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Investigating the Impact of Physical and Mechanical Characteristics of Palf/Glass Fiber Reinforced In Epoxy Resin

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Abstract: Recent times, the nature fibers deepen its roots in the field of composite materials. Owing to its ecofriendly characteristics, the natural fibers had its upper hand to the synthetic fiber. But, usage of natural fiber alone doesn't bring desirable characteristics to the fabricated material. Therefore, the amalgamation of synthetic and natural fiber as the reinforcement in the polymer composite brings desirable property to the newly fabricating material. In this paper, we utilized the Pineapple Leaf Fiber (PALF) and glass fiber as the reinforcement in the epoxy resin and fabricated the new material. The paper mainly concentrates to study the physical and mechanical characteristics of the material. The uniform distribution of PALF and glass fiber over the polymer matrix was confirmed with the help of images of Scanning Electron Microscope (SEM). The PALF and glass fiber of composition of 20 % and 15% of weight ratio shows significant resistance to brittleness and have high tensile strength. Consecutively, the PALF and glass fiber of composition of 25% and 10% of weight ratio yields higher bending strength and shows implacable resistance to compression and impact load.

Keywords: PALF, Glass Fiber, Mechanical Property, SEM, Physical Characteristics

1. Introduction

Recently, the polymer composites industry has started using plant fibres [1]. Currently, natural fibres are mostly used in drug administration, prostheses, and scaffolds for tissue regeneration [2-4]. Plant fibres are an excellent alternative to synthetic fibres derived from non-renewable petroleum sources, offering both eco-friendliness and sustainability [5]. Plant fibres offer numerous advantages due to their completely natural composition and lack of negative impact on the environment [6]. Previous study has demonstrated that pineapple (Ananas comosus) leaf fibres (PALF), an agricultural waste, are highly effective as a reinforcing material [7, 8]. The majority of PALF consists of holocellulose, which makes approximately 70-82% of its composition. Lignin comprises 5-12% of PALF, while ash accounts for 1.1%. Pineapple (PALF) is advantageous for reinforced polymer composites, biodegradable plastic composites, and low-density polyethylene (LDPE) composites due to its outstanding mechanical properties [9, 10]. The fiber arrangement in the composite matrix, the ratio of the matrix and fiber length influences the mechanical properties and physical appearance of composite materials [11, 12].

The major setback of using the PALF fiber is its inability to form concrete bonds with hydrophobic matrices at high temperature [13]. To enhance the interfacial properties of PALF the following chemical treatment process such as dewaxing, NaOH treatment, cyanoethylation and grafting acrylonitrile monomer are employed [10]. Applying the chemicals such as sodium hydroxide and benzyl peroxide over the surface of PALF composites will enhance the mechanical properties and reduce the water absorption capacity of the composite material [14]. Chemically treated PALF reinforced with LDPE composites shows low intent in moisture absorption property of the material [15]. Usage of resorcinol silica, which acts a bonding agent in PALF shows exceptional adhesion property of the composite with natural rubber [16].

Furthermore, researchers have investigated on the mechanical properties of PALF, when combined with other natural fibers reinforcement. The investigations mainly focused on following variables such as the quantity of fiber used, the treatment of the fibers, and fiber size [17- 20]. Hybridization between the two natural fibers shows less moisture absorption capacity of the material when compared to their individual reinforcement. Cement, oil palm fruit bunch fibre, and PALF are combined to construct buildings. The study

investigated the impact of clay content, fibre size, fibre type, and compressive strength on water affinity, elasticity modulus, and compressive strength. The soil type and testing requirements remained constant throughout the bio deterioration and characterisation process [21]. The findings indicated that the composite material created by combining oil palm fruit bunch fibre and PALF had superior mechanical characteristics and water resistance compared to the composites made from the individual fibres. Extensive research has been conducted on the impact of parameters such as fibre length, stress, and treatment on the properties of natural-PALF hybrid polymer composites. The hybrid composite, which consisted of PALF/KF fibres and phenol formaldehyde resin, displayed conflicting outcomes in terms of mechanical strength, although utilising the identical fibre loading and kind of fibre. However, the most optimal outcomes for TS (tensile strength), TM (tensile modulus), FS (flexural strength), and FM (flexural modulus) were obtained when KF (kenaf fibre) and PALF (palm leaf fibre) were used in equal amounts [22]. The observed behaviour can be attributed to the manipulation of the fibre and differences in the weight percentage of the resin, which in turn affect the composition of the fibre matrix.

The desired properties can be attained by combining PALF with synthetic fibre due to the synergistic effects [22]. Consequently, numerous researchers have been highlighting the beneficial impacts of hybridization [23–25]. The mechanical properties were found to be improved by integrating synthetic fibres in a hybrid configuration. Furthermore, while addressing the matter of PALF (palm leaf fibre) disposal, it is advisable to maintain a 50:50 ratio in order to get a more balanced set of mechanical qualities in comparison to composites made only from PALF or synthetic fibres. A study has been conducted on the mechanical characteristics of hybrid composites composed of Sisal, PALF, and GFRP fibres, which consist of a combination of natural and synthetic materials. The importance of using a combination of natural and synthetic fibres in reinforcing systems was emphasised over using only one type of fibre. The amalgamation of the two innate fibres was facilitated by their elevated cellulose content. The Sisal-PALF-GFRP samples had the highest tensile strength (TS), while the Banana-GFRP samples demonstrated the lowest strength [23]. In order to enhance the mechanical qualities, researchers have examined the impact of using SiC filler material. Reference [24] states that the presence of fillers has a delaying effect on the occurrence of failure when mechanical stress is increased. To assess the compatibility of jute, PALFs (Polyester Amide Long Fibres), and glass fibres, we measure the affinity at a consistent volume ratio of fibres and examine the influence of different resin types. Epoxy and polyester are the primary resins being evaluated. The mechanical characteristics of epoxy hybrid

composites surpassed those of polyester hybrid composites. Epoxy resin has an advantage over polyester due to its greater adherence to the fibre matrix [25]. When PALF is combined with synthetic fiber-nylon, a negative hybridization effect occurs, resulting in a loss in impact strength (IS) and tensile strength (IM). This can make the material more susceptible to notches [26].

Ensuring the preservation of the fiber's morphological and physical characteristics during treatment is of paramount importance. The adhesion amount is determined by the preparation of natural fibres before the fibre matrix phase. To promote the development of strong connections, it is crucial to utilise appropriate coupling agents and compatibilizers [27]. The underlying assumption was that the fibres may be subjected to treatment in order to enhance their surface area and separate them from each other. Fibres with a more uneven surface adhere more effectively to the matrix and, as a result, to surfaces in general [28]. During chemical processing, distinct chemical functional groups engage with hydroxyl groups present in the fiber's constituents (such as cellulose, hemicellulose, lignin, etc.). Fibre bundles can have their non-cellulose components removed by the process of generating fibrillation using chemical methods. In order to enhance the quality of the fibres, it is crucial to remove the lignin and create fibrils in the raw materials to get the greatest aspect ratio. Standard chemical processes used to treat natural fibres include mercerization, acetylation (esterification), peroxide treatment, and plasma therapy [29]. Scientists have utilised chemical techniques, specifically alkali and silane treatments, in a sequential manner, together with one-time solution treatments, to improve the mechanical properties. The study claims that the mechanical strengths have been improved by applying several chemical treatments, rather than using a single solution treatment. One example of combining an alkali with diluted epoxy treatments is illustrated by this combination [29–31].

From the former research, this paper concentrates on the fabrication and study the mechanical characteristics of PALF/glass Fiber reinforced with epoxy resin will play better role in the field of biomedical engineering applications especially in fabricating the prosthetic equipment.

2. Materials and Methods

2.1 Pineapple Leaf Fibers

The collected pineapple plant leaves were immersed in water for a duration of four weeks. This results in the earlier rigid pineapple leaves becoming pliable, which helps facilitate the process of separating the fibres [32]. This approach enhances the process of extracting fibres by enabling bacteria and fungus to break down the hemicellulose cement matrix. After being cleansed with deionized water, the separated fibres

were left to dry naturally for a period of fifteen days at room temperature [32]. In order to enhance the mechanical properties of the fibre, PALF is immersed in an alkaline solution (9% NaOH in de-ionized water) at room temperature for an additional hour [33]. Following the alkali treatment, the fibres were gathered and multiple rinses in deionized water was carried until their pH level turns to 7. Subsequently, they were permitted to naturally dry at a temperature of 26° C for a duration of one day.

Furthermore, the glass fiber is purchased as the fiber mesh cloth and it is chopped into small pieces and added to the matrix composites for reinforcement. Generally, the amalgamation of natural and synthetic fiber as reinforcement induces the mechanical properties of the composites. Owing to its exceptional mechanical properties such as high strength, stiffness, and resistance to corrosion, this material exhibits remarkable versatility and finds extensive application in the fabrication of a diverse array of products. To produce composite materials that possess high strength, low weight, and extended durability, glass fiber cloth is commonly employed as a reinforcing agent in combination with a resin matrix.

Epoxy resin, a type of thermosetting polymer, is commonly used as a coating or bonding agent. The material in question is composed of a resinous foundation and a hardening agent, which serve to enhance its durability. The amalgamation of these two substances results in a chemical reaction that yields a durable and potent compound. Epoxy resins have garnered significant acclaim for their exceptional mechanical robustness, chemical non-reactivity, and adhesive properties.

The processed fibers were chopped into pieces of 3 to 5 mm in length. Put the resin and the hardener in the same container and stir them together thoroughly. Following that, the fibers were cut and added to the container. Epoxy agent and blended fibers work just great. And then we pour this mixture into the compression moulding machine. The resin- fiber have been placed in a hot mould and resin is poured on top, if required in addition. After the resin has been poured into the mould, it is crushed at a high-pressure of 1500 psi and a high temperature of 100° C. The material has cured into a solid composite. Once the combined material is formed and shaped, any unwanted material is chopped down before it is released from the mould. Furthermore, to study the mechanical properties of the fabricated composite, the specimens were cut as per ASTM standards. By following the above procedure, we have fabricated three specimens for every test to study the mechanical characterization of fabricated composites. The composition of composites fabricated are shown in Table 1.

Table 1. Percentage composition of fibers

| Sample Name | Pineapple % | Glass% |
|-------------|-------------|--------|
| S1 | 15% | 20% |
| S2 | 20% | 15% |
| S3 | 25% | 10% |

3. Results and Discussion

3.1 Surface Morphology

Figure 1 a-c shows the Scanning Electron Microscope (SEM) image of composites based on the three different weight percentage of reinforcement. Based on the picture, it is clearly understood that the compression moulding process clearly bind the PALF and glass fiber with the epoxy resin. The signs of hybrid composites are clearly seen in the micrographs. The composites with 15% of PALF and 20% of glass fiber reinforcement exhibits smooth surface and fewer cracks over the surface of the composites. The composite with 20% PALF and 15% of glass fiber reinforcement have fewer cracks between boundaries the fiber and resin. Further in the third combination i.e. the composite with 25% of PALF and 10% glass fiber reinforcement shows more pours over the surface of the material. This is due to the minimum adhesion between the natural fiber and the synthetic fiber. It was inferred that the addition of more natural fibers while using the synthetic resin results in poorer adhesion between them.

3.2 Tensile Strength

The PINEAPPLE LEAF FIBRE/Glass hybrid composite is subjected to a tensile test utilizing the universal testing apparatus FIE-UTN 40, in accordance with ASTM D638 requirements. The greatest load that may be placed on the machine is 100KN. The table 2 and figure 2 shows the results obtained from the tensile test. It has been clearly verified that the pineapple fiber up to 20% in weight ratio and glass fiber up to 15% in weight ratio of reinforcement shows peak resistance to the tensile load applied. Furthermore, the natural fiber in this combination was little bit more than the synthetic fiber and it shows lesser ductility in this composite.

3.3 Impact Test

The Izod Impact testing apparatus was used to conduct the impact tests required by the ASTM standards. For this kind of test, the material to be tested is set up in accordance with ASTM D256 standards. The results of the proposed method's impact test are shown in Table 3 and Figure 3.

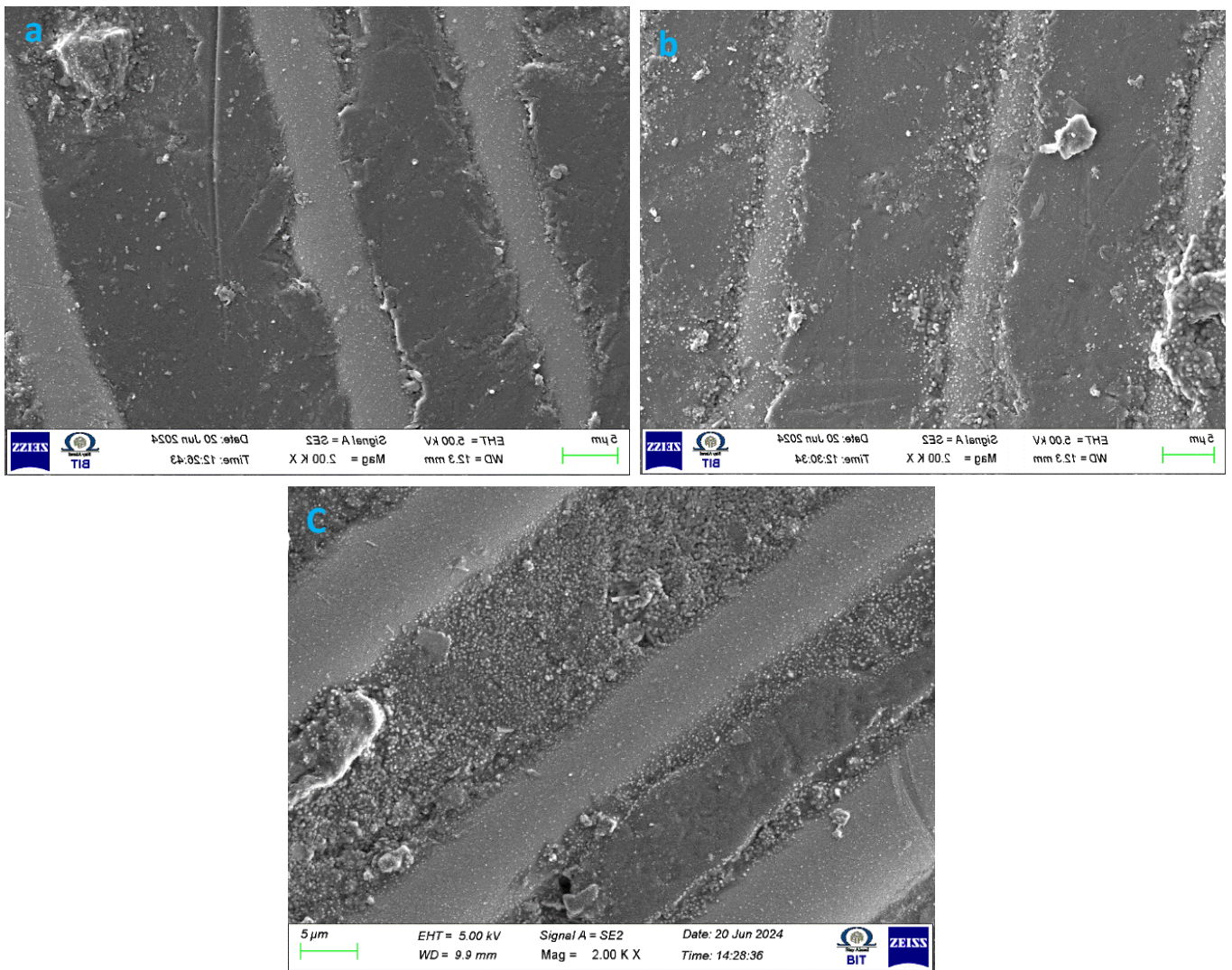


Figure 1. SEM images a) 15%PALF + 20% Glass fiber, b) 20% PALF + 15% Glass Fiber, c) 25% PALF + 10% Glass Fiber

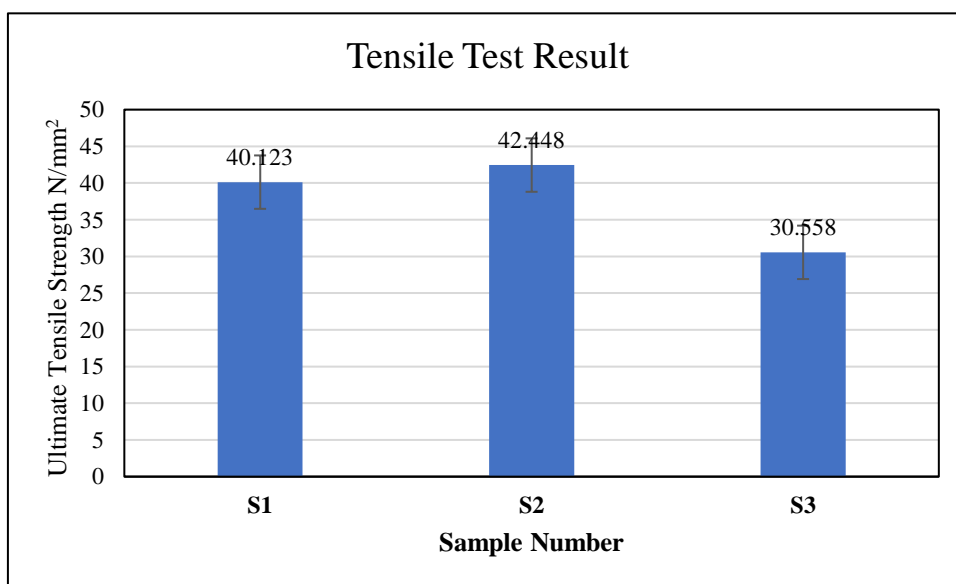


Figure 2. Tensile test result of fabricated specimen

Table 2. Tensile test result of fabricated specimen

| S.No | Sample No. | Peak Load (N) | % of Elongation | UTS (N/mm ²) |
|------|------------|---------------|-----------------|--------------------------|
| 1 | S1 | 3009.52 | 1.63 | 40.123 |
| 2 | S2 | 3183.55 | 1.42 | 42.448 |
| 3 | S3 | 2292.04 | 1.41 | 30.558 |

Table 3. Impact result of fabricated specimen

| S.No | Sample No. | Impact Strength (N/mm ²) |
|------|------------|--------------------------------------|
| 1 | S1 | 1.25 |
| 2 | S2 | 1.2 |
| 3 | S3 | 1.25 |

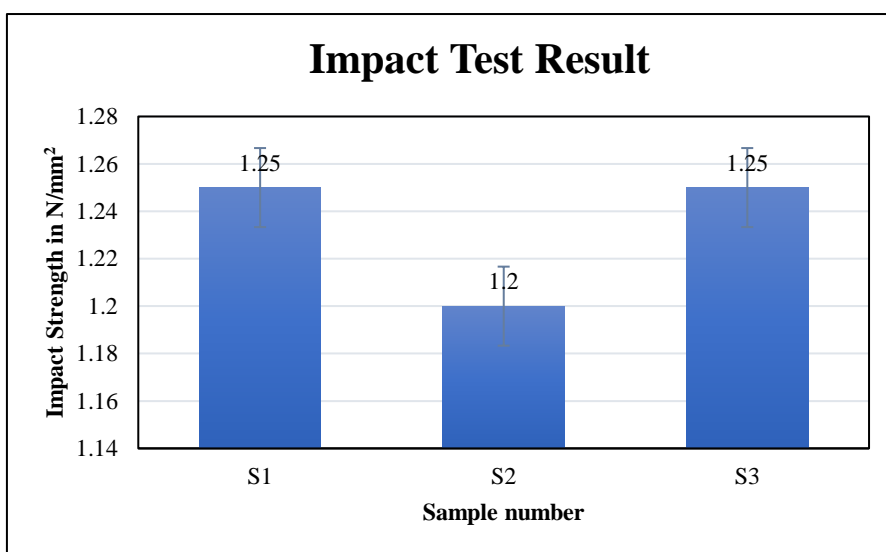


Figure 3. Impact result of fabricated specimen

From the result, it was understood that the sample with specimen of glass fiber with weight percentage of 20% or PALF with weight percentage of 25 % shows better impact resistance. Furthermore, addition of PALF equals to 25% of weight ratio or more might shows better resistance to impact load applied on the specimen. Addition of plethora of fibers might bring more absorption of impacts to the composites.

3.4 Flexural Test

Whenever a load is applied to a material, the amount by which it bends is determined by this test. The samples have a measurement of 125x13x3mm and a crosshead speed of 2 mm/min, which is in accordance with the standards set out by ASTM D790. The results of the flexural test for the suggested structure are displayed in Table 4 and Figure 4. The flexural modulus and flexural strength reach its peak when the addition of PALF reaches the 25% weight percentage of

composites. The addition of adequate amount of PALF increases the resistance to bending of the composites.

3.5 Compression Test

The objective of this analysis is to predict the behaviour of the material under real compression conditions. The production of test specimens measuring 150 mm by 25 mm by 3 mm adheres to the guidelines set forth in ASTM D3410.

The specimens were subjected to testing using a computerized universal testing system, and the results were recorded for each specimen. Table 5 and Figures 5 display the outcomes of the compression test conducted on the proposed technique. The compression strength reaches its peak when the addition of PALF reaches the 25% weight percentage of composites. The addition of adequate amount of PALF increases the resistance to compression of the composites.

Table 4. Flexural analysis of fabricated specimen

| Sample No. | Peak Load (N) | Flexural Stress (Mpa) | Flexural Modulus (Gpa) |
|------------|---------------|-----------------------|------------------------|
| S1 | 256.816 | 164.626 | 5427.97 |
| S2 | 227.7 | 145.962 | 5556 |
| S3 | 267.921 | 171.744 | 12612.6 |

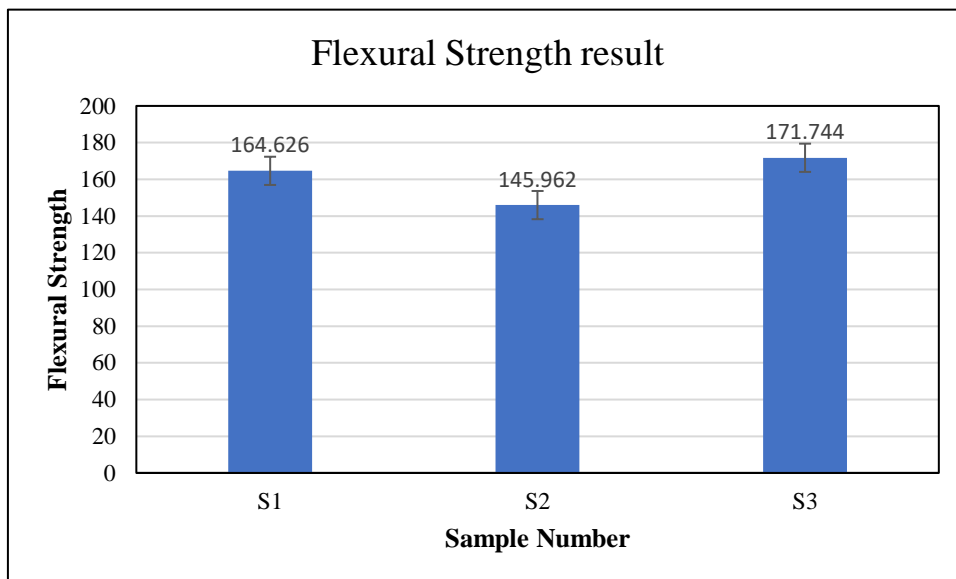


Figure 4. Flexural test of fabricated specimen

Table 5. Compression test result of fabricated specimen

| S.No | Sample No. | Peak Load (N) | CS (N/ mm ²) |
|------|------------|---------------|--------------------------|
| 1 | S1 | 3098.97 | 41.32 |
| 2 | S2 | 2901.92 | 38.691 |
| 3 | S3 | 3207.13 | 42.762 |

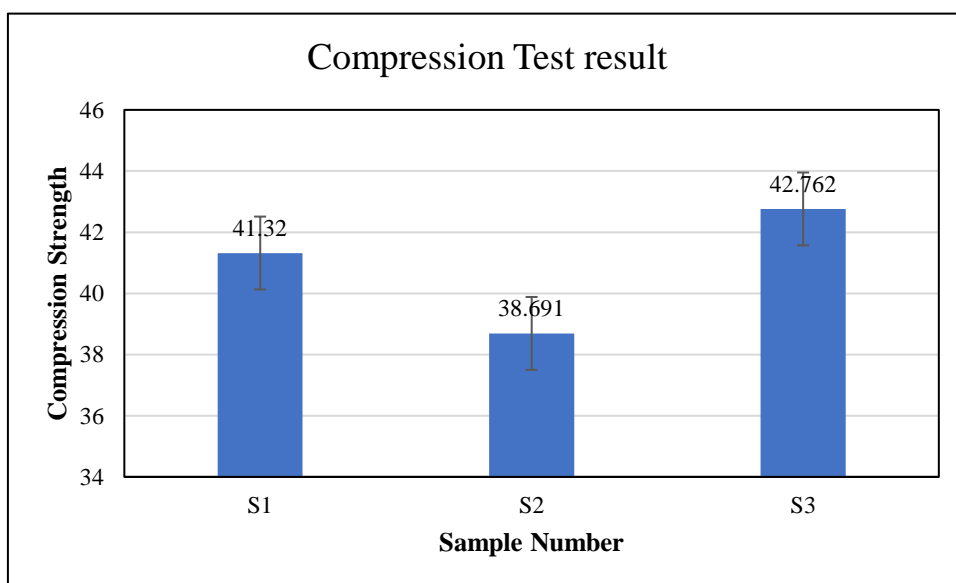


Figure 5. Compression test result of fabricated specimen

4. Conclusion

The physical and mechanical characteristics of the materials were examined by successful fabrication of composites by the thermo-compression moulding process. Based on the reinforcement of PALF and glass fibre in epoxy resin the following results were concluded:

- From the SEM image the PALF and glass fibers were uniformly distributed and forms a rigid solid composite material by the thermo-compression moulding process.
- The PALF with 20% of weight percentage and glass fiber with 15% of weight percentage produces higher resistance to brittleness and shows higher tensile strength
- The addition of more weight percentage of PALF (25% of PALF) in composites shows significant resistance to impact, flexural and compression load. The PALF fiber addition in adequate gives good response to the mechanical property of the composites.

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Authors Contribution Statement

S. Venkatesan: Conceptualization, Methodology, Validation, Supervision, Result Analysis. K.T.R. Thaimanavan: Conceptualization, Methodology, Visualization, Writing-Review and Editing. S. Bhuvana: Conceptualization, Formal analysis, Validation, Writing.

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Competing Interests

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Has this article screened for similarity?

Yes

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