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Effect of Alkaline Treatment on the Tensile Strength and Hardness of Pineapple Fiber Reinforced Epoxy Resin

Navinn Vijiyakumar[1], Mohd Yussni Hashim[1*]

1 *Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Batu Pahat, Johor, MALAYSIA*

*Corresponding Author: yusni@uthm.edu.my
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Abstract

This research is about fabricating a composite material using pineapple leaf fibre (PALF) reinforced epoxy resin. Different concentrations of alkaline treatment on pineapple leaf fibre were applied to fulfil the objective. The treated pineapple fibres were then reinforced with epoxy resin. The prepared samples were then tested mechanically to achieve maximum improvement in mechanical properties. The composite material is produced by open mould technique by applying a mould release agent to the samples, which compromise of 4 different material compositions such as pure PALF,2% alkaline treated PALF, 6% alkaline treated PALF, and 10% alkaline treated PALF coated with epoxy resin mixture with the ratio of 2:1. After the composite samples were obtained, they were tested mechanically to assess the material's strength and indentation resistance. Based on the results obtained from the mechanical test, the sample with the optimal ratio was selected to fulfil this study.

1. Introduction

Composite materials are a significant focus in materials engineering, with global production exceeding 10 million tons annually and growth rates ranging from 5% to 10%. They play a crucial role in various daily applications. In recent years, the focus on sustainable materials for engineering applications has grown, with fibre reinforcement in polymer composites being recognized for nearly half a century. Natural fibre-reinforced polymer composites, particularly those using pineapple fibres, offer a cost-effective, lightweight, and environmentally sustainable alternative to traditional materials [1]. Epoxy resin, a thermosetting polymer derived from petrochemical sources, boasts excellent mechanical properties. However, its neat form may not meet the demands of certain applications, necessitating the incorporation of reinforcing fibres. Studies on epoxy resin and various polymers, such as poly(ε-caprolactone) (PCL), polyhydroxyalkanoate (PHA), poly(3-hydroxybutyrate) (PHB), and their blends, have shown comparable or even superior mechanical properties compared to some polyolefins and vinyl polymers [2].

Alkaline treatment's impact on the mechanical properties of pineapple fibre-reinforced epoxy resin composites, specifically tensile strength, impact strength, and fatigue resistance, is a key area of interest in engineering [3]. Tensile strength, crucial for assessing a material's ability to withstand tensile forces without permanent deformation or breakage, may benefit from improved interfacial adhesion between fibres and the epoxy matrix due to alkaline treatment. This enhanced bonding can potentially elevate the composites' tensile strength. Hardness testing, which measures a material's resistance to indentation, provides valuable insights into material properties by assessing the permanent depth of indentation caused by a specifically dimensioned and loaded object.

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The project background discusses the increasing demand for sustainable materials that has prompted exploration into natural fibre-reinforced polymer composites as alternatives to petroleum-based polymers. Pineapple fibres, sourced from leaves, provide a renewable and abundant natural fibre for reinforcing epoxy resin, a versatile thermosetting polymer with favourable mechanical properties. Critical parameters, such as tensile strength and hardness, assess a material's ability to resist forces and withstand dynamic loading. Investigating the impact of alkaline treatment conditions on these properties is crucial for optimizing fabrication processes and tailoring composite properties for specific applications.

The problem statement addresses the lack of comprehensive understanding regarding the effect of alkaline treatment on the tensile strength, impact strength, and fatigue resistance of pineapple fibre-reinforced epoxy resin composites hampers their application in engineering sectors. A thorough investigation is required to bridge this knowledge gap and enable the development of optimized fabrication processes that yield composites with improved mechanical properties [4].

The scope of the project outlines the specific mixing ratio of composites with different concentrations of alkaline treatment on natural fibre. Materials were tested on tensile strength and hardness tests as an evaluation process. Overall, the project aims to identify the optimum level of alkaline concentration for pineapple fibre-reinforced epoxy resin composites to achieve maximum improvement in mechanical properties.

2. Materials and Method

The acquired pineapple leaf fibres were carefully separated as the first stage, and they were further chopped into pieces ranging in length from 5 to 10 mm using a granulator machine.

First of all, prepare a tile and affix a nano tape with a thickness of 3 mm onto it, ensuring it aligns with the dimensions of 170 mm×170 mm×3 mm. This will serve as a mould for the composite preparation. The mould was cleaned to prevent contamination of dirt or dust. Next, 4 coatings of the mould release agent (WD-40) were applied to the fabricated mould by using a dried cloth. Each layer of coating is left to dry for 2 minutes before applying the new coat. After the fourth coating dried, the pineapple leaf fiber was arranged inside the nano tape mould and the epoxy mixed with resin was poured onto it. The samples were differentiated by using various alkaline concentrations. The chemical used in this experiment is sodium hydroxide (NaOH), which was prepared with concentrations of 2%, 6%, and 10%, respectively. It was in pellet form, which was then poured into an amount of distilled water to get the appropriate concentration level. The amount of NaOH required is shown in Table 1.

Table 1 *Data sample for alkaline treatment*

NO	Sodium Hydroxide (NaOH) (%)	Mass of NaOH (pallet form)
1	2	8 g
2	6	24 g
3	10	40 g

The pineapple leaf fibre that has already been chopped into certain lengths will be immersed in all three different concentration levels at room temperature for 30 minutes. Another set of chopped pineapple leaf fibre was prepared as it is used as untreated natural fibre. After immersion, treated pineapple leaf fibres were rinsed in distilled water to remove the excess amount of sodium hydroxide to be washed away. Then, the treated fibres undergo a drying process to be used for composite fabrication. The samples were named according to the amount of NaOH listed in Table 2.

Table 2 *Sample's name according to amount of NaOH listed*

Sample's name	Amount of Sodium Hydroxide (%)
A	0
B	2
C	6
D	10

2.1 Hardness Test

The test is conducted to assess the hardness of the sample, employing a non-destructive method. Specifically, the Shore Durometer type D is utilized for measuring hardness, chosen for its compatibility with the characteristics of the material being tested. The entire testing process adheres to the standards outlined by ASTM D2240, which have been selected based on their suitability for the specific material properties involved in the experimentation. This meticulous approach ensures a reliable and consistent assessment of hardness, providing valuable insights into the material's resistance to indentation or scratching.

2.2 Tensile Test

A tensile test was performed in this investigation utilising a Universal Testing Machine (UTM) made by Gotech. The UTM could apply a maximum load of 5000 kg during the test because it had a 5000 kg capacity. A load applied to the specimen and the resulting deformation or elongation are measured by the equipment. The specimens were carefully prepped and held onto the device to ensure accurate readings. The test was conducted according to ASTM D638-03 type I standard.

3. Results and Discussion

This section highlights the observations and findings derived from experiments, with data analysis forming the foundation for the study's conclusions. Before conducting mechanical and physical tests on samples, preparation steps adhered to relevant standards. Two key experiments were performed on pineapple leaf fibre (PALF) reinforced epoxy composites: a hardness test, assessing resistance to an indentation or scratching, and a tensile test to determine tensile strength.

3.1 Hardness Test Analysis

Table 2 shows the hardness test results, while Fig. 1 shows the average hardness value for each sample.

Table 2 *Result summary of hardness test*

Sample	HV 1	HV 2	HV 3	HV 4	HV 5	Mean HV
A	68	66	65	68	67	66.8
B	76	75	74	74	76	75
C	71	73	72	74	73	72.6
D	68	70	69	70	71	69.6

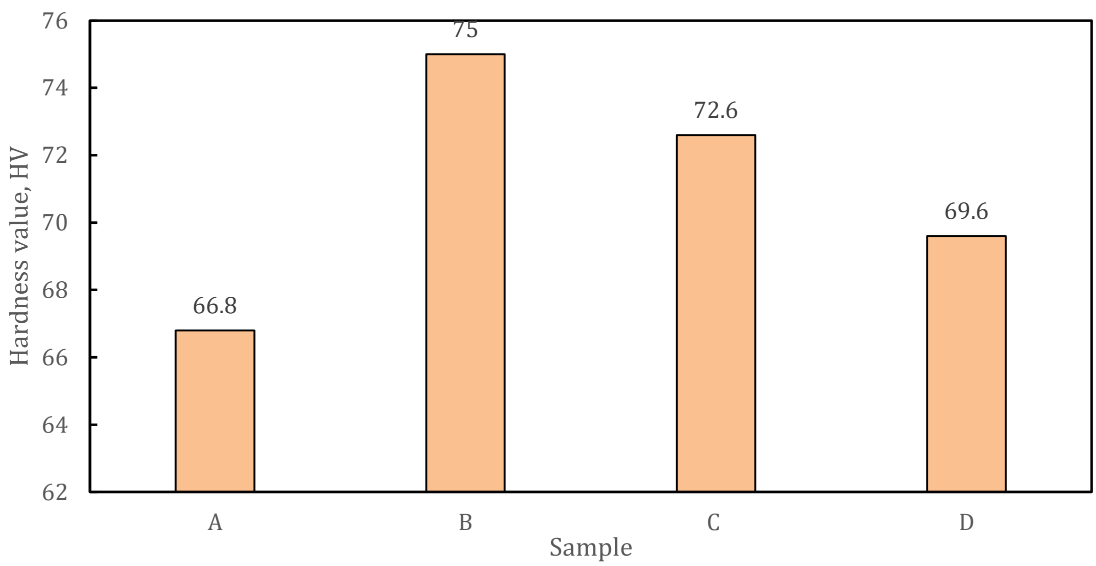

Fig. 1 *Chart of hardness value on treated and untreated pineapple leaf fibre-reinforced epoxy resin*

The hardness test results on pineapple leaf fibre (PALF) reinforced epoxy composites reveal a significant impact of NaOH treatment percentage on composite hardness. Sample B, treated with 2% NaOH, exhibits the highest hardness value at 76, surpassing untreated PALF (Sample A) and those treated with 6% (Sample C) and 10% (Sample D) NaOH. Analysis indicates an optimal treatment percentage for hardness, approximately 2%.

Possible explanations for increased hardness include treated fibres being stronger than untreated ones, making the epoxy resin more resistant to indentation. Another possibility is that treatment alters fibre surfaces, enhancing compatibility with the epoxy resin and improving adhesion, resulting in a stronger composite material.

The heightened hardness of 2% NaOH-treated PALF-reinforced epoxy resin offers potential benefits, such as increased resistance to wear and tear, which is crucial for applications like boat building and construction. Additionally, the material becomes more resistant to impact damage, making it suitable for aircraft and automotive parts. In summary, this study suggests that 2% NaOH-treated PALF-reinforced epoxy resin is optimal for applications requiring a strong and hard material, particularly in the automotive industry.

3.2 Tensile Test Analysis

Tensile tests serve as a crucial method for evaluating the mechanical characteristics of materials when subjected to static, axial tensile, or stretching forces. The application of tensile forces is particularly advantageous due to their straightforward visualization, making them an essential tool in establishing fundamental concepts related to the understanding of a material's mechanical properties. This testing approach aids in comprehending how materials respond to forces applied along their length and provides valuable insights into their behaviour under different loading conditions. The summary results were tabulated in Table 3.

Table 3 *Result summary of tensile test*

Sample	Max force (N)	Max displacement (mm)	Yield strength (MPa)	Break Force (N)
A	1091.57	1.82	1022.13	713.12
B	2175.83	2.16	1152.99	2039.44
C	1424.55	2.04	902.82	1406.25
D	1154.13	1.46	985.396	1068.23

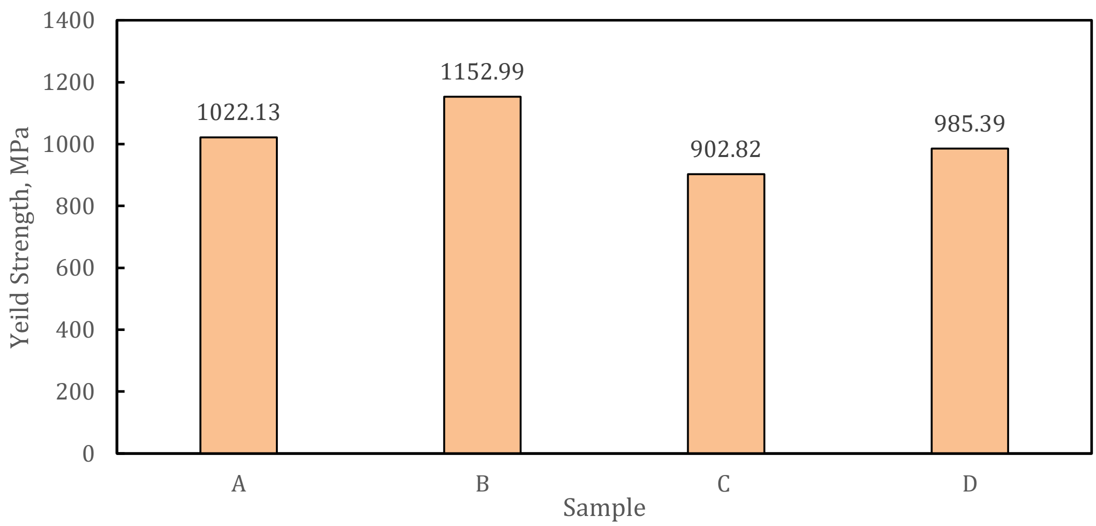

Fig. 2 *Chart of yield strength on treated and untreated pineapple leaf fiber reinforced epoxy resin*

Fig. 2 illustrates the yield strength of treated and untreated pineapple leaf fibre (PALF) reinforced epoxy resin. Sample B, treated with 2% NaOH, exhibits the highest yield strength at 1152.99 MPa, surpassing untreated PALF (Sample A). However, as the NaOH treatment percentage increases, the yield strength begins to decline. Sample C, treated with 6% NaOH, shows a yield strength of 902.82 MPa, lower than the tensile strength of Sample B. Sample D, treated with 10% NaOH, records a yield strength of 985.39 MPa, suggesting an optimal NaOH percentage for maximum yield strength, around 2%.

The chart indicates an initial increase in yield strength with higher NaOH concentration, likely due to the removal of more lignin and hemicellulose from the fibres. This removal enhances the bonding between the fibres and the resin, contributing to improved yield strength [5].

In conclusion, the study suggests that NaOH treatment effectively enhances the tensile strength of PALF-reinforced epoxy resin. These findings position pineapple leaf fibres as a more attractive option for use in composite materials, showcasing the potential of NaOH treatment to optimize mechanical properties.

4. Conclusions

In conclusion, the study on NaOH-treated and untreated pineapple leaf fibre (PALF) reinforced epoxy composites reveals that 2% NaOH treatment optimally enhances both hardness and yield strength. Sample B, treated with 2% NaOH, outperforms untreated PALF and higher NaOH concentrations in both hardness (75 HV) and yield strength (1152.99 MPa). This suggests that 2% NaOH treatment strikes a balance, improving PALF strength and resin adhesion. The findings contribute valuable insights for applications requiring enhanced mechanical properties, such as in the automotive and construction industries.

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