.333	0.345	8
Ra30	0.096	0.816	0.221	0.282	0.014	0.056	0.356	0.731	0.391	0.411	0.337	0.346	0.429	5
Ra40	0.255	1.000	0.000	0.384	0.061	0.167	0.401	1.000	0.333	0.448	0.348	0.375	0.484	4
Ra50	0.155	0.187	0.311	0.161	0.113	0.333	0.372	0.381	0.420	0.373	0.361	0.429	0.389	7

GRG represents a stronger correlation between the response and the input variables. From the table 1 represents Glass fibre with 50% wt. has a maximum average GRG value with rank 1, it is the condition where all the properties of a specimen are optimal with 50% wt. glass fibre reinforced with epoxy resin. Among the ramie fibres, Ra40 i.e., 40% wt. of ramie fibre has a maximum average GRG value with rank 4, whereas 30% wt. of ramie fibre has the second largest average GRG value. Since Ra40 has ranked 1 with average GRG value of 0.484, it is considered to be an optimal level of composite.

6. CONCLUSION

Mechanical properties of the different compositions of E-glass, ramie and epoxy used to prepare the individual composites by Portable Compression Moulding Machine are concluded as follows,

- Tensile test results revealed that the specimen with 50% glass fibre and 40% ramie fibre had the highest tensile strength.
- Glass fibre with a weight of 50% has increased the specimen's flexural strength and flexural modulus.
- The impact strength of Glass fibre with a weight of 50% has absorbed 22.26kJ/m2 more energy, Ramie fibre (20% wt.) absorbs the least amount of energy, in this composites.
- 50 % wt. glass fibre obtained the greatest hardness values of 89 and 32 of Shore D and Barcol hardness respectively, the increased values of Shore D hardness is due to the arrangement of fibers.
- GRG represents a stronger correlation between the response and the input variables. Glass fibre with 50% wt. has a maximum average GRG value with rank 1. It is the condition where all the properties of a specimen are optimal with 50% wt. glass fibre reinforced with epoxy resin.

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