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Mechanical Strength Analysis of Polymer Based Composite made with Natural Fiber of Khejri (Prosopis Cineraria)

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A B S T R A C T

Fiber-reinforced polymer (FRP) composite materials, such as glass fiber, are often used in products that require low weight and high strength and stiffness, such as airplanes. However, the production of glass fiber and its composite can be hazardous to workers' health. Natural fillers and fibers, which are biodegradable, non-abrasive, eco-friendly, regenerative, and low-cost, are being investigated as alternatives. Natural fibers are made up of cellulose, hemicellulose, lignin, and other components, and plant fibers also contain cellulose, hemicellulose, and lignin. Fillers, such as wood particles, rice husks, wheat husks, and coconut shell powders, can improve the hardness, damping properties, and thermal stability of polymer composites while also lowering their cost. Although natural fillers have been studied as reinforcement materials in polymer composites, Khejri (Prosopis cineraria) and Acacia Nilotica have not been researched on a large scale. The high carbon content of these fillers may contribute to the strength of the composite.

Keywords:Polymer (Epoxy Resin), Bio Filler, Natural Fiber, Khejri (Prosopis cineraria), Acacia Nilotica, Sisal Fiber.

1. Introduction

Composites made by combining epoxy resin with natural fibers have gained significant attention in recent years due to their potential to replace traditional materials in a variety of applications. These composites offer a range of benefits, including high strength, low weight, and improved sustainability compared to traditional materials such as metals and plastic.

Epoxy resin is a thermosetting polymer that is widely used as a matrix material in composite applications. It is known for its high strength and stiffness, good chemical resistance, and ability to bond well with a variety of different materials. Natural fibers, such as those derived from plants, are attractive reinforcement materials for epoxy resin composites due to their low cost, renewable nature, and improved sustainability compared to synthetic fibers.

There are several different types of natural fibers that can be used in epoxy resin composites, including cellulose, flax, hemp, jute, and sisal. Each of these fibers has unique properties that can contribute to the overall performance of the composite. For example, cellulose fibers are known for their high strength and stiffness, while flax fibers have good toughness and energy absorption properties. Hemp and jute fibers are also known for their high strength and stiffness, while sisal fibers have good resistance to abrasion and impact.

One of the main benefits of using natural fibers in epoxy resin composites is their ability to improve the mechanical properties of the material. These fibers can enhance the tensile, compressive, and flexural strength of the composite, as well as improve its stiffness and toughness. In addition, natural fibers can also contribute to the dimensional stability, thermal resistance, and flame retardancy of the composite.

In terms of applications, epoxy resin composites made with natural fibers have been used in a variety of industries, including aerospace, automotive, construction, and sporting goods. For example, these composites have been used to manufacture aircraft parts, automotive body panels, and structural components for buildings and bridges. They have also been used to make sports equipment such as golf clubs, tennis rackets, and skis.

One of the main challenges in using natural fibers in epoxy resin composites is the difficulty in achieving consistent fiber distribution and orientation throughout the material. This can affect the overall mechanical properties of the composite, as well as its appearance and surface finish. To overcome this challenge, researchers have developed various processing techniques, including melt blending, extrusion, and injection molding, to improve the fiber distribution and orientation in the composite.

In conclusion, composites made by combining epoxy resin with natural fibers offer a range of benefits compared to traditional materials, including high strength, low weight, and improved sustainability. These composites have been used in a variety of applications, including aerospace, automotive, construction, and sporting goods, and researchers are continuing to explore new processing techniques to improve their performance.

2. Literature Review

Composite materials, which are made up of two or more materials with different physical or chemical properties, have been used in the construction industry for many years. In the past, glass fibers were commonly used to reinforce these composites, but they are non-biodegradable and can cause irritation to the skin and respiratory system. In recent decades, natural fibers, such as those derived from agricultural and natural waste, have been used as an alternative to glass fibers as a way to reduce weight and cost and to utilize renewable resources. Natural fibers have a higher strength-to-weight ratio, lower density, and greater strength in many applications compared to synthetic fibers.

Fiber reinforced plastics, which are made up of very small fibers or particles, are low-density, robust, corrosion-resistant, and affordable compared to traditional materials. They are well-suited for low- and medium-load engineering applications, such as in the manufacturing industry. The addition of fillers, which can be natural or synthetic, to composite materials can increase their modulus, wear resistance, thermal stability, and dimensional stability, while also modestly enhancing their tensile and flexural strength. However, the use of fillers can also decrease the tensile strength of composites, depending on the type and amount of filler used.

Studies have shown that the inclusion of nanoclay in composites can increase their strength by up to 2%. Synthetic fillers can also improve the mechanical properties of composites, but their interaction with the polymer matrix is often weak, which can lead to a stiffer interphase around the filler and reduced elongation at break. In contrast, natural fillers, such as wood flour and snail-shell powder, have been found to improve the tensile, flexural, and impact properties of composite materials.

In recent years, there has been a growing demand for eco-friendly and recycled materials, leading to research on the use of natural fibers and fillers in composite materials. These materials can be biodegradable and offer a more sustainable alternative to synthetic options. Researchers have explored the use of natural fibers, such as coconut, jute, and banana, in composites, as well as the addition of nano clay to improve the mechanical properties of the materials. By utilizing natural resources and waste products in the production of composites, it is possible to reduce the environmental impact of their manufacture and use.

3. Objective and Methodology

The following objectives of the present study was present here:

- To fabricate the hybrid composite for different combinations of Khejri (Prosopis cineraria) and Acacia Nilotica by different percentage of weight (% wt)
- To analysis the mechanical properties of the fabricated composite material using ASTM standard.
- The effect of sisal fiber length and volume % on the mechanical properties of a polyester composite was studied
- The data was recorded using the Mini-Tab program and the conclusion of the study was drawn. The research flow diagram is shown in Figure 1.

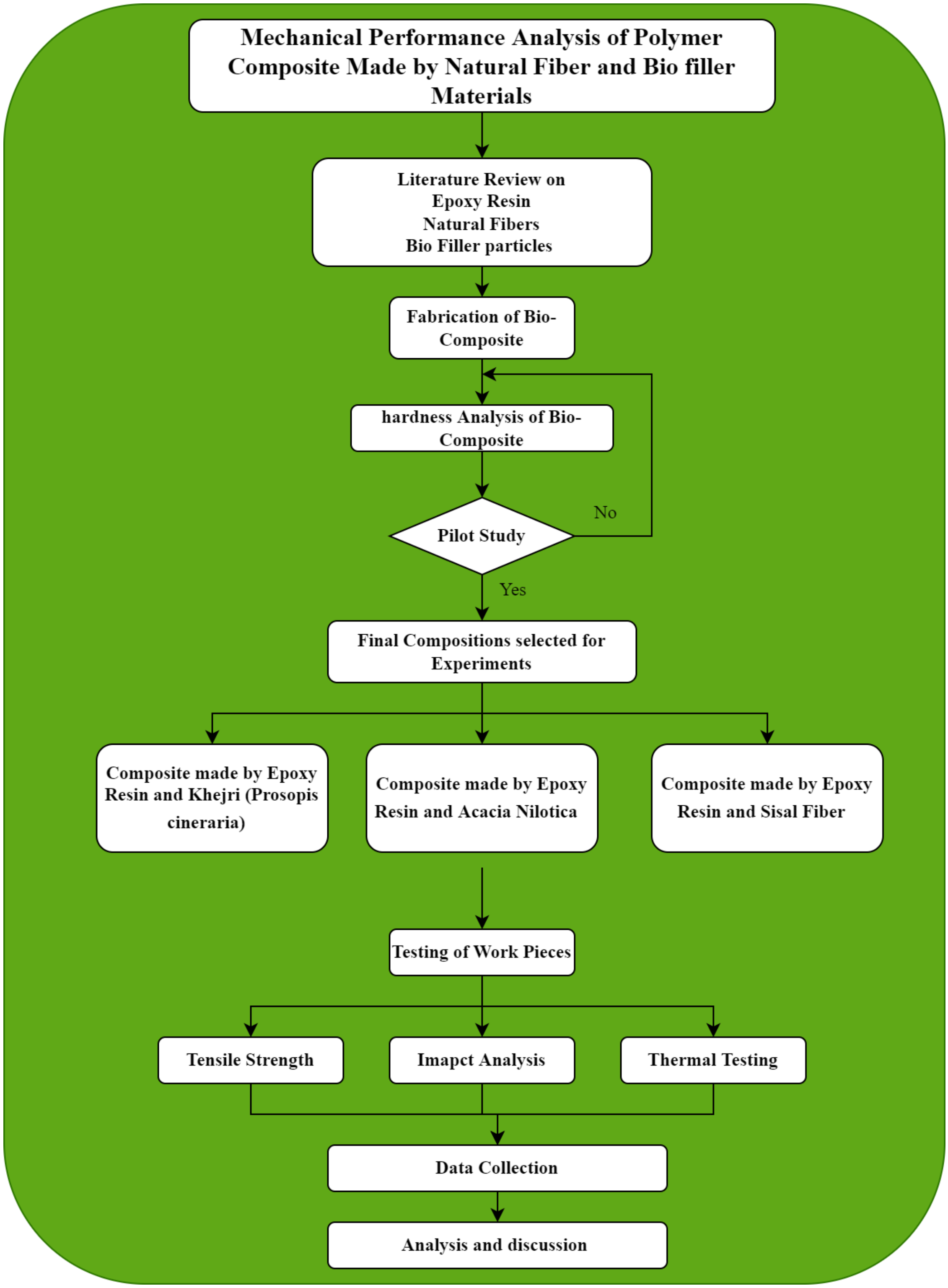

Fig.1.Research Flow Diagram for Present Study

4. Material and Methods

After conducting an exhaustive analysis of the relevant research, the materials for this project have been determined to consist of Khejri (Prosopis cineraria), Acacia Nilotica, sisal fiber, and polyester resin (Epoxy Resin). The detailed description of the all materials used in the present study was present in following sections.

Khejri (Prosopis cineraria) Filler material

Prosopis cineraria is gathered from the Khejri tree for its fiber. The Khejri tree is indigenous to India and may be found in the country's northern and western regions, which are separated physically by the Gangetic Plain. The Prosopis cineraria tree may attain a maximum height of 50 meters and a maximum trunk diameter of 5 meters at its widest point. They may attain heights between 10 and 15 meters and girths between 1 and 3 meters.

In India, the Sal tree is one of the varieties of trees produced for their commercial timber. Additionally, it contains an oleoresin that is highly valued for its usage as an incense in certain religious ceremonies. The Prosopis cineraria utilized in this experiment was purchased from a Jaipur-based vendor. The fat percentage of sal gum ranges between 12 and 19 percent. The solution in the alcohol may be used to create excellent varnishes, but only after removing specific impurities. By combining this resin with nitro-cellulose in the suitable proportions, quick-drying lacquers may be created.

Figures 3.1 and 3.2 depict, respectively, the sal tree and the two forms of Prosopis cineraria filler material that may be harvested from the sal tree. In India, black Prosopis cineraria filler is more commonly accessible than its white counterpart.

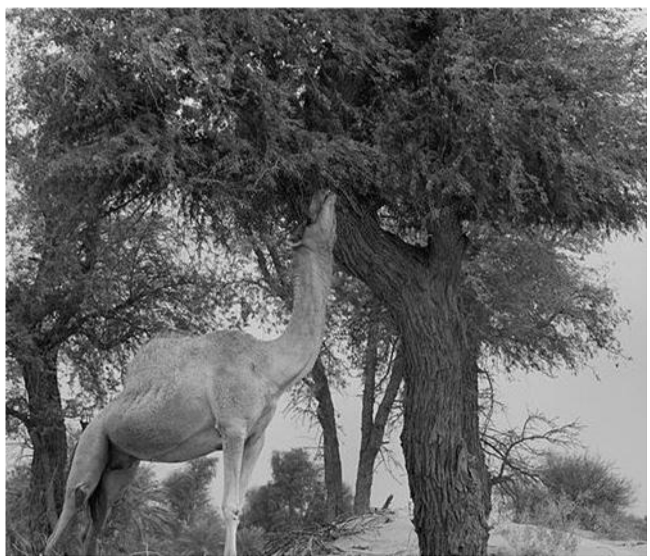

Fig. 2 Khejri (Prosopis cineraria) used for making the filler particles (reference)

5. Fabrication Method

Proficient series of trials are required for designing the tests in logical way. By the factual outline of tests, the task of arranging the analysis is completed. So required information will be gathered and examined by measurable strategies which bring about final conclusions. At the point when the issue includes information that is subjected to trial failure, factual strategy is the correct approach for further investigation. Consequently, there are two parts of a test: the plan of the trials and the investigation of the information that we get from trials. The benefits of plan of trials are as per the following:

Numbers of trials is reduced to very small number.

Important parameters which affect the quality and quantity of the item under production can be distinguished.

Optimal setting of the parameters can be reached.

Qualitative estimation of parameters can be made.

Experimental mistake can be assessed.

Effect of parameters on the qualities of the procedure can be made.

In the present work, the DOE’s technique based S/N proportion, and the response surface philosophy has been utilized to design the trials and further investigation of gathered information from trials. The sequence of the current research work is given in the form of a

flow chart in Figure 4.1. the final materials used in the making of the composite material are following

Khejri (Prosopis cineraria),

Acacia Nilotica,

Sisal fiber

Epoxy Resin

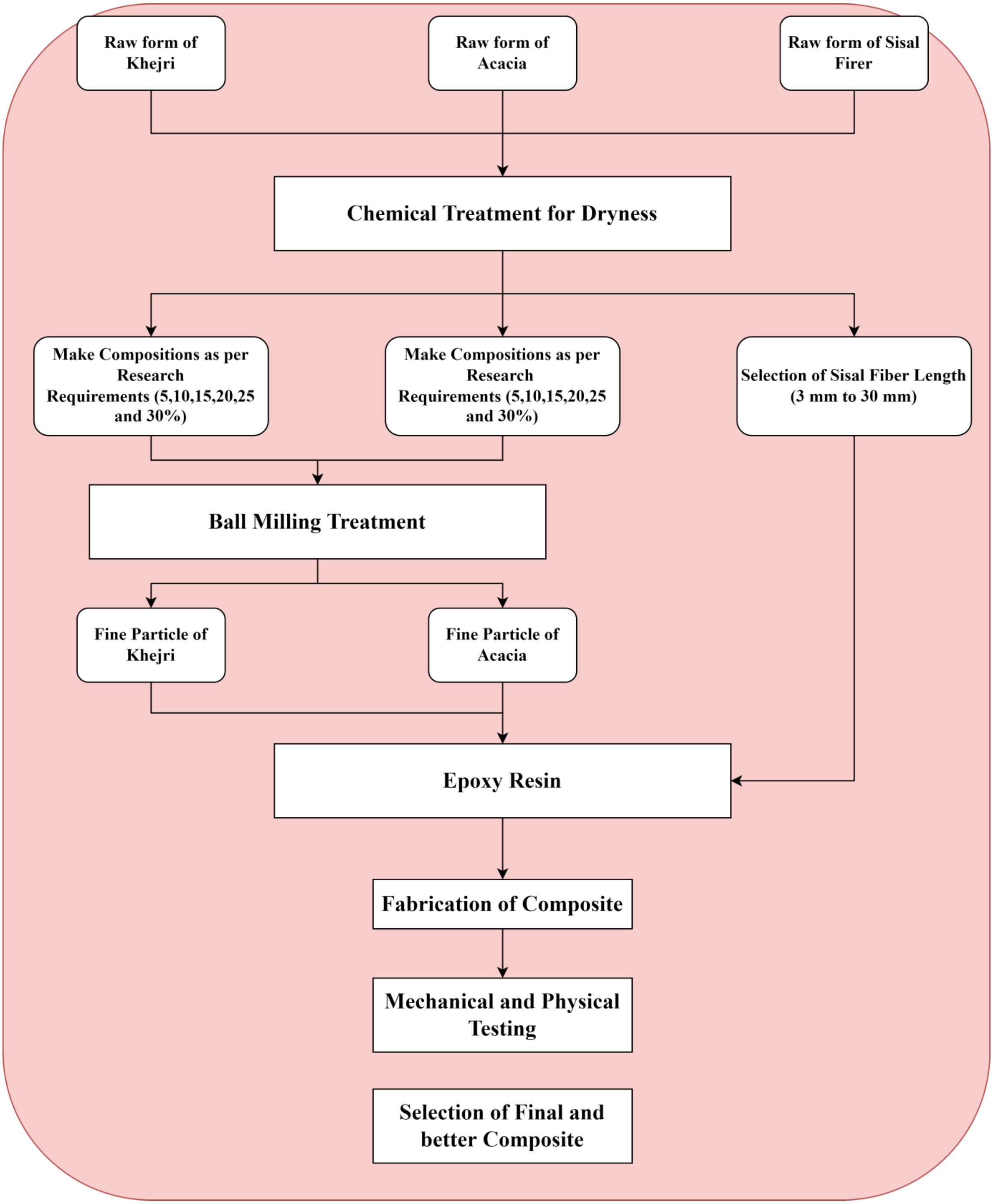

Fig. 3 Product made for pilot experiment (Stepped Turning)

Fabrication of Composite made by using Khejri (Prosopis cineraria)

Khejri (Prosopis cineraria) was mixed with unsaturated Epoxy resin in this instance. Khejri (Prosopis cineraria) was then added to the polyester matrix after being ball milled for five hours to a fineness of between five and ten microns (5, 10, 15, 20, 25 and 30%). A mechanical mixer ensured that the filler and matrix were evenly disseminated throughout the course of one hour. Khejri (Prosopis cineraria) fibres were utilised to reinforce hand-laid polyester laminates. We utilised a 300 millimetre by 300 millimetre by 3 millimetre silicon rubber mould. Both the upper and lower mould plates have a solid consistency. After pouring the resin filler mixture into the mould at the correct volume, After curing, the laminates were cut into sections for various ASTM testing as discussed.

Fabrication steps

The method used for the preparation of the composite specimen was as follows.

The mould is kept clean and dry.

The releasing agent is applied over the mould and kept in sunlight for 30 minutes for drying.

Using a brush, the polyester resin mixture was poured uniformly for the first layer into the mould.

The fibers and the filler were placed on the mould and spread uniformly.

Another layer of polyester resin was uniformly applied over the fiber and filler

The polyester was uniformly spread using a roller. During this process, excess of polyester was removed.

The mould was closed and the composite material was pressed uniformly for 24 hrs. for curing.

The composite laminate was dried completely and then removed from the mould.

6. Result and Discussion

Mechanical Properties analysis of khejri (Prosopis cineraria) filler and Epoxy Resin

This research attempt was carried out so that its findings could be compared to those obtained by using epoxy resin. The experiment was done with the intention of enhancing the properties of the composite material by incorporating filler made from khejri (Prosopis cineraria) into the epoxy resin.

Effect of Vol % of khejri (Prosopis cineraria) on mechanical properties

In this section the effect of volume percentage of the Khejri filler particles in epoxy resins are discussed for tensile strength analysis. The test pieces are fabricated as per ASTM guidance provided for plastics and composites. The tensile strength of the fabricated test pieces as per volume percentage of the filler material is shown in figure 4.

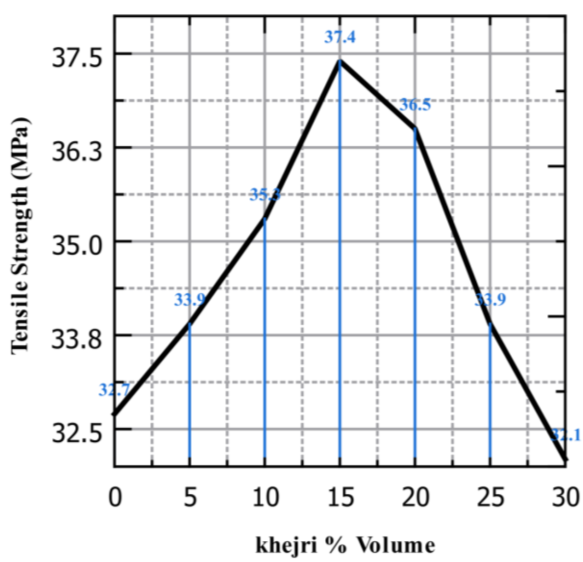

Fig. 4 Tensile Strength of Composite (ER+Khejri filler)

Experimentally, the tensile strength of epoxy resin was found to be 32.7 MPa, while the highest value was 37.4 MPa for a composite with 15% bio filler (Khejri). Figure 4 shows all of this information. Because the filler material was added to the epoxy composite, some of its mechanical properties were able to improve, as the figures show. The increment in tensile strength by mixing the Khejri filler in epoxy resin composite is going to 14.4% when compare with neat epoxy resin composite.

This modest improvement in properties is because the filler materials are in the form of particles, which keeps them from actively helping to carry the load that has been put on them. According to the results, adding the biofiller made the composite material stiffer more than it made it stronger. The tensile properties of the material were found to be better with up to 15 %volume of bio filler loading. The problem was caused by the fact that more than 15% of the bio-filler was used. This made the tensile properties worse. This is because the bio filler in the epoxy matrix has clumped together into bigger pieces.

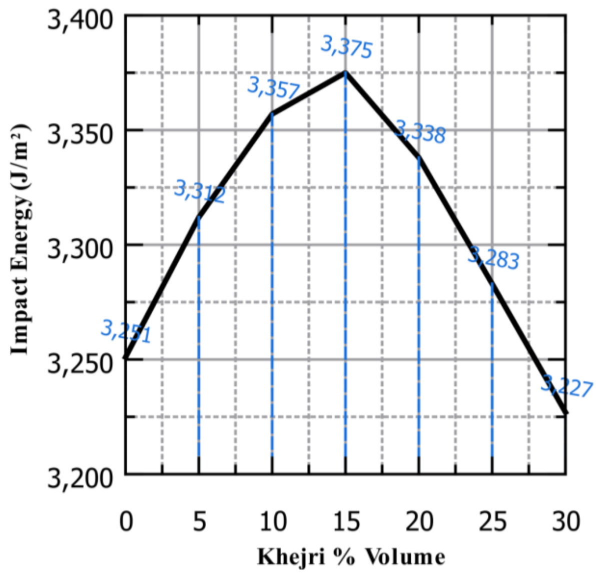

Fig. 5 Impact Energy of Composite (ER+Khejri filler)

When the impact load is applied, the matrix and particle fillers are separated, which takes energy. How well the filler material and the matrix material stick together determines how much energy is needed. Figure 5 shows the use of khejri filler might change the strong epoxy is when it hits something. As the figure shows, the impact strength of the composite material goes up in a fairly steady way as the filler is added up to 15 volume percent. This was found out when it was seen that the improvement was quite steady. But when the filler is added at a volumetric percentage of more than 15%, the impact strength of the composite materials is only lower then epoxy neat composites. This was because the composite material had a tendency to be on the brittle side. Also, the impact strength of the composite material went down when khejri (Prosopis cineraria) was added at a volume percentage of more than 15%. Even so, the value of the filler materials with the highest volume percentage of filler was less than that of the resin by itself.

The fillers don't do anything good when they mix with the epoxy matrix. Even if there isn't much contact between the fillers and the epoxy resin, the relatively small van der Walls force is enough to hold them together. Because this weak link can pass stress between the fillers and the epoxy, the material will have a higher modulus when small stresses are put on it. On the other hand, when materials are put under a lot of stress, they become more brittle and can't stretch as far before breaking. Also, the small size of the particles makes the matrix less likely to move around. This may even build an inter phase around the filler of a more rigid epoxy resin because the matrix is less likely to be broken. This is a problem that has happened a lot with very small particles, and it is one of the main problems with these fillers (this induces a low impact resistance). The results were very similar to those found by Olumuyiwa (2012), who said that 20 percent of the weight of the filler (coconut shell powder) in the polymer matrix was the best amount. The increment in impact energy when compare with neat composite and 15% filler made composite, the 4.4% increment is shown in the experiment results.

7. Conclusion

As part of this experiment, composites were made with 5, 10, 15, 20, and 25 volume percent of bio filler in the epoxy matrix. The results of the mechanical tests showed that the mechanical properties of the material got better when the amount of Khejri in the epoxy matrix was raised to a volumetric percentage of up to 20%. It was found that the value of tensile strength had gone up by 14.4 percent since the last time it was measured for 15% volume percentage of the filler material Khejri (Prosopis cineraria). the same analysis id performed for the impact energy analysis and the maximum impact energy was recorded on 15% filler with epoxy resins. The percentage growth is recorded to equal 3.8% when compare with neat epoxy composite.

As part of this experiment, composites were made with 5, 10, 15, 20, and 25 volume percent of bio filler in the epoxy matrix. The results of the mechanical tests showed that the mechanical properties of the material got better when the amount of Acacia Nilotica in the epoxy matrix was raised to a volumetric percentage of up to 25%. It was found that the value of tensile strength had gone up by 16.5 percent since the last time it was measured for 20% volume percentage of the filler material Acacia Nilotica. the same analysis id performed for the impact energy analysis and the maximum impact energy was recorded on 20% filler with epoxy resins. The percentage growth is recorded to equal 9.0% when compare with neat epoxy composite.

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